OFFICE OF COMMUNICATIONS

Award of available spectrum: 2500-2690MHz, 2010-2025MHz

This document sets out Ofcom's updated proposals for the grant of wireless telegraphy licences to use these spectrum bands and for the method of award

Discussion document

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Contents

Section 1

Executive Summary

1.1 Our Consultation Document published on 11 December 2006 set out a number of proposals relating to the award of available spectrum in the bands covering 2500-2690MHz, 2010-2025MHz and 2290-2300MHz. Key features of the proposals were to:

- hold awards for each of these bands as soon as practical via auction;
- to package spectrum in the 2.6GHz band in such a way as to allow an outcome consistent with the CEPT band plan for 2.6GHz (2x70MHz of paired spectrum and 50MHz of unpaired spectrum before allowing for guard blocks), but to allow flexibility for the split between paired and unpaired spectrum to vary from the fixed arrangement in the CEPT band plan based on relative market demands;
- for the award of the 2.6GHz band, to adopt a two stage auction approach using a Principal Stage in which bidders would compete for generic lots, in a clock phase followed by supplementary bids round, and an Assignment Stage during which these generic lots would be converted into assignments at specific frequencies;
- to package the 2010MHz band as a single lot to be offered as part of the same auction as the 2.6GHz band; and
- to package the 2290MHz band as a single lot to be awarded via a separate auction.

1.2 The responses to this consultation have raised a wide range of issues, including those relating to the technical and non-technical conditions of use and to the design and timing of the auctions. The breadth of the responses reflects the economic significance of the spectrum to the UK and its commercial significance to many individual companies. In light of the responses, we have carried out substantial further analysis, the results of which are presented in this Discussion Document, together with updated proposals where relevant.

1.3 The main focus of this Discussion Document is on technical conditions and auction design for the 2.6GHz band (and the 2010MHz band).

- Technical conditions for use of the bands. In the 2.6GHz band, we consider the significance of compatibility between paired and unpaired use for flexibility in spectrum packaging and auction design. In respect of uses in adjacent bands, we consider the significance of their likely impact for potential variations in technical constraints across different frequencies within the bands for award (and, conversely, the effect of their use on users in adjacent bands).
- Auction design. We review the options for addressing certain technical issues through auction design and propose changes to the December proposals to address issues raised by stakeholders.

1.4 We also provide an updated assessment of Ofcom's view on timing of awards and on non-technical licence conditions. In the case of award timing, we do so because we

recognise that parties who are contemplating participation in these awards need to plan in advance and will wish to understand the possible timetable. In the case of non-technical licence conditions, we do so because of the detailed nature of responses to these aspects of the December proposals, and our updated view is based on the assessment of more detailed arguments from some respondents rather than on new developments relevant to the issues. We emphasise, however, that Ofcom has not made final decisions on these matters and is not using this Discussion Document as a vehicle for announcing decisions. We will make and announce decisions in a Statement which we expect to publish before the end of this calendar year.

1.5 This additional step in the consultation process is intended to facilitate further input into the design of the award and thereby contribute to the development of an award process that is as robust and efficient as possible. However, this Discussion Document is not intended to give a comprehensive review of all comments raised in responses.

Technical analysis of interference conditions

1.6 The most significant concern over interference relates to the potential implications of allowing the market to determine the organisation of the 2.6GHz band, which may result in an outcome different from the CEPT band plan in terms of split between unpaired use (most likely to involve TDD technology) and paired use (most likely to involve FDD technology). Most particularly, this concern relates to the scope for mobile-to-mobile interference from TDD terminals into FDD terminals (the “blocking” effect), under a scenario in which TDD terminals are permitted to operate in the upper part of the 2.6GHz band (2620-2690MHz). We have carried out substantial further work on this issue including the development of Monte Carlo simulations to assess the scale of this blocking effect. The conclusion from this analysis is that the blocking effect can be expected to be very likely to materialise in certain types of situations (where a TDD user and an FDD users are in close proximity and both accessing services at the same time using the 2.6GHz band). However, our analysis suggests that the percentage of overall FDD connections that would suffer blocking would rise by no more than 0.5% under plausible assumptions, similar to the level of lost or failed connections that FDD terminals would typically suffer in their own network regardless of other users. If network operators acquiring 2.6GHz spectrum were concerned about the blocking effect in certain situations, then it is possible that they would be able to take a number of mitigation actions. Indeed, we note that an equivalent risk of a blocking effect may exist for users of TDD technologies (WiMAX in particular), caused by the use of FDD terminals in the 2.6GHz band, even under the CEPT band plan. However, prospective WiMAX operators seem to be confident that, overall, the risk of blocking is low (and/or that they can mitigate the likelihood of blocking).

1.7 In relation to technical conditions within the 2.6GHz band, concerns were also raised about interference between adjacent TDD and FDD users and about whether the use of a 5MHz restricted block was sufficient. This Discussion Document reports our further technical analysis of this issue and sets out the view that the conditions proposed in the December Consultation are likely to promote optimal use of the spectrum, by maximising the amount of spectrum available for use while allowing appropriate scope for interference to be managed efficiently by all users. However, some improvement in the risk of adjacent channel interference could be achieved (particularly in urban areas) if additional constraints were placed on outdoor TDD use of the restricted block adjacent to the FDD uplink and on outdoor TDD use of the restricted blocks between TDD users.

1.8 Turning to uses in adjacent bands, this document includes additional information on the use of radars above the 2.6GHz band.

- We provide new information on MoD radar use above 2700MHz that was not available at the time of the December consultation.

- We are currently carrying out some empirical work to measure the impact of radar use on UMTS and WiMAX equipment which we intend to publish when completed. In the absence of this, we have reviewed the results of some substantive analysis undertaken by one stakeholder which indicates that the presence of radar may require a local increase in cell density, in areas where signals from radars are strongest, but would not prevent effective use of the spectrum.

1.9 Two stakeholders expressed concerns about the impact of new uses of the 2.6GHz band on the ability of PMSE users to use frequencies immediately below 2500MHz and above 2025MHz. We are publishing the results of some empirical work undertaken by ERA on the performance of PMSE equipment. This work indicates that the assessment of interference risks should be based on parameters different from those used to prepare some of the analysis in support of the December Consultation. However, Ofcom's updated assessment is that no specific restrictions should be placed in respect of the risk of interference between existing PMSE use and new uses in the bands for award. Ofcom plans to consider this assessment with JFMG (the company currently responsible for managing access to spectrum for PMSE use on behalf of Ofcom) and interested PMSE users during the consultation period.

1.10 We have also obtained some further information on the levels of potential interference from neighbouring countries.

- We carried out a series of measurements of received signal strengths in the 2.6GHz band at a number of locations in Northern Ireland, West Wales and North West England (to test signal strengths from Irish MMDS broadcast services) and in the South East of England (to test signal strengths from current use of the 2.6GHz band in France). These showed no, or very weak, signals in all of these locations with the exception of those locations in Northern Ireland close to the border with the Republic.

- We have also received some new information from ComReg on the transmissions from MMDS services in Ireland. It suggests that the level of interference is likely to be slightly less than indicated in the December Consultation.

Technical licence conditions

1.11 In the December Consultation, we set out two alternative approaches to specifying technical licence conditions, one based on the use of spectrum masks and the other based on the use of spectrum usage rights (SURs). Although some stakeholders expressed support for the general SUR approach, there was no support amongst stakeholders for taking this approach forward in the context of the 2.6GHz award itself. In part, this reflects a perception of the time it would take to address outstanding issues. As a result, Ofcom is not proposing to pursue the SUR approach for this award. We therefore intend to specify the technical licence conditions in terms of spectrum masks.

1.12 Based on the technical analysis described above and having taken account of comments raised by stakeholders, this Discussion Document sets out our updated view that the detailed specifications for the spectrum masks included in the December Consultation remain appropriate.

1.13 However, there are three specific areas of possible change in which stakeholders' evidence in response to this Discussion Document will be particularly helpful:

- extending the out-of-block masks out to an offset of ±20MHz from assigned blocks;
- placing additional restrictions on the use of restricted channels between the FDD uplink and TDD to limit potential interference from their use outdoors (possibly by reducing the in-band power to 18dBm/MHz EIRP); and
- a reduction in mobile station maximum in-band power to 18dBm/MHz EIRP to help a modest reduction in the probability of interference in certain scenarios.

Auction design and related issues

1.14 A central feature of the proposed auction design on which we consulted was to package spectrum in the 2.6GHz band in such a way as to allow flexibility for the split between paired and unpaired spectrum to vary from the CEPT band plan. In response to the December Consultation, the flexibility to depart from the CEPT band plan was supported by stakeholders interested in WiMAX (particularly potential operators and manufacturers) and by one MNO and opposed by other MNOs and several 3GPP equipment manufacturers. Having considered the substance of these responses, in particular the underlying technical issues, our updated assessment is as follows.

- There is significant potential interest in gaining access to 2.6GHz spectrum for unpaired use and the level of interest is likely to exceed the limit of 50MHz of unpaired spectrum that would be available under the CEPT plan. The main interest for unpaired spectrum comes from parties who would generally be new holders of rights to spectrum suitable for the provision of mobile data services, looking to deploy WiMAX based services. This could deliver significant competition and innovation benefits for consumers. This provides a strong argument for retaining flexibility (in terms of relative amounts of paired and unpaired spectrum) within the packaging and auction design proposals.
- The retention of this flexibility creates the possibility that TDD terminals could operate in the upper part of the band and that this could lead to blocking of FDD handsets as noted above. This could reduce the value of the spectrum to FDD users. We have considered allowing FDD bidders to reflect their perception of the impact on value of the blocking effect by modifying the auction rules to allow for contingent bidding (whereby FDD bidders submit separate bids for the case where TDD terminal operation in the upper part of the band is prohibited and the case where TDD terminal operation in the upper part of the band is permitted). However, this modification would add significant complexity to the auction and raise potential concerns in relation to our duty to promote competition and innovation.
- Given that the technical scale and commercial impact of the blocking effect are expected to be modest, as noted above, we consider that any benefits that could

result from modifying the auction design to accommodate contingent bidding of this type would not outweigh its risks and disadvantages.

1.15 We note that the proposals do mandate key features of the CEPT band plan, notably the 5MHz channel widths and the 120MHz duplex spacing for paired spectrum. We also note that, depending on market demand as revealed through the bids in the auction, the CEPT band plan could be the outcome of the proposed award. We consider that these proposals, which have been widely supported, provide the opportunity for market-led harmonisation which will facilitate access to the economies of scale of a European handset market and will facilitate roaming.

1.16 A second key feature of the proposed auction design is the use of generic lots (with two types of lot in the 2.6GHz band, one for paired spectrum and one for unpaired). The use of generic lots underpins the division of the auction into the Principal and Assignment stages. Although several stakeholders expressed concerns regarding aspects of the proposal to use generic lots, our view remains that the use of two categories of generic lots for the 2.6GHz band provides the best balance between the technical and auction design issues for three main reasons.

- Our analysis (taking account of the effects of radar use, TDD / FDD adjacencies and interference from neighbouring countries) indicates that the potential for differences in value between lots within one category of lot would not be such as to risk creating substantial inefficiencies under the proposed two-stage auction process with use of generic lots. On the contrary, the proposed auction design, including the use of generic lots, is likely to be the most suitable for furthering the interests of citizens and consumers.

- No stakeholders came forward with suggestions for an alternative approach based on the use of specific lots rather than generic lots that would be likely to result in greater overall efficiency or benefits. Indeed, consideration of an SMRA auction using specific lots (the auction format generally associated with spectrum auctions with specific lots) suggests that this would be substantially more problematic, particularly because of the opportunities for strategic behaviour it creates.

- It would be possible to disaggregate the lots into more than two categories within the 2.6GHz band but this would add significant additional complexity which itself could introduce risks (see further below).

1.17 Although we are not proposing a change in approach on these two substantive features of the auction design (flexibility of the split between paired and unpaired, and the use of generic lots), we are proposing a number of more detailed changes in the auction rules in light of stakeholder feedback and further consideration. The main changes are summarised in the table below.

Table 1: Main changes to the auction design proposals compared to the December Consultation

Stage	Action	Description of change
Principal Stage: primary bid rounds	Primary bids contingent on no split award of unpaired lots	All primary bids for unpaired 2.6GHz spectrum are contingent on receiving contiguous spectrum. Primary bid rounds continue until such time as it is possible to accommodate all remaining bids without a split award of unpaired lots.
	Fungible eligibility	There is a single eligibility rule that applies across all three categories. Switching is allowed between paired and unpaired lots.
	Separate clock prices for the 2.6GHz paired and unpaired	Separate clock prices but the 2:1 price ratio remains for the 2.6GHz paired and unpaired lots, unless demand for unpaired lots falls below nine. In the event that the price for unpaired 2.6GHz lots falls below the 2:1 ratio, but demand subsequently rises above nine lots, the price will be returned to a 2:1 price ratio in the next round.
	Bidding cap	A cap of 18 eligibility points per bidder is proposed, corresponding to a safeguard cap of 90MHz.
	Extension rights replace waivers	Extension rights allow bidders extra time to submit bids in a round in the event that they experience technical problems. Bidders that still fail to submit a bid after using up an extension period will be reduced to zero eligibility.
Principal Stage: supplementary bids round	Supplementary bid submission	Supplementary bids can only be submitted in the supplementary bids round (not during primary rounds).
	Supplementary bids round always run	Supplementary bids rounds will always be run after completion of the primary bid rounds, even if supply and demand are exactly in balance in the last primary round.
	Two types of supplementary bids	In addition to ‘standard supplementary’ bids, bidders for unpaired 2.6GHz spectrum may submit ‘split supplementary bids’ for packages with specified splits between the lower and upper unpaired areas.
	Pricing rule	Second price rule for the Principal Stage has been refined.
Assignment Stage	Bid options	Rules for determining bid options have been refined and now cover the case where some lots from the Principal Stage are unsold.
	Split assignments	Identity of the bidder receiving a split assignment of unpaired 2.6GHz lots (if there is one) will be determined by the Principal Stage, and this will be taken into account in the available bid options for each bidder in the Assignment Stage. A bidder may only get a split assignment if it has placed a bid for the corresponding option.
	Pricing rule	A second-price rule analogous to that being use for the Principal Stage is proposed (instead of a pay-as-bid rule).

1.18 The auction design proposals set out in this Discussion Document also include more information on certain steps not previously covered in detail (for example on application and qualification to bid) and other specific aspects (such as deposit requirements or provisions for unsold lots).

1.19 Consultation respondents made a number of suggestions for other changes to the auction rules to:

- make it easier for MNOs holding TDD spectrum at 1.9GHz to bid for spectrum at 2600-2620MHz in order to use these lots for external pairing with their blocks at 1.9GHz;
- add extra categories of lot (such as distinguishing FDD channels which are immediately adjacent to the restricted block between TDD and FDD); and
- allow for a distinction between TDD lots, dependent on whether or not the lots are in the upper part of the band or are in, or below, the centre of the 2.6GHz band.

1.20 In preparing auction design proposals, there is a balance to be struck between the competing requirements expressed by interested parties: it is not possible to construct an auction that can facilitate all possible outcomes in a similar way without introducing efficiency risks and/or opportunities for strategic behaviour. In the case of spectrum at 2600-2620MHz which could be paired externally, our analysis suggests that this would have a number of disadvantages, including the introduction of significant additional complexity into the auction. We consider that any benefits that might flow from this are not sufficient to justify incurring these adverse effects. Similarly, whilst it would be possible in the other cases to amend the auction design to accommodate additional categories of lots, each additional category would add considerably to the complexity of auction design and execution. With additional complexity comes the risk that auction participants may not fully express their preferences for all the packages of lots in which they might be interested, thereby creating the possibility that the auction result becomes suboptimal. We note that some stakeholders who suggested such modifications also commented that they felt the auction design was already complicated. As such, we are not proposing to implement any of the suggestions listed above in paragraph 1.19.

Timing and linkages between awards and non technical licence conditions

1.21 As noted above, this Discussion Document provides an updated assessment on timing and on linkages between the awards of the different bands. The main focus is on the timing of the 2.6GHz award.

1.22 The substance of stakeholder feedback, both in responses to the December Consultation and in various meetings, together with further analysis which we have undertaken, have reinforced our view that it is desirable to hold the award of the 2.6GHz band as soon as is practical. Key aspects in this updated assessment are as follows.

- As a result of meetings with stakeholders, we consider it very likely that if the 2.6GHz award was held in 2008 then there would be parties who would participate in the award and who, if successful, would intend to bring the spectrum into use without delay.
- The main interest in imminent use of the spectrum comes from parties who would be new providers of mobile data services and who intend to deploy WiMAX

systems. This raises the prospect that the combination of innovation and competition benefits for consumers could be substantial, in part because the advent of the WiMAX standard seems to have prompted a competitive response from the 3GPP community to advance their own next generation standard (LTE).

- The majority of the existing MNOs would prefer a delay in the award until they have a more immediate need for 2.6GHz spectrum themselves and/or various sources of uncertainty were reduced. We accept that if the award were held a long time in advance of need for some potential users then this could present those users with some uncertainty over how much spectrum to bid for and this could be a source of inefficiency under certain assumptions (i.e. if it led to an outcome which was different to one that would have been arrived at had they had better foresight of their future spectrum requirements and one they could not replicate through subsequent trading of spectrum). However, we are not persuaded that this would be a source of substantial inefficiency. In addition, Ofcom notes that new information is available and expects further information to become available on such issues as 2G spectrum and European discussions on the WAPECS concept and its potential application to the 2.6GHz and 2010MHz bands. Any potential source of inefficiency also needs to be balanced against the potential loss of benefit from denying other users (and their consumers) access to the spectrum without delay.

- On this last point, the potential loss of benefit from denying earlier access relates not only to the direct loss of benefit from use of the spectrum over the period of delay. The loss of innovation and competition benefits could be magnified if, as seems plausible, there is a short term window of opportunity for new entry by providers of high bandwidth dependent mobile data services using new technology. This likely window of opportunity highlights the potentially large risks that would be associated with relying on demand from some MNOs that may exist in future rather than on clear demand that has been expressed for an award without delay and which may reduce or disappear in case of delay.

1.23 On the question of linkages between the awards of the bands under consideration:

- Stakeholders did perceive a linkage between the 2.6GHz and 2010MHz bands, primarily as substitutes for unpaired spectrum. Although we believe that the linkage may be relatively weak, we are minded to continue with the award of the 2010MHz band as part of the same auction, and therefore on the same timescale, as the 2.6GHz award.

- There was very limited interest in the 2290MHz band and varying views on whether any award should be held before the 2.6GHz auction as proposed in the December Consultation. We therefore intend to separate the 2290MHz band from the 2.6GHz award process and consider it again at a later date.

1.24 As noted above, a number of the existing MNOs made submissions relating to the proposals for non-technical licence conditions relating to roll-out obligations, technology neutrality, tradability and duration / tenure. We have carefully considered those submissions and comment in Section 8 on our preliminary conclusion that they do not provide grounds to alter the approach which was set out in the December Consultation. That approach is consistent with the policies in a number of spectrum policy decisions made by Ofcom over recent years, including those set out in the Spectrum Trading and Spectrum Liberalisation and the Spectrum Framework Review statements.

Next steps

1.25 We are inviting comments from stakeholders by 28 September on the issues raised in this Discussion Document. We intend to hold a seminar on the updated proposals during September, before the close of this period for comment. As noted above, the main focus of this Discussion Document is on technical interference issues and any implications for auction design, and it is in these areas that we particularly seek comment. However, stakeholders are welcome to comment on any issues raised in this Discussion Document. We would encourage stakeholders to substantiate comments on technical issues with supporting technical analysis where possible and to link comments on auction design with concrete proposals for modifying auction rules where relevant.

1.26 We intend to hold some more detailed workshops on auction rules during the autumn targeted at those parties that have a prospective interest in participating in the auction. If feasible, we may also hold some demonstrations with these parties during this period.

1.27 We aim to reach policy decisions on this award, to make a Statement and to publish an Information Memorandum and draft regulations (in particular the regulations that will define the award process and allow it to take place) before the end of this calendar year. If the decision is to proceed to award as soon as practicable then, on this timetable, we would expect to:

- make decisions for the regulations, publish statements on those decisions and make the regulations in March or April 2008;
- invite applications to participate in the award by the end of the first quarter of 2008/09 (after the auction regulations have come into force); and
- commence the bidding process of the auction as soon as possible thereafter.

Section 2

Introduction

2.1 Ofcom published a Consultation Document[1] on the award of available spectrum in the bands 2500-2690MHz (the "2.6GHz band"), 2010-2025MHz (the "2010MHz band") and 2290-2300MHz (the "2290MHz band") on 11 December 2006 (the "December Consultation"). We received 35 responses in March and have since held a number of bilateral meetings with interested parties, several of whom have submitted further analysis.

2.2 The responses raised a wide range of issues, both in general, and in relation to the 22 specific questions asked in the December Consultation. Overwhelmingly, the larger part of the responses concentrated on the 2.6GHz band rather than the 2010MHz or 2290MHz bands. Moreover, the issues which respondents felt to be contentious relate principally to the 2.6GHz band. As the purpose of this Discussion Document is to help move forward the debate to the point where decisions about the awards can be made, it therefore focuses almost entirely on issues surrounding the 2.6GHz band.

2.3 The most substantive set of issues in relation to the design of the award focused on the effects of interference. The areas that have attracted substantial comment relate to:

- the interference implications of an auction outcome that departs from the CEPT[2] band plan[3] for the 2.6GHz band, particularly an outcome in which TDD[4] use appears in the top end of the band;
- the nature of in-band adjacencies and their implications for size of the restricted block between adjacent FDD[5] and TDD users;
- the magnitude of interference effects from (and to) adjacent band users, notably radars above 2700MHz and Programme Making and Special Events (PMSE) users below 2500MHz; and
- the potential impact of neighbouring countries' use of the 2.6GHz band, in particular the impact of Multichannel Multipoint Distribution Service (MMDS) transmissions in Ireland and the possible future use of the 2.6GHz band in France.

[1] http://www.ofcom.org.uk/consult/condocs/2ghzawards/
[2] European Conference of Postal and Telecommunications Administrations, which includes the Electronic Communications Committee (ECC). See http://www.cept.org/.
[3] See ECC Decision (05)05, available at http://www.ero.dk/documentation/docs/docfiles.asp?docid=2056&wd=N.
[4] Time Division Duplex, two-way communication where the uplink, from handsets to base station, and downlink, from base station to handsets, take place at the same frequency, but are separated by timeslots i.e. a burst of uplink followed by a burst of downlink.
[5] Frequency Division Duplex, two-way communication where the uplink and the downlink take place at different frequencies at the same time.

2.4 These are critical issues to get right in order to meet Ofcom's statutory duties for the award and Ofcom is grateful for the comments and analyses which stakeholders have provided. Drawing on these contributions, Ofcom considered that the issues were of sufficient materiality that the correct approach was to carry out further analysis of the issues and evaluation of their implications for packaging and auction design. Ofcom therefore announced its intention to do this, and to hold a further consultation on the design of the award in the form of this Discussion Document, in an update statement[6] issued on 17 May.

2.5 Ofcom has carried out a range of additional work on these technical issues, the results of which are presented in this Discussion Document. In particular, Ofcom has:

- carried out substantial further analysis of the scale of the potential blocking effect on FDD handsets that could result from the operation of TDD terminals in the top part of the 2.6GHz band (which could happen under an auction outcome which departed from the CEPT band plan);
- conducted further work on the risks of interference at adjacencies within the 2.6GHz band (FDD uplink / TDD adjacency and TDD / TDD adjacencies) in order to prepare an updated view on the technical licence conditions required to manage these, in particular the conditions applied to restricted blocks;
- engaged consultants (ERA) to conduct empirical studies relevant to uses in adjacent bands, on the technical characteristics of PMSE equipment (below 2500MHz and above 2025MHz) and on the interference effects from radars (above 2700MHz);
- received and analysed information from the MoD on its use of radar above 2700MHz (this information was outstanding at the time of the December Consultation);
- obtained specific information from UPC / ComReg[7] on actual MMDS transmissions in Ireland which allows us to present a more realistic interference analysis based on actual transmission data rather than on the maximum limits specified in publicly available licensing information. We have supplemented this revised analysis with measurements of signal levels received at a variety of locations in Northern Ireland and along the west coast of England and Wales.
- held discussions with both the Irish (ComReg) and French (ANFR[8]) regulators about possible future international coordination for the 2.6GHz band.

2.6 The results of these technical studies and analyses have a number of important implications for the way that the spectrum might be packaged for award and for the design of the auction itself. In addition, Ofcom has gathered further valuable information on the ways in which potential bidders in the award might look to make use of the spectrum which has some implications for packaging. Moreover, respondents raised a number of issues directly related to the proposed auction design including:

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6 http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/2500_2690/

7 http://www.comreg.ie/

8 http://www.anfr.fr/

- the use of a two stage auction with the first stage based on the use of generic lots (rather than lots for specific frequencies);
- the possibility of external pairing of specific lots in the centre portion of the 2.6GHz band;
- the scope for switching between paired and unpaired lots during the auction process;
- the preference of bidders interested in unpaired spectrum for blocks of 10MHz (excluding restricted blocks); and
- the possibility that bidders interested in unpaired spectrum may not wish to receive a split assignment.

2.7 This Discussion Document therefore provides an assessment of the implications of all the above issues and a number of other, more detailed issues on packaging and auction design. It sets out updated proposals which differ from those described in the December Consultation in a number of respects. One of the main purposes of this Discussion Document is to seek further feedback which will help in reaching decisions on the central features of the award design. Once this "big picture" is defined Ofcom will be well placed to finalise all the details of the auction rules.

2.8 The December Consultation also set out proposals for the technical licence conditions, including two alternate approaches: one based on spectrum masks and the other based on SURs[9]. Ofcom received substantial comments on these proposals and has also held a number of meetings with those respondents who expressed detailed views on the issue of SURs. This Discussion Document sets out our updated proposals on the approach to technical licence conditions in the award of licences for the 2.6GHz and 2010MHz bands.

2.9 The primary focus of this Discussion Document is on technical and award design issues. It is on these issues that Ofcom considers that further consultation is desirable and, therefore, we are expecting feedback specifically on the technical issues and on their implications for packaging, auction design and technical licence conditions. In this context, we note that this Discussion Document is not seeking to cover all issues raised by respondents, but rather to focus on those issues which affect the main design aspects of the award.

2.10 Ofcom received substantial comments on other aspects of the proposals set out in the December Consultation, notably on issues around the timing of the award and concerning the non-technical licence conditions.

2.11 For clarity, Ofcom is not taking any decision on timing of the award at this point. However, we recognise that it is helpful for stakeholders to have a view of our updated assessment on the question of timing of the award since those that may wish to participate in the award need to make advance plans. As a result, this Discussion Document includes an updated assessment of the case for and against awarding the 2.6GHz band without delay and the implications that this may have for the timetable. Ofcom would like to emphasise, however, that a decision will be taken on the timing of award at the time of the Statement on the award, which we expect to make towards the end of 2007. This decision will take account of all the information

[9] Spectrum Usage Rights. See Ofcom's consultation document of April 2006, available at http://www.ofcom.org.uk/consult/condocs/sur/.

received to date and of any relevant new information and developments in the interim, such as those which may happen in the context of European regulatory fora.

2.12 A similar observation applies to the non-technical licence conditions in that Ofcom is not taking any decision at this point. However, there were some respondents who argued that the non-technical licence conditions had some bearing on the timing of award – or, more specifically, on whether the award should go ahead at all if the proposed licence conditions were to be used. Accordingly, we also give an updated assessment of issues relating to the non-technical licence conditions.

2.13 As set out above, this Discussion Document is structured to provide our updated views on the following issues:

- the conditions of interference, in the 2.6GHz band and with adjacent bands, and their implications for spectrum packaging;
- the resulting technical conditions for use of the various types of lots in the two available bands;
- the auction design for the award;
- certain issues relevant to access to spectrum by potential users and participants in the award;
- the timing of the award; and
- the non-technical licence conditions.

2.14 The last Section of this Discussion Document then sets out what we see as the next steps leading to an award which we believe could start with the application process by the end of the first quarter of 2008/09, shortly after the auction regulations have come into force.

Section 3

Interference and spectrum packaging

3.1 The December Consultation set out an analysis of potential sources of interference between in-band uses, with adjacent bands and with spectrum users in neighbouring countries. This analysis drew significant comment from stakeholders, both in respect of the interference effects themselves and in respect of their possible implications for spectrum packaging and high level auction design for the 2.6GHz award. Where relevant, Ofcom asked stakeholders to provide any analysis that they had carried out to substantiate their points and, in a few cases, stakeholders did indeed share their technical analysis of interference effects.

3.2 Given the importance of the issues raised, Ofcom has carried out substantial further analysis of the issues and has reviewed carefully the additional submissions from stakeholders as well as new technical analysis carried out by international technical bodies (notably the ITU[10]) since the time of the December Consultation Document. Ofcom has also obtained information on MoD radar use and on transmissions from Irish MMDS broadcast services, missing parts of the overall picture that were not available at the time of the December Consultation. Ofcom has also commissioned empirical work from its technical partner ERA, and from Ofcom's own monitoring team, to support its understanding of the interference effects.

3.3 The results of all this additional work on interference are summarised in this Section and presented in a series of Annexes to this Discussion Document as follows.

In-band interference effects

- **Annex 6** covers the **blocking[11] effect on FDD handsets**: the impact on the FDD quality of service of an auction outcome in which TDD user equipment appears in the top end of the band (i.e. in the frequencies 2620MHz to 2690MHz) – referred to as the "mobile to mobile" interference scenario;

- **Annex 7** considers **in-band adjacencies** within the 2.6GHz band: the nature and materiality of interference between adjacent FDD and TDD users, and between adjacent, unsynchronised TDD users - and the implications that these have for technical restrictions, including the size of the restricted block between adjacent users.

Interference effects with users adjacent to the 2.6GHz band

- **Annex 8** presents the results of an empirical study on the potential **interference caused to, and by, PMSE users and the mitigation effect of filters**: this work was carried out for Ofcom by ERA who undertook a programme of measurements of the effect of interference from UMTS[12] and WiMAX[13] equipment

[10] International Telecommunication Union. See http://www.itu.int.
[11] In the case of mobile communication, blocking refers to the inability of a mobile terminal to communicate with its home network as a result of some outside interference.
[12] Universal Mobile Telecommunications System, the mobile communication technology authorised in 3G licences in the UK.
[13] Worldwide Interoperability for Microwave Access, a family of fixed, nomadic and mobile communications technologies based on IEEE 802.16 standards.

on wireless cameras and looked at the effect of including prototype filters on the cameras;

- **Annex 9** draws together various pieces of work on the **impact of radar use above 2700MHz** on frequency blocks within the 2.6GHz band.

Coordination with neighbouring countries

- **Annex 10** addresses the subject of **MMDS broadcast services in Ireland.** Ofcom has obtained new information via ComReg on actual transmissions from MMDS sites in Ireland and this has allowed for the derivation of updated interference maps from those which were presented in December (which were based on the maximum transmission levels recorded in licensing data). Ofcom's monitoring team also undertook a series of measurements of the received signal levels at various locations in Northern Ireland, Wales and the North West of England and these are summarised in this annex; full results are published in a separate report alongside this Discussion Document. Annex 10 also covers the issues relating to current and future **coordination with France** over use of the 2.6GHz band and summarises additional measurements carried out in the South East of England.

3.4 These interference effects raise a number of important potential implications both for spectrum packaging and for the approach to auction design. In particular, the following four subject areas are addressed below in this Section and in the following Section on auction design:

- the **implications of allowing a departure from the CEPT band plan,** which draws on the analysis of the blocking effects in Annex 6;

- the nature of the **technical restrictions that are required to manage interference between adjacent users**, both within the 2.6GHz band and with adjacent PMSE use above 2025MHz below 2500MHz (no equivalent technical restrictions are required at the top end of the 2.6GHz band);

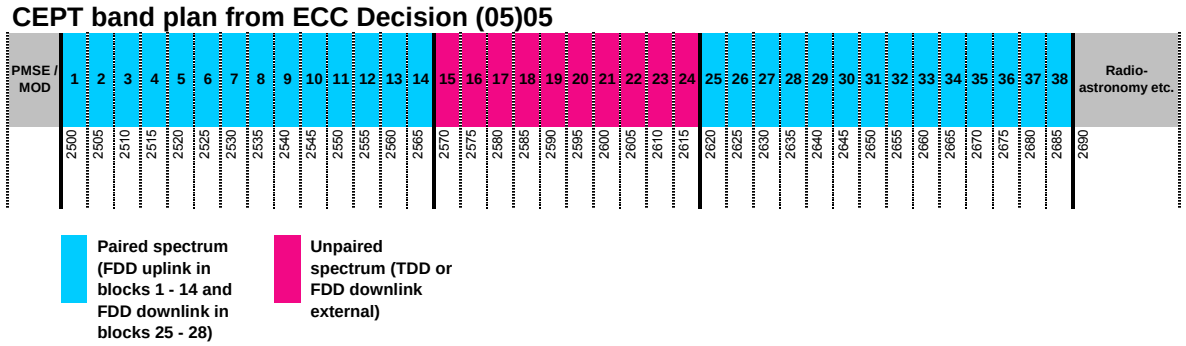
- the potential implications for **international coordination in the 2.6GHz band** to minimise the impact of interference from use of the 2.6GHz band in France and Ireland, which may result in restrictions on the geographic use of lots; and

- the possible impact of in-band and out-of band adjacent users, and of neighbouring international users, on the utility of different frequencies within the 2.6GHz band and, in consequence, the **implications for the viability of the generic lot approach** which underpinned the auction design proposals in the December Consultation.

Implications of allowing a departure from the CEPT band plan - blocking effect (mobile to mobile interference)

3.5 The CEPT band plan, which is illustrated in Figure 1 below, divides the band up into 2 x 70MHz of paired / FDD spectrum and 50MHz of unpaired spectrum (available either for TDD or for downlink FDD spectrum which can be paired with uplink frequencies outside of the 2.6GHz band).

Figure 1: CEPT band plan from ECC Decision (05)05



3.6 The proposals put forward by Ofcom in the December Consultation maintain the 5MHz channel size and mandate the 120MHz duplex spacing between paired (FDD) uplink and downlink used in the CEPT plan. However, the December Consultation proposals allow two important departures from the CEPT band plan.

- They do not restrict the choice of technology to the IMT-2000 family (which includes 3GPP technologies but currently excludes WiMAX, although there is a process in train to add WiMAX standards to the IMT-2000 family).
- They allow for the unpaired (TDD) portion to expand to occupy more than 50MHz **if** the competitive process revealed demand for this through the auction.

3.7 Ofcom recognised in the December Consultation that, in auction outcomes where TDD is present in the top of the 2500–2690MHz range (2620 – 2690MHz), there could be additional blocking of FDD mobiles over and above that which could be expected under the CEPT band plan. Both Mason Communications[14] and Ofcom carried out some initial analysis of this problem in the December Consultation and concluded that the probability of unacceptable interference to FDD mobile terminals was small.

3.8 Several respondents to the consultation expressed concern with the Ofcom proposals to allow the auction to determine the split between paired and unpaired spectrum. In particular, there were concerns expressed about the possibility of the award resulting in a band plan in the UK that differed from the CEPT plan in ECC Decision(05)05. These concerns were expressed by some of the existing mobile operators (H3G, O2, Orange and T-Mobile) and by some equipment manufacturers (Nokia, Ericsson, Qualcomm and Siemens), all of whom are interested in the ability of operators to access FDD spectrum for use under 3GPP standards. In contrast, other respondents who appear interested in operators having access to TDD spectrum supported the proposals for flexibility.

3.9 The main concern of the first group of respondents about allowing a departure from the CEPT band plan was that the presence of TDD terminals in the top of the band would cause significant interference to FDD handsets operating anywhere in the band (the blocking effect)[15]. In particular, they felt that the Ofcom / Mason analysis underestimated the significance of the blocking effect which they felt could be much larger and which, in their view:

[14] See the Mason report, available at http://www.ofcom.org.uk/consult/condocs/2ghzawards/.
[15] Whilst they also noted the potential for interference from TDD base stations, it was accepted that these were of minor significance.

a) could lead to the need for UK specific FDD handsets which would be either impractical or prohibitively expensive; and

b) could further lead to problems for international roaming of terminals.

3.10 Some respondents (including Nokia) questioned the interpretation of the analysis in the December Consultation and suggested that, rather than the probability of interference across a network being the important factor, it is the probability of interference from the perspective of an individual user that is important.

3.11 Given the nature of the responses, Ofcom has examined further the question of whether the presence of TDD mobiles in the upper part of the 2.6GHz band (2620 – 2690MHz) could result in a significantly higher level of FDD blocking from TDD mobiles (with the worst case being that UK specific FDD terminals would be the only viable way that a potential FDD operator could make use of the band and maintain a reasonable level of service to its subscribers). The results of a new analysis of this blocking effect is summarised below.

3.12 In this part of Section 3 we therefore consider:

- the nature of blocking effect and its potential implications;
- results from a further study on the mobile-mobile interference;
- the interpretation of these results in terms of their practical implications for users, taking account of possible mitigation strategies; and
- Ofcom's overall assessment of the blocking effect.

3.13 Some respondents also commented that the use of the top of the band for TDD would require the use of at least one additional guard block and so would be spectrally inefficient. However, the relevant objective is to promote economic efficiency of spectrum use (i.e. the achievement of greatest value from use of this finite resource) and not to focus on technical efficiency *per se*, although it is often the case that pursuit of spectral efficiency will be consistent with pursuit of economic efficiency. The key point is that the auction design will take proper account of the loss of utility associated with the need for an extra guard block. This is because the winning combination of bids in the auction will be the one that maximises total value of use of the 2.6GHz band – and extra TDD use will only be part of this winning combination if the value associated with extra TDD use (as expressed in the value of bids submitted) exceeds the loss of value from this combination leading to the need for an extra guard block[16].

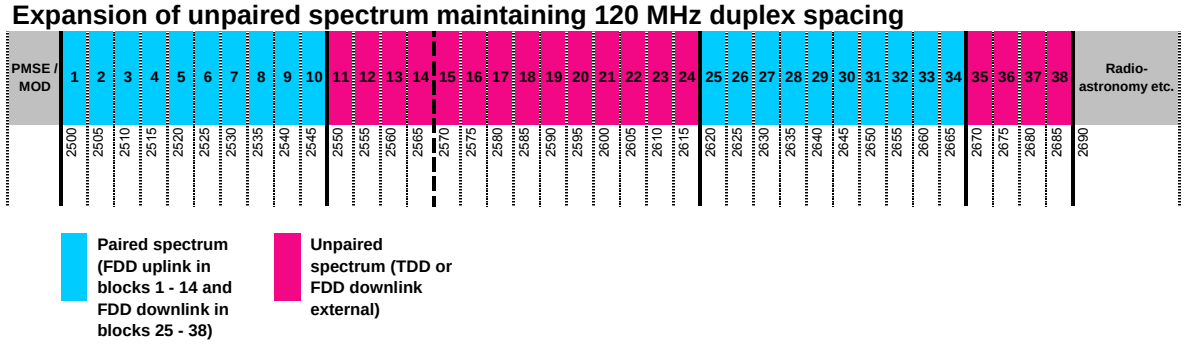
Nature of blocking effect and its implications

3.14 The blocking effect could occur if the auction outcome led to a presence of TDD terminals in the top part of the band as in the illustrative outcome in Figure 2 below

[16] We note, in passing, that it is not necessarily the case that additional TDD use, even allowing for the need for guard blocks, would lead to a less spectrally efficient outcome (in terms of total Mbit/s of data transmission across the whole 2.6GHz band). Both TDD and FDD have particular features that promote efficient use of the spectrum that they use, and the overall data transmission volumes will depend on a wide variety of factors such as the TDD and FDD technologies used, the balance between uplink and downlink data flows and the level of consumer demand for the services that might be provided using each type of spectrum.

(N.B. this diagram, and the one above, do not show restricted blocks and guard blocks for simplicity).

Figure 2: band plan with expanded TDD use



3.15 The blocking effect could arise for the following reasons.

- If customers are using standard 3G FDD handsets that have been designed for the European-wide market (which probably means “in conformity with the CEPT band plan”), then these handsets will have pass band filters that are designed to allow through any signals within the frequency range of 2620MHz to 2690MHz (channels 25 to 38).

- The FDD handset will be tuned to listen to the specific frequency channel that it has been assigned by its own FDD base station (i.e. somewhere in channel 25 to 34 in the example). However, if it also receives a strong signal at other frequencies allowed through by the pass band filter then it might suffer interference and be “blocked” (i.e. dropped connection / unable to find connection) as the tuning technology may not itself fully exclude these signals.

- If the outcome of the auction were to result in the use of TDD systems in the top end of the band (channels 35 to 38 in the diagram above) then there could indeed be TDD user equipment (laptops, PDAs etc) transmitting signals at frequencies which are at the top end of the band. Moreover, the signal strength received at the FDD handset could be high if the TDD user equipment is located very close to the FDD user.

- Of course, other FDD base stations would also be transmitting in the top end of the band at frequencies represented by channels 25-34. But as there will usually be significant physical separation between the FDD handset and FDD base stations, these unwanted FDD base station transmissions will not usually be sufficiently strong by the time they reach the FDD handsets to cause blocking.

3.16 We note that the blocking effect is associated only with TDD uplink use in the top half of the band (i.e. if TDD is used in channels 35 to 38 in the example in Figure 2). It would not result from an expansion of TDD into the bottom half of the band (channels 11 to 14 in the example). It would therefore be incorrect to imply that, if the blocking effect were considered material, there should be **no** departure from the CEPT band plan for this reason. At worst, it might be appropriate to constrain the use of TDD equipment in the top part of the band so as to limit its transmission characteristics (e.g. in the limit, make it “downlink only”) - but it would not be necessary to constrain the full use of TDD equipment in the lower half of the band (i.e. in lot 14 and below).

3.17 If the blocking effect were significant then, in principle and on the basis of submissions from stakeholders who oppose flexibility in the band plan, an FDD operator could react in one of two ways:

- use UK handsets designed specifically to cope with the UK allocation to TDD and FDD that results from the auction; this would increase the costs of service provision for UK customers (without removing the blocking risk for European FDD handsets roaming into the UK);

- use European handsets that are designed for the CEPT band plan and accept that there is scope for the blocking effect to reduce the quality of service experienced by users (although there would be no need to make special provisions to facilitate either inward or outward roaming in this case).

3.18 In practice, it seems very unlikely that the first option would be viable for a number of reasons. Special receiver filters could be required which would obviously add costs to handset manufacture. Whilst the costs of these filters may not be particularly high, the need to set up UK specific production runs and distribution channels would be more significant. It has also been suggested that, in effect, a new standardisation release would be required with a completely new band added to the 3GPP bands already defined and that new conformance testing arrangements would be needed. In practice, any given mobile design can only accommodate a limited number of specific bands. If a specific UK band is required then this will have to use up one of the limited number of 'band slots' available in a terminal and there is an opportunity cost of using this 'band slot' for a UK specific band when compared to using it for a band that might be used more globally. This opportunity cost is likely to be significantly larger than the actual cost of any UK specific components needed in the terminal. In addition there is an opportunity cost associated with the investment the handset manufacturer has to make to develop the UK specific terminal as opposed to designing a terminal which might have a much wider market and may be better able to leverage economies of scale. As a result, the number of FDD handset models available to UK consumers could be limited (and of higher cost than comparable handsets in countries where harmonisation benefits were able to be leveraged).

3.19 Discussions with handset manufacturers have reinforced the view that they would have limited interest in manufacturing a range of UK specific handsets.

3.20 Accordingly, we have concentrated our further analysis on the size of the blocking effect for an FDD handset designed with a pass band filter to match the CEPT band plan and on the potential for quality of service degradation.

3.21 We note that the potential for mobile-to-mobile blocking is not confined to FDD mobile terminals. The reverse scenario with (i.e. FDD mobile terminals blocking TDD mobile terminals when they operate within the receive pass band of the TDD mobile terminals) is equally relevant. It is Ofcom's understanding that WiMAX mobile terminals are likely to have a receive pass band which encompasses the entire 2.6GHz band (or a significant part of it) and are therefore likely to suffer a potential blocking problem regardless of whether or not the result of the award is consistent with the CEPT band plan. However, prospective WiMAX operators have not expressed concerns about the impact of blocking.

Summary of mobile-to-mobile interference study

High-level summary of the study methodology

3.22 In order to investigate the implications of introducing unpaired spectrum at the top of the 2.6GHz band, Ofcom has undertaken a simulation of UMTS performance in the presence of WiMAX interference. Full details of this simulation (and its results) are available in Annex 6.

3.23 In brief, the simulation examined the service implications for UMTS mobiles receiving UMTS downlink signals in the presence of WiMAX interferers. The study analysed the variation in the probability of blocking with changes in:

- the density of WiMAX mobiles within the UMTS network;
- the proximity of a WiMAX interferer to a UMTS mobile; and
- the use of power control by WiMAX mobiles.

3.24 In order to achieve these aims, a Monte Carlo[17] simulation technique was used to model the effect of WiMAX mobile terminals on a UMTS network, with the following assumptions being applied to all of the modelled scenarios:

- the UMTS network consisted of 37 hexagonal base stations (cells), with a centre cell surrounded by 3 layers of further cells;
- the UMTS mobiles were placed using a random distribution of mobile terminals across the 37 cells, and power control was applied to these terminals to reflect real-life operation;
- the WiMAX mobiles were represented as stand-alone active interferers which are transmitting 100% of the time and are placed in the UMTS environment in accordance with a defined distribution (which the modeller can adjust), while the WiMAX network itself was not modelled;
- an estimated WiMAX power control profile was used (IEEE 802.16e does not specify power control parameters) and was applied using a statistical distribution of where in the WiMAX cell the terminal was located;[18]
- parameters for the UMTS network and mobiles were drawn from 3GPP specifications, with parameters for the WiMAX mobiles from IEEE 802.16e and for propagation modelling from reference CEPT and ITU models;
- all WiMAX mobile terminals were taken to operate within the pass band of UMTS mobiles, in the upper part of the 2500–2690MHz band.

3.25 The simulation offered several degrees of freedom which allowed the model user to examine the impact on the probability of blocking through the variation of a number of parameters and assumptions (linking to the three variables highlighted earlier).

[17] Monte Carlo is a term used to describe solutions to mathematical problems which have many variables that cannot easily be solved. It involves randomly selecting a value (from a stated range) for the variables and then using these values for each individual calculation. This process is then repeated a finite number of times to build up a statistical result.
[18] This takes account of the fact that a complete WiMAX network is not modelled.

- Two types of WiMAX distribution could be modelled, with the user able to define the WiMAX mobile densities used in each:
  - a uniform probability distribution;[19] and
  - a hot spot distribution[20] initially centred upon the central UMTS base station.
- Two 'Interference Modes' were available:
  - Mode 0 - the WiMAX mobiles are left as they fall according to the distribution (either uniform or hot-spot); and
  - Mode 1 - the set of WiMAX mobiles are subject to a translation to place a randomly selected WiMAX interferer a set distance away from a randomly selected UMTS victim within the centre cell[21].
- Two values for WiMAX power control: "on" or "off".

3.26 For each set of inputs, the simulation carried out 1000 iterations to provide a statistically valid set of results. As such, it should be noted that the results of this analysis are subject to some level of statistical variance.

Summary of the study results

3.27 Figure 3 below shows the mean percentage of UMTS mobiles within the centre cell of the UMTS network which are rejected. The different series on the chart show:

- Background call rejection for UMTS mobiles in a standalone UMTS network (with WiMAX power control applied) (i.e. without the presence of WiMAX mobiles);
- Background call rejection for UMTS mobiles in a standalone UMTS network (without WiMAX power control applied);
- Background call rejection for UMTS mobiles and additional rejections through WiMAX interference (with WiMAX power control applied); and
- Background call rejection for UMTS mobiles and additional rejections through WiMAX interference (without WiMAX power control applied).

3.28 The first two of these series should, in theory, exhibit the same behaviour (as the use of WiMAX power control is irrelevant when WiMAX mobiles are not present). The differences between these two series in the chart highlight the statistical basis of the simulation and the fact that the results presented here are subject to statistical variance.

3.29 The charts show that UMTS background call rejection is approximately 0.5% in the absence of any WiMAX mobile transmissions. We would expect a similar level of

[19] Where the probability of a mobile being at any location is equal to the probability of it being at any other location (i.e. the probability is uniformly distributed).
[20] Where the distribution of WiMAX mobiles within 25m of the central UMTS base station was assumed to have a different (higher) density than mobiles outside of 25m of the central UMTS base station.
[21] This allows the examination of the blocking effect on the selected UMTS mobile in close proximity to a WiMAX interferer.

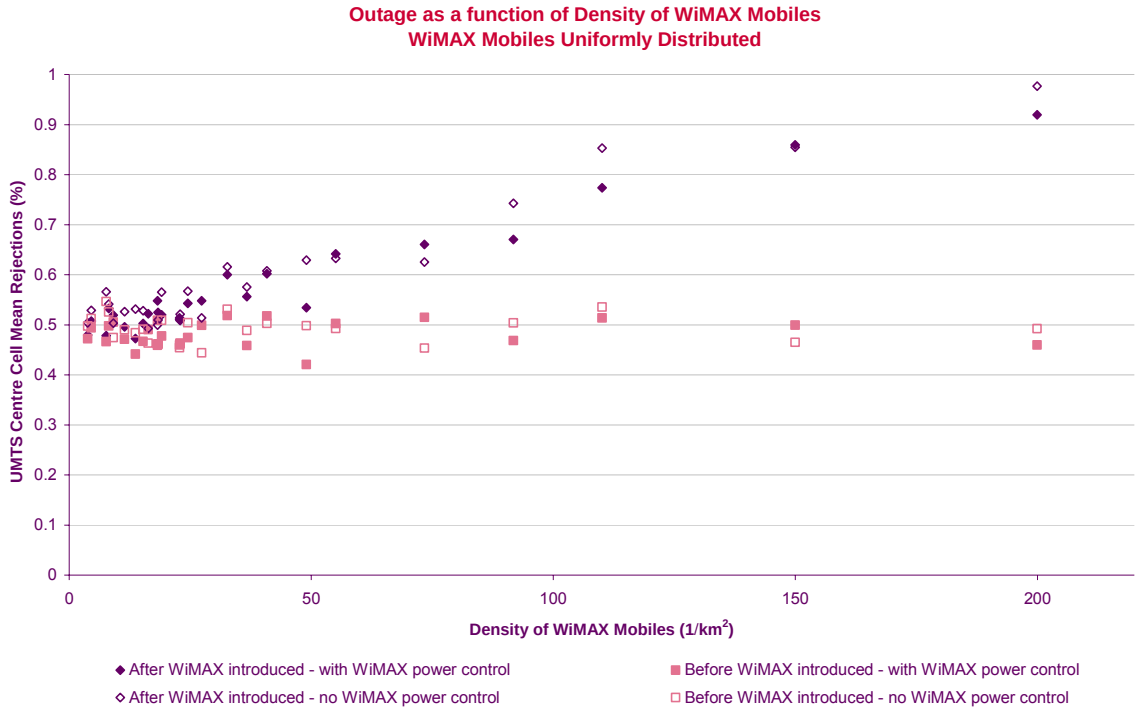
rejection could be expected for mobile terminals in a TDD/WiMAX network in the absence of other transmissions.

3.30 Using a uniform probability distribution of WiMAX mobiles across the UMTS network, the probability of UMTS rejection increases approximately linearly with increasing density of WiMAX mobiles.

- The additional probability of rejection (over and above that from UMTS self-interference) is less than 0.5% even up to a relatively high density of 200 WiMAX mobiles/km^2 (which equates to an average separation of approximately 80m between WiMAX mobiles)

- WiMAX power control marginally reduces additional rejections.

Figure 3: Probability of UMTS rejection – uniform WiMAX distribution with and without power control



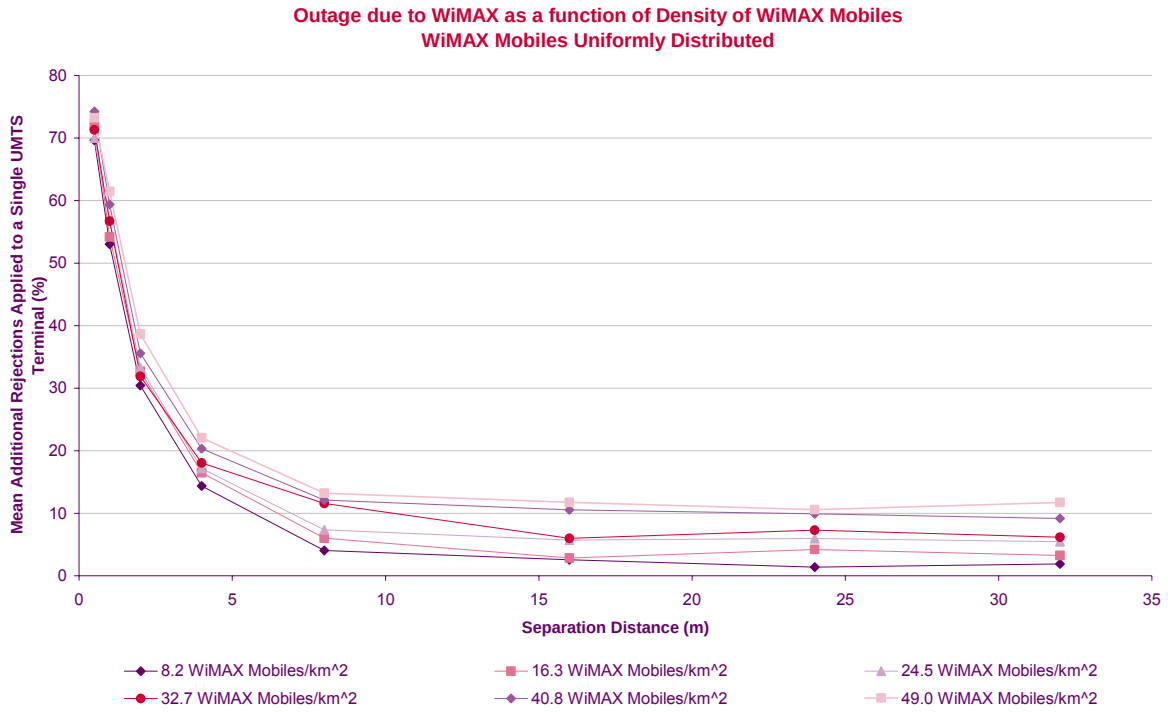
3.31 Figure 4 below shows the mean additional probability of a single UMTS terminal being blocked as separation distance from a WiMAX interferer varies for a range of WiMAX densities. As is the case for all of the results from the technical study, it is dependent on the underlying assumption that the UMTS mobile will be receiving and the WiMAX mobile transmitting at the same time.

3.32 Importantly, Figure 4 shows that the probability of UMTS rejections appear to be dominated by the proximity of a WiMAX interferer (rather than the overall density of WiMAX mobiles).

- Considering the likelihood of a single UMTS terminal to be rejected, the proximity of a WiMAX interferer does not significantly increase the likelihood of a UMTS mobile being blocked until separation distances drop below approximately 8 metres.

- For separation distances of approximately 8 metres or less, WiMAX interference increases rejections significantly until a single UMTS mobile is approaching 75% likely to be blocked at a separation of 0.5 metres.

Figure 4: Additional probability of UMTS rejection with separation distance and WiMAX density – uniform WiMAX distribution



3.33 The above results used a maximum power of 23dBm EIRP for the WiMAX mobiles. Figure 5 below shows how the effect of different power levels on the mean additional probability of a single UMTS terminal being blocked as separation distance from a WiMAX interferer varies (taking the WiMAX distribution of 8.2 WiMAX mobiles/km^2 for this purpose).

3.34 This graph displays results for three different maximum powers for the WiMAX terminals:

- 16dBm EIRP – representative of the average effect of pass band filters in the FDD mobile terminal in relation to the maximum WiMAX power (of 23dBm). This was chosen to help understand the impact of TDD terminals at the top end of the CEPT band plan centre gap which would exist regardless of whether the UK adheres to the CEPT band plan or not;

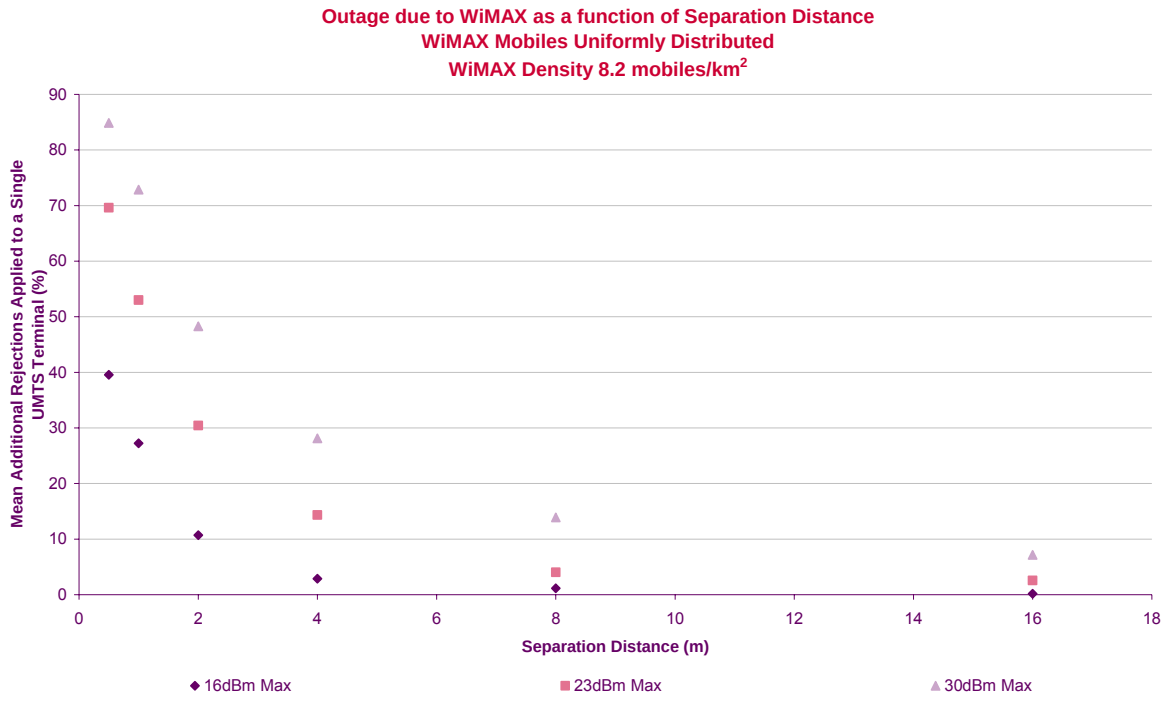
- 23dBm EIRP – the WiMAX terminal power used in the ITU-R working party 8F sharing studies; and

- 30dBm EIRP – the maximum mobile terminal power contained in the December Consultation (unlikely to be seen in real-life WiMAX terminals).

3.35 As shown in Figure 5 below, an increase or decrease in the power of the WiMAX mobile terminal results in a corresponding increase or decrease in the curve of probability of rejection and this variation is, in absolute terms, greater for shorter separation distances. Moving to larger separation distances (which would be more

representative of a uniform distribution) suggests that a variation in the power of the WiMAX mobile terminal has a limited effect under a uniform distribution This trend is exhibited regardless of the assumed WiMAX mobile density.

Figure 5: Additional probability of UMTS rejection with separation distance for a selection of powers of the WiMAX interferers – uniform distribution with 8.2 WiMAX mobiles/km^2



3.36 The main conclusions from the technical study are as follows.

- For both the uniform and hotspot WiMAX distributions studied, the introduction of WiMAX interferers using a uniform probability distribution for FDD handsets is not expected to raise the overall UMTS rejection rate to unacceptable levels – the additional call rejection rates (over and above the background UMTS call rejection rate) does not exceed 0.5%.

- However, when viewed from the perspective of an individual UMTS victim terminal, UMTS rejection rates start to become noticeable once separation distances decrease below 8 metres, with rejection rates for the victim terminal reaching levels approaching 75% at a separation distance of 0.5m.

- Varying the radiated power of the WiMAX interferers makes a significant difference to the probability of a single UMTS mobile being rejected when a WiMAX terminal is close by, but has a limited effect on overall UMTS rejection rates for the centre UMTS cell under a uniform distribution.

Interpretation of results on mobile-to-mobile interference

3.37 In light of the study results we now consider:

- the implications of average call rejection rates:

- the implications of short range blocking and potential mitigation; and
- the implications for European harmonisation.

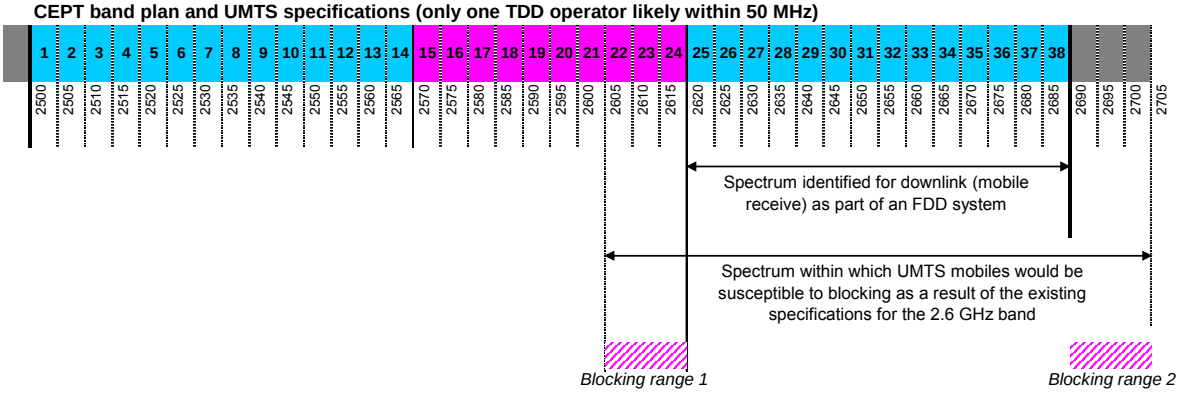
Implications of average rejection rates

3.38 When considering the implications of the above rejection rates it is important to note that a number of other factors will impact on the quality of service experienced by a UMTS handset. In particular:

- the Monte Carlo analysis indicates that the UMTS handsets will suffer a background call rejection rate of around 0.5% in any case;
- FDD handsets can expect to experience some blocking from TDD handsets even under the CEPT band plan because the specification for the pass band filter extends into the centre block for the reasons explained below.

3.39 The 3GPP specifications define both in-band and out-of-band blocking requirements for UMTS mobiles. Mobile terminals are expected to continue to operate satisfactorily in the presence of much higher signals when these appear out of band than when they appear in-band. The in-band blocking specification defined by 3GPP extends for ±15MHz either side of the nominal downlink reception band i.e. 2605 – 2705MHz. As shown in Figure 6 below, under the CEPT band plan this 15MHz range includes the top part of the centre band (2570–2620MHz) where it is likely that TDD mobile terminals would be operating (blocking range 1 in the figure below). FDD mobile terminals could therefore encounter blocking interference from TDD mobile terminals operating in this range, even if TDD mobiles were not operating in the upper part of the band. This would be as a result of a choice made by those involved in the standardisation process for UMTS at 2.6GHz in 3GPP, since they have the option of defining a pass band range that is narrower.

Figure 6: Blocking of UMTS mobiles under the CEPT band plan



3.40 In practice, FDD mobile terminals will be fitted with a pass band filter designed to attenuate out of band signals to a level where the terminal can meet the out-of-band blocking specification. This filter will use the 15MHz of spectrum between 2605–2620MHz to roll-off (i.e. gradually change from allowing in-band emissions to pass through to filtering out-of-band emission). Therefore, interfering emissions from TDD mobile terminals in the range 2605–2620MHz will be attenuated somewhat by this pass band filter. According to 3GPP TS 25.101, the blocking performance goes from –56dBm to –44dBm across this 15MHz range (an improvement of 12dB). Therefore, the effect will be similar to a reduction in the effective radiated power of the TDD

mobile terminal (see paragraph 3.34 above). In Figure 5 above, we have simulated the results of a reduction in EIRP of the WiMAX terminal of 7dB. This has the effect of roughly halving the rejection rate. The use of 7dB as an average attenuation due to the pass band filter across the 15MHz range is not an unreasonable proxy for the effect of interfering transmissions from TDD mobile terminals in the range 2605–2620MHz.

3.41 Therefore, although the introduction of unpaired spectrum towards the top of the 2500–2690MHz band would increase rejection rates, it would be incorrect to portray this as an entirely new issue for FDD operators and equipment manufacturers to consider.

3.42 Furthermore, when interpreting the impact of the average rejection rates, it should be borne in mind that that interference (blocking) is just one of a number of factors that could cause a call to be dropped including poor coverage, network congestion, user error, etc. In the context of overall quality of service Ofcom considers that a modest increase in blocking probability of less than 0.5% is not likely to make a significant difference to customer perception.

Short range blocking and potential mitigation

3.43 The analysis indicates that the chance of WiMAX mobile terminals causing blocking of UMTS mobile terminals if both are in operation begins to become noticeable at separation distances below 8 metres. Under a normal distribution of terminals, the likelihood of this proximity is relatively small (even when hotspot WiMAX distributions are considered). However, the average numbers do not necessarily reflect specific scenarios in which devices could be expected to be in close proximity (and in parallel use), such as in railway carriages, airport terminals, sports venues, etc. Although the analysis suggests there is still a significant chance of being able to achieve connections down to quite small separation distances, these scenarios could be a cause of concern to operators.

3.44 However, there are a number of potential mitigating factors which could substantially lessen the impact of blocking of FDD devices when TDD devices are in close proximity. These factors include:

- the potential presence of indoor micro- or pico-cells for UMTS or WiMAX (or both);
- the potential availability of alternative methods of service provision for UMTS operators in the case of interference from WiMAX; and
- the relative impact of blocking on the quality of service of voice communications and data communications.

3.45 In addition to the above factors, there could be mitigating factors in the design of UMTS handsets and these are discussed in more detail below.

3.46 Blocking is most likely to occur when the victim handset is at the edge of its reception area and when the interferer is at maximum power (i.e. the received signal from the base station is at its lowest strength and the interfering signal is at its strongest). As discussed above, the probability of blocking is highest when victim and interferer are in close proximity (which is, again, related to the strength of the interfering signal), such as in a hotspot or clustered environment.

3.47 Many of these 'hotspots' (such as airports, sports stadia and conference centres) are in fixed locations rather than being a randomly placed gathering of users. As such, it is likely that these locations would be covered by dedicated local cells (e.g. indoor micro- or pico- cells) by UMTS or WiMAX operators. In the case of a UMTS micro- or pico-cell being nearby, a UMTS mobile will not be operating at the edge of its reception area (and the received signal strength would be high). In the case of a WiMAX micro- or pico-cell, the WiMAX interferer may be transmitting at a lower power and would provide a lower level of interference to the UMTS mobile. The result of this is that blocking is much less likely to occur when user hotspots are covered by dedicated cells (either UMTS, WiMAX or both). This might not apply in the particular case of railway carriages as micro- or pico-cells are not deployed in these at the moment. We note, however, that other issues currently affect call quality on a train including lack of coverage in tunnels and cuttings and a generally inconsistent level of coverage along a given line.

3.48 The majority of interest in the future use of spectrum for FDD shown in the responses to the December Consultation came from the existing Mobile Network Operators[22] (MNOs). An existing mobile operator may use the 2.6GHz band to supplement their existing spectrum holdings (by essentially using it to provide greater capacity to offer similar services) or to complement their existing spectrum holdings to offer services that are difficult or not practical to offer elsewhere (maybe due to bandwidth limitations). In either case, these operators would have alternative spectrum available. For a subscriber to one of these operators, access to a range of spectrum bands will be available in the user terminal and through the network management software of the operator, which will attempt to balance the traffic from all their subscribers across their different network layers (different spectrum bands) as efficiently as possible. If a user is denied service (either when looking to initiate a connection or during a call) due to a blocking problem at 2.6GHz then it may be possible for the connection to be switched to an alternative band (if available).

3.49 It is also possible that the 2.6GHz band is more likely to be used for data services rather than voice. Packet-based data services are bursty by their nature (i.e. transmissions are limited to the duration of each packet). This means that, unless the victim is receiving a packet simultaneously with the interferer transmitting a packet, then blocking interference may not be relevant. There will obviously be a statistical relationship between the probability of a packet being transmitted by an interfering terminal and one being received by a victim terminal and this will vary depending on the nature of the services in question. However the probability of a collision (between a victim receiving a packet and an interferer transmitting a packet) will be low and therefore the impact of blocking will be much reduced in data based networks. For instance it is very unlikely that non real time services will fail completely (as lost packets can be re-sent). Also for real time services such as VoIP or video streaming, forward error correction techniques may well mean than even though quality of service deteriorates somewhat, there will not be a complete failure of service.

3.50 It should be noted that other European regulators are contemplating allowing TDD mobiles to operate in the upper part of the band. For example, both Norway and the Netherlands have published plans to award the 2.6GHz band that include potential TDD operation in the pass band of UMTS mobile. It is possible that other regulators within Europe could similarly allow for TDD operation within 2620-2690 MHz. The European landscape is therefore likely to be rather complex as far as the split between TDD and FDD is concerned. In some countries the CEPT band plan will

[22] The MNOs include four 2G MNOs (O2, Orange, T-Mobile, Vodafone) and five 3G MNOs (H3G, O2, Orange, T-Mobile, Vodafone).

probably be used, whilst in others, a different band plan including TDD use within 2620-2690MHz may be preferred. Given this, it is possible that FDD terminal manufacturers could consider this flexibility in their handset designs to ensure that these have as large a market as possible in Europe while offering the greatest protection possible from harmful interference.

3.51 It has been put to Ofcom that a practical and cost-effective way of achieving such a flexible design is to incorporate tuneable filters into terminals built for the European marketplace. These filters could allow the handset to narrow its effective receiver pass band to the subset of frequencies assigned to the particular operator to whose network the equipment is connected. Filters require some frequency range to roll off but the use of this technique could significantly improve the blocking performance of terminals in the presence of in-band TDD.

Harmonisation benefits

3.52 One of the concerns expressed in responses was that the introduction of flexibility into the design of the award could undermine the benefits of harmonisation of the 2.6GHz band across Europe.

3.53 A key advantage of many countries making spectrum available under similar technical conditions is that it makes it easier for vendors to access the economies of scale available from making equipment for a much larger marketplace. It can also make it easier to provide roaming between countries (though there are various possible solutions to this, not all of which rely on harmonised spectrum, e.g. a handset can have dual chipsets which access different frequencies). These are substantial benefits which we support by working with other regulators in Europe to open the door for market-led harmonisation (i.e. through the creation of harmonised band plans which industry can exploit but which are non-mandatory and are not exclusive to one technology).

3.54 In fact, Ofcom's proposals for the 2.6GHz band adopt key aspects of a mandatory harmonisation by using the 5MHz channel size and mandating the 120MHz duplex spacing between FDD uplink and downlink used in the CEPT plan. These proposals have been universally supported by stakeholders in their responses. This approach should, in our analysis, facilitate a market led harmonisation in which the scale and roaming benefits can be achieved where similar FDD technologies are deployed in different countries because:

- the 5MHz channel lot size, and the 120MHz duplex spacing, will define the basis for design and manufacture of handsets that can operate on a European wide basis using the 2.6GHz band (N.B. operators might deploy 3G technology in the FDD parts of the 2.6GHz band using 5MHz channels; or they might acquire several 5MHz lots in order to create channel widths of 10MHz, or possibly even 15MHz or 20MHz in future, for example for LTE[23] technology);

- it seems unlikely that operators and vendors would respond to concerns over blocking of 3G handsets by making handsets specifically tailored for the UK market. Indeed, several 3G operators and 3G vendors made this point to us quite strongly. Hence, if the 2.6GHz band is used to expand capacity on 3G networks in the UK then the handsets that are used in UK are likely to be the same as those used throughout Europe (i.e. they are likely to have a pass band filter that covers the full FDD downlink band from 2620MHz to 2690MHz).

[23] Long Term Evolution, the planned successor to 3G/UMTS technology.

3.55 As regards the unpaired, or TDD, use of the 2.6GHz band, feedback indicates that the most likely use will be for WiMAX. Ofcom understands that WiMAX mobile terminals are likely to be sourced from international specifications which have a receive pass band encompassing the entire 2.6GHz band (and that prospective WiMAX operators seem unconcerned about the equivalent blocking effect). This should permit access to the economies of scale in handset manufacture and access to roaming benefits across Europe and, indeed, outside of Europe as well.

Overall conclusions on the blocking effect

3.56 Ofcom recognises that the blocking issue is a source of legitimate concern. However, the further analysis undertaken suggests that its significance needs to be assessed in the context of the following points.

- Monte Carlo analysis suggests that, from the perspective of an entire cell, it is unlikely that Ofcom's proposed award would lead to a situation where there are unacceptable levels of blocking of FDD mobile terminals by TDD mobile terminals operating within the receive pass band of the FDD terminals. Additional call rejection rates are below 0.5% in all cases considered.

- Monte Carlo analysis further suggests that, from the perspective of an individual victim terminal, blocking can be a problem for separation distances below 8 metres with the blocking probability typically rising towards 75% for a distance of 0.5 metres where both devices are in operation simultaneously.

- In most situations it is unlikely that purely random use of terminals would lead to situation where FDD and TDD terminals will be operating closer than 8 metres together. But there are specific situations where the assumption of random distributions (both spatially and temporally) is not valid (such as conference centres, railway carriages, airports, sports stadia, etc.). Blocking could be a more significant issue in these specific situations. However, there are a number of potential mitigating factors which could substantially lower the probability of a UMTS user being subject to blocking:

  - use of dedicated micro- or pico-cells to cover hotspots would significantly reduce the probability of blocking interference;

  - FDD operators with alternative spectrum bands could balance traffic across their different network layers and avoid interference problems by hopping from one band to another (the interest expressed in FDD use so far comes from parties in this position);

  - where both FDD and TDD users are using packet based data services then interference is only likely to occur when packets are actually being transmitted (by a TDD user) and received (by an FDD user). Given the bursty, intermittent nature of packet based transmissions this would effectively reduce the probability of blocking when compared to services which rely on continuous transmission.

- Other European countries could deviate from the CEPT band plan, which may increase the incentive to produce more flexible mobile devices anyway; for example, it may be possible for the blocking performance of FDD terminals to be significantly improved by the use of tuneable filters.

- The packaging proposals retain the essential features (5MHz channel width and 120MHz duplex spacing) required to facilitate a market-led harmonisation across Europe.

3.57 In reaching a view on whether to allow the flexibility to depart from the CEPT band plan (not restricting the band to IMT-2000 and allowing the paired / unpaired split to be market-led) it is necessary to strike the appropriate balance between:

- the potential for increased interference to FDD handsets;
- the economic value that might be released by allowing increased access to the 2.6GHz band for non-IMT technologies and for technologies that use unpaired spectrum.

3.58 Overall, Ofcom's assessment is that the proposal in the December Consultation to allow flexibility for the auction to determine the split between FDD and TDD spectrum should not lead to unacceptable levels of interference due to mobile-to-mobile blocking. And, as discussed in Section 7, we believe that there could be significant economic advantage from allowing scope for increased market entry using unpaired spectrum in excess of 50MHz.

3.59 In Section 5 we consider the related issue of whether, under the proposed flexible approach, the potential for increased interference into FDD handsets should be recognised in a modification to the auction design (whereby bids become contingent on whether or not the auction results in TDD use in the upper part of the 2.6GHz band).

Question 1: Do stakeholders agree with Ofcom's assessment of the blocking effect and of its implications for spectrum packaging?

Technical restrictions to manage interference between adjacent users: FDD-TDD in-band adjacencies

3.60 A number of stakeholders commented on the nature of interference effects between adjacent users and on the implications for the technical restrictions that will be required in the technical conditions attaching to the licences. Annexes 7, 8 and 9 report on the further work that we have carried out on these matters. This sub-section considers the potential interference from FDD-TDD in-band adjacencies and draws conclusions on the nature of the technical restrictions required to accommodate adjacent users.

3.61 The two sub-sections following this one consider the interference to and from adjacent PMSE users and interference from radar use above 2700MHz.

Concerns raised in responses to the consultation

3.62 On the issue of FDD-TDD in-band interference, several respondents to the December Consultation expressed the view that the proposal for a 5MHz restricted block and modified out-of-band emission mask between adjacent FDD and TDD users was not sufficient to provide adequate interference protection. Of the existing mobile operators H3G, Orange and T-Mobile supported this view as did certain equipment manufacturers including Ericsson, Motorola, Qualcomm and Siemens.

3.63 However, many other respondents agreed with Ofcom's proposals including O2 and Vodafone, BT, BAA, Inquam Broadband, Intel, National Grid Wireless and Samsung.

3.64 Of those respondents who raised concerns, many believed that Ofcom should adopt a guard band approach with emissions specifically prohibited in spectrum between adjacent FDD and TDD uses and that these guard bands should be significantly larger than 5MHz.

3.65 As a consequence of the concerns raised, Ofcom has carried out an additional study specifically looking at the FDD/TDD adjacent use issue and the adequacy or otherwise of our proposed mask. This study has concentrated specifically on the impact of a WiMAX network on UMTS WCDMA[24] network deployed in adjacent spectrum. The study is summarised below and the full report is provided in Annex 7.

3.66 As noted, the principal concern that has been expressed relates to circumstances in which FDD is the potential sufferer of interference caused by TDD. Similar concerns could be raised in relation to TDD suffering interference from FDD. However, respondents to the December Consultation did not raise this as a concern and it is therefore not considered in detail in this document.

Summary of FDD/TDD adjacent channel interference study

Scope of the interference study

3.67 In order to inform the design of the technical licence conditions and the award process, Ofcom has endeavoured to understand more about the relative cost to deploy a network under different adjacent channel interference (ACI) conditions that might arise as a consequence of our original award proposals.

3.68 The study looked in detail at the network requirements of a licensed operator of paired spectrum deploying an FDD system to provide a consistent quality of service in the presence of different types of ACI.

3.69 The main focus has been to compare the cost of any mitigating measures required by a national network operator to counter the effects of ACI given the presence of another national operator in the adjacent channel. Specifically, the impact of a TDD neighbour has been compared with that of a FDD neighbour assuming that both are compliant with the spectrum masks proposed in the December Consultation. However, this methodology would allow other types of ACI to be assessed quickly in a similar manner and it is the case that a TDD network operator would see interference from neighbouring FDD systems and other TDD systems.

3.70 Given a victim system, in this case the FDD operator, there are generally 4 sources of adjacent channel interference that can have a detrimental effect on the performance of the network. These are:

- cell shrinkage through base station to base station uplink interference;
- cell shrinkage through mobile to base station uplink interference;
- dead zones due to base station to mobile downlink interference; and
- dead zones due to mobile to mobile interference.

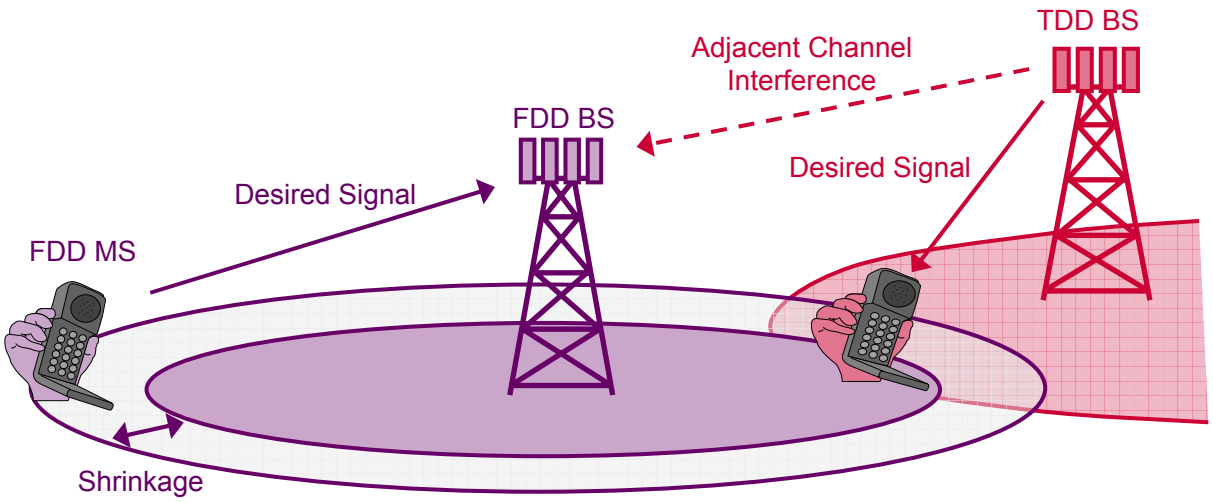
[24] Wideband Code Division Multiple Access, a modulation technique.

3.71 As indicated above, the study has focused on the impact of ACI on network infrastructure (i.e. base stations) and therefore concentrates on the first two cases above (interference to base stations) and we describe each of these scenarios in turn below. Dead zones are the result of interference into mobiles and Ofcom has carried out a separate study on the probability of FDD mobile terminals being blocked by TDD mobile terminals in such a way (see the previous sub-section above for a summary of the blocking effect from mobile to mobile interference, with the full study available in Annex 6).

Cell shrinkage through base station to base station uplink interference

3.72 An example situation is shown in Figure 7 where a victim base station receives interference from an interfering base station nearby. The interference appears as noise on the front end of the victim base station and this has the effect of desensitising the victim receiver. The result is that the victim can no longer 'hear' its own mobiles at the cell edge and so effectively the individual cell coverage is diminished (i.e. the cell shrinks).

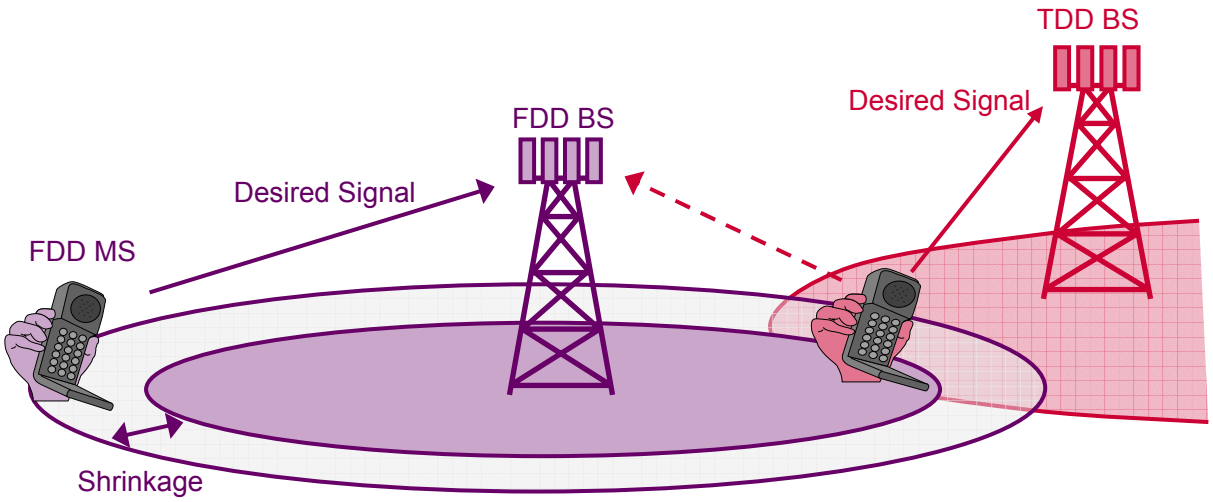
Figure 7: Base station to base station ACI uplink cell shrinkage



Cell shrinkage through mobile to base station uplink interference

3.73 This situation is similar to that described above and is illustrated in Figure 8 below. In this case the interference is from a TDD mobile on an adjacent carrier operating within the coverage area (or even beyond in extreme cases) of a victim base station. Again, the interference appears as noise on the front end of the victim desensitising the receiver and shrinking the effective coverage.

Figure 8: Mobile to base station ACI uplink cell shrinkage



Comparison to the FDD/FDD case

3.74 In FDD systems the problem of ACI is rendered negligible in most cases. In such systems the uplink and downlink signals are separated in frequency by a "duplex spacing" which is normally at least several times greater than the bandwidth of the system. This means that sensitive receivers are separated from potentially hostile transmitters by a significant amount of spectrum. ACI produced by a transmitter can be reduced enormously over a large bandwidth using standard filtering techniques thereby avoiding the need for expensive, high performance equipment.

3.75 On the other hand, TDD systems by their nature transmit and receive in the same band. Therefore, there exists the possibility that a network element (base station or mobile) could be attempting to receive a relatively weak signal whilst another element nearby is transmitting at high power. If the two systems are in adjacent channels then the interference can be significant and degrade system performance. Traditionally in TDD systems this can be resolved by synchronising uplink and downlink transmissions across networks in the band.

3.76 In the case of the spectrum in the 2,6GHz band, the main problem is that the spectrum contains sub-bands of paired and unpaired frequencies that will likely be used to deploy FDD and TDD systems respectively. Where these bands meet there is the possibility to have an FDD system in one channel and a TDD system in the adjacent channel (though, with Ofcom's proposals for a restricted channel the immediately adjacent TDD carrier could only be used at a low power). In this case there is no duplex spacing or synchronisation to reduce the effects of ACI and hence other measures must be found to prevent a degradation of system performance.

Methodology used in the study

3.77 The methodology adopted for the study is as follows.

a) Calculate link budgets for the candidate technologies deployed in the different bands.

b) Conduct a baseline dimensioning exercise for green-field networks (i.e. with no adjacent channel interference).

c) Calculate Adjacent Channel Protection ratios based on proposed spectrum masks and equipment specification standards.

d) Use the technique of Minimum Coupling Loss (MCL) to establish the isolation required between systems and how this translates to minimum site-to-site distances needed to prevent interference.

e) Assess mitigation measures and recalculate the minimum separation distances.

f) Where ACI is still an issue, the final step is to relate the resulting cell shrinkage to site density and hence relative network cost.

3.78 In the following sub-section, we summarise the results of the analysis for the TDD base station adjacent channel interference to FDD base station and the TDD mobile adjacent channel interference to FDD base station cases, assuming conservative mitigation estimates). Full results and details on the input parameters are contained in Annex 7.

Analysis of the results of the TDD base station ACI to FDD base station case (taking into account conservative mitigation estimates)

3.79 Our analysis assesses the potential for interference at a FDD base station for three possible cases for TDD (WiMAX) base station power in the adjacent channel:

- Unrestricted – this represents the case where a 10MHz WiMAX system is deployed at the maximum power allowed for by the December Consultation proposals (i.e. 63.5dBm assuming a 9MHz carrier);

- Typical – this represents a case where an in band power likely to be more representative of a 'real' deployed WiMAX system is used (i.e. 56.3dBm assuming a 9MHz carrier[25]); and

- Restricted - this represents the case where a 5MHz WiMAX system is deployed in a restricted channel (i.e. 34.5dBm assuming a 4.5MHz carrier).

3.80 A conclusion that can be drawn from the analysis in Annex 7 is that without some element of additional mitigation ACI is likely to be a problem for most deployment scenarios where TDD systems occupy spectrum adjacent to FDD systems.

3.81 In this case, the ACI is not necessarily catastrophic. As the interferer moves closer to the victim site, the effect is to raise the noise floor and effectively shrink the coverage area of the victim cell.

3.82 In practice several measures can be implemented to mitigate against ACI and these have been covered extensively by Mason Communications.[26] However, various responses to the December Consultation commented that the values chosen in that report were towards the limit of what is achievable and in some cases (e.g. antenna azimuth alignment) not practical.

[25] 'Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation', WiMAX Forum, August 2006

[26] See Mason's report at http://www.ofcom.org.uk/consult/condocs/2ghzawards/.

3.83 For the purposes of the study in Annex 7, therefore we have restricted ourselves to more pessimistic values that better reflect what is readily achievable in practice, with Table 2 below showing the values of additional isolation we have assumed.

Table 2: Additional isolation from base station to base station ACI mitigation

Mitigation: conservative estimates (dB)	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Co-lo antenna separation	25	25	25	25
Building penetration loss	10	0	0	0
Antenna downtilt	0	0	1	1
Antenna azimuth	0	0	2	2
Antenna filtering	10	10	45	45
Total co-located	**35**	**35**	**70**	**70**
Total far field	**20**	**10**	**48**	**48**

3.84 Table 3, Table 4 and Table 5 below represent the probability of ACI occurring (assuming the above mitigation) for different unrestricted, typical and restricted cases for the range of different geo-types considered in the analysis (see Annex 7 for more details). The first columns in Table 3 and Table 4 are blank as it is not possible under the spectrum mask restrictions to allow an unrestricted transmitter at 2.5MHz offset from the band edge.

Table 3: Probability of interference with ACI mitigation (unrestricted TDD base station power)

Probability of interference: unrestricted	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban		0.5%	0.1%
Suburban		0.1%	0.0%
Rural		0.0%	0.0%
Road/rail		0.7%	0.3%

Table 4: Probability of interference with ACI mitigation (typical TDD base station power)

Probability of interference: typical	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban		0.1%	0.0%
Suburban		0.0%	0.0%
Rural		0.0%	0.0%
Road/rail		0.3%	0.1%

Table 5: Probability of interference with ACI mitigation (restricted TDD base station power)

Probability of interference: restricted	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	1.8%	15.1%	0.0%	0.0%
Suburban	0.2%	1.7%	0.0%	0.0%
Rural	0.0%	0.2%	0.0%	0.0%
Road/rail	1.4%	4.0%	0.1%	0.1%

3.85 As can be seen above the worst case of interference occurs when restricted channels are used at 2.5MHz offset outdoors (i.e. 15.1 %). This reflects the fact that there is no frequency separation between the edge of the victim FDD base station and the interfering TDD base station and that building penetration loss is not available as a mitigating factor. This is very much a worst case, with the next worst probability of interference being considerably lower than this (at 1.8% at 2.5MHz offset indoors) with the main difference to the outdoors case being the inclusion of building penetration loss.

Analysis of the results of the TDD mobile ACI to FDD base station case (taking into account conservative mitigation estimates)

3.86 A similar analysis to the above TDD base to FDD base case has been carried out for the case of TDD mobile causing ACI to FDD base station.

3.87 For this analysis two cases where considered as follows.

- Unrestricted – this represents the case where 5MHz or 10MHz WiMAX mobiles are deployed at the maximum power allowed for by our consultation proposals (i.e. 33.5dBm assuming a 9MHz carrier and 30.5dBm assuming a 4.5MHz carrier).

- Typical – this represents a case where an in band power likely to be more representative of a 'real' deployed WiMAX mobile is used (i.e. 23dBm for both 9MHz and 4.5MHz carriers[27]).

3.88 Table 6 below shows the values of additional isolation we have assumed.

[27] 'Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation', WiMAX Forum, August 2006

Table 6: Additional isolation from mobile to base station ACI mitigation

Mitigation: conservative estimates (dB)	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Co-lo antenna separation	25	25	25	25
Building penetration loss	10	0	0	0
Antenna downtilt	0	0	0	1
Antenna azimuth	0	0	0	2
Antenna filtering	10	10	45	45
Total co-located	**35**	**35**	**70**	**70**
Total far field	**20**	**10**	**48**	**48**

3.89 Table 7 and Table 8 below represents the probability of ACI occurring (assuming the above mitigation) for different unrestricted and typical cases for the range of different geo-types considered in the analysis (see Annex 7 for more details).

Table 7: Probability of interference with ACI mitigation (unrestricted TDD mobile power)

Probability of interference: unrestricted	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	1.5%	5.3%	0.0%	0.0%
Suburban	0.7%	2.4%	0.0%	0.0%
Rural	0.7%	2.4%	0.0%	0.0%
Road/rail	8.1%	15.6%	0.0%	0.0%

Table 8: Probability of interference with ACI mitigation (typical TDD mobile power)

Probability of interference: typical	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	0.9%	2.0%	0.0%	0.0%
Suburban	0.2%	0.9%	0.0%	0.0%
Rural	0.2%	0.9%	0.0%	0.0%
Road/rail	5.0%	9.6%	0.0%	0.0%

3.90 As for the base station to base station case the worst case interference occurs for the 2.5MHz offset outdoors case. However, here the worst case occurs for the road/rail scenario rather than the urban scenario that occurred in the base station to base station case above. The reason that, for TDD mobile to FDD base station, the road/rail case is the worst is that mobiles are typically restricted to one dimension (i.e. along the road or railway line) rather than to an area – the probability of interferers being within a certain distance (r) of a victim base station is proportional to $1/r$ rather than $1/r^2$ (as would be the case for an area distribution). As $1/r$ falls off much less rapidly than $1/r^2$ with increasing r then a probability of interference based on a linear distribution of interferers is likely to be higher than one based on an area

distribution (as interference is more likely to occur the nearer to the FDD base station a TDD mobile is located).

Cost implications

3.91 For an operator wishing to deploy a WCDMA network in the FDD spectrum adjacent to the TDD band where a WiMAX system is deployed, the main additional cost will be from additional filtering to mitigate against the effects of ACI.

3.92 As a coarse estimate a filter will cost of the order of £500. Assuming 2 TRxs per sector on a 3-sector site equates to 6x£500 = £3000 per site.

3.93 Site acquisition and build costs are generally of the order of £40 to £50k per site, thus additional filtering would represent a small fraction of the overall cost to deploy a network.

3.94 For a national roll-out of say 7000 sites, this would represent an additional cost of approximately £20 million (compared to site costs of £280–350 million).

Conclusions of the FDD/TDD in band interference analysis

3.95 The main conclusions to be drawn from this analysis are as follows.

- Acceptable levels of performance can be readily achieved by implementing a relatively modest level of mitigation between the systems in the form of additional filtering applied to the WCDMA base station receiver.
- It should be possible to achieve greater isolation than the mitigation figures presented imply which will result in even better performance.
- The spectrum masks proposed in the December Consultation are adequate to limit interference to adjacent channels from the TDD band. The limiting factor on the adjacent channel performance is the specification of the receiver equipment.
- Implementation of additional receiver filtering will be a significant cost to a network operator in the band adjacent to TDD systems. However, compared with site acquisition and deployment costs it is likely to be a relatively small fraction of total wireless network costs.
- However, use of TDD in the restricted channel adjacent to the FDD uplink can still cause ACI problems in some scenarios.

3.96 As a result, Ofcom considers that the proposals set out in the December Consultation in respect of FDD/TDD coexistence remain largely appropriate. However, there may be a case for placing additional restrictions on the use of TDD in the restricted channel adjacent to the FDD uplink to improve the outdoor interference case – this is discussed further in Section 4 on technical licence conditions.

3.97 It should be noted that although our analysis has been restricted to the case of TDD interference into the FDD uplink, largely similar results would be expected for the TDD to TDD case where synchronisation is not possible and this supports the proposal for a restricted block between TDD users that was contained in the December Consultation. Any additional restrictions on the use of TDD in the restricted channel adjacent FDD uplink would equally well apply to the TDD to TDD case.

Technical restrictions to manage interference between adjacent users: PMSE adjacencies at 2500MHz and 2025MHz

3.98 Programme making and special events (PMSE) use for video applications is adjacent to the 2.6GHz and 2010MHz bands. PMSE users share the adjacent bands with other users such as the MoD, in both cases, and licence-exempt applications such as WiFi in the range 2400-2483.5MHz. PMSE users were notified in 2002 that the 2.6GHz band would be removed from the pool of spectrum bands available for PMSE use, in order to allow the development of mobile services in accordance with international regulatory provisions, and PMSE users have had access to the bands 2025-2110MHz and 2200-2290MHz from 2003 in place of the 2.6GHz band. The 2010MHz band had also been identified internationally for mobile use and was identified for award in due course.

3.99 In response to the December Consultation, JFMG and the BBC considered that the conditions at the two adjacencies needed to be clarified and that the initial assessment carried out by Mason was based on parameters that over-estimated the ability of PMSE equipment to operate in the presence of interference from neighbouring users.

3.100 Ofcom has carried out further work, commissioning ERA to assess the technical characteristics of PMSE equipment as well as the benefits and practicality of using filters on PMSE receivers to improve coexistence. The results from this work, presented at Annex 8, highlight that the parameters suggested by JFMG provide a more accurate basis for modelling PMSE equipment. The results also show that PMSE users could achieve additional mitigation in the first two channels from the adjacencies by using receiver filters with reasonable form factors. Based on this information, Ofcom has updated its assessment of the risk of interference between likely future uses in the 2.6GHz band and PMSE use below 2500MHz and above 2025MHz; the results are set out at Annex 8.

3.101 It should be noted for the 2500MHz boundary, as indicated in the December Consultation, that base station transmitters are only likely to be deployed adjacent to PMSE channels if all lots in the 2.6GHz band were to be used for unpaired use. In such a case restrictions would apply to base station transmissions in the bottom two 5MHz lots at 2500-2505 and 2505-2510MHz which would help to limit any impact on PMSE use.

3.102 This updated assessment shows that, in the expected environment of operation, there remains some risk of interference between new mobile uses and adjacent PMSE in two channels adjacent to a boundary (i.e. PMSE use at 2480-2500MHz and 2025-2045MHz). It is important to note that for the risk of interference to materialise, a number of factors would need to be combined within a given perimeter, with a PMSE user operating in channels at the adjacency (rather than any other PMSE channel), equipment operating in the 2.6GHz or 2010MHz bands operating in adjacent channels while in close proximity to the PMSE receiver (and probably in direct line of sight), and both the PMSE receiver and the mobile system transmitter being active at the same time.

3.103 Ofcom's view is that, although a risk of interference is likely to exist at frequencies close to the boundaries, mitigation is likely to be available to PMSE users in a range of circumstances. In particular, it will be possible to:

a) give consideration to the environment in which they operate, by placing receivers as a function of where base stations and/or mobile stations may be located to avoid direct line of sight within relatively short perimeters;

b) take advantage of the directionality of the equipment (or possibly to improve it);

c) lower the modulation of the transmission (though at the expense of resolution);

d) consider the deployment of diversity receivers;

e) use other channels; and

f) possibly use receiver filters.

3.104 Ofcom considers that the risks of interference occurring in practice are sufficiently low. We also note that PMSE users make use of channels directly adjacent to spectrum used for 3G services (downlink/base station transmit, above 2110MHz), including in dense urban areas.

3.105 Consequently, Ofcom is not proposing to impose any restrictions on uses either side of the 2.6GHz or 2010MHz boundaries. Users of the 2.6GHz and 2010MHz bands would therefore be able to use all blocks, including 2500-2505MHz and 2010-2025MHz, without specific restrictions in respect of the adjacency with PMSE, and PMSE users would retain access (subject to existing restrictions) to existing channels, including 2480-2500MHz and 2025-2045MHz. It would be for PMSE users to employ available mitigations measures as they see fit. PMSE users may also decide to use other channels further away from the adjacencies.

3.106 Ofcom plans to consider these matters further with JFMG and interested PMSE users during the consultation period.

Technical restrictions to manage interference between adjacent users: radar use above 2700MHz

Background

3.107 This sub-section provides an update on the potential impact that out-of-band (OOB) emissions from current radar allocations may have on candidate mobile systems that are likely to operate in the 2.6GHz band. It expands on the analysis presented in December 2006 within the Ofcom technical study on adjacent and in-band compatibility[28] (the “December Ofcom Technical Study”) by providing Ofcom’s estimates of interference that may be received from ground-based military radar systems that are operational within the UK, based on the information available to Ofcom.

3.108 Ofcom has also commissioned a study from ERA Technology Ltd to estimate the effect that adjacent channel interference from different types of radar systems may have on candidate mobile systems. Its provisional results are briefly discussed in this sub-section and Ofcom expects to make ERA’s report available in due course, when tests and measurements are completed.

3.109 The band 2700 – 2900MHz has a primary allocation to the Aeronautical Radionavigation service and a secondary allocation to the Radiolocation service.

[28] http://www.ofcom.org.uk/consult/condocs/2ghzawards/technicalassessment/

These allocations are identified within the UK Frequency Allocation Table (2007)[29] and the International Telecommunication Union (ITU) Table of Frequency Allocations contained within the Radio Regulations. In the UK the band is jointly managed by the Directorate of Airspace Policy of the Civil Aviation Authority (DAP/CAA) and by the Ministry of Defence (MoD). It is extensively used for air traffic control (ATC) by the National Air Traffic Services (NATS), by other organisations that operate airports and by the MoD operating at fixed locations and from designated training areas. The MoD also uses the band for meteorological and other military purposes.

3.110 Most UK civil regional airports and military airfields are equipped with ground-based ATC radars used for aeronautical surveillance operating within the 2700 – 2900MHz band. Such radars provide the main radar coverage around airfields.

3.111 As indicated in the December Ofcom Technical Study, the DAP/CAA has provided Ofcom with information on twenty two civil radar systems that it manages that have frequency assignments in the 2700 – 2790MHz band. Ofcom has selected this range to capture the majority of the radar OOB emissions that are likely to fall into the 2.6GHz band.

3.112 Based on the information provided by the CAA on current civil ATC radar assignments, Ofcom presented coverage area plots within the December Ofcom Technical Study estimating the areas of the UK where the OOB interference from civil radar systems was likely to exceed two interference threshold values which Ofcom has identified as representative for current mobile technologies. These coverage plots remain the best assessment of existing conditions that Ofcom is able to make available in respect of civil radars. Ofcom is not aware of any subsequent changes in civil ATC radar usage in the band 2700 – 2900MHz from the time of publication of the December Ofcom Technical Study. However, it should be noted that there may well be changes in future as new or revised radar assignments are made by the CAA.

UK Military Radar Usage in the Band 2700-2900MHz

3.113 Ofcom noted in the December Consultation that the interference assessment presented in that document did not include consideration of military radar systems. Subsequent to the consultation, the MoD has provided Ofcom with technical information on ten ground-based military ATC radar installations that it operates that currently have frequency assignments within the band 2700 – 2790MHz. These radars provide similar ATC management functions to those of their civilian equivalents.

3.114 In addition to the primary MoD ATC surveillance radars, the MoD has also provided Ofcom with information on a ground-based tactical radar system. This system provides air defence (AD) functions and has no equivalent civil application. Presently, six radars are part of this AD system. The assigned frequencies for these radars are subject to change according to military operational needs and may well be allocated frequencies within 2700 – 2790MHz.

3.115 MoD ATC surveillance radars and MoD AD radars may be in continuous use at fixed locations in the UK. In addition, the MoD's AD radars may also be operated intermittently, depending on operational requirements (usually limited to training and testing) from selected military sites and training areas located throughout the UK. Possible sites and areas used for MoD AD radars are shown in Annex 9. Some of the

[29] http://www.ofcom.org.uk/radiocomms/isu/ukfat/ukfat07.pdf

MoD AD radar systems may also be deployed outside the UK on an occasional basis which has the resultant impact of reducing the total number of systems that may be resident and operational in the UK at a particular time.

3.116 Emissions from meteorological radars (wind profiler radars) are not considered further in this document as Ofcom expects their interference potential to be small and localised. Such radars are currently assigned frequencies with significant frequency offset from 2690MHz and their transmissions are generally directed vertically upwards by their main antenna beams.

3.117 Ofcom is unable to publish detailed information on the characteristics of individual civil or military radar systems (in terms of their location, frequency assignment, type of transmitter technology and other key radio frequency parameters). This information is considered sensitive and much of the MoD information is protected under the Official Secrets Act 1989 in the interests of national security.

3.118 However Ofcom is providing in this document as much information as possible on radar usage within the 2700 – 2900MHz band, in order to help interested parties to assess the potential impact that radar OOB emissions might have into the 2.6GHz band. As a complement to this information, interested parties are invited to consider conducting their own band occupancy measurement surveys (subject to applicable law, in particular regarding wireless telegraphy) to gain additional information on the likely levels of OOB emissions from radar and other systems falling into the award bands.

3.119 Table 9 below provides a summary of the information available on radars. This information is supplemented by a series of plots contained in Annex 9.

3.120 Annex 9 also contains representative parameters of ATC radar usage (both civil and military) within the UK. The majority of military ATC radars employ Travelling Wave Tube (TWT) Class-C amplifier technology, operate on multiple frequencies (typically 2, but up to 16 for training purposes) and have a peak EIRP power level of 81dBW. The current tactical AD radars employ solid-state amplifier technology of 89dBW peak EIRP.

3.121 It should be noted that Ofcom's modelling may not reflect the actual coverage areas and locations of MoD or civil radars at or subsequent to the award, as these are subject to change according to military or civilian operational requirements. The MoD and CAA retain the right to deploy and operate radars within the 2700 – 2900MHz band as a primary service in accordance with the UK Frequency Allocation Table (2007) and ITU-R Radio Regulations (Edition 2004) Article 5.337. It should also be noted that while an ITU-R Recommendation exists for unwanted emissions in the OOB domain for primary radars[30], currently there is no regulatory basis for limiting OOB emissions for ground-based military radar systems, the operational requirements of which are subject to change. Recently installed civil radar systems are subject to the R&TTE Regulations.

3.122 The use that may be made of the 2.6GHz band could be affected by possible changes in the way that the neighbouring 2700 – 2900MHz band is used by the MoD and civil aeronautical radar. The Government and Ofcom have committed to the wider application of market mechanisms, such as through spectrum trading and administered incentive pricing (AIP), to public sector spectrum holdings in order to

[30] ITU-R SM 1541-2,"Unwanted emissions in the out-of-band domain, Annex 8, OOB domain emission limits for primary radar systems".

promote greater spectrum efficiency. It is possible that the application of such mechanisms may lead to the sharing of the 2700 – 2900MHz band with non-radar systems or to changes to the level of OOB emissions from this band into the 2.6GHz band.

3.123 On 12 July 2007, Ofcom published a consultation[31] setting out proposals for a new framework based on the introduction of spectrum trading and spectrum usage rights for public sector spectrum holdings. Subject to the responses, Ofcom expects to make further proposals later in 2007 concerning the implementation of the framework. Ofcom also expects to consult later in 2007 on the application of AIP to aeronautical radar, including in the 2700 – 2900MHz band. The nature and extent of any changes that might take place as a result in usage of the 2700 – 2900MHz band and their effect on the 2.6GHz band will depend on factors that cannot be estimated at this time. These include the response of the MoD and civil radar operators to the introduction of market mechanisms, if it is decided to proceed with their introduction following the consultations.

[31] http://www.ofcom.org.uk/consult/condocs/sfrps/

Table 9: Summary of current UK radars systems operating in the band 2700-2790MHz

Number of installations	*Radar Type*	*Comments*
Civil radars with frequency assignments within 2700 – 2790MHz (July 2007)		
22	11 Magnetron @ peak EIRP up to 92dBW 6 TWT @ peak EIRP up to 82dBW 5 Solid State @ peak EIRP up to 80dBW	Radars used at fixed locations on a continuous basis (see coverage area plots in the December Ofcom Technical Study). Centre frequencies fixed subject to reorganisation of the band by the DAP/CAA. Magnetrons likely to be replaced by Solid State radars over the longer term.
Military radars: ATC radars with frequency assignments within 2700 – 2790MHz (July 2007)		
10	8 TWT of 81dBW peak EIRP 1 estimated TWT of 50dBW EIRP 1 Magnetron of 89dBW EIRP	Radars used at fixed locations (see Annex 9) on a continuous basis. Centre frequencies fixed subject to the operational requirements of the MoD.
Military radars: AD radars with the possibility of assignments within 2700 – 2790MHz (July 2007)		
6	Solid State of 89dBW EIRP	Four installations are predominantly deployed individually a four fixed locations (see Annex 9). They are typically used on an intermittent basis at carrier frequencies that are fixed but may be assigned anywhere in the band 2700–3100MHz subject to the operational requirements of the MoD. However frequencies will need to be coordinated with other civil and military ATC radars at the time of deployment. Remaining installations are used on an intermittent basis from various locations within the UK (see Annex 9). Carrier frequencies for these installations may be assigned anywhere within the band 2700-3100MHz according to military operational requirements and are similarly co-ordinated at the time of deployment.

3.124 Further information on radar RF parameters, the likely OOB emission characteristics and the different types of radar usage within the UK can also be found in the following references.

- Study into spectrally efficient radar systems in the L and S Bands. A report by BAE Systems Integrated Systems Technology Limited for the Ofcom Spectrum Efficiency Scheme, May 2006.[32]
- A study into techniques for improving radar spectrum utilisation. A report by QinetiQ consortium for Ofcom Study AY4490, April 2004.[33]
- The report of an investigation into the characteristics, operation and protection requirements of civil aeronautical and civil maritime radar systems. A report by Alenia Marconi Systems Limited for the Radiocommunications Agency, August 2001.[34]
- Assessment of the technical, regulatory and socio-economic constraints and feasibility of the implementation of more spectrally efficient radiocommunications techniques and technology within the aeronautical and maritime communities. A report by InterConnect Communications consortium, June 2004.[35]
- ITU-R Recommendation M.1464-1. Characteristics of radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and meteorological radars in the radiodetermination service operating in the frequency band 2 700-2 900MHz.
- ITU-R SM 1541-2,"Unwanted emissions in the out-of-band domain, Annex 8, OoB domain emission limits for primary radar systems".

Estimated Interference Areas

3.125 Annex 9 presents coverage plots estimating the areas of the UK where the OOB emissions from military ATC radar signals are expected to exceed the two interference field-strength threshold levels (of values indicated within the Annex) into Channels 22, 30 and 38 of the 2.6GHz band. The plot shows the areas where interference is expected to originate from a radar main-beam as it sweeps through the reception area of candidate mobile and base-station receivers and through radar side-lobe transmissions. It should be noted that these plots are estimates based on Ofcom's understanding of military usage of the 2700-2790MHz band. They should be considered together with similar plots published in the December Ofcom Technical Study for civil ATC radar usage.

3.126 The coverage plots are derived using the methodology, assumptions and propagation model presented in Section 2 of the December Ofcom Technical Study. In summary, the OOB interference power falling into Channel 22, 30 and 38 of the 2.6GHz band is estimated on the basis of the spectral masks published in the December Ofcom Technical Study which relate to the type of technology used for radar transmission (e.g. magnetron, TWT or solid state), the carrier EIRP and

[32] http://www.ofcom.org.uk/research/technology/overview/ese/sers/
[33] http://www.ofcom.org.uk/research/technology/spectrum_efficiency_scheme/ses2003-04/ay4490/
[34] http://www.ofcom.org.uk/static/archive/ra/topics/research/topics/s-studies/civil-radio-systems.pdf
[35] http://www.ofcom.org.uk/research/technology/archive/other/sss/ay4620/

frequency offset from the carrier centre frequency. A 7dB bandwidth conversion factor is then added to scale the estimated OOB interference from a 1MHz to a 5MHz bandwidth.

3.127 Similar coverage plots for MoD AD radar usage are not shown as these systems can be assigned any frequency in the band 2700 - 3100MHz. Ofcom does not have information on the specific frequency assignments for MoD AD radars (which are coordinated at time of deployment), their likely period of operation, or their specific locations.

Interference from Radar systems into Adjacent Band UMTS and WiMAX Systems

3.128 In response to comments received to the December Consultation, Ofcom commissioned a study from ERA Technology Limited to investigate further the effect that radar OOB emissions may have on WCDMA/UMTS and OFDM[36]/WiMAX systems that are likely to operate in the 2.6GHz band. The main aim of this study was to quantify the extent to which the forward error correction coding techniques employed in modern mobile communications systems can perform in the presence of interference from different types of radar systems. A secondary aim of the study was to measure the OOB emissions characteristics from different types of ATC radar systems (i.e. magnetron, TWT & solid state) deployed at three major UK civil airports.

3.129 Ofcom does not have the final results of this study available at the time of publication of this Discussion Document. However, in indicative preliminary results, ERA has provided indicative preliminary results in the form of measurements of OOB interference into a W-CDMA/UMTS test receiver from a TWT-based radar operating with a various frequency separations from Channel 38. With a separation of 20MHz, ERA's preliminary results indicate that the C/I for a bit error rate of 0.1% is around -30 dB to -40 dB, using peak detection of interference power. In a similar test, with a separation of 100MHz, ERA's preliminary results indicate that, the measured C/I fell to around -20 dB for a bit error rate of 0.1% using peak detection of interference power.

3.130 These preliminary results should be treated with caution. However they support Ofcom's the previous estimate in the December Ofcom Technical Study that WCDMA / UMTS systems should be able to tolerate significant amounts of OOB interference from radars systems having relatively short pulse transmissions such as those based on TWT & magnetron amplifiers.

3.131 The final report of the ERA study will be made available on the Ofcom website when completed (expected by end August 2007), at: http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/.

Confidential submission regarding the impact of radars

3.132 In a confidential submission to Ofcom, a stakeholder shared its detailed analysis of the potential impact of radars on the use of mobile technologies in the 2.6GHz band. Two relevant findings from the analysis were that:

a) Radar emissions in the band 2700-2900MHz, both civil and military, are likely to have a localised impact on mobile network performance in areas close to radars when clutter does not provide sufficient mitigation.

[36] Orthogonal Frequency Division Multiplexing, a modulation technique.

b) Consistent with Ofcom's analysis of forward error correction in the December Consultation, the nature of the impact is to reduce the coverage area of cells in those areas and/or to reduce their capacity by a limited factor. (It is not the case that radar use is expected to prevent base stations from operating altogether in large areas surrounding the radars.)

3.133 Based on the interference plots prepared by Ofcom, it is also expected that the effect of radars is relevant across most frequencies in the 2.6GHz band (i.e. all unpaired lots and all paired downlink blocks are likely to be affected to some extent), although the effect reduces across the range of frequencies down from 2690MHz.

International coordination in the 2.6GHz band

3.134 In the December Consultation we set out an analysis of the potential effects of interference from and to neighbouring countries, in particular France and Ireland. This drew on comments from a number of stakeholders on the potential for this to impact on the value of the 2.6GHz band.

Interference from Irish MMDS broadcast services

3.135 Since the publication of the technical studies accompanying the December Consultation we have gathered two additional sources of information relating to the potential for interference from MMDS broadcast services from Ireland.

- Ofcom's Baldock monitoring team have carried out a series of measurements of received signal strength in various locations in Northern Ireland, West Wales and North West England (at locations where the plots of received signal levels had indicated there could be some, albeit weak, reception).

- We have received more up to date information from ComReg on MMDS transmitter parameters and have carried out updated signal propagation analysis.

3.136 The results of this new work are summarised in Annex 10. The measurements of received signal strength were carried out in May and June 2007 under normal weather and propagation conditions. No signal strength at all was detected in North West England, some signal was detected in Angelsey and stronger signals in Northern Ireland near the border with the Republic. The measurements confirm that the MMDS service uses all of the frequencies across the band from 2500MHz up to around 2670MHz.

3.137 We have carried out new propagation analysis using updated MMDS transmission data provided by ComReg. The revised plots of received signal strength, shown in Annex 10, indicate that the coverage of the signal into the West of England and Wales is a little less than under the plot shown in the December Consultation.

3.138 When assessing the potential impact of the received MMDS signals on future systems that might operate in the UK in the 2.6GHz band following the award, the main interference scenario to consider is interference into the base station receive. The scope for the MMDS signal to degrade the reception of the base station will be a function of:

- The strength of the unwanted received signal from MMDS;

- The percentage of time for which the unwanted signal exceeds a threshold value at which the potential for interference might start to be a concern; and

- The strength of the wanted signal that the base station receives from the user terminal which will depend on where the terminal is within the cell and on the use of mitigation techniques employed, on antenna height and orientation etc.

3.139 The plots shown in the December Consultation (and at the 8 February seminar) represented extremes which were included in order to illustrate the limit of reach of MMDS signals. However, when considering the areas where users of mobile services in the 2.6GHz band might suffer a material degradation of service for more than a few percent of the time, it is probably more relevant to look at a plot of where the received signal strength just exceeds the ambient background noise level for no more than, say, 10% of the time (this should translate to a lower percentage of time for which a user suffers service degradation). A plot of this nature is shown in Annex 10 and indicates virtually no MMDS coverage in England and Wales with MMDS coverage in Northern Ireland limited away from the border areas.

3.140 Stakeholders that are interested in bidding in the 2.6GHz award should make their own assessments and/or measurements if they have concerns. However, the information presented here suggests that the existence of MMDS services is unlikely to have a material impact of the value of 2.6GHz spectrum. There are likely to be some constraints in some parts of Northern Ireland which suggests that future use of the 2.6GHz band in Northern Ireland may need to be more closely coordinated with ComReg and UPC, the company that provides the MMDS broadcast service. It is also possible that the use of this band in Ireland may change from MMDS broadcast services to mobile use in future and this would provide opportunity to establish such coordination arrangements in accordance with Recommendation 01-01.[37]

Coordination with French use of the 2.6GHz band

3.141 In the December Consultation, Ofcom provided an assessment of the potential for interference from and to potential future mobile uses in France. In Annex 10 and a separate document providing results of measurements carried out by Ofcom (published alongside this Discussion Document), Ofcom is providing further information in the form of:

a) an additional assessment of the potential for interference from base stations in the UK and France;

b) comments made by ANFR to Ofcom on current uses and the scope for mobile services to be introduced in France in the future; and

c) sample measurements of received signal strength in the 2.6GHz band in coastal areas of the UK.

3.142 At present, there is no Memorandum of Understanding (MoU) between France and the UK in respect of systems operating in the 2.6GHz band or the 2010MHz band. Several respondents to the December Consultation (including BT, O2, Orange, T-Mobile and Vodafone) expressed the view that it was important to clarify cross-border coordination requirements ahead of an award. Ofcom plans to progress as far as possible in its discussion with ANFR ahead of the proposed award. In order to establish future MoUs, for either current service or future services in France, Ofcom will continue to engage with ANFR to explore suitable conditions for coordination, taking account of CEPT Recommendation 01-01 which considers cross-border arrangements for the operation of UMTS networks. In the interim, the process

[37] See http://www.ero.dk/documentation/docs/docfiles.asp?docid=1587&wd=N.

defined by the ITU for registering transmitters would apply for coordination, in accordance with articles 9 and 11 of the ITU Radio Regulations.

Implications for the generic lot approach

3.143 One of the central features of the auction design proposed in the December Consultation is the use of a two stage process:

- Stage 1 (the Principal Stage) which is structured around the use of generic lots, with bidders invited to place bids for quantities of lots in the three generic categories identified (2.6GHz paired, 2.6GHz unpaired, 2010MHz);

- Stage 2 (the Assignment Stage) in which winning bidders are invited to express any preference they may have for specific frequencies in the categories for which they have won lots.

3.144 One of the main properties of the use of generic lots is that it enables the auction to determine the relative amounts of spectrum that are paired and unpaired in the 2.6GHz band. Given the uncertainties concerning the optimal split between these two categories of lots and corresponding types of uses, Ofcom considers that the award should be used to determine the outcome, based on bids made by participants.

3.145 An issue raised by several respondents relevant to the use of generic lots is whether the usability of each lot within a generic category is sufficiently similar for bidders not to be exposed to significant risks of receiving lots which they do not really want or receiving lots at a price that is substantially higher than they would have wanted to pay (which might occur if in the generic category of interest, a bidder placed a significantly higher value on certain lots). In the proposed auction design, we considered that there would likely be differences in value between lots contained within each of the two categories, but that these differences would be sufficiently small to be addressed as part of the Assignment Stage where winning bidders may place top-up bids for specific frequencies. Again, for this arrangement to lead to an efficient outcome, the differences in value which bidders may attach to different frequencies within a given category of generic lot should be relatively small.

3.146 The main purpose of this sub-section is therefore to consider the extent to which the value of lots within a particular category might differ by frequency. We begin with a summary of the technical information set out above (on in-band adjacencies, adjacent band use, in particular radars, and use in neighbouring countries) and our assessment of the chance that these potential sources of interference could result in (large) differential values between lots within a single lot category.

Impact of the various sources of interference on wireless networks

3.147 The various sources of interference discussed above could potentially affect the way in which wireless networks (base stations in particular) may be designed to mitigate interference from within the band and from adjacent bands.

3.148 The analysis set out earlier in this Section highlights several aspects of the nature of the interference that could be experienced by a user of the 2.6GHz band (its potential impact, the locations, how different frequencies may be affected differently) and the main mitigations that are available (certain modifications to standard wireless network equipment, increase of base station density to compensation for cell shrinkage).

3.149 The table below summarises Ofcom's assessment of the potential impacts. The table does not include the impact of potential blocking of FDD mobile terminals by TDD mobile terminals as this affects the whole of the 2.6GHz band equally and has no bearing on the appropriateness of generic lots.

Table 10: Summary of potential interference in-band and from adjacent bands

Source of potential interference	Likely impact and locations	Estimated variation across the 2.6GHz band	Potential mitigation for 2.6GHz user
In-band – TDD/FDD uplink	Impact limited depending on mitigation. Locations mainly dense urban environments.	For those frequencies at the FDD uplink / TDD adjacency.	Attention to siting and site engineering. Filters for out-of-band emissions.
Adjacent – radars	Potential coverage and/or capacity reduction in areas around radars.	Across the band, with decreasing impact as frequency decreases.	Built-in forward error correction. Local increase in base station density.
Adjacent – PMSE	Temporary and restricted to where PMSE use occurs, mainly in urban centres.	At the 2500MHz boundary only.	Attention to siting and site engineering.
International – France	Coordination requirements in a limited area in the South East.	Limited.	Attention to siting and site engineering. Also possible to apply power reductions in certain directions and/or use additional filters.
International – Ireland	Potential interference in Northern Ireland and limited coastal areas of Great Britain.	Limited.	Local increase in base station density in parts of Northern Ireland.

3.150 Overall, Ofcom's view is that the risk of any significant differential impact on specific lots (for their use for likely wireless networks operating in the 2.6GHz band) is low. In particular, we consider that the potential mitigation techniques are either modest operational considerations when deploying new sites or, in the case of additional filters, only likely to represent a small share of the capital expenditure for the wireless equipment of any given site.

3.151 In the case of potential interference from radar, it is worth noting that the impact is across the whole of the 2.6GHz band (decreasing with decreasing frequency) and is likely to have a localised impact on mobile network performance in areas close to radars when clutter does not provide sufficient mitigation, reducing the coverage area of cells in these areas by a limited factor. This could require an increase in base station density in these areas (although we note that these radars are at fixed locations and network operators would be likely to, where possible, build sufficiently far away from radars to minimise interference). Similarly, interference from the use of the 2.6GHz band in France and Ireland may require local increases in base station density in limited areas of Northern Ireland and coastal South East Great Britain.

3.152 Importantly, the share that wireless network costs represent in the overall recurring cost of providing mobile services is limited, with typically approximately 20% of

operating expenditure related to the mobile network for mobile operators.[38] Not all of this operating expenditure will be directly related to the number of base stations but, assuming that it is to arrive at a ceiling, in order to increase total operating expenditure by 5% the number of base stations would need to increase by approximately 25%. Considering the population and area of the limited parts of the UK which are likely to be subject to interference from radar and international use of the 2.6GHz band, it is highly unlikely that the additional base stations required to mitigate against this interference will be sufficiently large to materially affect operating expenditure. Similarly, while a higher proportion of capital expenditure is related to base stations than is the case for operating expenditure, it is Ofcom's view that the limited geographic area (and population coverage) over which an increase in base station density is required is sufficiently small for the differential impact of interference to be relatively limited.

3.153 Ofcom's view is therefore that the impact of the interference considered above is, in effect, likely to be sufficiently modest (in terms of the value that a bidder could attach to specific frequencies over other frequencies within the band) that it would not materially affect the efficiency of the auction.

3.154 Ofcom's view is therefore that the use of generic lots for the award of the 2.6GHz band is unlikely to lead to material inefficiency.

3.155 Ofcom also notes that any changes to the auction design to reflect the potential differences would have to be measured against:

a) the scope for the revised design to allow the market to efficiently determine the split between paired and unpaired spectrum in the 2.6GHz band; and

b) the risks of any increase in complexity for the efficiency of the process and its ability to ensure optimal use of the spectrum.

3.156 These issues are discussed further in Section 5.

Summary and conclusions

3.157 In this Section, we set out our analysis of the interference conditions relevant to the 2.6GHz band (and, in some instances, to the 2010MHz band). In summary, our assessment is as follows.

a) Allowing flexibility for the auction to determine the split between FDD and TDD spectrum and deviate from the CEPT band plan should not lead to unacceptable levels of interference due to mobile-to-mobile blocking.

b) The technical conditions proposed in the December Consultation for TDD/FDD adjacencies seem appropriate (with the possible exception of outdoor TDD use of the restricted channel adjacent to the FDD uplink).

c) MoD radars may have an impact and the information provided in this document will help interested parties form their own view of this impact.

[38] Including maintenance, backhaul, site rental and technical staff costs. Non-network opex includes subscriber retention and acquisition, CRM/call centres, interconnection, payroll and IT. Source: broker reports, operator data and Analysys Research.

d) PMSE users may experience interference from new uses in channels adjacent to the bands for award (and new uses may experience interference). However, the probability and impact of the interference seem limited.

e) Uses in neighbouring countries may result in localised impact in terms of interference received and/or coordination requirements, but the overall effects seem modest.

f) Potential variations in the usability of specific frequencies across the 2.6GHz band seem limited and their significance for the value of lots (in light of the costs involved in providing services) seems unlikely to be of a size that would risk a material inefficiency through the use of generic lots.

Question 2: Do stakeholders agree with Ofcom's analysis of interference conditions that are relevant to the use of generic lots?

Section 4

Technical Conditions

4.1 Section 9 of the December Consultation set out two alternative approaches to the technical licence conditions for the licences:

- transmitter spectrum masks; or
- spectrum usage rights (SURs)[39].

4.2 In the December Consultation, Ofcom asked respondents to express their preference for either of the two approaches. It also asked for comments on the details of the approaches as proposed by Ofcom.

4.3 Having reviewed the comments from respondents, Ofcom is using this Discussion Document set out its current view on the most suitable technical licence conditions, taking into account comments received following the December Consultation.

4.4 This Section is therefore structured as follows.

- Summary of responses to the consultation in relation to the overall approach
- Ofcom's current view on the overall approach to technical usage conditions
- Detailed comments received on Ofcom's transmitter spectrum mask proposals
- Discussion of the comments received on the transmitter spectrum mask approach
- Summary of Ofcom's current assessment of technical licence conditions

Summary of responses to the consultation in relation to the overall approach

4.5 A strong preference for the transmitter spectrum mask approach was the almost unanimous response from those who expressed a view (including H3G, O2, Orange, T-Mobile, Vodafone, BT, BAA, Ericsson, Intel, Intellect, Motorola, National Grid Wireless, Nokia, Nortel, and Samsung). Many respondents were concerned that the SUR approach was not mature enough, raised concerns about the SUR methodology adopted and/or were concerned that the legal framework for SURs was not yet sufficiently clear.

4.6 Only Inquam Broadband expressed a preference for the SUR approach.

4.7 However, a number of respondents (including GSA, Qualcomm and UMTS Forum) did not consider either approach appropriate and felt that Ofcom should base technical licence conditions directly on international standards.

[39] Based on the SUR approach set out in the consultation document available at http://www.ofcom.org.uk/consult/sur/.

Ofcom's current view on the overall approach to technical usage conditions

4.8 Following the publication of the December Consultation, Ofcom held a series of individual meetings with interested parties where the issue of SURs was discussed. In these meetings a number of refinements to the SUR proposals were put forward to address concerns raised in responses to the December Consultation. These included moving to a modelling rather than measurement approach to enforcement and to adopt a hybrid approach that included a specific EIRP cap on individual transmitters alongside the aggregate PFD approach included in the SUR consultation. An outline of the major points raised during these discussions is as follows.

- Some parties wanted SURs ruled out for 2.6GHz, primarily because they were concerned that using them would unduly delay the auction.
- One party was very supportive and was in favour of the SUR approach including the changes.
- Issues raised included legal certainty, modelling accuracy, measurement areas, the level of risk in applying novel concepts to a valuable band.
- Most parties broadly welcomed the fact that Ofcom had revised its SUR proposals in the light of their comments but, while willing to continue to work with Ofcom on the approach, reserved judgement on whether they would change their view on the appropriateness of SURs.

4.9 However, it was apparent that most interested parties do not believe that they need the extra protection an SUR approach might give them since, in their view, the 2.6GHz band will likely be used for broadly similar types of services. They believe that 2.6GHz operators should therefore be able to work together to minimise interference (similar to the way in which the current MNOs cooperate with each other to minimise interference issues between existing 2G and 3G networks). Under such a scenario they believe that the risk of interference would not be sufficiently high to merit the time and cost associated with designing and implementing SURs.

4.10 Whilst it is Ofcom's view that the SUR approach could be developed further with respect to the 2.6GHz band, it is apparent that the vast majority of interested parties are still concerned that the SUR proposals require refinements and that any added benefit of greater certainty over interference is not perceived to be significant. There is also insufficient certainty over the time it would take to resolve the outstanding issues for Ofcom to be confident that pursuing SURs would not risk a significant delay to the award. Ofcom is therefore not proposing to pursue the SUR approach in relation to the 2.6GHz award.

4.11 In relation to the suggestion that Ofcom should instead rely on international standards, this is clearly incompatible with the technology neutral approach proposed for this award (see the discussion in Section 8). International standards developed by bodies such as 3GPP and IEEE are specific to particular technologies and truly technology neutral standards do not exist at the present time. However, Ofcom does acknowledge that it is very important to consider the standards that are relevant to the most likely uses of the spectrum when setting technical licence conditions and this was carefully considered when making the proposals contained in the December Consultation. For example, the transmitter spectrum masks were largely derived from existing 3GPP specifications and the proposals for specific SUR parameters were based on the relevant available standards.

4.12 Therefore, taking the above into consideration, Ofcom's current view on technical licence conditions is that it should proceed with conditions based on transmitter spectrum masks. This is consistent with the work in Europe on WAPECS[40] being carried out by SE42 and with the interim CEPT response to the WAPECS mandate to the European Commission. Annex III of the CEPT response contains details of a block edge mask approach which, in large part, is based on our transmitter spectrum mask proposals.

4.13 The remainder of this Section discusses in detail the comments received on the transmitter spectrum mask proposals as set out in the December Consultation and specifies Ofcom's current proposals for the spectrum masks.

4.14 Although Ofcom received a number of specific comments on the details of the SUR proposals, this Discussion Document will not discuss these in further detail given our proposal not to pursue the SUR approach. Ofcom is however planning further publications on SURs in general and their use in relation to other awards and appropriate comments received in response to the December Consultation will be considered in these publications.

Detailed comments received on Ofcom's transmitter spectrum mask proposals

4.15 In relation to the details of the transmitter spectrum mask approach a number of concerns were raised.

4.16 H3G commented that the relevant spectrum masks should be fully compliant with the 3GPP specifications to ensure that standard equipment can be used in any block. This comment was echoed by Nokia, Siemens and the UMTS Forum who were concerned that the out-of-band limits were in some cases 25dB tighter than the 3GPP/ETSI specifications for UMTS meaning that special base station filters would be necessary. Ericsson also raised concerns and considered that moving away from the current proven approach to interference control based on international standards would be misguided.

4.17 Orange, Motorola, Nortel, Siemens, T-Mobile and Qualcomm commented that masks based on nominal 5MHz bandwidth were not appropriate for use with technologies that use wider bandwidths (such as 10MHz WiMAX and 10 and 20MHz LTE). Nokia suggested that the masks would need to be reviewed when the LTE masks are more stable.

4.18 Orange raised concerns about the use of restricted blocks rather than guard bands (between pared/FDD and unpaired/TDD users) and felt that this would not properly protect against harmful interference. Ericsson and Pipex suggested that 5MHz may not be sufficient to protect all usage scenarios, while Ericsson suggested that the Mason Study actually recommends 10MHz guard blocks.

4.19 Qualcomm suggested that the mobile station in-band power should be reduced by 6dB to bring it into line with UMTS specifications and that Ofcom's proposals allow more interference between TDD and FDD than assumed in the system (i.e. UMTS) design. Qualcomm also thought that the 5MHz restricted blocks between FDD/TDD and TDD/TDD would be unusable.

[40] Wireless Access Policy for Electronic Communications Services, a concept developed by the EU's Radio Spectrum Policy Group. See their opinion of 23 November 2005, available at http://rspg.ec.europa.eu/doc/documents/opinions/rspg05_102_op_wapecs.pdf.

4.20 T-Mobile commented that the proposed in-band EIRP for base stations is 4dB lower that that allowed for by the current UMTS licences at 2.1GHz and commented that this may make it difficult to achieve good indoor coverage. T-Mobile also suggested that the in-band mobile EIRP for restricted blocks should be lowered to prevent interference.

4.21 BT commented that the restricted block in-band power limit for base stations may be more severe than necessary. They commented in particular on lot 24 and the additional 'restricted' block that may appear between the FDD downlink and TDD if TDD were to appear in the upper portion of the band.

4.22 A number of additional specific issues were also raised such as TDD/FDD blocking, adjacent channel interference between TDD and FDD, interference to and from use in adjacent bands and cross border interference. These issues have been discussed in detail in Section 3 and will not be considered in detail again here.

Discussion of the comments received on the transmitter spectrum mask approach

4.23 In the sub-sections below we deal with each of the comments highlighted in paragraphs 4.16 – 4.21 above in turn. We then provide a summary of conclusions.

Alignment of the masks with the 3GPP/ETSI specifications

4.24 It should be noted that Ofcom directly based the spectrum mask proposals in the December Consultation on the 3GPP specifications. In order to achieve this it was necessary to convert the out-of-band limits in the specifications (which are expressed as values relative to the carrier) to absolute values.

4.25 The starting point for this conversion was to establish the appropriate in-band EIRP. For base stations in unrestricted channels, this was calculated as follows.

- Maximum base station power (FDD or TDD) = 43dBm
- Maximum antenna gain + feeder loss combination = 17dBi
- EIRP per carrier = 43dBm + 17dBi = 60dBm in a single UMTS channel (3.84MHz)
- EIRP/MHz = 60dBm – 6dB (to convert from 3.84MHz to 1MHz) = 54dBm/MHz

4.26 For base stations in restricted channels, this was calculated as follows.

- Maximum base station power (FDD or TDD) = 31dBm
- Maximum antenna gain + feeder loss combination = 3dBi
- EIRP per carrier = 31dBm + 3dBi = 34dBm in a single UMTS channel (3.84MHz)
- EIRP/MHz = 34dBm – 6dB (to convert from 3.84MHz to 1MHz) = 28dBm/MHz

4.27 For mobile stations, this was calculated as follows.

- Maximum mobile station power (FDD or TDD) = 30dBm
- Maximum antenna gain = 0dBi

- EIRP per carrier = 30dBm + 0dBi = 30dBm in a single UMTS channel (3.84MHz)
- EIRP/MHz = 30dBm - 6dB (to convert from 3.84MHz to 1MHz) = 24dBm/MHz

4.28 These in-band EIRP/MHz values were then used to convert the out-of-band spectrum masks contained in 3GPP specifications TS 25.101, TS 25.102, TS 25.104 and TS 25.105 to absolute values (keeping the same measurement bandwidths as used in these specifications).

4.29 For the case of the FDD uplink/TDD adjacency and the TDD/TDD adjacency (i.e. the lowest TDD block that a TDD operator acquires) this will be a restricted block with a restricted base station in-band power as defined in paragraph 4.26 above. The out-of-band emissions from TDD base station into the FDD uplink and from TDD base stations into the TDD block below is based on the restricted power.

4.30 From the above discussion it is clear that the transmitter spectrum masks outlined above are fully consistent with the 3GPP specifications. We also believe that WiMAX spectrum masks will be fully compatible with our proposals.

Consideration of the need for masks based on blocks sizes greater than 5MHz

4.31 It is noted that many of the potential uses of the 2.6GHz band may use technologies with wider bandwidths than 5MHz (10 and 20MHz LTE, 10MHz WiMAX). However, Ofcom is not proposing to restrict how operators utilise the available spectrum provided that they comply with the overall spectrum mask to be defined in the licences. There is no reason why an operator could not combine two (or more) adjacent 5MHz lots to utilise a 10MHz (or larger) carrier.

4.32 It has been put to us that OFDM waveforms have considerably different out-of-band emission behaviour with sharper drops than CDMA technologies. The WiMAX community appears confident that a 10MHz WiMAX carrier (which is based on OFDM) will fit within an emission mask based on a 5MHz UMTS one. As LTE is also based on OFDM (for the downlink) there is no reason to believe that a 10MHz LTE carrier will find it any more difficult to fit within a mask derived from a 5MHz UMTS carrier than would a 10MHz WiMAX carrier.

4.33 Ofcom's proposed out-of-band masks stretch for ±10MHz either side of each operator's assigned frequencies (out to 250% of the channel width from the centre of a 5MHz channel). Out-of-band limits are specified in order to cover the characteristics of a signal due to its own modulation. It has been put to us (by Orange, for example) that out-of-band limits are therefore clearly proportional to channel bandwidths. However, Ofcom does not consider it necessary to adjust the shape of the out-of-band mask to be proportional to the width of the carrier. Given the nature of OFDM waveforms, it is our view that ±10MHz is sufficient to cover the relevant modulation characteristics. However, even if we accepted the argument that we should specify out-of-band emissions ±20MHz either side of each operator's assigned frequencies, this could in principle be done simply, possibly by extending the limits that are in place at the 10MHz offset out to 20MHz. However, it does not seem to Ofcom that this will provide any significant additional benefit.

4.34 Ofcom therefore considers that it is not necessary to alter its proposed mask to cater for wider bandwidth systems. However, Ofcom would welcome evidence from respondents to this Discussion Document concerning the benefits (and disadvantages) of extending the masks out to an offset of ±20MHz as indicated above.

Restricted blocks vs. guard bands

4.35 Further technical study of the FDD uplink / TDD adjacency in Section 3 and Annex 7 of this Discussion Document indicates that our proposed spectrum masks will not lead to unacceptable levels of interference across the FDD uplink / TDD boundary. However, where the restricted block between TDD and FDD uplink is used for TDD then this study does indicate that outdoor TDD use could potentially cause an increased level of interference to the adjacent FDD block mainly in urban areas and that Ofcom may need to consider placing restrictions on the outdoor use of this restricted block. Though not explicitly included in the study, a similar conclusion can be drawn for the restricted blocks between TDD users where synchronisation is not achievable. One option available to Ofcom would be to reduce the in-band power of base stations using the restricted block to 18dBm/MHz EIRP (a reduction of 10 dB – equivalent to the assumed building penetration loss). This would largely overcome the issue in case of outdoor use.

4.36 Ofcom therefore does not believe there is a justified reason to alter our general approach to the use of restricted blocks at the FDD uplink / TDD boundary and between TDD users. There may be a case however to place additional restrictions on the use of these restricted channels to overcome the potential problem that their use outdoors might bring (possibly by reducing the in-band power to 18dBm/MHz EIRP).

4.37 Ofcom would welcome evidence from respondents concerning the benefits (and disadvantages) of reducing the in-band base station power in the relevant restricted blocks at the FDD uplink / TDD and TDD/TDD boundaries to 18dBm/MHz EIRP.

Mobile station power

4.38 The 3GPP specifications place an upper limit on mobile station power of 24dBm per carrier. In our December Consultation we proposed an upper limit of 24dBm/MHz EIRP (i.e. 6 dB higher – accounting for the 3.84MHz bandwidth conversion). For WiMAX the majority of compatibility studies have been based on a mobile power of 23 or 24dBm but as far as we are aware, an absolute upper mobile station power limit is not specified by either WiMAX or IEEE 802.16.

4.39 The interference analysis we have conducted (for the December Consultation and for this Discussion Document) does not lead us to believe that an in-band mobile station power of 24dBm/MHz EIRP is unreasonable. However, a reduction in this power to 18dBm/MHz EIRP would still be consistent with the 3GPP specifications and the most likely upper limit for practical WiMAX handsets. A reduction to this level will make a modest reduction in the probability of interference in a number of scenarios such as mobile to mobile blocking, TDD mobile adjacent channel interference into FDD uplinks, TDD mobile to TDD base station adjacent channel interference (where synchronisation is not achievable) and interference to adjacent use outside the 2.6GHz band such as PMSE.

4.40 Ofcom is not minded to propose a change compared to the conditions set out in the December Consultation. However, we would welcome evidence from respondents concerning the benefits (and disadvantages) of reducing the in-band mobile station power to 18dBm/MHz EIRP.

Base station power ('standard' blocks)

4.41 The 3G licences at 2.1GHz specify a power limit of either 62 dBm per carrier or 58 dBm/MHz (whichever is the lower). The proposal for 2.6GHz set out in the December

Consultation is for a limit of 54 dBm/MHz. If this is converted to a power in a 5MHz channel this equates to 61 dBm per 5MHz carrier (i.e. a 7 dB bandwidth conversion). This gives a 1 dB difference (rather than 4 dB as mentioned by T-Mobile) from the 3G licences at 2.1GHz. In practical terms this is expected to make an insignificant difference to coverage and building penetration.

4.42 Ofcom does not consider that there is a material difference in terms of maximum base station power in our 2.6GHz proposals when compared to existing 3G licences at 2.1GHz. Even if there were a material difference there is no reason why Ofcom should treat the bands identically as different circumstances apply.

4.43 Ofcom therefore considers that it is not necessary to alter the maximum base station power from the proposed 54 dBm/MHz EIRP.

Treatment of blocks between the FDD downlink and TDD (including lot 24)

4.44 In the December Consultation, Ofcom proposed that lot 24 and possibly one other lot between lots 26 and 38 would be treated as restricted blocks and only become available in the final assignment stage (they would not be included in the Principal Stage of the auction).

4.45 It was not explicitly stated in the December Consultation what technical licence conditions would apply to these blocks though it may have been assumed that, as they were described as restricted blocks, then the in-band power and out-of-band emissions would be the same as for the other restricted blocks which are included in the earlier stages of the auction (i.e. base station in-band power of 28 dBm/MHz).

4.46 Ofcom has reviewed this situation. In fact, if these frequencies are assigned in the Assignment Stage of the auction for unpaired use then there is no need to have special restrictions attached to their use. Taking lot 24 as an example, TDD base transmitters in this band will cause no more interference to FDD mobile receivers than would be caused to FDD base station transmitters in lot 26. The issue of mobile to mobile interference would still exist, however this has already been discussed in Section 3 and Ofcom considers that there is no need to alter our proposals (although Ofcom may consider reducing the in-band mobile station power depending on further evidence on the issue). The remaining problem will be FDD base transmitters in lot 25 potentially causing interference to TDD base receivers in lot 24 as the preferred mitigation measure for TDD bases stations is to synchronise with the neighbouring network and this is not possible with an FDD neighbour. For this reason, Ofcom concludes that if lot 24 and the other comparable boundary lot are assigned in the Assignment Stage then there is no need to restrict their use to low powers for base station operation. However, anyone who does acquire them would be aware of the transmission rights in adjacent blocks and would have to accept a much higher probability of interference from their FDD neighbour.

Summary of proposals

4.47 Ofcom does not consider it necessary to change the transmitter spectrum mask proposals contained in the December Consultation. However, there are three specific areas supporting which we would specifically welcome further evidence in response to this Discussion Document:

- extending the out-of-block masks out to an offset of ±20MHz from assigned blocks;

- placing additional restrictions on the use of restricted blocks between the FDD uplink and TDD to overcome the potential problem that their use outdoors might bring (possibly by reducing the in-band power to 18dBm/MHz EIRP); and

- a reduction in mobile station in-band power to 18dBm/MHz EIRP to make a modest reduction in the probability of interference in a number of scenarios.

Question 3: Do stakeholders agree with Ofcom's updated proposals for technical conditions or have views on the possibility of
- extending the out-of-block masks out to an offset of ±20MHz from assigned blocks;
- placing additional restrictions on the use of restricted blocks between the FDD uplink and TDD; or
- a reduction in mobile station in-band power to 18dBm/MHz EIRP?

Section 5

Auction design

5.1 The December Consultation Document sought views from stakeholders on whether an auction would be an appropriate mechanism for authorising use of the spectrum bands 2500-2690MHz, 2010-2025MHz and 2290-2300MHz. Ofcom also proposed to combine the award of the 2.6GHz and 2010MHz bands, and to hold the 2290MHz band separately. A description of a provisional auction format and rules for each of these awards was provided in the annexes, and stakeholders were invited to comment on them.

5.2 A number of stakeholders responded with comments on the auction design proposals. A large majority agreed with the proposals to auction the three bands, and to hold a combined award for 2500-2690MHz and 2010-2025MHz. However, there were diverse opinions about the merits of the proposed 'combinatorial clock' auction format and associated packaging arrangements for the 2.6GHz band. Whereas some parties were strongly supportive of the flexible packaging arrangements that are facilitated by the proposed auction design, others raised concerns that aspects of the proposed approach may leave some bidders unduly exposed to valuation uncertainty.

5.3 A key feature of the proposed auction format is the use of two categories of 'generic' lots, one each for paired 2.6GHz spectrum and unpaired 2.6GHz spectrum. In the first stage of the auction – known as the Principal Stage – bidders submit bids for a number of generic lots, not specific frequencies. This stage determines the identity of the winning bidders, the number of lots that they have won and the split between lots allocated to paired and unpaired usage rights. Winning bidders then proceed to a second stage – known as the Assignment Stage – which determines the assignment of specific frequencies. This approach allows the market to determine the efficient split between paired and unpaired spectrum, while also ensuring that paired usage rights are co-located and unpaired usage rights are co-located within the band, and that, whenever feasible, bidders receive contiguous assignments of spectrum. Many respondents were supportive of this approach but some voiced concern.

5.4 More specifically, there were five areas where some respondents suggested that current proposals may not adequately support some potential bidders.

- **Valuation of lots.** With respect to the use of generic lots, respondents identified a number of reasons why the valuation of lots within the paired and unpaired categories may vary. These issues, which are discussed in Section 3, include **in-band adjacencies** and the **impact of radar use above 2700MHz**.

- **Split assignments of unpaired spectrum.** One stakeholder expressed concern that some possible split assignments of unpaired spectrum between the lower unpaired area (below 2620MHz) and upper unpaired area (above 2620MHz) may result in assignments that are unusable for some TDD applications, and that this would be a source of valuation uncertainty for bidders.

- **Substitution between paired and unpaired spectrum.** A number of respondents argued that bidders should be allowed to switch demand between paired and unpaired spectrum during the open phase of the auction, and that the auction rules could easily be adapted to facilitate this.

- **Blocking effects on FDD mobile terminals.** There was concern that the presence of TDD mobile terminals in the top of the band (above 2620MHz) could cause significant interference to FDD mobile terminals operating anywhere in the band. This blocking effect, if it were material, would be a potential source of uncertainty for bidders for paired lots, as it may not be easy for them to predict whether or not the auction outcome will result in unpaired use above 2620MHz.

- **Pairing of lots from 2570-2620MHz with other bands.** A few respondents complained that the generic lot approach would make it very difficult to pair specific lots in the centre band (2570-2620MHz) with spectrum in other bands, such as the existing 3G TDD spectrum.

5.5 There were also some comments from respondents on the detailed rules of the auction, although these were relatively limited. The issues that stakeholders commented on, which are discussed below, were the:

- complexity of the process;

- transparency rules;

- timing of submission of supplementary bids (previously called best and final offers [BAFOs]);

- second price rule for determining licence prices;

- format for the assignment process; and

- possible application of a spectrum cap on bidders.

5.6 In light of these comments, Ofcom has, with help from its advisors DotEcon, Professor Peter Cramton and Dr. Ian Jewitt, developed a revised version of the combinatorial clock auction format for this award, which is its preferred auction format. This format is similar to the one described in the December Consultation Document, but with changes to address concerns about split unpaired assignments and substitution across categories, and revisions to the detailed rules, including a new version of the pricing rules. A detailed description of the proposed rules for this auction format is provided in Annex 11.

5.7 This new version has, in part, been influenced by the work that is being undertaken on two other Ofcom awards – 10-40GHz and L-band (1452-1492MHz)[41] – that are also expected to use combinatorial clock auction formats. The terminology used and many of the procedures described in the Annex are common across all these awards, although the detailed rules are tailored to the specific circumstances of each band. Further refinements of the combinatorial clock format developed in the context of the 10-40GHz award or the L-band award may be relevant to the auction design for the 2.6GHz and 2010MHz bands.

5.8 The remainder of this Section is divided into three parts. We begin with a detailed response to the high-level issues raised in the consultation responses. We then provide an overview of our preferred auction format, and highlight the main revisions

[41] See http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_10_40/ and http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_1452/ for more information.

to this from the format presented in the December Consultation Document. We conclude with a discussion of the detailed auction rules.

High-level issues raised in the consultation responses

The use of generic lots

5.9 The December Consultation Document addressed the choice between specific and generic lots in the auction design. It concluded that having categories of generic lots was appropriate for the Principal Stage of this award for a number of reasons.

- With generic lots, it is possible to ensure that winners of paired spectrum and winners of unpaired spectrum are located in separate parts of the 2.6GHz band. This avoids the risk of fragmentation, which would otherwise be a source of uncertainty for bidders for paired spectrum, and might result in inefficient use of spectrum (by increasing the number of channels effectively used as guard bands) and unnecessary restriction of the supply of usable spectrum. By contrast, with specific lots, it is not possible to guarantee that there will not be a fragmented outcome.

- Using generic lots can eliminate aggregation risks for bidders seeking contiguous spectrum, as it is possible to limit the outcome of the Assignment Stage to contiguous assignments only. This could also be achieved through package bids for specific lots, but the bidding process would be necessarily more complex, as there would be many more bid options.

- Generic lots within the categories of paired lots and unpaired lots should have broadly similar value; therefore, there should not be any significant valuation uncertainty for bidders from bidding for generic lots instead of specific lots in the Principal Stage. Further, to the extent that bidders do have valuation differences between lots, they will be able to express these in the Assignment Stage.

5.10 A number of respondents questioned the conclusion that lots within categories were likely to have similar value. There was concern that the value of lots at the upper end of the band may be devalued owing to the impact of radar above 2700MHz. Some bidders also said that the value of a package of lots may vary depending on the nature of the adjacent use. In particular, there was concern that the proposed 5MHz separation between TDD users and between an FDD user and TDD user may not be sufficient to mitigate interference effects.

5.11 Notwithstanding these concerns, many (but not all) of these respondents still supported the general approach of using generic lots. A few stakeholders suggested potential revisions to the auction design.

- Several bidders suggested adopting a more transparent information policy during the primary bid rounds, so it is possible to observe each bidder's choice of lots.

- One bidder suggested abandoning the generic lot approach and instead having each of the 38 lots as separate categories. Such an approach would be similar to the auction design proposed for the L-band award.

5.12 Ofcom has reviewed the scope for in-band adjacencies and external interference effects to affect the value of lots, as discussed in Section 3. Ofcom remains of the view that these effects are sufficiently small that there is not likely to be any significant efficiency loss from using generic lots in the Principal Stage. Had they

been more significant, then a possible solution would have been to allow bidders to submit multiple bids during the Principal Stage, contingent on particular outcomes in relation to in-band adjacencies and external interference. However, this would have added significant complexity for bidders.

5.13 Ofcom therefore proposes to maintain its proposed approach of using generic lots. Ofcom has considered the scope for switching to specific lots, but rejects this because it risks fragmentation of paired and unpaired spectrum, which would be a source of valuation uncertainty for bidders and which could inefficiently restrict the supply of usable spectrum. In particular, the potential use of a traditional Simultaneous Multi-Round Ascending auction format, involving specific lots, is discussed later on in this Section.

5.14 The approach to transparency is discussed below under detailed rules and procedures, as it does not affect the choice of generic lots.

Split assignments of unpaired spectrum

5.15 A key feature of the auction design proposed in the December Consultation Document was that all bidders, with one possible exception, would be guaranteed to be assigned contiguous spectrum. The possible exception was that in the case that some spectrum in the upper part of the band is allocated to unpaired use, it may be necessary for one winner of unpaired lots to receive a split award. In this case, the bidder would be awarded their spectrum in two contiguous blocks, one in the lower paired area (below 2620MHz) and one in the upper paired area (above 2620MHz). In the upper area, they would also receive an additional lot as a guard block in spectrum immediately below their core assignment.

5.16 Most respondents did not comment on this issue. However, one stakeholder expressed concern that certain configurations of split awards may result in one or both blocks being unusable for some TDD applications. Bidders that wanted to deploy such applications could therefore be at a disadvantage during the Principal Stage, as they cannot be sure whether they will win usable spectrum.

5.17 Ofcom has reviewed this issue and has concluded that this effect may be material, given that some TDD applications have minimum carrier sizes of 10MHz or 15MHz.

5.18 Accordingly, Ofcom proposes revisions to the auction design that should eliminate any uncertainty for bidders for unpaired spectrum. The revised rules are explained below in the description of Ofcom's preferred auction format and described in detail in Annex 11.

Substitution between paired and unpaired spectrum

5.19 The original auction design proposed that eligibility for paired lots and unpaired lots (both in the 2.6GHz band and 2010-2025MHz band) are determined separately. This rule had the implication that it would not be possible to switch demand between paired and unpaired lots. It was proposed primarily because the restriction simplifies bidding in the Principal Stage but also because it was not clear at the time that potential bidders may see paired and unpaired spectrum as substitutes.

5.20 Three respondents argued that this rule was unduly restrictive, and that bidders should be allowed to switch demand between paired and unpaired spectrum as the auction progresses. Two main arguments were given for the requirement to switch.

- Bidders may have a common budget constraint across paired and unpaired spectrum and hence, by restricting bidders from switching between paired and unpaired spectrum, Ofcom would create a risk of an inefficient outcome.

- Paired and unpaired spectrum may be substitutable for an operator as the technologies that can be deployed can deliver similar services.

5.21 In practice, because the prices of TDD and FDD are typically linked in a fixed ratio during the primary bid rounds, the circumstances under which a rational bidder would want to switch demand between paired and unpaired categories are probably limited. Nevertheless, as the respondents point out, changing the auction design to allow bidders to switch demand is simple to implement, has no knock-on implications for other aspects of the auction rules and does not greatly increase complexity.

5.22 Accordingly, Ofcom has revised the proposed auction rules to allow bidders to switch demand between paired and unpaired lots.

Blocking effects

5.23 As discussed in Section 3, a number of respondents expressed concern that the presence of TDD mobile terminals in the top of the band (above 2620MHz) could cause interference to FDD mobile terminals receiving anywhere in the range 2620-2690MHz (the "blocking" effect). They argued that the blocking effect could be material and that a failure to recognise this could weaken the ability of bidders for paired spectrum to compete in an auction as they would face valuation uncertainty (i.e. their valuations of FDD lots would depend on whether or not some of the upper end of the band from 2620-2690MHz was allocated to unpaired use). They suggested that FDD bidders might, as a consequence, submit lower bids in order to reflect this risk, potentially leading to an inefficient outcome to the award. For example this might happen if the "right" outcome was that 2x70MHz should be allocated to FDD use on the basis of full FDD valuations, but the actual outcome was a lower FDD / higher TDD allocation because FDD bidders had reduced their bid values to take account of the blocking risk.

5.24 It has been suggested that one way of addressing this issue, irrespective of the scale of the blocking effect in practice, would be to allow bids from FDD bidders to be made contingent upon whether or not there would be unrestricted TDD mobile terminals operating within 2620-2690MHz. In light of these comments, we have considered the way that contingent bidding might work, as well as the potential consequences for auction efficiency.

5.25 In brief, the auction design could be modified so that bidders participate in two simultaneous sub-auctions:

- the first in which bidders submit bids on the basis that any TDD use in the upper area of the band would be unrestricted (i.e. as per the auction design outlined in the December consultation); and

- the second in which bidders submit bids contingent on any TDD use in the upper area being restricted to downlink only. For this second sub-auction, it would be necessary to divide the unpaired spectrum into two categories of lot, one for unrestricted TDD use in the centre band and below (i.e. below 2615MHz), and one for restricted TDD use in the upper area (i.e. above 2620MHz).

5.26 The results of the two sub-auctions would then be compared to determine which would generate the highest value allocations.

5.27 The advantage of this contingent bidding / simultaneous sub-auction approach is that it could, under certain conditions, remove the risk of an inefficient outcome on account of the blocking effect. The key conditions in this context are that:

- FDD bidders are able to assess the impact of the blocking effect on value of FDD lots;
- the impact on value of FDD lots in the first sub-auction is largely independent of how much of the upper band is allocated to TDD (or, alternatively, the first sub-auction needs to be replaced by a number of simultaneous sub-auctions, each of which assumes a different number of TDD allocations in the upper band, e.g. the first sub-auction assuming 10MHz of TDD in the upper band, the next assuming 20MHz of TDD in the upper band and so on);
- FDD bidders submit bids that reflect their true valuations in both (all) of the sub-auctions.

5.28 There are two main disadvantages of this contingent bidding / simultaneous sub-auction approach.

- FDD bidders might adopt an overly conservative approach to bidding for lots in the first sub-auction where FDD use is at risk of blocking (i.e. where unpaired lots could be present within 2620-2690MHz). In the limit, if there were only a few FDD bidders and they all decided to bid zero in this sub-auction, but bid full value in the second sub-auction (where there is no downlink TDD in the upper band), then this could bias the outcome towards the second sub-auction and make it much more likely that TDD would be restricted to the central 50MHz (including guard blocks). The implications of this are considered further below.
- It would increase the complexity of the process for bidders. Instead of making just one bid in each primary round, bidders would have to make up to two bids, one for each sub-auction (or more if there needs to be several sub-auctions to reflect different levels of unrestricted TDD presence in the upper band). Further, bidders must submit up to two sets of supplementary bids, one for each sub-auction (ditto). For the auction to be effective in trading off the relative value of allocations under the two sub-auctions, it would be essential for bidders to submit a full set of bids for each sub-auction. The greater the number of available bid options, the greater the risk that some bidders fail to express adequately their full set of preferences, with the result that the efficiency of the auction outcome may be compromised.

5.29 Both of these effects are undesirable and could lead to inefficient outcomes. We would be particularly concerned about the first effect. On the basis of stakeholder feedback, the most likely use of the unpaired spectrum would be for WiMAX applications and the amount of spectrum likely to be required for this purpose by one operator might be 30-40MHz (excluding restricted blocks). Hence, a scenario where only 50MHz of unpaired spectrum is effectively available would mean that there would be room for only one WiMAX operator. Given the potential value to consumers from the combination of service innovation and new entrant competition in the 2.6GHz band (see Section 7), this would be a significant source of concern.

5.30 It might be possible to mitigate this concern by adding further modifications to the auction design by, for example:

- requiring that matching bids be made in the first sub-auction (i.e. matching the numbers of lots bid for in the second sub-auction) and limiting the size of discount that can be applied to these bids so that they are equivalent to no less than, say, 80% of the equivalent bid value in the first sub-auction;

- reserving some spectrum within 2500-2570MHz for a new entrant, while again introducing the 'restricted' category of lot within 2620-2690MHz.

5.31 However, both of these options would add additional complexity and would run the risk of significant regulatory failure as the regulator would need to set the maximum discount in the first case and the amount of spectrum reserved for new entrants in the second.

5.32 Significantly, our analysis in Section 3 suggests that the scale and impact of the blocking effect is likely to be modest and that there are a number of mitigating actions that could be taken to reduce this impact. Taking all these factors into account together with our analysis in Section 3 of the scale of the blocking effect, Ofcom considers that the balance of these considerations points strongly against a modification to the auction design to introduce contingent bidding via simultaneous sub-auction(s). It would introduce significant additional complexity. To the extent that the blocking effect could reduce the efficiency of the award outcome, we would be minded to err in favour a format that has a modest bias towards new entry and innovation rather than one which has a bias towards the use of spectrum by existing mobile operators.

Pairing of lots with spectrum outside the 2.6GHz band

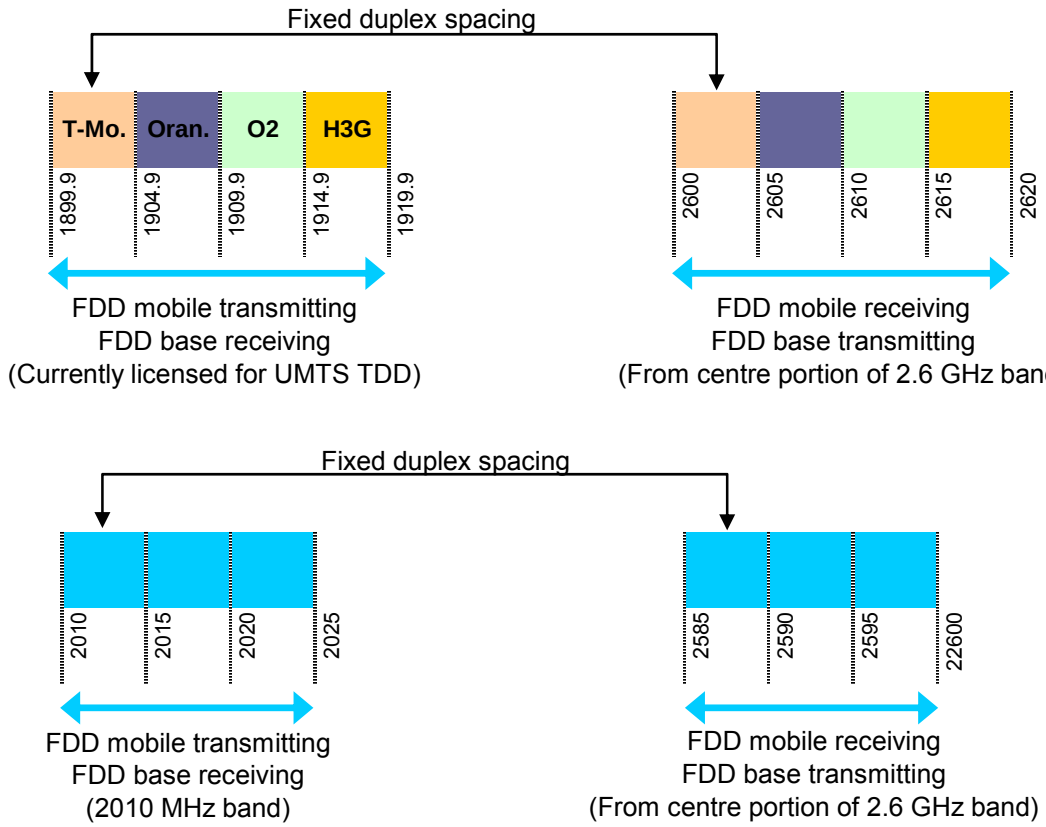
5.33 In response to the December Consultation, some of the MNOs suggested that the auction design should make it possible to pair spectrum within 2570-2620MHz externally with other spectrum bands. Two options for externally pairing spectrum were put forward:

a) pairing one or more blocks within 2600-2620MHz with blocks that have already been awarded in the 3G auction of 2000 at 1899.9-1919.9MHz; and/or

b) pairing 2585-2600MHz with the 2010MHz band.

5.34 Both options would involve the use of specific lots within 2585-2620MHz for downlink only, with a fixed duplex spacing for pairing with other specific lots, based on standards prepared by ETSI/3GPP.

Figure 9: illustration of the suggested external pairing options (licensed 1.9GHz spectrum and 2010MHz band for pairing with specific lots at 2.6GHz)



5.35 Ofcom recognises that these represent viable pairing options which, in an ideal world, would be accommodated within the auction design. However, the inclusion of additional options adds further complexity to the auction design and a balance needs to be struck between:

- the increased complexity of adding these options into the auction design; and
- the likelihood that these options would form part of the winning combination of bids (or, put another way, the likelihood that the omission of these bidding options would lead to a suboptimal outcome to the award).

5.36 We consider both these aspects below, discussing them in the context of the first of the external pairing options (pairing one or more blocks within 2600-2620MHz with blocks that were awarded in the 3G auction of 2000 at 1899.9-1919.9MHz) since this was the option in which more interest was expressed. We begin with a summary of the modification that would be needed to accommodate this option within the auction design.

5.37 Under this modification, each of the four MNOs that hold unpaired spectrum in the 1899.9-1919.9MHz range would be able to bid for its specific corresponding lot for use as a downlink (with the existing spectrum being used as an uplink), as shown below.

Table 11: frequency blocks currently licensed for 3G TDD at 1.9GHz suggested for pairing with specific frequency blocks at 2.6GHz

2.6GHz lot (MHz)	2600-2605	2605-2610	2610-2615	2615-2620
Channel number	21	22	23	24
1.9GHz pair (MHz)	1899.9-1904.9	1904.9-1909.9	1909.9-1914.9	1914.9-1919.9
MNO	T-Mobile	Orange	O2	H3G

5.38 The mechanism for accommodating these bids within the auction design is indicated below. But the essence of the approach is that bids for these specific lots would be included alongside all the bids for generic lots from which the winning combination of bids is identified (that combination which gives the highest bid value).

5.39 Of course, successful bid(s) for these lots would need to take into account the requirement for guard blocks between TDD and FDD use. Hence, the full range of possible assignments from lot 20 up to lot 24 are as indicated in the table below, with TDD representing use by a TDD operator, DL representing use of a downlink-only block (by an MNO for use in an external FDD pair) and GB representing use as a guard block between FDD and TDD use. For example:

- In outcome 0, no external pairing bids are successful and the channels 20 to 24 are assigned to TDD, with channel 24 remaining a guard block;
- Outcomes 1, 2, 3 and 4 represent cases where just one of the MNOs submits a (successful) bid for its specific lot. The impact is materially different for each MNO however:
  - If H3G submit a successful bid for channel 24 (outcome 1) then the guard block moves from channel 24 to channel 23 and H3G effectively replaces one TDD lot (crudely speaking, H3G would be competing against the value of one TDD lot);
  - If O2 (alone) submits a successful bid (outcome 2) then either an extra guard block is required or it has to win an additional downlink-only lot (crudely speaking, to win their specific 5MHz lot O2 would be competing against the value of two 5MHz TDD lots)
  - If Orange (alone) submits a successful bid (outcome 3) then either two extra guard blocks are required or it has to win two additional downlink-only lots (crudely speaking, to win their specific lot Orange would be competing against the value of three TDD lots)
  - If T-Mobile (alone) submits a successful bid (outcome 4) then either three extra guard blocks are required or it has to win three additional downlink-only lots, except in the unlikely event that there was a winning TDD bidder that wanted a single usable 5MHz channel (crudely speaking, to win their specific lot T-Mobile would be competing against the value of four TDD lots)
- Outcomes 2a (H3G and O2), 3a (H3G, O2 and Orange) and 4a (H3G, O2, Orange and T-Mobile) represent those cases where more than one MNO submits successful bids in such a way that no additional guard blocks are required (or they do not have to win additional downlink-only lots). In these cases the MNOs

are, crudely speaking, competing with the equivalent number of TDD lots so that they don't necessarily have to value the lots more highly than TDD bidders in order to win.

- Outcomes 3b, 4b and 4c represent the other potential outcomes which carry the weight of varying degrees of "overhead".

Table 12: main possible outcomes for external pairing of 2600-2620MHz with currently licensed spectrum at 1.9GHz

2.6GHz lot (MHz)	2595-2600	2600-2605	2605-2610	2610-2615	2615-2620
Channel number	20	21	22	23	24
1.9GHz pair (MHz)		1899.9-1904.9	1904.9-1909.9	1909.9-1914.9	1914.9-1919.9
MNO		T-Mobile	Orange	O2	H3G
Outcome 0	TDD	TDD	TDD	TDD	GB
Outcome 1	TDD	TDD	TDD	GB	DL
Outcome 2	TDD	TDD	GB	DL	GB
Outcome 3	TDD	GB	DL	GB	GB
Outcome 4	GB	DL	GB	TDD or GB	GB
Outcome 2a	TDD	TDD	GB	DL	DL
Outcome 3a	TDD	GB	DL	DL	DL
Outcome 3b	TDD	GB	DL	DL	GB
Outcome 4a	GB	DL	DL	DL	DL
Outcome 4b	GB	DL	DL	DL	GB
Outcome 4c	GB	DL	DL	GB	GB

5.40 On the basis of the above, only H3G could be confident of acquiring its corresponding lot, regardless of the bidding decisions of the other MNOs, without facing the opportunity cost of creating small and/or non-contiguous unpaired assignments. In other words, H3G would likely be the only MNO potentially seeking this external pairing that could enter the auction with a reasonable degree of confidence that they would be able to establish the external pairing independently from the other MNOs. However, this still depends on the opportunity cost of this outcome with regards to displacing unpaired bids. The opportunity cost could be large if a bidder wanted this block as part of a large package of unpaired spectrum which could not be accommodated by an alternative arrangement of the spectrum.

5.41 T-Mobile would be in the least advantageous position in this regard. If only T-Mobile chose to bid for its corresponding lot then, in order to arrive at a result in line with Option 4, T-Mobile would be required to bid an amount for one downlink-only lot which would be sufficient to displace assignments for TDD bidders involving four lots as part of either a split or non-split award (in order to avoid Option 0 being the result).

5.42 Turning to the modification of the auction rules, the above approach would require:

- a new lot category to be created for each of channels 21 to 24 with its own clock;

- the process for determining the end of the clock phase to be adjusted so as to take account of the bids for these specific lots when assessing whether total demand is less than or equal to the 190MHz on offer (with this process taking account of the potential number of guard blocks required for different combinations of bids); and

- an adjustment to the activity and switching rules.

5.43 We consider that it would be possible to modify the auction rules, and the winner determination and pricing algorithms, in order to introduce this external pairing option. However, it would come at the price of a considerable increase in complexity.

5.44 Turning to the likelihood that these external pairing options would form part of the winning combination of bids, this likelihood will be influenced by:

- the cost of acquiring paired spectrum via this option as opposed to other options; and

- the value of this type of paired spectrum as against the value of other types of paired spectrum which will depend, amongst other things, on the size of the related handset market.

5.45 Those MNOs that were interested in the external pairing option noted that they already own the uplink part of the pair which they are not currently using (implying that its use as part of an external pairing would have no opportunity cost). Accordingly, they argued that the cost per MHz of this external pairing option might be less than the cost of acquiring a 2x5MHz internally paired lot in the 2.6GHz award. Whilst this would be true for H3G, it would not necessarily be so for others if:

a) the marginal price per MHz of FDD and TDD lots is the same in the 2.6GHz band (which will be the case unless TDD demand drops below 45MHz “faster” than FDD demand drops below 140MHz as the clock price rises); and if

b) only some of the MNOs submit successful bids so that additional guard blocks have to be created in the manner described above.

5.46 For example, in the case where only T-Mobile submitted a (successful) bid for its specific lot, then it would probably have to bid four times the price of an equivalent TDD lot. And, if the marginal price per MHz of TDD and FDD lots is the same, then this single 5MHz lot could actually cost T-Mobile twice as much as buying a 2x5MHz paired lot in the 2.6GHz band.

5.47 Ofcom also notes, as discussed in Section 7 and 8, that it expects to publish a consultation on the liberalisation of mobile spectrum. The corresponding proposals may provide scope for an increase the options for use of licensed 3G spectrum at 1.9GHz through alternative applications. In scenarios where trading is introduced, there would be a (non-zero) opportunity cost attaching to the MNOs’ existing holdings at 1899.9-1919.9MHz.

5.48 Turning to the relative value of paired spectrum, this relative value will be heavily influenced by the cost and availability of handsets for the particular pairings in question. This, in turn, will be influenced by the size of market for the handset and so by the number of customers using this external pairing in Europe.

5.49 Ofcom is not aware of any substantial evidence that the external pairing arrangements put forward above are likely to become available across a number of geographical markets. Ofcom notes that other European regulators who have made proposals for the award of the 2.6GHz band (Sweden, the Netherlands, Norway) have not included this option in their plans. Also, even where the option may become available, it is not clear that operators would have any significant demand for pairing spectrum in such a way. An indication of the level of interest in these pairing options is given by the process of standardisation. The degree of involvement of industry also seems relatively low, when comparing the number of participants and scale of working group activity for ETSI's external pairing work, with those for other 3G standardisation work such as 3GPP's work on UMTS for use in the 900MHz range. While pairing spectrum at 2.6GHz externally may have some potential merits as an option (for example if demand for spectrum at 2585-2620MHz in the 2.6GHz award is low), it does not seem to be central to commercial plans for use of the band in Europe.

5.50 Manufacturers have indicated to Ofcom that they would not manufacture handsets for a particular spectrum band unless there was a significant market size for such handsets, likely to be measured in several millions of units. Allowing for the fact that MNOs will typically wish to offer customers a choice of handsets, and based on the observations above, it seems that the market size for handsets catering for either of the two external pairing options set out above is likely to be particularly challenging. In addition, Ofcom understands that, for practical reasons, there is a limit of probably 4 or 5 to the number of band arrangements that can be supported in any given handset if it is to have a reasonable form factor. Industry's expectations appear to be that future 3G handsets should, in due course, be operating at 2.1GHz, 900MHz, 1800MHz and 2.6GHz (internally paired) for UK and European purposes, but also accommodate UMTS bands in the USA and/or Japan which differ from those in Europe. This suggests that it is unlikely that any of the external pairing options based on the 2.6GHz centre portion would form part of plans to develop 3G handsets on a large scale, if at all.

5.51 Taking all these factors into account, it seems that these externally paired options are likely to be very much less attractive than other sources of paired spectrum such as the paired lots within the 2.6GHz band.

5.52 We also note that those MNOs who felt in a position to express any preference in our meetings with them, indicated that they were more interested in paired spectrum *within* the 2.6GHz band (i.e. spectrum from 2500-2570MHz paired with 2620-2690MHz) than in pairing outside the band (as would be the case with the two options suggested above). We note, further, that option (b) (involving pairing with the 2010MHz band) attracted the least amount of interest from respondents. On this basis, the only rationale for bidding for 2.6GHz spectrum for external pairing would be if MNOs felt they had exhausted more attractive sources of paired spectrum for 3G (given that this would be the most likely application for a 2x5MHz externally paired channel). However, we note that there is a substantial existing and prospective supply of spectrum for 3G technologies including up to 140MHz of additional internally paired spectrum in the 2.6GHz band (and including, in due course, 900 and 1800MHz spectrum, following implementation of the RSC Decision relevant to these bands).

5.53 Drawing the above analysis together, the option to facilitate external pairing (based on existing ETSI arrangements) through a change to the auction design would introduce, in Ofcom's view, a disproportionate amount of complexity compared to any potential benefit.

Preference for combinatorial clock auction format over traditional SMRA with specific lots

5.54 Ofcom recognises that its proposed auction format is significantly different from the formats that its predecessor, the Radiocommunications Agency, used for previous multi-round spectrum auctions in the UK. For the UK 3G, BFWA and PFWA auctions, the RA used formats based on the so-called 'standard SMRA' approach pioneered by the US FCC in the 1990s.

5.55 Ofcom, assisted by its advisors, has carefully considered the merits of using a standard SMRA format using specific lots (rather than generic lots), either with separate 5MHz lots or pre-packaged larger lots (e.g. 2x5MHz or 10MHz lots etc.). Ofcom recognises that this format offers some advantages. In particular, the basic rules will be familiar to some potential bidders, they are easy to understand and there is a direct relationship between the bids made by bidders and the price that they pay. However, Ofcom has also identified severe disadvantages associated with using the standard SMRA approach for this award, including the following.

- The available spectrum could be used for either TDD or FDD applications. Ofcom believes that it would be more efficient to allow the market to decide the appropriate split between paired and unpaired spectrum, rather than determine this by administrative decision. However, it recognises that in order to promote efficient use of spectrum and ease uncertainty for bidders over their prospective interference environment, it would be appropriate to locate paired and unpaired spectrum in separate contiguous blocks. A standard SMRA auction format could not be relied upon to produce such an outcome, as bidders must bid for individual lots without certainty as to the type of use that a winner of adjacent spectrum may deploy.

- Bidders seeking multiple lots in this auction will typically have strong preferences for contiguous spectrum. With a standard SMRA auction, because bidders are bidding for individual lots rather than packages, they face potential aggregation risks. Though aggregation risks could be addressed in an SMRA by allowing package bidding, this would be at the cost of considerable complexity for bidders because of the number of packages they might need to bid on.

- When bidders are seeking multiple lots but have flexible demand, standard SMRA auctions are strategically complex for bidders. In particular, there may be strong incentives for demand reduction in order to attempt to reduce final prices. This can lead to inefficient auction outcomes.

- Experience of use of SMRA suggests that such formats can suffer from strategic gaming behaviour.

5.56 By contrast, the proposed combinatorial clock auction format offers a number of strong advantages. It should ensure an efficient separation of paired and unpaired spectrum; avoids aggregation risks for bidders seeking contiguous spectrum; and creates strong incentives for bidders to bid their true value, so is strategically simple for bidders. Accordingly, Ofcom is confident that the proposed combinatorial clock auction format can deliver a more efficient auction outcome than would likely be achieved if a standard SMRA auction format were used.

5.57 In reviewing the options for using of specific lots, Ofcom has also considered the option of using a combinatorial clock auction format but with each lot as a separate category instead of abstract lots. Such an auction would be similar to the format

proposed for the award of 1452-1492MHz. Instead of bidding for packages containing a number of lots in one or more of the available categories, bidders would bid for specific combinations of frequencies in the primary bid round and supplementary bids round. In this case, no assignment stage would be required, as the distribution of frequencies amongst winning bidders would be determined by the winner determination process at the end of the Principal Stage. The main drawback of this approach is that it could not guarantee an efficient separation of paired and unpaired users, which would be a source of uncertainty for bidders and inefficiency of the process. There would also be a very large number of combinations of lots possible, which would increase the complexity of the auction for bidders; this seems undesirable and unnecessary given that lots within categories are likely to have similar value. For these reasons, Ofcom is not proposing an approach that uses specific lots.

Preferred auction format

5.58 Ofcom's preferred auction format is derived from the original combinatorial clock auction format presented in the December Consultation Document. The auction rules and terminology have been updated in light of the work that Ofcom has undertaken on other spectrum awards, and to take into account some of the issues raised in the consultation responses. Below, we provide a short description of this auction format and highlight significant changes from the December Consultation Document. A complete set of rules is provided in Annex 11. These rules are currently work in progress and may change. They are presented at this stage to assist stakeholders in understanding the preferred format. In accordance with its normal practice, Ofcom will consult on the rules for the auction when it publishes the relevant draft Statutory Instrument.

Short description of the preferred auction format

5.59 The auction proceeds in five stages, as described below.

Application Stage

5.60 Prospective bidders submit their applications to participate in the award process, including initial deposit.

Qualification Stage

5.61 Ofcom determines which applicants are qualified to bid. The determination is based on a check of the applications and initial deposits, and assessment of bidder groups. Ofcom announces the number and identity of the qualified applicants. Those qualified applicants then have an opportunity to withdraw from the process by a defined date. The remaining participants after the last day for withdrawal are bidders and are committed to accepting a licence at the reserve price, subject to the outcome of the auction. Ofcom announces the number and identity of the bidders. If there is only one bidder, the bidder will be entitled to select the frequency lots it wishes to purchase (subject to such restrictions as the spectrum cap) and the award will then progress directly to the Grant Stage. If there is more than one bidder, then a bidding process is required.

Principal Stage

5.62 There are two phases of bidding, which determine the identity of the winning bidders, the number and type of spectrum lots that they will receive, the allocation of spectrum

between paired and unpaired lots within the 2.6GHz band and whether or not a split award of unpaired spectrum will be necessary. The available lots are described in the table below. Note that, under certain outcomes, it may be necessary to designate between 1 and 2 lots as guard blocks, which are withheld from the initial allocation of lots, but are assigned on a restricted use basis to winners of adjacent spectrum in the Assignment Stage on the understanding that they are likely to be subject to greater levels of adjacent channel interference than other blocks.

Table 13: Categories and lots available in the auction

Category	Spectrum endowment	Number of lots	Eligibility pts per lot	Reserve price per lot*
2.6GHz paired	2x5MHz	Between 0 & 14	2	£100,000
2.6GHz unpaired	1x5MHz	Between 9 & 38	1	£50,000
2010-2025MHz	1x15MHz	1	2	£100,000

* Reserve prices are subject to further review by Ofcom

5.63 The first phase is the **primary bid rounds**, which follow a clock auction format. Bidders top up their deposits and the amount determines their eligibility to bid in the auction. Bidders make a single bid each round for a package of lots across the three categories in response to a set of prices notified to them by Ofcom (there will be a price per lot for each category of spectrum).

5.64 In the primary bid rounds, all bids for packages containing unpaired lots within the 2.6GHz band are contingent on all unpaired lots being contiguous. This has the implication that if such a bid was successful, any unpaired lots awarded must be located either in the lower unpaired area (i.e. below lot 24) or the upper paired area (i.e. from lot 38 downwards), and not split across the two areas.

5.65 For unpaired 2.6GHz lots, prices are increased in the next primary bid round if there is excess demand for the 2.6GHz band as a whole and demand for unpaired 2.6GHz lots exceeds nine. For paired 2.6GHz lots, prices increase whenever there is excess demand for the 2.6GHz band as a whole. For the unpaired 2010-2025MHz lot, the price increases whenever there is excess demand for this lot. The primary bid rounds continue until (a) there is no excess demand in any category and (b) it would be possible to accommodate all demand for unpaired lots without a split award.

5.66 The second phase is the **supplementary bids round**, which always follows the primary bid rounds. This is a single round sealed bid process, in which bidders have the opportunity to make multiple, mutually exclusive bids for packages of lots across categories, subject to constraints created by their primary round bids. In the case that bidders have submitted a primary bid that included unpaired lots or intend to submit a supplementary bid that contains unpaired lots, they will also be allowed to submit further bids for the same packages contingent on their unpaired spectrum being split between the upper and lower areas.

5.67 Ofcom then identifies the highest value combination of bids that can be accommodated, drawing on all valid bids from the primary and supplementary bids rounds and taking at most one bid from each bidder. A ‘base price’ for each winning bid is also identified using a ‘second price’ rule (see Annex 11 for an explanation). The outcome determines the allocation of lots between paired and unpaired in the

2.6GHz band, whether there is a split award for unpaired lots and the number of guard blocks, if required.

Assignment Stage

5.68 The Assignment Stage determines how the available frequencies within the 2.6GHz band that are assigned to paired, unpaired and guard blocks are distributed amongst the winning bidders from the Principal Stage (the winner of the 2010-2025MHz lot having already been determined). Bidders participate in two parallel, sealed bid auctions for the paired lots and unpaired lots respectively, and make 'assignment round bids' for particular ranges of frequencies compatible with the number of lots that they won in the Principal Stage. The guard blocks are included in selected bid options.

5.69 Ofcom identifies the highest value combination of bids that can be accommodated, subject to all bidders being assigned contiguous paired and contiguous unpaired frequencies (or two blocks of contiguous unpaired frequencies in the case of a split award). Additional prices are calculated using a second-price rule for each set of paired and unpaired frequencies. A final price for each bidder is then identified, which combines the base price and any additional prices.

Grant Stage

5.70 After the conclusion of the Assignment Stage, the award progresses to the Grant Stage, in which payments are finalised, licences are granted and the auction results are published.

Changes to the proposed format since the December Consultation Document

5.71 A number of changes and additions have been made to the auction format and rules since the December Consultation Document. A summary of these changes in relation to each stage of the auction is provided below.

Application, Qualification and Grant Stages – rule changes

5.72 Ofcom has proposed rules for the application, qualification and grant stages. These were not included in the December Consultation Document.

5.73 Ofcom has also proposed rules in the case that there are no bidders or there is only one bidder. If there are no bidders, there will be no auction and Ofcom will consider an alternative award process. If there is only one bidder, there will be no auction and the bidder will be entitled to select the frequency lots it wishes to purchase up to the eligibility cap. In all other cases, the auction will proceed to the Principal Stage.

Principal Stage – rule changes

5.74 The primary bid rounds were previously referred to as the Clock Stage. The supplementary bids rounds was previously referred to as the best and final offers (BAFO) round and supplementary bids were previously referred to as BAFOs.

5.75 The following changes are proposed to the rules for the primary bid rounds.

- In the primary bid rounds, all bids for unpaired 2.6GHz spectrum are contingent on receiving contiguous spectrum (i.e. not receiving a split award). It is still possible for a bidder to receive a split award of unpaired spectrum, but only if

they actively bid for such an option in the supplementary bids round (see below). Reflecting this change, the primary bids rounds will continue until such time as it is possible to accommodate all bids received in a round without any bidder for unpaired lots being subject to a split award.

- There is a single eligibility rule that applies across all three categories. Eligibility is fungible across the three categories, with the result that bidders can switch demand between paired and unpaired lots. This is a change from the previous rules, where it was proposed that switching would be limited to the unpaired 2.6GHz lots and 2010-2025MHz lot.

- There is a separate clock price for the 2.6GHz paired and unpaired lots. However, the 2:1 price ratio between these lots will be maintained throughout the primary bid rounds unless demand for unpaired lots falls below nine. In the event that the price for unpaired 2.6GHz lots falls below the 2:1 ratio, but demand subsequently rises above 9 lots, the price will be returned to a 2:1 price ratio in the next round.

- Ofcom has provisionally proposed a cap of 18 eligibility points per bidder (see discussion in the final part of this Section).

- Extension rights will be used instead of waivers. These allow bidders extra time to submit bids in a round in the event that they experience technical problems. Bidders that still fail to submit a bid after using up an extension period will be reduced to zero eligibility. Waivers are undesirable because if bidders failed to bid in a round but still had eligibility remaining, this could distort the level of aggregate demand, which is a key metric for bidders.

5.76 The following changes are proposed to the rules for the supplementary bids round.

- Supplementary bids can only be submitted in the supplementary bids round. This is a change from the previous design that envisaged allowing submission of some supplementary bids (BAFOs) during the primary bid rounds. This will simplify implementation of the auction and allow bidders to tailor the number and value of supplementary bids in light of the information revealed by the primary bid rounds.

- The supplementary bids round will always be run after the completion of the primary bid rounds. Previously in the December Consultation Document, it was envisaged that if the primary bids round ended with supply and demand exactly in balance, then the supplementary bids stage would not be necessary. However, the former approach risked creating an inefficient outcome, as it prevented bidders from expressing a full set of bids for available packages.

- Bidders can submit two types of supplementary bid: standard supplementary bids; and split supplementary bids. Standard supplementary bids are bids that include some combination of lots across the three categories, with any unpaired 2.6GHz lots being contingent on not receiving a split award. Bidders that submitted primary bids or standard supplementary bids for packages of lots containing unpaired 2.6GHz lots will be permitted to make additional split supplementary bids for the same package of lots but with specified splits between the lower and upper unpaired areas.

- Bidders will have 190 options for standard supplementary bids, i.e. every possible combination of lots with a number of eligibility points of 18 or less (in accordance with the safeguard cap of 90MHz).

5.77 When determining the winning bids and base prices (previously called the first stage winning prices), Ofcom will take into account all primary bids, standard supplementary bids and split supplementary bids from all bidders. Ofcom has proposed rules for determining tie breaks between potential winning sets of bids. The proposed second price rule for the Principal Stage has been refined (see discussion in the final part of this Section).

5.78 Ofcom has considered rules for transparency throughout the Principal Stage. It proposes to reveal information about aggregate demand and may also publish details of the number of lots each bidder requested in each category, but on an anonymous basis, subject to further consideration of the implications for potential strategic behaviour. At the end of the Principal Stage, it will inform all bidders of the identity of winning bidders and the number of lots they have won in each category. Winning bidders will be told their base price.

5.79 Ofcom's initial thinking is that it will use rules for deposits that are similar to those which are proposed for the 10-40GHz auction.

- Ofcom will determine the initial eligibility for each bidder based on the size of their deposit at a fixed date and time prior to the first round of the auction. Each bidder receives 1 eligibility point per whole £50,000 of deposit.

- During the primary bid rounds, Ofcom may on any number of occasions announce a deadline by which time bidders must have raised their deposit to a level that is probably at least equal to their highest primary round bid submitted prior to the announcement that deposits had to be raised. Bidders that fail to comply with this notice will not be able to submit further primary bids.

- Before the end of the day on which the supplementary bids round closes, bidders must have on deposit with Ofcom an amount probably at least equal to their highest bid made across both the primary bid rounds and the supplementary bids round. If a bidder does not meet this deposit obligation, all its bids from the primary and supplementary bid stage will be void.

5.80 Ofcom would welcome respondents' view on the issue of deposits.

Assignment Stage – rule changes

5.81 The following changes are proposed to the rules for the Assignment Stage.

- A second-price rule analogous to that being used for the Principal Stage is proposed for the Assignment Stage (instead of a pay-as-bid rule). This will simplify the decisions of bidders about the amounts of their bids in the Assignment Stage.

- Ofcom has proposed refined rules for determining the bid options in the Assignment Stage. These include rules for cases where some lots from the Principal Stage are unsold.

- The identity of any bidder receiving a split assignment of unpaired 2.6GHz lots (if there is one) will be determined by the Principal Stage, and this will be taken into

account in the available bid options for each bidder in the Assignment Stage. This bidder will always receive an additional guard block in the upper unpaired area, which will be located immediately below and adjacent to its core upper area assignment.

- Any other guard blocks will be assigned to the adjacent unpaired winner (or paired winner in the case that there is a guard block at lot 38 in which case there is no adjacent unpaired bidder).

- Before the end of the day on which the assignment bid round closes, bidders must have on deposit with Ofcom an amount probably no less than the aggregate sum of their base price and their highest assignment round bids for each of the categories where they have submitted such bids. If a bidder does not comply, all the bids it submitted in the assignment round will be void and it will be deemed to have submitted bids of zero for all frequency range options.

Table 14: Summary of proposed changes to the auction design set out in the December Consultation

Stage	Action	Description of change
Application, Qualification and Grant Stages	Rules provided	No specific rules were provided in previous consultation document.
Principal Stage	Terminology changes	'Primary bid rounds' instead of 'Clock Stage'; 'Supplementary bids round' instead of 'best and final offers (BAFO) round'; and 'supplementary bids' instead of BAFOs. (Changes made to align with terms used in the 10-40GHz auction)
	Information policy	During principal stage, Ofcom will reveal information about aggregate demand, and may reveal information about bids from each bidder on an anonymous basis. At the end of the Principal Stage, it will announce the identity of winning bidders and the number of lots they have won in each category.
	Deposits	Bids will need to be backed by deposits subject to deadlines notified by Ofcom during the auction.
Principal Stage: primary bid rounds	Primary bids contingent on no split award of unpaired lots	All primary bids for unpaired 2.6GHz spectrum are contingent on receiving contiguous spectrum. Primary bid rounds continue until such time as it is possible to accommodate all remaining bids without a split award of unpaired lots.
	Fungible eligibility	There is a single eligibility rule that applies across all three categories. Switching is allowed between paired and unpaired lots.
	Separate clock prices for the 2.6GHz paired and unpaired	Separate clock prices but 2:1 price ratio remains for the 2.6GHz paired and unpaired lots, unless demand for unpaired lots falls below nine. In the event that the price for unpaired 2.6GHz lots falls below the 2:1 ratio, but demand subsequently rises above 9 lots, the price will be returned to a 2:1 price ratio in the next round.
	Bidding cap	A cap of 18 eligibility points per bidder is proposed.
	Extension rights replace waivers	Extension rights allow bidders extra time to submit bids in a round in the event that they experience technical problems. Bidders that still fail to submit a bid after using up an extension period will be reduced to zero eligibility.

Stage	Action	Description of change
Principal Stage: supplementary bids round	Supplementary bid submission	Supplementary bids can only be submitted in the supplementary bids round (not during primary rounds).
	Supplementary bids round always run	The supplementary bids round will always be run after completion of the primary bid rounds, even if supply and demand are exactly in balance in last primary round.
	Two types of supplementary bids	In addition to 'standard supplementary' bids, bidders for unpaired 2.6GHz spectrum may submit 'split supplementary bids' for packages with specified splits between the lower and upper unpaired areas.
	Cap on standard supplementary bids	Cap of 190 proposed for number of standard supplementary bids of 190 (this is sufficient to allow bidders to bid for every possible package of lots consistent with the provisional eligibility cap).
	Winner determination	Ofcom will take into account all primary bids, standard and split supplementary bids from all bidders. Rules for determining tie breaks have been added.
	Pricing rule	Second price rule for the Principal Stage has been refined.
Assignment Stage	Bid options	Rules for determining bid options have been refined and now cover the case where some lots from the Principal Stage are unsold.
	Split assignments	Identity of the bidder receiving a split assignment of unpaired 2.6GHz lots (if there is one) will be determined by the Principal Stage, and this will be taken into account in the available bid options for each bidder in the Assignment Stage. A bidder may only get a split assignment if it has placed a bid for the corresponding option.
	Guard blocks	Guard blocks will be assigned to the adjacent unpaired winner (or paired winner in the case that there is a guard block at lot 38 in which case there is no adjacent unpaired bidder).
	Pricing rule	A second-price rule analogous to that being use for the Principal Stage is proposed (instead of a pay-as-bid rule).

Detailed auction rules and procedures

5.82 A number of respondents made comments about the detailed rules and procedures, as discussed below.

Transparency rules

5.83 The respondents who commented on transparency generally agreed that there is a trade off between more transparency to reduce common value uncertainty and higher risk of collusion. Some argued that in this auction the risk of collusion is small and that the auction could be made more transparent as common value uncertainty is the more important concern. One respondent also argued in favour of transparency so that bidders can better observe the technology choices of their rivals.

5.84 Ofcom agrees that the risk of collusion in the preferred auction format is small. However, Ofcom is not convinced that bidders would benefit greatly from having more information available about the bids and technology choices of individual bidders. Bidders will be told the identity of participants and the level of aggregate demand for each category of lot at the end of each primary round; this should typically be significant information for price discovery. Ofcom may also release details of the number of lots each bidder requested in each category but on an anonymous basis, subject to further consideration of the implications for strategic behaviour in the auction. If Ofcom provided more details of individual bids each round, this would be a large amount of data for bidders to digest and may be unduly distracting. Moreover, smaller bidders may lack the resources to process such information, so greater transparency might reinforce bidder asymmetries.

5.85 Accordingly, Ofcom does not currently intend to release information about individual bids on a round-by-round basis, although it may do so on an anonymous basis subject to further consideration.

Timing of submission of supplementary bids

5.86 Two respondents argued that supplementary bids (previously called BAFOs) should only be submitted at the end of the Principal Stage and not at the end of every round where a bidder drops eligibility. This change reduces the bid submission burden during the primary rounds, meaning that the auction can be run more quickly, and gives bidders more time to review their supplementary bids. However, it also increases the bid submission burden in the supplementary bids round.

5.87 Ofcom is minded to implement this change. The electronic auction system will include a bidding tool that allows bidders to prepare their supplementary bids in advance of the supplementary bids round, so as to reduce the burden during the round.

Pricing rules

5.88 One respondent commented that the pricing rule for the Principal Stage is not well understood and that, despite the second price rule, there is still room for strategic bidding as it is not always the case that the price a bidder pays is independent of the price bid.

5.89 Ofcom believes that the revisions to the pricing rules described in Annex 11 should largely address this point. The pricing rule is described in detail to allow potential bidders and others to carry out these calculations independently. Further details on this will be provided when Ofcom publishes draft regulations for this auction. A similar rule is being proposed for the 10-40GHz award[42].

5.90 It is true that the proposed pricing rule is such that the price a bidder pays is not completely independent of the amount bid (i.e. the second prices are not Vickrey prices). However, the pricing mechanism is such that the amount that bidders would expect to pay is typically more sensitive to the bids of others than to the individual's own bid. Moreover, it is difficult for bidders to anticipate whether or not lowering their bid would lead to a materially lower price paid. Therefore, although it is not the case that bidding one's value cannot be bettered, bidding close to value is likely to be an effective strategy. This provides a great simplification for bidders as compared with

[42] See http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_10_40/.

the difficult problem of trading off the price paid and the chance of winning that occurs in first-price auctions.

Format for the assignment process

5.91 One respondent suggested that the format used for the Assignment Stage should be an open, multi-round process rather than sealed bid. They argued that this would improve efficiency, as bidders could benefit from price discovery in relation to the value of individual lots.

5.92 Ofcom recognises that a multi-round assignment process may offer efficiency benefits relative to the proposed sealed bid. However, Ofcom's view is that any benefits are probably marginal, as price discovery should have been largely resolved during the Principal Stage. Therefore, it seems unlikely that any benefits would be sufficient to justify the additional cost to Ofcom and to bidders of elongating the award process.

5.93 Accordingly, Ofcom proposes to use a single round, sealed bid for the Assignment Stage. However, Ofcom would welcome comments from other stakeholders on whether they would prefer this approach or a multi-round process.

Spectrum caps

5.94 A large number of stakeholders responded with comments on whether there should be a cap on the amount of spectrum that an individual bidder can bid for in the auction. A majority of these respondents clearly supported a cap, although opinion differed on the appropriate level, while a minority were against any cap being imposed.

5.95 Some respondents also asked for clarification as to whether a cap:

- would include existing spectrum holdings in the 2GHz band; and
- would apply to secondary trades following the auction.

5.96 A number of respondents also suggested that some sort of use-it-or-lose-it provision be considered. They argued that Ofcom should continue to monitor the utilisation of spectrum and possibly even require licensees to put unused spectrum up for sale or arbitrate when a potential user wanted to buy unused spectrum of a licensee.

5.97 This is considered in more detail in Section 6. In summary, Ofcom considers that a safeguard cap of 90MHz would serve to prevent a low probability outcome (with one party acquiring a large majority of the 2.6GHz band) but with potentially large negative consequences for competition and innovation. It is therefore proposed to use a cap of 90MHz per bidder across both categories of lots in the 2.6GHz band. This is equivalent to a maximum eligibility of 18 points in the detailed rules set out in Annex 11.

Electronic bidding

5.98 Both the Principal Stage and the Assignment stage of the proposed auction will be conducted using an electronic auction system. Bidders will be able to access the system over the public Internet using a standard web-browser. The minimum requirements in terms of hardware and software will be described in a user manual

that will be distributed to Bidders prior to the auction. These requirements will not be onerous.

5.99 Digital certificates – which are password protected and specific to each bidder – will be distributed to bidders by Ofcom. Installing the certificates is a simple process and instructions will be provided in the user manual. Bidders will be able to log in to the auction system only from computers on which they have installed the necessary digital certificates. A further login username and password is required to access the electronic auction system, which will be communicated to Bidders by Ofcom prior to the auction. Bidders will be identified by the electronic auction system through their digital certificates and their username and login password. Bidders will need to ensure that these are not disclosed to third parties.

5.100 The electronic auction system allows bidders to enter bids and to observe the progress of the auction. It provides a display of the key aspects of the auction state, such as the number of completed primary bid rounds, whether a round is currently running and a countdown timer for submitting decisions when deadlines are in force. It also displays a clock synchronised with the auction server to aid bidders in submitting bids. Bids are not processed by the electronic auction system and results are not released until after the end of the round, so there is no strategic advantage to bidders from delaying submission of their bids.

5.101 Further information about the electronic auction system is provided in Annex 11.

Question 4: Do stakeholders agree with the proposed changes to the auction design set out in the December 2006 consultation?

Section 6

Other conditions relevant to access to spectrum

6.1 In their responses to the December Consultation and during the seminar held in February 2007, stakeholders raised a number of points that are relevant to spectrum access in addition to those relating to auction design and technical licence conditions (which are discussed in detail in Sections 4 and 5 of this document).

6.2 In this Section, we consider the following issues and set out proposals for the award of the available spectrum.

a) The position of BT in respect of the award of the 2.6GHz band (and the 2010MHz band) and the arguments raised by H3G and T-Mobile in favour of placing specific restrictions on BT.

b) The scope for applying a safeguard cap on the amount of spectrum within the 2.6GHz band that any one bidder could win at award.

c) The potential to introduce a licence condition to prevent inefficient hoarding of spectrum.

d) Restrictions on the association between separate applicants for participation in the award of the 2.6GHz band.

e) The potential for Ofcom to take specific measures for the licensing of the 2.6GHz and 2010MHz bands in respect of the 2012 Olympic Games.

f) The exemption from licensing of handsets for use at 2.6GHz and 2010MHz.

Competition issues and BT's participation in the auction of the 2.6GHz band

6.3 Both H3G and T-Mobile submitted responses relating to the potential participation of BT in the auction.

6.4 H3G argued that, unless accounting separation is forced on any new mobile venture from BT, there is a risk of anti-competitive behaviour from:

- BT providing network services from its fixed business where it has Significant Market Power (SMP) to a new BT mobile entity on preferential terms compared to other MNOs in order to drive competitors out of the provision of mobile services; and

- BT bundling existing retail services with new mobile retail services in order to foreclose competition across the range of bundled services.

6.5 Moreover, H3G claimed that the 1999 Information Memorandum for the 3G auction implied that, had BT been awarded a 3G licence, it would have been required to undergo accounting separation between its 3G business and the rest of its business. H3G claimed that there was no evidence to support a change in circumstances which would mean that accounting separation was no longer warranted. It also did not

consider that the Undertakings given by BT, pursuant to the Enterprise Act 2002, were a substitute for accounting separation.

6.6 T-Mobile argued that Ofcom's proposals in the December Consultation amounted to preferential treatment of BT despite its dominance in certain markets, and could threaten competition, innovation and investment in mobile services. T-Mobile stated that BT could use 2.6GHz spectrum to enter the market, and it would not be subject to rollout obligations.

6.7 Ofcom's assessment, as set out below, is that no specific restrictions on participating in the auction should be placed on BT (or any other individual organisation). Ofcom has set out its view that it is appropriate not to include rollout obligations in 2.6GHz licences in Section 8.

6.8 Ofcom notes that in the Information Memorandum (IM) for the 3G auctions, published in 1999, it was stated that the prime objective of the accounting separation rules on BT was to ensure that BT's network services were demonstrated to be provided to other operators on the same basis as they were to BT's retail business. Pursuant to this, the IM noted that the concern relating to the auction was to prevent cross-subsidies from BT's fixed business, where it had SMP, to BT's 3G activities. Ofcom notes that it has various tools to address any anticompetitive bundling and the vertical leveraging of market power (including Competition Act powers). Accounting separation is not the regulatory instrument that Ofcom uses directly to address these issues.

6.9 Ofcom also considers that telecommunications markets in the UK have undergone substantial changes (both market and regulatory) since the publication of the IM in 1999, such that the rationale which supported accounting separation in 1999 no longer applies. In particular, following Ofcom's Strategic Review of Telecommunications,[43] BT gave a number of Undertakings, pursuant to the Enterprise Act 2002, with the goal of promoting effective competition in the telecommunications market both now and in the future.

6.10 Ofcom believes that the main concerns voiced by H3G and T-Mobile regarding potential foreclosure of the market by BT are likely to refer to mobile *data* services rather than mobile *voice* services. Mobile voice services in the UK are well developed, with a high number of subscribers across a number of network operators, and achieving foreclosure in relation to these services would require significant effort, both in cost and elapsed time, in churning subscribers from existing voice providers to a new mobile voice entrant.

6.11 In contrast, mobile data services are at a relatively earlier stage of development but are forecast to grow rapidly should suitably priced services and devices come to market (see Annex 12 for further details). Ofcom is proposing an open, competitive award process for the 2.6GHz band which would allow multiple providers to supply mobile broadband services using a range of technologies including 3G and WiMAX. Therefore, other organisations would have the same opportunity as BT to provide mobile data services through the award of the 2.6GHz and 2010MHz band, and to develop new low cost services.

6.12 In the context of mobile data services, we consider in the following paragraphs:

[43] Ofcom's Strategic Review of Telecommunications can be found at http://www.ofcom.org.uk/static/telecoms_review/index.htm.

a) in relation to any network services where BT has SMP, the potential for BT to leverage this market power vertically and foreclose competition in any new retail mobile services; and

b) in relation to any retail services where BT has SMP, the potential for BT to foreclose competition in any new retail mobile services through horizontal leveraging of market power (through, for example, anti-competitive bundling).

Vertical leveraging of market power in network services

6.13 As discussed earlier, there have been major changes in regulation since 1999. The most important has been Ofcom's Strategic Review of Telecommunications, and as a result of that process, the Undertakings given by BT pursuant to the Enterprise Act 2002. The goal of the Undertakings is to promote effective competition in the telecommunications market both now and in the future.

6.14 The Undertakings are forward looking in that they commit BT to provide equivalence (equality of access) for new as well as for existing services - wholesale products would be made available to competitors to enable them to provide retail services on an equivalent basis before new services are introduced. This should prevent BT from leveraging market power in network services in order to foreclose competition in retail mobile data services. Ofcom does not consider, therefore, that the respondents to the December Consultation have made a convincing case that the Undertakings should be less effective for mobile services than for fixed services.

Horizontal leveraging through bundling of retail services

6.15 The retail services in which BT has currently been found to have SMP are:

- residential exchange line services: analogue and ISDN[44];
- business exchange line services: analogue and ISDN;
- residential calls: local; national; calls to mobiles; operator assisted calls; IDD[45] calls;
- business calls: local; national; calls to mobiles; operator assisted calls; IDD calls; and
- retail low bandwidth leased lines.

6.16 BT is able to request permission to bundle business services in which it has SMP with non-SMP services on a case by case basis. This means that Ofcom would have to approve a request to bundle 2.6GHz services with the above business services and would take into account any potential impact on competition in deciding whether to approve the request. Moreover, Virgin and Sky already bundle retail services such as mobile telephony, fixed telephony, television and broadband. This degree of flexibility, together with the Undertakings given by BT, suggest that other providers would likely be able to replicate potential service bundles that BT could provide, and therefore that the scope for anticompetitive behaviour through bundling appears limited (subject to the particular situation).

[44] Integrated Services Digital Network
[45] International Direct Dial

6.17 If BT were to bundle residential mobile data services with other residential services in which it had SMP and such bundling led to concerns over foreclosure in relation to mobile data services, any concerned parties could seek to challenge such an action on competition law grounds (either through a private action or by making appropriate submissions to Ofcom).

6.18 Moreover, the Undertakings are intended to allow other operators to provide retail services on an equivalent basis to BT. Therefore other operators using BT products (such as CPS, Wholesale Line Rental, Local Loop Unbundling and others) should be able to replicate any bundle offered by BT.

6.19 Importantly, there have also been significant changes in the key retail markets in which BT competes, which have reduced the degree to which BT is dominant and the potential scope for BT effectively to leverage market power.

- BT's share of total voice calls has seen a substantial fall since 2000, partly driven by:
  - o substantial growth in products that offer access for voice services, particularly carrier pre-selection (CPS) – over 6.1 million lines in March 2006[46];
  - o wholesale line rental lines (analogue and ISDN) increased from close to zero in early 2004 to 3.6 million in June 2006.[47]
- BT's retail residential price controls expired in 2006 and were not replaced. Ofcom did not carry out a material change review, and therefore BT is still judged to have SMP in the same markets as assessed in the last market reviews carried out in 2003. However, Ofcom did note the increasing competitive pressure and, taking account of this together with assurances from BT including assurances relating to basic line rental charging, decided that it was appropriate to remove these controls.
- The number of broadband connections has risen from a very small number to over 13 million residential and small business customers in 2006. BT has not been found to have SMP in the retail fixed broadband market, which could be a major platform for the future delivery of a diverse range of communications services.
- 3G networks and services are now established and therefore the potential for foreclosure is reduced.

6.20 As a result, Ofcom considers that the potential scope for BT to behave anti-competitively in retail markets is significantly diminished in comparison to the position in 1999.

6.21 Accordingly, Ofcom considers that market and regulatory conditions are different to those prevailing in 1999. The regulatory regime now in place is appropriate to deal with competition concerns regarding BT and in particular Ofcom does not consider that, if BT were to acquire a 2.6GHz licence, its activities using this licence should be subject to accounting separation. Moreover, to the extent that potential competition concerns might arise in future these could also be addressed under existing competition law legislation.

[46] The Communications Market 2006, Ofcom. See http://www.ofcom.org.uk/research/cm/.
[47] The Communications Market 2006, Ofcom

Use of a safeguard cap

6.22 In the December Consultation, Ofcom considered whether there was a case for reserving spectrum for particular technologies, or for ensuring a minimum number of players in relevant downstream markets. Ofcom concluded that the market would be a better judge of which technologies would best promote innovation and consumers' interests, therefore it did not propose to reserve spectrum for particular technologies. Ofcom also considered that it would be very challenging for the regulator to determine the efficient number of firms in the relevant downstream markets, and it would also imply some pre-determination of the most efficient uses of the spectrum. Ofcom considered that it would be better to devolve determination of these issues to the market and that, given the large amount of spectrum available, there was sufficient spectrum available for a number of players to win access to the spectrum bands.

6.23 Similarly, Ofcom considered that it would be unwarranted for the regulator to try to determine the optimal assignment of spectrum to an individual user, given the uncertainties over potential uses of the spectrum and user requirements. However, Ofcom did recognise that there was a small chance that one party could win a large amount of the available spectrum, thus potentially limiting the scope for competition in the provision of innovative services in so far as this depends on access to these bands.

6.24 Ofcom therefore consulted on whether there should be a "safeguard" cap set at 90MHz, a level which is comfortably higher[48] than the largest individual requirement of which Ofcom was then aware. This would allow one bidder to acquire up to 2 x 45MHz of paired spectrum, up to 90MHz of unpaired spectrum or an equivalent combination.

Responses to the December Consultation

6.25 Ofcom received a range of responses on these issues. In general, a clear majority were in favour of having some kind of safeguard cap. Of the 23 responses which clearly stated agreement or disagreement with Ofcom's proposals on this issue, 17 clearly supported a cap and 6 were against.

6.26 Of those who supported the idea of a spectrum cap, most felt that 90MHz was a sensible level although some argued for a lower cap (e.g. Nomad for 30MHz) though without providing analysis to demonstrate the nature of the potential competition concern that could justify a lower figure.

6.27 Several respondents asked for clarification on whether the cap should extend to trading. One respondent would only countenance a cap if it were removed immediately after the auction, whereas others argued that the cap could fail to serve its purpose if it could be circumvented in the secondary market immediately after the auction.

6.28 Finally, 4 respondents (including the BBC and National Grid Wireless) argued that a use-it-or-lose-it condition should be included in the licences as an additional measure to prevent the hoarding of spectrum.

[48] Set at 50% above 60 MHz

Ofcom's current assessment on the case for spectrum caps and restrictions on participation in the award

6.29 Ofcom reviewed the potential for foreclosure of entry into a relevant market as a result of this award in considering whether restrictions should be placed on specific bidders in this award. Ofcom considered the potential for foreclosure in the two current markets that could be identified (mobile communications and fixed broadband services) and a potential future mobile broadband services market. Ofcom concluded that the likelihood of an attempt to foreclose entry through this auction would appear to be low. Substitute spectrum is available that would support mobile communications, and fixed and mobile broadband services. No player is dominant in the relevant retail markets. Finally, attempting to acquire sufficient spectrum in the auction to foreclose entry would likely be prohibitively expensive.

6.30 As a result, Ofcom considers that the main justification for employing a spectrum cap is as a safeguard against the risk (which Ofcom considers to be low) that one party could acquire a large amount of spectrum in the award and limit the opportunities for efficient spectrum use and for promoting competition in downstream markets.

The size of the safeguard cap

6.31 Given this, the safeguard cap should be set at a size which is:

- large enough not to preclude any plausible business case for use of the spectrum; and
- low enough to prevent the (low) risk of foreclosure in markets that could be served by users of this spectrum.

6.32 Following responses to the December Consultation and bilateral discussions, the largest individual requirement that Ofcom is aware of is for 60MHz of unpaired spectrum for a WiMAX network, with a number of stakeholders stating that they would require a minimum of 30-40MHz to offer competitive services. Allowing for some margin over and above the largest individual business requirement for use of this spectrum indicates a minimum size of cap of somewhere between 70 and 80MHz.

6.33 In assessing the maximum size of cap we note that, if two new entrant WiMAX providers required 30MHz each of usable spectrum, then they would need to acquire a total of 70MHz between them (allowing for the requirement to acquire an additional lot as a restricted channel). Deducting 70MHz from the total of 185MHz available in the band (190MHz less the 5MHz for the guard block at channel 24), suggests that the safeguard should be no more than 115MHz.

6.34 As a result, any cap within the range 70-115MHz would satisfy Ofcom's two criteria for setting the cap (above the maximum credible requirement and allowing a plurality of service providers). The choice of where between these numbers the cap should lie is essentially arbitrary. Unless any stakeholders provide persuasive arguments in favour of another number, Ofcom is minded to set the size of the safeguard cap at the same level as previously proposed, i.e. 90MHz in total: either 90MHz unpaired (including restricted channels), 2 x 45MHz paired, or some combination of the two.

Whether to apply the safeguard cap to the secondary market

6.35 Ofcom has considered whether a cap should apply in the secondary market. In terms of consistency it would appear justified that a spectrum cap should apply at least in the short term in the secondary market, in order that prohibitions in the auction were not immediately undone through a trade subsequent to the auction. In the medium term spectrum requirements may change, therefore arguably greater flexibility should be permitted and the spectrum cap lifted. Moreover, players would have been given time to establish themselves and competition issues could be dealt with under general competition legislation.

6.36 On the other hand, it can be argued that any restriction on trading in the secondary market could be circumvented by one firm acquiring another, if the entity holding the spectrum licence is a separate company. Hence, extending the spectrum cap to the secondary market could be of little value.

6.37 Ofcom's conclusion is that, on balance, it is better not to apply the safeguard cap to the secondary market on the grounds that such regulations would add little incremental benefit in achieving Ofcom's objectives, and that it is consistent with Ofcom's duties to take the least interventionist approach to achieving its objectives.

Inclusion of a condition to prohibit inefficient hoarding

6.38 In the December Consultation, we set out proposals for the licences for use of the 2.6GHz and 2010MHz bands to have an indefinite term with an initial period of 20 years during which time it is proposed that Ofcom would not have the power to revoke licences for spectrum management reasons.

6.39 Concerns have been raised generally in relation to Ofcom's spectrum awards on the issue of inefficient hoarding of spectrum by successful bidders. In light of these concerns, Ofcom has considered whether, in order to help secure the optimal use of spectrum, it would be appropriate for it to retain the power to revoke the licences to be awarded in the circumstances where there was inefficient hoarding of the spectrum, even if this was within the initial 20 year period. Concerns about inefficient hoarding were also raised in relation to the award of the band 1452-1492MHz and a similar analysis has been presented in the consultation document "The award of available spectrum: 1452-1492MHz" relating to that band published on 25 July 2007[49].

A condition which prohibits the inefficient hoarding of spectrum

6.40 Ofcom's policy towards spectrum management, set out in the Spectrum Framework Review: Implementation Plan (SFR:IP)[50], is that the market is best placed to secure the optimal use of the spectrum. Moreover, Ofcom expects that the market will ensure that spectrum is put to good use, as an input to providing services for end-users. As such, Ofcom does not expect that spectrum will be left idle or be under-utilised for long periods of time if it is efficient for that spectrum to be in use (although Ofcom recognises that there are legitimate circumstances in which it can be appropriate for spectrum not to be used for a period, and that this can be beneficial).

6.41 However some parties have expressed the view that Ofcom could fail to meet its statutory duties to secure the optimal use of the spectrum in the event that the

[49] See http://www.ofcom.org.uk/consult/condocs/1452_1492/.
[50] See http://www.ofcom.org.uk/consult/condocs/sfrip/.

2.6GHz band (and by implication spectrum being awarded in other valuable spectrum bands) is bought by a bidder that is not interested in providing services using the spectrum, but is interested in holding the spectrum for a significant period of time, with the intention of then selling it on the secondary market. If such speculative behaviour were to occur, some have argued that this may not be in the best interests of citizens and consumers.

6.42 In light of these concerns, Ofcom has considered whether it might be appropriate for it to maintain powers to intervene in the market in specific circumstances. These circumstances might be where:

- the spectrum has lain idle or significantly under-utilised for a significant period of time since it was awarded; and
- there is clear evidence of a (significantly more) valuable use of the spectrum; and
- the current holder of the spectrum has no credible plans to bring the spectrum into effective use within a reasonable period of time.

6.43 Were Ofcom to maintain powers to intervene in such circumstances it is envisaged that Ofcom would first bring its concerns to the attention of the licensee and urge it to find ways to bring the spectrum into effective use as quickly as possible. This could be either directly themselves or through transfer of the rights of use to another party.

6.44 If nonetheless the situation persisted and Ofcom continued to have strong grounds to believe that the spectrum could be put to significantly more valuable use within a reasonable period of time, Ofcom could then take action to revoke the licence on spectrum management grounds in accordance with the procedures set out in paragraphs 6 and 7 of Schedule 1 to the Wireless Telegraphy Act 2006 (the "WT Act").

6.45 Ofcom recognises that such a policy would differ from the policy that has been adopted in earlier Ofcom spectrum awards. However, the likely greater economic and social significance of forthcoming spectrum awards (including the 2.6GHz band) places a greater imperative on Ofcom to ensure that it is used to good effect.

Potential benefits and costs of the inclusion of an anti-hoarding condition in 2.6GHz and 2010MHz licences

6.46 The main benefit from including such a condition in the licences would lie in maintaining Ofcom's power to intervene in specific circumstances to address inefficient hoarding of spectrum, where this was found to be a concern.

6.47 While the potential benefits of the inclusion of such a condition have been identified above, there are also costs associated with such a condition that may lead to an inefficient use of spectrum.

6.48 The most significant concern is the introduction of regulatory uncertainty; particularly that the inclusion of such a condition will likely introduce uncertainty for all bidders, including those that intend to make productive and immediate use of the spectrum. Such uncertainty will increase the risks faced by bidders and likely introduce barriers to potential bidders raising capital. As a result the likelihood of the spectrum being put to efficient use may be reduced.

6.49 A specific consequence of the uncertainty that would likely be created in this award is that it could reduce the likelihood of some services being deployed. As discussed further in Section 7, much of the benefits that are likely to result from the award of the 2.6GHz band relate to new competition and innovation through the introduction of new technologies and services. However, Ofcom is aware that there are considerable commercial, economic and technical risks associated with the potential use of this spectrum, and that the business case for potential bidders is therefore uncertain. These risks reflect many factors, including the unavoidable uncertainties involved in planning use of new technologies (such as WiMAX), offering new services and establishing new players in mature mobile communications markets such as the UK's. We consider that the potential for a licence condition to increase those risks and potentially affect the ability of potential spectrum users to raise capital and participate in the award is undesirable.

6.50 In the specific case of the 2.6GHz award there is an additional consideration in relation to the position of existing MNOs who may want to use the band. If the award is held in advance of the time at which some MNOs might wish to be able to bring 2.6GHz spectrum into use (e.g. to add capacity to existing 3G networks or to deploy LTE technology when it is available in the short to medium term) then it may be entirely appropriate for them to acquire spectrum in the award and then to delay use of it for a period, possibly up to a few years. Whilst Ofcom would not expect to make use of a condition relating to inefficient hording in these circumstances, the existence of such a condition could increase the perception of regulatory risk for these parties. Again, this could affect their ability to participate in the award, even though such participation could bring important benefits.

6.51 Finally, we note that the risk of adverse scenarios associated with inefficient hording is reduced by the large amount of spectrum available in the 2.6GHz band (190MHz less 5MHz guard blocks).

Initial conclusion on a condition to prohibit hoarding of spectrum

6.52 After weighing up the costs and benefits, Ofcom doubts that it would be appropriate to include such a condition within the WT Act licence(s) to be awarded for the 2.6GHz band and we therefore propose not to include it. We welcome views on this matter. The absence of such a condition would not affect Ofcom's other statutory powers, including those to address anti-competitive behaviour.

Association between applicants and consortia in the award

6.53 As with other spectrum awards, Ofcom recognises that interested parties could jointly participate in the proposed award of the 2.6GHz band and that investors may consider financing more than one potential bidder.

6.54 We therefore provide an indication of the approach Ofcom is likely to follow in placing restrictions on the links between participants in the proposed award. These restrictions would apply from the time of application to completion of the award process. The main objectives of these restrictions are to limit the scope for coordinated behaviour between participants and to avoid circumvention of the safeguard cap on the amount of spectrum any one bidder can win.

6.55 The approach is likely to follow a similar line to that followed for past awards for which Ofcom made regulations which can be found on the Office of Public Service Information's website[51].

6.56 It is for interested parties to determine in detail how the provisions of those example regulations would apply to their specific circumstances. However, at a high level, the provisions are concerned with:

i) restrictions on the flow of confidential information; and

ii) restrictions on the potential for one applicant (or bidder) to exert direct or indirect control over another applicant (or bidder).

6.57 The example regulations include definitions of a number of key concepts such as "confidential information", "bidder group", "associate" of an applicant or bidder and "provider of finance".

6.58 The following paragraphs provide a brief summary of the main provisions. This summary should not be construed as a replacement for detailed consideration of the corresponding regulations in their entirety.

a) To prevent the flow of confidential information between separate applicants or bidders, applicants and bidders are required to identify their "bidder group", i.e. those organisations or persons that have a material interest in them (by way of shareholding or rights to determine the conduct of their business) or to whom they have disclosed confidential information. Ofcom can then assess whether confidential information may have been passed between groups and investigate what the nature of that information may be. A provider of finance may be in receipt of confidential information from several applicants or bidders. However any transmission of such confidential information by a provider of finance to another group would be considered by Ofcom to be against the requirements relevant to qualification to become a bidder (including the scope for distortion of the award process) and activity rules designed to prevent coordinated behaviour.

b) For bidder groups, one of the tests used to determine whether an organisation or person has a material interest in an applicant or bidder is whether that organisation or person has any interest in shares carrying more than 25% of the votes entitled to be cast at a general meeting of the applicant or bidder.

c) There should be no overlap between bidder groups of the applicants and, if there are overlaps at time of application, then the period between application and Ofcom's determination on qualification should be used to address these overlaps.

6.59 Ofcom expects to use a similar framework for the award of the 2.6GHz and 2010MHz band. If stakeholders interested in participating in the award consider that the above framework may place significant constraints on the way they could participate in the

[51] See www.opsi.gov.uk, with
- http://www.opsi.gov.uk/si/si2006/uksi_20060338_en.pdf for the regulations applicable to the award of spectrum at 1781.7/1880 MHz (Statutory Instrument 2006 No. 338);
- http://www.opsi.gov.uk/si/si2006/uksi_20061806_en.pdf for the regulations applicable to the award of spectrum at 412/424 MHz (Statutory Instrument 2006 No. 1806); and
- http://www.opsi.gov.uk/si/si2007/uksi_20070378_en.pdf for the regulations applicable to the award of spectrum at 1785-1805 MHz in Northern Ireland (Statutory Instrument 2007 No. 378, as amended).

award, then Ofcom would welcome information from those stakeholders in order to help us understand and assess the nature and implication of those constraints.

2012 Olympic Games

6.60 On 6 July 2005, London was chosen to host the Games of the XXX Olympiad, which will take place between 27 July and 9 September 2012. The Olympic Park will be built on a 500-acre site in the Lower Lea Valley, while Wembley Stadium, the All England Lawn Tennis and Croquet Club, Lord's Cricket Ground, Greenwich Park, Regent's Park, Hyde Park and Horse Guards Parade will also host events in London. The Eton College Rowing Centre at Dorney Lake, Weymouth Bay and Portland Harbour and five other football grounds – Hampden Park, the Millennium Stadium, Old Trafford, St. James' Park and Villa Park – make up the remaining venues.

6.61 As well as the Games themselves, test events will take place at Weymouth and Portland in 2010 and at other venues during 2011 and into 2012.

6.62 The Government has given certain guarantees to the International Olympic Committee (IOC) in connection with the Games. Guarantee 15.8 of London's bid for the Games stated that:

> By early planning and understanding all the frequency requirements (including broadcasters, teams, organisers, policy, security and emergency services etc.), Ofcom will organise a full frequency plan for the Games and will arrange all the spectrum licences in good time in support of the plan. This will guarantee access to spectrum for all the licensees. . . . The Secretary of State for Trade and Industry has guaranteed on behalf of the UK Government the allocation of the frequencies required for the organisation of the Games.

6.63 Ofcom is working closely with the Government and the London Organising Committee of the Olympic Games and Paralympic Games (LOCOG) to take forward this spectrum plan. It expects to publish a discussion document on its approach in autumn 2007.

6.64 Guarantee 15.9 of the bid stated that:

> The Secretary of State for the Department of Trade and Industry has guaranteed on behalf of the UK Government to the waiving of fees payable for the allocated frequencies required for the Games.

6.65 The Secretary of State's letter to the President of the IOC clarified that this guarantee applied in respect of the following constituent groups:

- athletes;
- the IOC;
- LOCOG;
- national Olympic committees;
- international federations;
- the media;
- rights-holding broadcasters; and
- Olympic partners.

6.66 Ofcom and the Government have considered the relevance of these guarantees to the spectrum bands being awarded under the spectrum award programme.

6.67 In particular, on 15 March 2007, Ofcom published a discussion document[52] which sought comments on the likelihood of spectrum in the 10GHz band being required for the Games and the most appropriate way of ensuring access for the Games to this spectrum following its award to successful bidders in the auction. Ofcom suggested that a condition might be included in the licences to be awarded that would allow Ofcom to vary the licence terms for the purpose of meeting the UK's international obligations relating to the Games. Ofcom received five responses and has placed the non-confidential responses on its website[53]. The responses provided a diversity of views. There was no consensus that 10GHz would be suitable for wireless cameras or that the inclusion of the proposed licence condition would be appropriate. In particular, there was concern that the proposed licence condition would create significant uncertainty for licensees, and therefore have a negative impact on the optimal use of the spectrum.

6.68 In light of the outcome of this consultation, Ofcom has decided that no condition should be included in the licences for use of the 10GHz band to be awarded under that award process and plans to set out this decision in a forthcoming statement on the award of the 10GHz band and other spectrum bands. Ofcom considers that similar risks and disadvantages apply in the case of the 2.6GHz and 2010MHz bands and is therefore not proposing to include such a condition in the licences for award of these frequencies.

6.69 Section 5 of the Communications Act provides that the Secretary of State may direct Ofcom in relation to its functions relating to the management of the radio spectrum. The Secretary of State's power extends to issuing directions to Ofcom for the purpose of securing compliance with international obligations of the United Kingdom. The Government has advised Ofcom that the guarantees given to the International Olympic Committee constitute international obligations of the United Kingdom.

6.70 It is not possible for the Secretary of State to fetter his discretion about the exercise of his power to issue directions to Ofcom relating to the management of the radio spectrum. However, neither the Government nor Ofcom expect to exercise their powers to vary or revoke the licences to be awarded under the proposed award process, without the consent of the licensees, for the purpose of meeting obligations relating to the 2012 Olympic Games.

6.71 Ofcom will make further information available about the Games in due course and expects to publish in the autumn of 2007 a discussion document about its approach to spectrum planning.

Exemption of handsets

6.72 Some stakeholders considered that to ensure the successful development of mobile use of spectrum, it was important to ensure that the authorisation process did not prevent mobile stations (handsets) from being widely available to consumers. For that purpose, they considered that it was necessary to exempt from licensing mobile stations due to operate in the 2.6GHz and 2010MHz bands.

[52] http://www.ofcom.org.uk/consult/condocs/2012olympics/
[53] http://www.ofcom.org.uk/consult/condocs/2012olympics/responses/

6.73 Currently, by way of background, mobile stations operating as part of 2G and 3G licensed networks are exempt from the need to operate under a licence (subject to compliance with the relevant interface requirements). Also, the main potential uses identified for the 2.6GHz and 2010MHz band are either identical to, or have strong similarities with, 2G and 3G use. In addition, it is likely to be in the interest of consumers, by facilitating their access to equipment for mobile use and by allowing roaming of mobile stations from other countries.

6.74 However, not all licensees in the 2.6GHz or 2010MHz band may wish user equipment to be exempt from licensing in the specific frequencies to which they hold rights.

6.75 Ofcom therefore plans to amend the regulations that give effect to licence exemption after the award, at the request of interested licensees, in order to exempt mobile stations operating in connection with a licensed network that comply with its decisions in respect of technical conditions for the bands, but only in the frequencies licensed to those who request such an exemption. We therefore expect to consult on draft exemption regulations shortly after completion of the award, when licensees have had an opportunity to request the exemption of user terminals in their licensed frequencies.

Section 7

Timing of the award

7.1 The December Consultation set out a range of considerations in relation to the timing of the 2.6GHz band award and in relation to the linkage between the award(s) of the 2.6GHz, 2010MHz and 2290MHz bands. This drew a wide range of comments and analysis from stakeholders. Although we are not seeking to take any decisions on the timing of the 2.6GHz award at this point we believe that it is appropriate to update interested stakeholders on our current view of timing issues as this should be helpful for those parties that are considering participation in the awards. In the context of providing this update, we begin with a summary of the main features of the responses.

7.2 The overwhelming majority of responses to the December Consultation focussed their comments on timing of the proposed awards on the 2.6GHz band, with few comments of note on the timing of the 2010MHz and 2290MHz bands. Therefore, this Section focuses on the 2.6GHz band, with the linkages to 2010MHz and 2290MHz bands considered towards the end of the Section.

7.3 This Section is therefore structured as follows.

- Summary of responses to the Consultation concerning the timing of the award
- Current assessment of appropriate timing for award of the 2.6GHz band
- Award of the 2010MHz band
- Award of the 2290MHz band
- Summary of Ofcom's current assessment of award timings and linkages

7.4 For convenience, this Section refers to "the MNOs" when summarising concerns raised by the five existing mobile network operators (the four 2G and 3G operators – O2, Orange, T-Mobile and Vodafone – and 3G operators H3G). In many cases, not all of the MNOs may have raised a particular issue and the use of this shorthand should be taken to refer to some subset of the 5 MNOs.

Summary of responses to the Consultation concerning the timing of the award

7.5 All of the respondents to the December Consultation agreed that the 2.6GHz and 2010MHz bands should be awarded, that they should be licensed and (with the exception of 1 out of 35 responses) that an auction process was the most suitable process. Ofcom therefore remains of the view that it should allow the use of the bands by granting licences via an auction mechanism.

7.6 However, respondents disagreed over the timing of the award of the 2.6GHz band and, where an opinion was expressed on this issue, the responses (both presented in writing and in meetings) fell into two broad categories:

- the view held by most of the 3G MNOs and 3G equipment manufacturers was that **the award should be delayed, possibly by several years**; and

- the view held by those typically associated with the WiMAX community (such as existing and potential service providers and equipment manufacturers) was that **the award should take place as soon as is practicable**.

7.7 In response to the December Consultation, some stakeholders (including H3G, O2 and T-Mobile) argued that demand for use of the 2.6GHz band was unproven, or that the December Consultation did not provide sufficient proof that demand exists. Orange agreed that "*the 2.6GHz spectrum is potentially of significant interest to users, including mobile operators such as Orange. This potential is dependent on how and when Ofcom chooses to allocate the spectrum.*" Vodafone did not address the question of demand in its response and was of the opinion that the award need not necessarily be delayed as long as uncertainties over 2G liberalisation were resolved in advance. Other respondents (including BT, Intel, Siemens, Sprint Nextel, the WiMAX Forum and the UMTS Forum) were of the view that significant and sufficient demand exists for use of the 2.6GHz band in the immediate future or that the award should take place in accordance with the proposed timing.

7.8 In addition to querying the existence of demand for the 2.6GHz band, the first group of stakeholders, including several of the existing MNOs, raised further issues in support of their view that the award process should be delayed, referring to:

- technology and market uncertainties (for example, surrounding future technologies such as LTE[54] and IMT-Advanced[55] and the associated end-user demand that would drive their introduction);

- regulatory uncertainties that are relevant to their potential demand for 2.6GHz spectrum and which could be addressed over time such as-

  - liberalisation of 2G spectrum (which is currently licensed for GSM technology only but could be used for 3G technologies);

  - liberalisation of 3G TDD spectrum (as this would increase the scope for use of this licensed spectrum, which could be linked to the 2.6GHz band);

  - availability of other substitutes for the 2.6GHz band such as DDR spectrum;

  - potentially forthcoming RSC Decision(s) on applying WAPECS which covers the 2.6GHz band;

- the need to resolve technical interference issues and the treatment of adjacencies between different types of user;

- the immaturity of spectrum usage rights (SUR) concept and concerns over their application, the consideration of which would require a delay to the award;

- novel and untested features of the auction design (with the observation that the 2.6GHz auction design should be finalised only after the 10-40GHz award, in which a similar design is planned, has taken place); and

[54] Long Term Evolution, a term covering the potential next generation of cellular mobile technologies in the 3GPP UMTS family and likely to require spectrum in blocks of 2x10 or 2x20 MHz if used at 2.6 GHz

[55] A family of future mobile and nomadic broadband standards currently under consideration in ITU. Potentially able to support data rates up to approximately 100 Mbit/s in the mobile environment and 1Gbit/s in the nomadic environment. IMT-Advanced was formerly know as systems beyond IMT-2000 – see Recommendation ITU-R M.1645 for further information

- claims that legitimate expectations existed, arising from the 3G licence auction in 2000, that the 2.6GHz band would be reserved for use as a 3G expansion band (and that the award should not take place until the there was demand for use by 3G technologies / by 3G licensees).

- uncertainties over legal restrictions on third party use of spectrum linked to the Floe Telecom and VIP cases.

7.9 There were differences in views between the respondents who argued in favour of delay. The four 2G MNOs focused mainly on regulatory uncertainty, while H3G was also concerned about technology and market uncertainty[56]. Vodafone did not consider that delay was necessarily required, but considered that the uncertainties relating to 2G liberalisation should be resolved before any award of the 2.6GHz frequencies. All five MNOs argued, however, that some of the regulatory uncertainties would affect them differently to other bidders - in particular, that the uncertainties relating to liberalisation of 2G (and, in some cases, 3G TDD) spectrum would place them at a disadvantage compared to other bidders in the auction if it were not delayed until those issues were clarified. They argued that this disadvantage would result from the difficulty for them to assess the private value for the spectrum as accurately as others and that it could impair the efficiency of the auction.

7.10 In contrast, respondents who were in favour of awarding the band as soon as is practicable argued that:

- there was an immediate need for the spectrum by operators to serve a large market of end-user demand that they had identified for mobile data services;

- the spectrum was available and could be used for new and innovative uses in the near future with some equipment available now and further equipment expected to become available in the short term;

- equipment is available for use based on new technologies such as WiMAX;

- there were clear examples of substantial investments for innovative services in large markets for mobile use at 2.6GHz, in particular with Sprint Nextel in the USA;

- the UK would otherwise lag behind other European countries which have announced awards of the 2.6GHz band in late 2007 and early 2008;

- a timely award in the UK would stimulate market dynamics in Europe with a beneficial impact on equipment volumes and prices, which could be passed onto service providers and consumers; and

- the window of opportunity for new mobile data services to enter the market is relatively narrow and a material delay could see the establishment of substantial barriers to entry for new entrants[57].

[56] Some manufacturers also argued that the award should not take place until LTE standards were agreed.

[57] For example, if the 3G operators were able to cement their incumbency advantages and establish evolutions of 3G technology as the dominant platform for mobile data.

7.11 In the remainder of this Section, we set out our current assessment of the appropriate timing for award of the 2.6GHz band.

Current assessment of the appropriate timing for award of the 2.6GHz band

7.12 In forming an updated view on the appropriate timing for the award of the 2.6GHz band, Ofcom has considered four main questions.

- Is there interest in making the band available as soon as practicable?
- Is making the spectrum available likely to create consumer benefit?
- Would a delay in the award increase these benefits further?
- What other factors are relevant to award timing?

7.13 We examine each of these in turn.

Interest in making the band available as soon as practicable

7.14 During bilateral discussions held with stakeholders following the December Consultation, Ofcom received a number of confidential concrete expressions of interest in using the band in the immediate future. These parties expressed a desire to have the opportunity to participate in a competitive award to access the band as soon as possible. These came from both large established companies already providing telecommunications services as well as smaller companies seeking to develop new services using the 2.6GHz band. In general, these parties are concerned with acquiring TDD spectrum for WiMAX based services and, if one or more of these parties were successful in the award, then this would lead to the entrance of new players in the market for mobile data services.

7.15 In addition, feedback from interested parties indicates that some existing MNOs (and possibly others) might also participate in an award if it were held as soon as practicable, even though they might prefer the award to be delayed until they had more immediate need to use the spectrum. They indicated that their participation would be with the aim of acquiring spectrum for later use, for example when LTE based services become technically ready and / or when they require extra capacity on their 3G networks.

7.16 We appreciate that those stakeholders who have expressed doubt about the existence of demand from potential service providers do not have the benefit of being privy to the bilateral discussions to which we refer. We are also aware that the only absolute test of whether there is demand for use by operators is to actually hold the award. However, we are persuaded from our conversations that real interest exists and that if the award were held in 2008 then it is very likely that there would be parties who would participate in the award who, if successful, would intend to bring the spectrum into use without delay.

Consumer benefit from making the spectrum available

7.17 In the December Consultation, we noted that the 2.6GHz and 2010MHz bands are available for new uses and that the 2010MHz band has been unused for some time. We also referred to a number of sources of potential consumer benefit associated with the award of the 2.6GHz band):

- new entrant(s) coming into the market using this spectrum causing an increase in competition resulting in a reduction in prices and greater choice for consumers;

- innovation in services through the availability of the spectrum and/or the entry of new providers (visible as new or improved services that would not be possible or would be delayed otherwise); and

- potential cost savings for existing operators which may be (partially) passed onto consumers.

7.18 In light of feedback from stakeholders and further research, we believe that there could be substantial benefits created by the interaction between the effects of competition and innovation through the use of this band. Whilst the band could also allow existing operators to make cost savings in due course, we do not consider this to be an important factor in our current assessment[58]. Accordingly, the summary below of our updated view on consumer benefit focuses on the competition and innovation aspects. We also summarise briefly the evidence of demand for mobile data services since this provides a sense check on the existence of future demand for prospective use of the 2.6GHz band.

Consumer benefit from competition and innovation

7.19 There is a substantial body of opinion supported by empirical evidence which suggests that greater competition can lead to increases in innovation[59]. For example, innovation may be more intense as a result of the threat of competition or as a response to it. This interpretation appears pertinent to the case of the 2.6GHz award for the following reasons.

- There is a competitive process in train between supporters of the 3GPP and the IEEE standards setting bodies in relation to the standard for advanced mobile data services with 3GPP developing the LTE standard and IEEE developing the mobile WiMAX standard 802.16e.

- These standards embody (in the case of both LTE and WiMAX) a range of new techniques such as OFDM, MIMO[60], beam forming and an all IP architecture, that is likely to offer significant cost and bandwidth advantages over current 3G standards (although current 3G standard are themselves developing via HSPA[61] for example).

- The WiMAX standard appears to be a few years ahead of the LTE standard and, in particular, appears to be ready for deployment in 2008 (indeed, Sprint is currently rolling out a WiMAX network in the US that is planned to commence service at the end of 2007).

[58] The potential source of cost saving is different depending the frequencies at which operators are currently providing services. Existing 3G operators could use 2.6GHz to add capacity, and so deploy fewer sites to meet traffic demand when their existing networks become strained, particularly in densely used urban areas. The 2.6GHz band would provide wireless broadband operators (such as Pipex) access to spectrum with better propagation characteristics than their existing holdings in the 3.5GHz range; this would reduce the number of sites required to offer coverage, particularly outside of dense urban areas.

[59] See for example “Competition and innovation: an inverted U relationship” P Aghion, N Bloom, R Blundell, R Griffith and P Howitt, Quarterly Journal of Economics May 2005.

[60] Multiple Input Multiple Output, a type of antenna.

[61] High Speed Packet Access, a development of existing 3G/UMTS standards.

- If an award for the 2.6GHz band is held in 2008 then there is an opportunity for new entrants to the mobile data services market to offer services using the new WiMAX standard that could offer a combination of cost and service advantages over technologies currently used for 3G and so give them some chance to compete against the significant advantages that come with incumbency.

7.20 The emergence of new entrants using WiMAX could stimulate two levels of competitive response.

- In terms of standards development, it seems very possible that the threat of WiMAX will encourage 3GPP to develop its LTE standard faster than would otherwise be the case. Indeed, it has been suggested that this has already prompted the recent acceleration of efforts to develop the LTE standard.

- From 3G MNOs in the UK as they respond to new entrant competition in existing mobile data markets and potentially advance their own plans for next generation deployment which they could do using either LTE when it is available (which would present a natural evolution path from 3G) or, possibly, using WiMAX themselves as a complement to their existing 3G networks[62].

7.21 It is plausible that consumers could derive benefits through a combination of:

- lower prices through the effects of competition for the types of services that can already be provided over 3G;

- innovation in services that is made possible by more advanced technology, either because these services are dependent on the higher data rates that become possible, or because the lower cost per Mbps makes it commercially viable to deliver services that are technically possible but not commercially viable over 3G; and

- a medium term dynamic effect if 3G MNOs advance their own deployment of new technology which may benefit the wider customer base whether or not they take services, or are in a location which is subject to competition from, new entrants.

7.22 The significance of the 2.6GHz band in this context is that it appears to be central to this contest for deployment of advanced mobile data technologies as:

- it provides sufficient spectrum to cater for the larger bandwidths likely to be supported by LTE (e.g. 10 and 20MHz) and to support the use of WiMAX in 10MHz and 20MHz blocks; these larger channel sizes are key to achieving some of the performance gains - and channels of more than 5MHz width are likely to be harder to find at the lower, heavily congested frequencies, and they are certainly not available in the near term at other mobile / IMT frequencies;

- it is **the** band for which WiMAX services have been developed for deployment on a global basis so as to support roaming and economies of scale in equipment manufacture. This is because 2.6GHz is the only band which is available

[62] Vodafone has been reported as indicating it may choose WiMAX instead of LTE as its next generation mobile technology. See for example AFX's news release of 15 February 2007, 'Vodafone CEO says Ericsson's LTE standard development must be speeded up', available at http://www.forbes.com/technology/feeds/afx/2007/02/15/afx3429008.html.

internationally in the near term[63], although WiMAX profiles may be developed for other frequency bands that may become available for mobile services in future.

7.23 We also note that WiMAX in its current form has been developed for use in unpaired spectrum whereas 3G technologies, and probably LTE technology, use paired spectrum. Thus the competitive opportunity for WiMAX depends on the availability of unpaired spectrum in the 2.6GHz band: this underlines the importance that we attach to allowing flexibility between paired and unpaired spectrum as discussed in Section 3.

7.24 Estimates of the types of consumer benefits referred to above are subject to very considerable uncertainty by their nature. However, it is not unreasonable to use mobile data services as a meaningful reference point. Revenues for these services are currently in the order of £700m in the UK[64] and are forecast by some analysts to grow significantly. It is also worth noting that past innovations in communications services such as the introduction of SMS by 2G operators have led to substantial consumer benefits and that the potential size of the addressable market could be significant given that there are several million users of mobile services in the UK. This suggests that the size of the innovation and competition benefits from the award of the 2.6GHz band could be particularly large.

7.25 Of course, it is also by no means certain that the benefits of competition and innovation referred to would come about. It would depend on whether the award led to new entry and on how successful the new entrants were which, in turn, could depend on how WiMAX technology performs in practice. We are aware that there is a diverse range of opinion on the chances of WiMAX making a significant market impact, including some which is sceptical. However, it should be for the companies and their investors to make judgements about their market prospects and not for the regulator; as noted above, a number of parties have indicated their interest in participating in the award. We also note that consumers might derive significant indirect benefit through the competitive response of existing operators even if new WiMAX operators had only modest success on their own.

Evidence of demand for mobile data services

7.26 We have undertaken some research to review the state of demand for mobile data services as this is relevant as a cross-check on consumer interest in services that might be provided using the 2.6GHz spectrum. Of course, information on current demand is only of limited relevance when assessing the market appetite for new services which are not yet available and we anticipate that the 2.6GHz band could be used to provide a mix of both existing and new types of service.

7.27 Annex 12 summarises the evidence available to Ofcom showing demand for mobile data services. In this context, we are interested in information on current and future demand, for data services, regardless of whether this is, or might in future be, served through the 2.6GHz band or through other spectrum bands (such as those currently held by the 3G MNOs). In addition, Annex 12 also considers interest in the 2.6GHz band from operators and equipment manufacturers in particular.

7.28 In summary, Annex 12 concludes that there would appear to be material, and growing, near-term demand for mobile data services, as well as a high level of interest in the use of the 2.6GHz band globally.

[63] Further details on the interest in the 2.6 GHz band globally are available in Annex 11.
[64] Source: Ofcom and operators' data for 2006.

- There could potentially be significant end-user demand for mobile data services[65] in the near term, which could be served by technologies using the 2.6GHz band.

- Operators and equipment manufacturers are investing heavily in developing technologies capable of operating in the 2.6GHz band (including both 3G and WiMAX).

- Where licences for the 2.6GHz band are already held, operators are already rolling out networks, launching services and undertaking significant capital investments in use of the band.

- In addition to Ofcom's work on the award of the 2.6GHz band, there are numerous other upcoming 2.6GHz licence awards outside of the UK.

7.29 This evidence suggests that there is material prospective consumer demand for the kinds for data service that might be provided by the 2.6GHz band. In addition, as demand grows over time it is likely that, in due course, the capacity of existing mobile spectrum would become constrained. At this time, the ability to use the 2.6GHz band will, of course, add considerable further value by mitigating the effects of network constraints that would otherwise exist.

Impact on consumer benefits of a delay in award

7.30 Ofcom's current assessment is that there are likely to be significant consumer benefits from bringing the 2.6GHz band into use. However, it is appropriate to consider whether these benefits might actually be larger if the award were to be deferred for a while as has been suggested by some MNOs.

7.31 The case that delaying the award for perhaps a few years might increase consumer benefit, compared to an award that is held as soon as is practicable, is based on the argument that there is a class of potential users (primarily the MNOs) who:

- do not have an immediate need for the spectrum but may derive value from making productive use of it in a few years[66]; so if the award were held as soon as practicable they could be forced to participate in the award to secure spectrum for future use ahead of need; and

- are faced with uncertainties now about how much spectrum they may require, and about the time at which they might require it; their ability to assess future requirements, and to bid accordingly in the award, will be impaired by this uncertainty.

7.32 To the extent that this group bases its bidding on projections and valuations that turn out to be wrong, then this could lead to an inefficient award outcome and, potentially, to an allocation that turns out, in a few years' time, to be have been suboptimal.

7.33 Ofcom recognises that the concern raised here is legitimate. If a company does not have an immediate requirement for spectrum then they are bound to be faced with

[65] The third party forecasts considered in this analysis cover 3G/LTE and WiMAX (as these are the technologies which are widely expected to be used to supply mobile data services) but are considered to show strong demand for mobile data services as a whole (regardless of technology).

[66] In the case of the MNOs, their current spectrum holdings are likely to support the requirements of 3G/HSPA over the next few years but potential plans for the deployment of LTE would likely increase their spectrum needs.

more uncertainty if they choose to bid in an auction today rather than if the auction were delayed until a date which was nearer to the time that they needed to bring the spectrum into use. Under the delayed award the company would, by definition, be able to make more accurate bids (both with respect to the number of lots and to the valuation of those lots), based on the most relevant and up to date information at that time.

7.34 In assessing the impact of a delay in the timing of the award, we need to judge which of the following two considerations are the more important:

- the potential gain in consumer benefit that may result from a more efficient award outcome on account of the bids from one (important) group of potential users being subject to less valuation uncertainty; and

- the potential loss in consumer benefit that may result from a delay to the timing of the award, both in terms of the forgone benefits during the period of delay and in terms of any longer term competition and innovation benefits that may be jeopardised.

7.35 In this context, we note that there are also issues for bidders who (may feel they have to) acquire spectrum in advance of need. In particular, if a company has to hold spectrum unused for some years after they acquire it then this will have a direct cost to them. However, Ofcom notes that the value such bidders would ascribe to the spectrum in this case would be discounted to take into account the time it would lie unused by them. This should be reflected in bids during the award and does not create any particular issues for efficiency.

7.36 In terms of the first consideration, the MNOs have pointed to a number of potential sources of uncertainty that might be reduced through delay including those relating to: the Digital Dividend; 2G liberalisation; possible upcoming European regulatory decisions (e.g. in relation to WAPECS); demand for mobile data services; and the market for and technical characteristics of LTE or other potential future technologies. The nature of concerns expressed in responses differed significantly across the MNOs. For example, Vodafone's main point was that Ofcom should resolve uncertainty about 2G liberalisation before a 2.6GHz award as this affected different groups of bidders differently (unlike other uncertainties that were common to all bidders); however, it felt that it was possible to resolve this uncertainty without delaying the award. Other MNOs also placed a strong emphasis on the 2G position but they expressed, to varying degrees, additional concerns about many other sources of uncertainty.

7.37 Ofcom agrees that it is desirable to reduce uncertainties where it is possible to do so. Significantly, Ofcom is expecting to issue a consultation in the near future on the subject of 2G liberalisation.

7.38 However, Ofcom considers that the potential effect of these uncertainties on the degree to which interested parties can value spectrum accurately, and hence on the efficiency of the award, should not be over-played.

- The 2.6GHz band is unlikely to be a close substitute for Digital Dividend spectrum, the 900MHz band or the 1800MHz band, particularly in providing coverage for 3G networks (given the significant differences in propagation characteristics and their impact on coverage and building penetration in particular). Access to the 2.6GHz band could potentially have a redistributive effect across the MNOs' spectrum portfolios (e.g. if it is possible to move certain

applications to UHF frequencies from 1800 or 2100MHz then services that might be provided at 2.6GHz could be provided in the spectrum freed up at 2100MHz instead); but it would not be costless to effect this sort of reorganisation. And if MNOs wished to deploy wide channel width services at 2.6GHz (e.g. LTE or WiMAX in 10MHz or 20MHz channels) this would be very hard to achieve in lower frequency bands.

- Ofcom expects that a number of remaining uncertainties on future use of 2G spectrum and the process and timing for liberalisation of 3G licences are likely to be reduced prior to the award (and will not require an additional delay to the process). It is now clear, as a result of the EC Decision relating to 2G spectrum (900MHz and 1800MHz)[67], that such spectrum must be made available for UMTS and potentially other technologies in due course. As noted above, Ofcom expects to publish a consultation on the implementation of the decision in the near future.

- Ofcom will continue to participate actively in European regulatory discussions and monitor developments regarding any potential RSC decision on WAPECS which could be relevant to the conditions of use of the bands. We will also keep potential bidders informed of these developments. Ofcom considers that the risk of an inconsistency between its proposed approach and any potential binding European approach is low[68]. In Ofcom's view, the interim report[69] approved by ECC in July 2007 in response to the EC's mandate on WAPECS supports this assessment.

- Future demand for mobile data services is uncertain and may, in fact, be a much more significant source of uncertainty than some of the regulatory factors referred to above. But these uncertainties apply to all potential bidders.

- All bidders face market and technical uncertainties such as the uncertainties which the MNOs face over LTE. It is also unclear how long a delay would be necessary for LTE to be fully developed (particularly if delay in the award of the 2.6GHz band reduced competitive pressure from other technologies such as WiMAX) or if, after any delay, demand for spectrum for LTE at 2.6GHz would necessarily be as substantial as demand for spectrum for WiMAX at 2.6GHz appears to be now. Also, there is no guarantee that any delay would result in a reduction of the uncertainty overall. In any case, Ofcom considers that for operators to decide to wait for a technology to be available in future (LTE), rather than favour technologies that are available now (e.g. WiMAX), they must have in their possession enough information to indicate that this is a rational course of action.

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[67] See the Chairman's report of the RSC meeting held in June 2007, noting the positive outcome of the written procedure used to finalise the decision (http://ec.europa.eu/information_society/policy/radio_spectrum/docs/ref_docs/rsc20_public_docs/rsc20_chairm_rep.pdf), and the text approved by the RSC (http://ec.europa.eu/information_society/policy/radio_spectrum/docs/ref_docs/rsc20_public_docs/07_04%20final_900_1800.pdf).

[68] This view was confirmed by a number of respondents with, for example, Vodafone stating that it believed that there was no need to delay the award on these grounds as long as Ofcom kept bidders informed of any changes.

[69] See 'Annex 11 to ECC(07)091 Final' available from the ERO's website (document download section at http://www.ero.dk/download?mid=4799E6C3-4BEA-48B7-B49F-64507990BD86&frames=no for Group ECC, Year 2007, Constantza / Mamaia, Romania, Minutes).

- Any party facing significant uncertainties in their demand for spectrum, which they expect may be reduced in the future, also has the choice not to participate in the auction, and to seek to acquire spectrum at some later date, either through future primary awards of spectrum or through the secondary market.

- Subsequent trading of 2.6GHz spectrum could help reduce any inefficiency of the primary award although we recognise that if this required a conversion between paired and unpaired use then this might not be straightforward and would need to take account of adjacency restrictions. However, if the primary award led to an outcome that turned out to be significantly suboptimal (in the sense that the value to the acquirers of spectrum in the primary award turned out to be significantly below the value that another group, with an alternative use, subsequently came to attach to it) then the differential in the revised commercial valuations would make these trades much more likely to take place.

7.39 Turning to the potential loss in consumer benefit that may result from deferring the award, the main points to consider here are:

- the direct consumer benefits forgone during the period of the delay itself; and

- the potential loss of wider market benefits associated with competition and innovation that could be triggered by new entrants.

7.40 A delay in the award process will lead to the loss of direct consumer benefit from mobile data services during the period of delay. Annex 12 provides some evidence that there could be a significant and growing demand for new services that could be provided in the 2.6GHz band.

7.41 As discussed above (paragraphs 7.19-7.25), there may be significant consumer benefits from the combination of competition and innovation pressures that could be released through the award of the 2.6GHz band. Moreover, there are examples of empirical research suggesting significant losses in consumer welfare from delay in the award of spectrum for mobile communications[70]. For the 2.6GHz award, the potential benefits stem, in large part, from the opportunity for new service providers using WiMAX–based technology, given that these WiMAX technologies appear to have a lead of a few years over competing technologies. It seems very possible that if the award were delayed for a year or two, then what may be a temporary window of opportunity for new entrants using WiMAX-based services may actually disappear. If this were to happen then a significant element of the competitive dynamic around the incentives to provide new, innovative services and deploy new, lower cost technologies could be lost. This could be a very material cost to delay.

7.42 Ofcom also considers that to delay the award with the purpose of waiting for technologies such as LTE to mature to the point that they can be used by some MNOs would, in effect, create barriers for customers to access similar services provided using different platforms.

7.43 Ofcom recognises that a number of the uncertainties related to the award process can be reduced and, where such uncertainties are within Ofcom's ambit, it will aim to do so in advance of the award where this is consistent with Ofcom's statutory duties.

[70] For example, Hausman estimates that the delay in the US making spectrum available for cellular telephony cost over $US100 billion in consumer welfare. "Valuation and the Effect of Regulation on New Services in Telecommunications," Brookings Papers on Economic Activity: Microeconomics. J Hausmann, 1997.

Other relevant factors for award timing

7.44 The considerations around consumer benefit must clearly carry significant weight in Ofcom's assessment of the appropriate timing of the award. However, other factors may also be relevant and stakeholders raised a number of issues including those relating to:

- The untested nature of the auction design; they argued that the 2.6GHz auction design should be finalised after the 10-40GHz award, where a similar design has been adopted, has taken place;
- the time required to resolve technical issues including the immaturity of spectrum usage rights (SURs) and concerns over their application, interference issues and the treatment of adjacencies between different types of user;
- legal restrictions on third party use of spectrum, which were considered uncertain because of lack of legal certainty over the implications of the Floe Telecom case; and
- claims relating to the frustration of legitimate expectations and to the scope for discrimination that could arise if the award were not delayed.

7.45 Concern was expressed about the desirability of testing the 2.6GHz auction design given that this form of auction has not been used before. Under the current timetable, the 10-40GHz award will take place prior to the 2.6GHz spectrum award and Ofcom will ensure that it draws on any relevant lessons from this award regarding the auction format.

7.46 The use of SURs and the other technical issues raised above are reviewed in Sections 3 and 5 of this document and Ofcom believes that its current approach will not introduce undue uncertainty into the auction. As explained in Section 5, we are not proposing to use SURs for this award.

7.47 Ofcom does not consider that the issues associated with the Floe Telecom case are of sufficient direct relevance so as to result in the delay of any award.

7.48 The issues relating to legitimate expectations and discrimination are considered below.

Arguments relating to legitimate expectations

7.49 H3G and T-Mobile argued that the circumstances around the 3G auction in 2000 gave rise to legitimate expectations which, they claim, mean that Ofcom should delay the timing of the proposed award (or amend the conditions of any award). The claims of legitimate expectations in this regard are set out below.

- H3G argued that it had a legitimate expectation from the 1999 Information Memorandum for the 3G licence auctions that the 2.6GHz band would be available for use as a 3G expansion band (and, by implication, that it should not be made available until there was demand for its use in such a way).
- T-Mobile argued that it had legitimate expectations arising from the conduct of the Radiocommunications Agency during the 3G auction process and from the general wording of the 3G Information Memorandum that Ofcom's approach to spectrum management would not change without a significant change in

circumstances. Additionally, while there was discussion of the possible release of additional spectrum, T-Mobile's interpretation was that it was reasonable for the market to assume that any such release would not substantially harm the interests of licensees of the original 3G auction.

7.50 Ofcom has carefully reviewed proceedings at the time of the 3G auction. The 1999 Information Memorandum noted the government's intention at the time to support the identification of additional spectrum for terrestrial IMT-2000 use, and referred to a number of potential bands for such use, one of which was the 2.6GHz band. The document also noted that "*It is not currently possible to indicate the timing of allocation of any further spectrum, or the means by which any spectrum which did become available would be allocated.*" Ofcom does not consider that statements or representations were given at the time of the 3G auction or since which would give rise to a "legitimate expectation" in law that Ofcom would only make the 2.6GHz band available for use as a 3G expansion band at a time that would reflect demand for the spectrum from MNOs holding 3G licences awarded in 2000.

7.51 Further, as discussed in Section 8, a number of significant regulatory, legal and policy changes have taken place since the 3G auction, of which the existing MNOs are all fully aware. The policy changes relevant to spectrum management in the UK implemented by the Radiocommunications Agency and Ofcom since the 2000 auction have been developed in accordance with the law applicable at the time, including substantial changes to the European and UK legal frameworks that have come into force since then. Furthermore, within the legal context, it is entirely proper for the regulator to develop new policies to respond to changes in legal, technical, market and other conditions. Ofcom does not consider that its current proposals would "significantly harm" the interests of the existing 3G licensees or any other licensee, as a result of the proposed timing or otherwise, as discussed further in this Section. In particular, Ofcom does not consider that the wording or spirit of the statements made at the time of the 3G auction could or should be construed as to imply that the 3G licensees would be protected from potential competition in the future. Rather, Ofcom considers that the proposed awards present the existing 3G licensees with further opportunities to develop services if they so wish and that the awards are likely to benefit operators, consumers and citizens in the UK as discussed elsewhere in this Section.

Discrimination

7.52 Some of the MNOs have argued that if Ofcom proceeds with the proposed auction before a number of the alleged uncertainties (as listed at paragraph 7.8 and repeated below) are resolved, then it would effectively be discriminating against those MNOs. The alleged uncertainties could be resolved over time through changes in the market, regulatory or technical environment. Those arguments related to:

- market and technology uncertainties (for example regarding LTE and IMT-Advanced);
- the supply of potential substitutes for the 2.6GHz band (including liberalisation of 2G spectrum, liberalisation of 3G TDD spectrum and the award of DDR spectrum);
- potential EC regulatory decisions affecting the band; and
- novel and untested features of the award such as the auction design and spectrum usage rights (SURs).

7.53 We have considered above (see paragraphs 7.36 to 7.38 in particular) the issues around uncertainty, some of which have been claimed could give rise to discrimination. In light of the above, Ofcom does not consider that awarding the band as soon as is practicable would be discriminatory. All bidders are subject to uncertainty, although the significance of particular uncertainties will naturally differ as between bidders depending on their exiting circumstances and future plans. It would be impossible for Ofcom to select an award date in such a way that all differences in the effects of uncertainty as between potential bidders would be removed. Nor would it be sensible, or consistent with Ofcom's duties, to delay the award in order to seek to achieve this objective over and above other aims such as to promote the interests of consumers through promoting competition and innovation.

7.54 Some MNOs also raised points on the potential for discrimination in relation to proposed licence conditions. These are considered in detail in Section 8.

Award of 2010MHz band

7.55 The responses to the December Consultation indicated less general interest in this band compared to the 2.6GHz band.

- The BBC argued that the spectrum should be reserved for PMSE use because of the interference conditions and that it should be allocated to this use as soon as practicable.

- One MNO expressed a view that the award should make it possible to pair 2010 with the centre block of 2.6GHz (however, they appeared to be more interested in pairing the 2.6GHz band with their existing 3G TDD channel and in obtaining FDD pairs in the 2.6GHz band).

7.56 Ofcom notes that there remain potential uses and technologies for which unpaired spectrum in the 2010MHz and 2.6GHz bands could be substitutes. However, this scope appears to be relatively limited since the development of WiMAX, which is the technology option which was of most interest to respondents interested in unpaired spectrum, is focussing on the 2.6GHz and 3.5GHz bands across the globe, and not on the 2010MHz band. As discussed in Section 5, the case for the existence of complementarity between the 2.6GHz band and the 2010MHz band for the purposes of external pairing seems weak.

7.57 Given the scope for some (albeit, modest) substitutability between the 2010 band and the unpaired lots in the 2.6GHz band and given the potential efficiency and logistical gains to be made through combining the two bands in a single award process, Ofcom's current assessment is that there it would still be sensible to combine the award of the 2010MHz band with the award of the 2.6GHz band. Ofcom notes that the BBC (and others interested in the use of spectrum for PMSE) will be free to participate in this award process.

Award of 2290MHz band

7.58 The responses to the December Consultation showed that there was no interest in linking the award of the 2290MHz band with the award of the other bands. As was the case for the 2010MHz band, the BBC argued that it should be reserved for PMSE because of the interference conditions and that it should not be awarded via auction but should, instead, be allocated for PMSE use as soon as practicable.

7.59 The BBC's opinion aside, there were no strong views expressed on the timing of the award or on the need to hold it in advance of the 2.6GHz and 2010MHz combined award, although some suggested it could be awarded later (being less of a priority) and some supported the view that it could be awarded first.

7.60 Ofcom's updated view is that any risk to parties interested in the 2290MHz band of holding an award after the 2.6GHz and 2010MHz award is lower than assessed at the time of the December Consultation. Therefore, Ofcom is proposing to prioritise the 2.6GHz and 2010MHz award over that of the 2290MHz band. We will consider the 2290MHz band again at a suitable time, but do so quite separately from the award process for the 2.6GHz and 2010MHz bands.

Summary of Ofcom's assessment on timing and linkages between awards

7.61 Ofcom's current view on the timing of the awards for 2.6GHz, 2010MHz and 2290MHz spectrum, based on the discussions set out above and responses to the December Consultation, is that:

- the use of all three bands should be allowed by granting licences via auction mechanisms;
- the 2.6GHz band should be awarded as soon as is practicable, with the potential benefits that could thereby be realised through competition and innovation significantly outweighing the downside risk of the auction resulting in an inefficient outcome on account of uncertainties affecting bidders;
- the award of the 2010MHz band should be combined with that of the 2.6GHz band given the potential scope for substitutability between 2.6GHz and 2010MHz[71]; and
- the award of the 2290MHz band should take place after the award for the 2.6GHz and 2010MHz bands given the weak linkages, the less pressing evidence of demand in contrast to the other two bands and the absence of evidence that a later award would affect efficiency.

7.62 As noted at the beginning of this Section, the purpose of including this updated assessment on award timing and linkage issues in this Discussion Document is to provide guidance for those parties who are contemplating participation in the award(s) and wish to undertake advance planning. However, we stress that Ofcom will not take a decision on the timing of the award(s) until it makes its Statement on the matter, which we expect to make before the end of this calendar year. The decision which we make at that time will take account of all relevant information at that time, including any relevant regulatory developments in the UK and in Europe.

7.63 Stakeholders made, in many cases, substantive comments on the timing questions that we set out in the December Consultation and we are not setting out new questions in respect of the updated assessment provided in this Discussion Document. However, stakeholder are invited to provide further comments if they wish to bring new points to our attention.

[71] In Ofcom's view, the potential gains from substitutability outweigh potential inefficiencies in the auction from increased complexity and increased scope for strategic behaviour

Section 8

Non-technical licence conditions

8.1 In the December Consultation, Ofcom set out proposals for the conditions for use of the spectrum bands. Those proposals relating to non-technical licence conditions covered broadly four areas:

- rollout obligations;
- technology neutrality;
- tradability; and
- licence duration/tenure.

8.2 Some responses to this aspect of the proposals in the December Consultation were lengthy and, even through the substance of the issues has not changed since the December Consultation, we respond to the main arguments in this Section. As highlighted earlier, we emphasise that Ofcom has not made final decisions on these matters and would welcome further input into the design of the award to contribute to the development of a robust and efficient award process.

8.3 The responses to the December Consultation fell into two main camps. One group, mainly the MNOs, argued that the non-technical licence conditions in the spectrum bands and in existing 3G licences awarded following the auction in 2000 should be the same or similar, in order to avoid undue discrimination and/or to avoid distortions of competition. Others broadly supported Ofcom's proposals. This Section, therefore, considers the arguments put forward by the MNOs.

Rollout obligations

Ofcom's initial proposal

8.4 Ofcom proposed that licences for these spectrum bands should not include rollout obligations. Ofcom considered that roll-out obligations were unlikely to be required to meet the objective of ensuring that the spectrum is used efficiently. There are a number of reasons why imposing rollout obligations in licences for use of the 2.6GHz band would not promote optimal use of the spectrum. In summary, these include the following.

a) Ofcom is proposing a technology and service neutral award (in light of the range of potential technologies that could be used and services that could be provided, now and in future). It is not possible to know exactly what services will be provided in advance and how rollout obligations could be applied to different services. It may be that some uses based on particular coverage areas may in fact be more efficient and deliver greater benefits than other potential uses based on greater coverage areas. The proposed auction is designed to ensure that spectrum licences are held by those who value them most. This could be frustrated if rollout obligations were introduced, by limiting or removing opportunities for some potential users. For example, Ofcom understands that existing MNOs are likely to consider using the 2.6GHz band to provide extra

capacity for 3G service in areas where such additional capacity is required. Rollout obligations may in effect prevent such a use of the 2.6GHz band.

b) The commercial case for most likely services is uncertain. In order to calibrate rollout obligations appropriately, it would be necessary to judge the socially optimal level of rollout and to ensure this was affordable by licensees.

c) If there is a social case for ensuring rollout levels are met, then this is likely to be better achieved via subsidies (as has been the case for fixed broadband).

d) Other mechanisms are proposed to create the appropriate incentives for efficient use of the 2.6GHz and 2010MHz bands to be secured, such as spectrum trading and liberalisation.

The MNOs' arguments

8.5 The 3G MNOs made various arguments that allowing competitors to provide 3G or similar services on different terms to the incumbents will have negative consequences for consumers and that Ofcom has not assessed these consequences. Their main arguments are detailed below.

8.6 Firstly, MNOs claimed that it would be unduly discriminatory for there to be rollout obligations on the 3G licences auctioned in 2000, but not on the 2.6GHz licences. They contested Ofcom's analysis that there were differences between the award of the 3G licences and the award of the 2.6GHz band as set out in the December Consultation. O2 argued that the rollout obligations in the 3G licences should be removed. Vodafone also urged Ofcom to consider this, but did not argue that this was a prerequisite to proceeding with the award process (as O2 did). In contrast, H3G and Orange argued that rollout obligations should be placed on 2.6GHz licensees. T-Mobile argued that Ofcom should make the presence (or absence) of rollout obligations consistent across 2.6GHz and 3G licences.

8.7 Secondly, it was contended by the majority of the MNOs (excluding Vodafone) that not imposing a rollout obligation on 2.6GHz licensees would allow new entrants to target the more profitable geographic areas and lead to distortions in tariffs and competition. O2 in particular argued that competition would be unsustainable because geographically focused new entrants would be able to secure roaming agreements at incremental/marginal costs which may be below the 3G MNOs' unit costs for their own services. A confidential response also asked Ofcom to explain how prices may be affected by this sort of "cream-skimming" entry.

8.8 O2 set out scenarios to illustrate that, if rollout obligations remained on incumbents, a new entrant without rollout obligations could obtain the same geographic coverage as the 3G incumbents, but at lower overall cost. This, it was claimed, was because the new entrant would be likely to build a network that covered the most profitable areas of the country, whereas the incumbents would be forced to cover a wider area in order to comply with their rollout obligation. It was argued that the new entrant's average costs would be the same as the incumbents in the areas that the new entrant targeted. However, where it did not built a network the new entrant would be able to roam onto one or more incumbents' networks. According to the respondent, roaming would be provided at low or even incremental costs (thus it would not contribute to the incumbent's fixed costs).

8.9 Thirdly, it was argued by O2 that disparities in licence terms could increase a 3G MNO's cost of capital and reduce investment and the potential for innovation. This

argument referred to the difference in licence duration terms and stated that uncertainty over the future of the 3G licences may lead to reduced investment in 3G, particularly when the lifetime of new assets begins to exceed the end date of the current licences. This could either increase investment costs in 3G and/or disincentivise efficient 3G investment. A confidential response makes a similar point.

Ofcom's initial view on the MNOs' responses

Ofcom's General Duty not to Discriminate

8.10 Ofcom notes that as a public authority, it is under a general duty not to discriminate unduly. It is settled case law that undue discrimination may only arise where different treatment is given to persons in similar circumstances, or where the same treatment is given to persons in different circumstances, and there is a lack of objective justification for the treatment given.

8.11 In this case, Ofcom acknowledges that there are differences between the conditions of the existing 3G licences and the proposed award licences. These were highlighted in Ofcom's consultation of 11 December 2006 ("the December Consultation") on the spectrum to be awarded.

8.12 As set out in that consultation, at a general level Ofcom considers that past decisions on licensing conditions do not necessarily determine how future licensing decisions should be made, subject to relevant consideration of the requirements under EU and UK law. A number of significant changes have taken place since the 2G and 3G licences were awarded. These were set out in the December Consultation and are repeated below.

8.12.1 The prevailing spectrum management policy at the time of award has changed in recognition of the benefits of market mechanisms and flexibility. The 2G and 3G licences were awarded at times when different spectrum policy conditions prevailed. For example, when 2G licences were awarded in the 1990s, the conditions of spectrum scarcity were different. Also, the application of market mechanisms, such as spectrum trading and spectrum auctions, and the introduction of a technology neutral approach to spectrum awards were only being considered as policy options whereas they have since been adopted as the basis of spectrum policy following consultation.

8.12.2 The manner of award differs, especially with regard to the 2G licences. The 2G licences were awarded by comparative selection, with the regulator (at the time, the Secretary of State) deciding who licence holders should be, not by auction.

8.12.3 International obligations are different, particularly in relation to technology neutrality relating to the relevant spectrum. The GSM Directive applied to part of the 900MHz spectrum and its existence prevented the application of a technology neutral approach to that spectrum[72]. At the time of 3G licence award the UMTS Decision applied, requiring a technology specific award for some of the spectrum that was awarded. In contrast, there are presently no binding international obligations on the 2.6GHz and 2010MHz bands.

[72] Ofcom notes that the GSM Directive is expected to be abrogated in Autumn 2007, when an RSC Decision relating to 900MHz and 1800 MHz will come into force, requiring Member States to designate and make available those frequencies for GSM and 3G technology. This is to be the subject of a separate consultation by Ofcom.

8.12.4 Moreover, the EU legal context has changed. The Framework Directive that came into force in April 2002 permitted trading whereas, at the time of the 3G auction in 2000 it was understood in the UK that trading was not permitted under the previous Licensing Directive[73].

8.12.5 It is also possible that the services offered using the available bands could compete in different downstream markets to those served using 2G spectrum (at 900MHz and 1800MHz) and using 3G spectrum (at 2.1GHz).

8.13 In the December Consultation Ofcom noted that these differences in circumstances at the time of the award are such that Ofcom does not consider that the proposals involve undue discrimination. In addition, Ofcom noted that the MNOs will be able to participate in any new awards for these bands on the same terms as potential new entrants. Hence, there would be no source of discrimination against them in the proposed awards.

8.14 In its response to the December Consultation, O2 sought to set out the equivalence between the spectrum to be awarded and the 3G spectrum auctioned in 2000. It highlighted in particular the similarities in the volume of available spectrum, the level of European harmonisation, the basis of the technical licence conditions, the maximum permissible transmission powers, the total fade margin, various international constraints relating to border co-ordination and the availability of equipment for use of the spectrum. O2 claimed that, given this apparent equivalence, any more favourable terms in the new licences such as the lack of a roll-out obligation should be reflected in the existing 3G licences.

8.15 Ofcom considers that whilst there are some similarities in the technical nature of the spectrum to be awarded and the 3G spectrum, the changes in the legal, regulatory and market position since the 3G licences were auctioned indicate that the overall environment has significantly changed on a number of levels since the 3G auction. As such, the current spectrum award will not take place under similar conditions to those which prevailed at the time of the 3G auction. Ofcom rejects the argument that only the characteristics of the spectrum assignment should be taken into account when determining whether different licensees can justifiably be treated differently, and not the circumstances in which the award is made. The changes in circumstances set out above are central to the nature of the award. To be precluded from taking them into account would effectively prevent Ofcom from developing and enhancing its spectrum policy in an environment in which technology is rapidly developing and demand for spectrum to deploy new technologies is increasing, and it would run the risk that Ofcom was unable to fulfil its statutory duties, including to promote competition and to ensure optimal use of the radio spectrum

8.16 As explained in the December Consultation, the existence of conditions in current licences that are different from those proposed for new licences is not a justification for preventing the introduction of measures when their overall benefits have been identified and when changes to the legal framework have been made to make their implementation possible. Ofcom considers that this remains valid today.

8.17 In the December Consultation, Ofcom set out its reasoning (at paragraphs 6.119 – 6.126) as to why it did not consider that undue discrimination or unfairness would arise in relation to four areas: the licence term and roll-out obligations, the cost of rights to use the spectrum, the claimed lack of demand for the spectrum, and

[73] See in particular paragraph 2.2.8 in the Information Memorandum for the 3G auction of 2000.

technology neutrality for the available bands. These arguments are not rehearsed again in this document, but Ofcom considers that they too remain valid.

8.18 Finally, Ofcom also rejects O2's argument that the concept of non-discrimination in the Authorisation Directive is set at a lower threshold than that set out in the WT Act, which refers to no undue discrimination, and that the lower threshold should apply. The respondent selectively quotes the European Commission's 10th Implementation Report on the Framework for European Communications as stating that "*the application of this concept by the United Kingdom authorities imposes a higher standard of proof than required by EU law, since it arguably involves the need to show a material adverse effect on competition".* Ofcom notes that the full sentence in the report in fact reads:

> *8.19 "The United Kingdom has used the term 'undue discrimination' when transposing the non-discrimination requirement under the new framework. The Commission services are examining whether* ***the application of this concept by the United Kingdom authorities imposes a higher standard of proof than required by EU law, since it arguably involves the need to show a material adverse effect on competition****. Ofcom intends to publish guidelines on this issue for consultation."*

8.20 Ofcom subsequently set out its position in a document entitled "Undue discrimination by SMP providers" published on 15 November 2005 following a consultation in June 2005. As explained in that document, the term "non-discrimination" in the EC Communications Directives is transposed into UK law by the term" undue discrimination", reflecting previous telecoms regulation in the UK.

8.21 Ofcom maintains that the correct test for it to apply is that as set out in the WT Act.

8.22 In conclusion, Ofcom does not consider that the responses received to the December Consultation are sufficient to change its views on the non-discriminatory nature of its proposals.

Legitimate Expectations

8.23 T-Mobile stated in its response to the December Consultation that it considered that the MNOs have legitimate expectations that licence conditions in the current licences should match those in the 3G licences.

8.24 Ofcom notes that substantive legitimate expectations such as those claimed in this regard may arise where a public authority's conduct or statements clearly and unequivocally support a party's interpretation of the promises, undertakings or representations made by the public authority.

8.25 Ofcom does not consider that statements or representations were made or given at the time of the 3G auction or since which would give rise to a "legitimate expectation" in law that any future licence conditions would match those in the existing 3G licences, such that Ofcom would now be prevented on the basis of the principle of legal certainty from imposing different conditions on new licences.

8.26 Further, Ofcom considers that events at the time of the 3G auction should (in any case) in principle not be used to prevent the realisation of benefits that might follow from the nature of the licence conditions which may be imposed in the current award. Spectrum licensees are not entitled to expect that spectrum management regulation and policy will remain static.

8.27 In light of the above, and additionally for the reasons set out above in relation to non-discrimination, Ofcom does not consider that the 3G licence holders could reasonably have expected that conditions contained in the 3G licences would necessarily be replicated in all future licences.

Promotion of competition

8.28 Ofcom recognises that one possible outcome of the auction is geographically or customer segment focussed entry (see paragraph 8.7). Ofcom considers that such entry is likely to promote competition and set out its analysis in some detail in the December Consultation. Firstly Ofcom noted that it was made clear at the time of the 2000 auction that further spectrum would be made available that could be used for similar technologies and services (and therefore that there could be future entry into mobile communications). It was not stated that future awards of spectrum would be subject to the same conditions, including roll-out obligations, as in the 2000 award. The means by which future awards of spectrum would be allocated were also not stated.

8.29 Participation in the 2000 auction should have reflected awareness of those conditions. The prices paid by the winning bidders in the auction should also have reflected the implications of those conditions. Similarly, we would expect the prices paid in any new award to reflect the conditions attaching to the licences to be awarded. Therefore, Ofcom is of the view that the award of licences with the conditions proposed in the December 2006 Consultation would not be unfair to holders of existing licences.

8.30 Secondly, although Ofcom agrees that, as a result of entry, it is possible that the market share of existing 3G operators might change, Ofcom reiterates that it does not accept that this award will have an adverse impact on competition. We believe it is reasonable to assume that existing 3G MNOs already possess flexibility in their tariff packages to respond if new entrants choose to target the more profitable areas.

8.31 Moreover, the incumbents have a number of advantages over new entrants. Experience suggests that there are advantages to providing mobile telephony and data services to a large majority of the UK. For example, the development of 2G networks world-wide has shown that extensive network coverage has been a pre-requisite for success in mobile markets

8.32 The 3G MNOs also have well established commercial identities and customer bases, and therefore have early mover advantages. A new entrant would have to go through a phase of brand development to be in a position to attract customers and would initially incur higher costs as a result. Moreover, by the time competitors were able to enter the market, the 3G MNOs will have had considerable opportunity to reap the benefits of early mover advantages.

8.33 Furthermore, Ofcom research has shown that the cost of providing 3G services tends to increase with frequency. More base stations are required to provide the same levels of coverage, quality and capacity because of the characteristics of the specific frequencies being used (and different technologies may have different sensitivities to these differences). Incumbents with access to 2.1GHz (and possibly the ability to use liberalised 2G spectrum) could have considerable cost advantages over a new entrant using UMTS at 2.6GHz (though entrants are not limited to using UMTS).

Potential for inefficient entry

8.34 O2's argument that inefficient entry could arise as a result of not imposing rollout obligations in 2.6GHz licences rests on the premise that a new entrant could gain access to a 3G incumbent's network (in areas where there was no business case for the new entrant to build out) at or near the incremental cost to the incumbent of providing the service in those specific areas. The incumbent MNOs, on the other hand, set end-user prices on the basis of the incremental cost taken across all the areas that they serve, and this is likely to be higher than in the areas targeted by the new entrants for their own network build.

8.35 The implication is that new entrants would enjoy a lower average cost across the whole of the UK and consequently be able to price services below the prices set by the MNOs. This assumes firstly that entrants will have incentives to compete on a more geographically limited basis than the incumbents (although one MNO's response acknowledges that entrants may benefit from having coverage in non-urban areas). It also assumes that new entrants require and are able to implement roaming technically, but this may not necessarily be true as entrants would not be restricted to using 3G technologies. Finally, network costs are not the only operating cost faced by a new entrant and it assumes that new entrants are able to roll out networks in urban areas and operate with a total per unit cost base which is approximately equivalent to that for the incumbent MNO's network in such areas. This may not be the case as new entrants would likely be unable to benefit from the economies of scale open to the MNOs in procuring equipment from vendors, running back office and billing systems, marketing and advertising costs, transmission (backhaul) rental, etc.

8.36 O2 describes a scenario in which the price of roaming is driven down to the incremental cost of providing roaming to an entrant. It assumes that each of the five incumbents competes for a contract to provide roaming according to a "Bertrand[74]" model of oligopoly competition. In the Bertrand model, prices (for roaming in O2's particular scenario) get driven down to marginal cost. If one firm sets price above marginal cost it creates an opportunity for its competitors to undercut it, in which case it would in principle lose its entire market share. As a result, the only rational decision is to price at marginal cost (below this level all firms would make a loss). This is a partial analysis.

8.37 If there are sunk costs involved in providing roaming, then roaming charges will not be set equal to cost (and if fact will be set at a monopoly level), even if the Bertrand model were otherwise an accurate description of the market. This is because, if two or more firms provide roaming services, no firm will be able to recover their sunk costs since, in the Bertrand model, prices will be set equal to marginal costs when there is more than one firm competing. Consequently, the only stable outcome is that one firm will provide roaming and will set its prices at the monopoly level[75].

8.38 O2's analysis also does not take into account the possibility that if roaming services are provided competitive intensity may increase, putting downward pressure on end-

[74] In the Betrand model of competition in market where there are only a few firms, it is assumed that firms compete on the basis of price. The market will settle on an equilibrium where price equals (marginal) cost - assuming inter alia that products are identical. This is because, if the market price is above cost, a firm has an incentive to undercut the market price because it can thereby increase its market share. Thus the market price will fall down to cost, at which point it will no longer be profitable for any firm to undercut the market price.

[75] See "Sunk Costs and Market Structure" J Sutton, 1991.

user prices. If this effect is greater than the potential profit from supplying roaming, then no firm would have an incentive to provide roaming.

8.39 Moreover, the Bertrand model is one of many economic models that may apply to competition in a market supplied by a few firms (i.e. an oligopoly). It makes a number of assumptions which Ofcom believes may not be relevant to a wholesale market for access to 3G networks. It assumes that incumbents choose to set prices rather than the quantity they wish to supply, that roaming services are homogeneous and that incumbents must make a once and for all decision on whether to supply access and at what price (in the language of game theory it is a one-shot game).

8.40 However, using what Ofcom considers to be more realistic assumptions on the nature of the interaction between new entrants and incumbents, a number of other economic models are relevant and they all predict that roaming charges will be set above incremental costs. Firstly, Ofcom believes that roaming services are likely to be differentiated. 3G operators have different levels of coverage now and are pursuing different strategies in their approach to promoting and supporting the development of new services. Moreover, roaming agreements could come with complex service level agreements which allow considerable scope for variations in quality. If services are differentiated, then even if firms compete by setting prices, economic theory tells us that prices will be set above marginal cost.

8.41 Secondly, Ofcom is not convinced that providing roaming services should be treated as a one-off interaction. Contracts are not necessarily long term and can be renegotiated. Therefore Ofcom considers it more appropriate to consider how competition might evolve when multiple interactions between incumbents and entrants are possible. One implication of this is that the incumbents may behave differently. In a one-off interaction firms may be forced to set low prices because they cannot be sure that their rivals will not undercut them as long as prices are above cost. However, when there are multiple interactions, firms do not risk losing everything if they price above cost because there will be future opportunities to win contracts. Generally, where firms face the possibility of repeated interactions with their rivals, game theory shows that prices above the incremental cost can be sustained.

8.42 Instead, it is quite possible that roaming charges could be set on an “opportunity cost” basis that would compensate the incumbent for the loss in its margin on sales in the downstream market due to increased competition, i.e. prices could be significantly above incremental costs.

8.43 Thirdly, the outcome may be different if firms face capacity constraints in the provision of roaming services. Economists commonly model oligopoly competition in this situation as a two-stage process. First firms decide how much capacity to install, second they set prices. The outcome of this strategic interaction is one in which prices are set above marginal (or incremental) costs and generally speaking, the fewer the firms in the market, the greater the difference between prices and marginal costs.

8.44 Fourthly, there are further economic models which suggest that when a new entrant wishes to buy an access service from an incumbent, and the access service is differentiated (as described above), then it is not certain that access will be supplied[76]. Even if roaming were provided in this model, if roaming services are

[76] Ordover J., Shaffer G. Wholesale access in multi-firm markets: When is it profitable to supply a competitor? Int J. Ind. Organ (2007)

differentiated then it is unlikely that price would be driven down towards incremental cost. It is more likely to be closer to the opportunity cost level as described above.

8.45 In conclusion, Ofcom does not accept O2's argument that competition is likely to be distorted by not imposing rollout obligations on 2.6GHz licensees. Ofcom does not find the case compelling that new entrants are likely to be able to gain roaming at low or incremental costs and therefore considers that incumbents are likely to have ample flexibility to respond to entrants with 2.6GHz licences as currently proposed.

Disparities in the cost of capital

8.46 O2 argued that its cost of capital may rise in relation to that of a new entrant as a result of entry by competitors without rollout obligations and that it would therefore suffer competitive harm.

8.47 Ofcom's view, however, is that the potential impact on an incumbent's cost of capital relates specifically to new entry and is not affected by whether new entrants are subject to rollout obligations[77]. O2's argument taken to its logical conclusion would amount to requiring Ofcom *not* to promote further competition in order to protect the MNOs from the effects of new entry. Ofcom considers that this would not be consistent with its statutory duties.

8.48 Nevertheless, Ofcom has looked in detail at the arguments put forward by O2 who identify three ways in which an MNO's cost of capital may increase as a result of geographically targeted entry:

- the MNO's revenues may become more correlated with the economic cycle;
- the MNO's operational gearing (the ratio of fixed costs to total costs) may increase; and
- the MNO's debt premium (i.e. the cost of debt financing) may increase.

8.49 **Revenues may become more correlated with the economic cycle:** O2 argues that new entrants with different licence conditions may be better able to target and serve contract customers, particularly higher quality services for business or data users. As a result an MNO's revenue stream will become more weighted towards call revenues rather than access revenues as the proportion of pay-as-you-go customers increases. O2/Oxera assumes that call revenues will fluctuate much more with the economic cycle than access revenues. As a result, the MNO is likely to have a higher cost of capital.

8.50 Ofcom agrees that this result is theoretically possible. The issue is however whether the incumbent's cost of capital would be higher than the new entrant's. It could be argued, for example, that the converse is possible. Consumption of higher-quality services might be characterised by a greater level of discretionary spend than traditional voice services. This could lead to higher-quality services having a greater income elasticity of demand. This would lead to more systematic risk and therefore a higher cost of capital for the new entrant compared to incumbents.

[77] Provided that it is profitable overall to enter (since the rollout obligations may require coverage of areas which are unprofitable), new entrants would follow the same (profit maximising) strategy in areas which are profitable to serve, regardless of whether they have rollout obligations.

8.51 Whether systematic risk might increase, decrease or stay the same is therefore not clear. It would depend on many factors, including the exact nature of the new services, their take-up by different customer groups and the extent to which customers view the new services as being discretionary. Ofcom reiterates that this issue relates to entry in general (rather than specifically entry by operators without rollout obligations).

8.52 **Operational gearing may increase:** it is argued that the asymmetric licence requirement for 80% coverage increases an existing MNO's operational gearing (the ratio of fixed to total costs), which in turn increases its "beta[78]" and hence its cost of capital.

8.53 Everything else being equal, Ofcom accepts that higher operational gearing generally leads to a higher beta and hence a higher cost of capital. High operational gearing means fixed costs are a large share of total costs. The larger the share of fixed costs, the more sale volumes affect profits. In the extreme, if all costs are fixed and there are no variable costs, then a decrease in revenue results in profits falling by the same amount. Conversely, the impact of a fall in revenue from lower sales would have a more muted impact on profit if variable costs are significant. Therefore, the greater the share of fixed costs, the more changes in sales volumes affect returns. To the extent that sales are correlated to the economic cycle, this means a higher share of fixed costs will result in a higher asset beta and higher cost of capital.

8.54 O2 also argued that not imposing a rollout obligation on entrants would increase the operational gearing of an existing MNO compared to a new entrant as follows:

- the new entrant will enter the market and take market share from the incumbents;
- loss of market share reduces an MNO's variable costs, but not its fixed costs;
- compared to a new entrant, the incumbent's fixed costs are a higher proportion of its total costs because it has a coverage obligation; and
- the higher share of fixed costs increases operational gearing and hence the incumbent's cost of capital compared to a new entrant.

8.55 Ofcom does not accept this argument. Firstly, according to O2's argument, an increase in its operational gearing could equally be due to entry in general as to entry by an operator without rollout obligations. Secondly, a new entrant might have higher operational gearing than an MNO. While the new entrant is developing its business and has low market share, it is likely to have a higher share of fixed costs and lower share of variable costs relative to total costs than the incumbents. Its operational gearing is therefore likely to be higher initially. As the entrant gains market share, variable costs would increase and operational gearing reduce. Whether over time its operational gearing might reduce below the incumbents' is difficult to assess. It would depend on many factors including the nature of the services being offered, rates of take-up and geographical concentration of users. The entrant's cost structure could also be different if it deployed a different technology.

8.56 Ofcom therefore does not believe there is any robust evidence to justify the belief that the MNO's operational gearing will necessarily be higher than that for a new

[78] A company's beta measures how much more risky it is to invest in that company (its systematic risk i.e. risk that cannot be avoided by investing in other companies) than in the average company in the market as a whole.

entrant, or that differences in the application of rollout obligations would, in themselves, lead to differences in operational gearing.

8.57 **The debt premium may increase:** it is argued that if licence asymmetries result in more volatile profit, 3G MNOs are more likely than new entrants to breach their debt coverage ratios, which will increase the cost of debt.

8.58 For the reasons given previously, Ofcom does not accept that MNO profits would necessarily be more volatile than those of a new entrant (regardless of differences in the application of rollout obligations).

8.59 Ofcom has set out its view that its proposal not to impose rollout obligations on 2.6GHz licences is neither unduly discriminatory nor likely to distort competition in mobile services. Ofcom considers that the continued application of rollout obligations to the 3G licences is a separate matter and that the appropriate place to discuss these issues was in Ofcom's Consultation on the enforcement of the 3G rollout obligations in the 3G licences. Ofcom provided guidance on its approach to enforcing the 3G rollout obligations in the document "3G Rollout Obligations: Statement and Consultation", published in July 2006[79].

8.60 Ofcom's view is also that the question of legitimate expectations in relation to rollout obligations as raised by some respondents does not determine whether there should be rollout obligations for new licences should be examined on its own merits in relation to the available spectrum. As set out above at paragraph 8.4, in light of the risks and disadvantages of such requirements, we are not proposing to place rollout obligations in licences to use the 2.6GHz and 2010MHz bands.

Technology neutrality

Ofcom's current proposals

8.61 In the December Consultation, Ofcom set out its preferred approach to licensing: to impose the minimum necessary restrictions in existing wireless telegraphy licences, in order to give users more freedom to make efficient use of the spectrum and to deploy the most appropriate services and technologies. Ofcom also stated that it considered this was consistent with the Framework Directive and its statutory duties.

8.62 Ofcom, therefore, proposed that the spectrum should have only those technology and usage restrictions that are the minimum necessary for the efficient management of the radio spectrum and the avoidance of interference, and compliance with Ofcom's statutory duties and international obligations.

The MNOs' arguments

8.63 The MNOs, with the exception of Vodafone who supported a technology neutral approach, made a number of arguments against Ofcom's proposals for technology neutrality.

8.64 Firstly it was claimed that the UK risks being misaligned with the rest of Europe, possibly harming consumer interests by not keeping to the CEPT Band Plan. Some MNOs suggested that Ofcom may not be following its duty to promote the common market in the EU and may be unnecessarily obstructing harmonisation. In addition it

[79] See http://www.ofcom.org.uk/consult/condocs/3g_rollout/.

was claimed that Ofcom's proposals do not contain sufficient analysis or a cost benefit analysis to justify moving away from the CEPT Band Plan.

8.65 Secondly, Orange contended that Ofcom was being inconsistent in the application of technology neutrality. It suggested that Ofcom had recognised the benefits of harmonisation in maintaining the CEPT Band Plan's 120MHz duplex spacing between FDD uplink and downlink, but not in respect of making the whole band conform to the CEPT Band Plan. In addition, it was proposed that allowing flexibility over unpaired spectrum will impose higher costs and lead to a worse outcome for UK consumers.[80]

8.66 Thirdly, it was claimed that the discussion of technology neutrality did not discuss the impact on the 3G MNOs of their spectrum not being technology neutral. Specifically, it was suggested that differences in technology neutrality or rights to change use can lead to cost asymmetries between firms in the downstream market. One respondent presented several models of the impact that entry of firms with lower costs (as a result of this asymmetry) could have on competition and incumbent profits.

8.67 Fourthly, it was argued by H3G that MNOs had legitimate expectations that the 2.6GHz spectrum was going to be reserved for 3G use according to the Information Memorandum for the 3G auction in 2000. According to this argument, not only should Ofcom use the CEPT Band Plan, but it should also only award the spectrum when the licensed 3G operators have a demand for the spectrum - which currently they do not. This argument is considered in detail in paragraphs 7.49 to 7.51.

Ofcom's current views

Promoting market-led harmonisation

8.68 Ofcom has already carried out a detailed impact analysis of making the 2.6GHz band technology neutral. This was contained in Ofcom's response to a European Commission Request for Comment on Technology and Application Neutrality in the 2.6GHz Band[81]. Ofcom considers that, for the 2.6GHz band, a technology neutral approach allowing the use of the spectrum to be decided by the market is the most likely to promote the efficient use of the spectrum, and, that if there were significant benefits from harmonisation, they could be realised in a market based approach as well as by regulated harmonisation through mandating technologies. Therefore Ofcom does not agree that its proposed technology neutral approach is likely to harm consumer interests, as some respondents to the December Consultation suggested. Our reasons for this view are set out below.

8.69 If 3G is not the highest value use for some or all of the band, there will be a different outcome depending on whether Ofcom follows the CEPT Band Plan. Under Ofcom's proposed approach, some of the spectrum at 2.6GHz would be used by alternative technologies. However, under a regulated harmonisation approach either all of the spectrum would be used for 3G, or could even remain unused. Either way spectrum use would be inefficient.

8.70 It is also worth noting that the highest value use of spectrum in this band may change over time. Thus, even if 3G were to generate the highest value at the present time, innovation and technological progress may result in higher value uses being

[80] Orange also stated that they agreed with the proposed approach to maintain the 120 MHz duplex spacing.
[81] See http://www.ofcom.org.uk/radiocomms/isu/sip/eu/2_6ghz.pdf.

developed in future. Such development may be prevented if Ofcom were to constrain the award so that the outcome could not deviate from the CEPT Band Plan.

8.71 However, if 3G is the highest value use for the band, we would expect the same use of the band to occur whether or not the UK follows the CEPT Band Plan, unless there was a significant risk of market failure.

8.72 Ofcom considered whether there were any risks of market failure in relation to the band, including market power, interference externalities, economies of scale externalities, interoperability and network externalities, and information asymmetries/uncertainty. Ofcom concluded that, in most cases, the risk that the market might be unable to identify and co-ordinate its use of the 2.6GHz band was minimal. In those cases where there is thought to be a risk, Ofcom found that either:

- some issues would still be present, at least to some extent, under harmonisation with exclusive access e.g. interference externalities;

- the market would be able to take account of the positive externality, e.g. if there are substantial benefits from economies of scale, operators and manufacturers have strong incentives to coordinate in order to take these potential benefits into account when bidding for spectrum. There are many examples of this kind of coordination in a number of areas e.g. telecoms and IT; or

- the likely impact of these problems in the 2.6GHz band is small, e.g. interoperability benefits are unlikely to be affected because operators have incentives to facilitate interoperability in order to internalise its benefits e.g. faster growth and because mobile communications technologies are increasingly using IP based standards which facilitate interconnection between different technologies. .Interoperability benefits are also unlikely to be lost because operators will still be able to use the core UMTS bands at 2.1GHz.

8.73 Ofcom also considered the costs and benefits of regulated harmonisation (i.e. restricting the use of spectrum to conform to the CEPT band plan) and concluded that it carried a considerable risk of regulatory failure, particularly given the uncertainty over the most valuable uses of the spectrum, and the limited flexibility under regulated harmonisation to respond to changes in the market. However, Ofcom is actively participating in European regulatory discussions relevant to the 2.6GHz and 2010MHz bands and promoting an approach to harmonisation that reduces the risks of regulatory failure.

Inconsistency in the application of technology neutrality

8.74 In proposing that a 120MHz duplex spacing between FDD uplink and downlink is maintained, Ofcom has considered the risks of its proposed approach and the likely detriment to consumers and operators. Ofcom is of the opinion that its proposals reach a fair balance between allowing flexibility in the spectrum award and avoiding additional complexity in the award process.

8.75 Ofcom has reviewed the potential current and future uses of the band and has not found any evidence that maintaining the 120MHz duplex spacing is likely to be a material constraint on the ability of different services to use the band.[82] On the other hand, retaining the CEPT Band Plan would substantially limit the amount of spectrum

[82] Respondents to the December Consultation (including Orange, who raised the issue of an apparent inconsistency) were universally in favour of the 120 MHz duplex spacing.

available for unpaired use. Ofcom's research has shown, and responses to the December Consultation suggest, that there is potentially demand for more unpaired spectrum than the CEPT Band Plan would allow. Maintaining the CEPT Band Plan, therefore, carries a material risk that services would not be provided (or would be delayed) because they could not gain access to spectrum.[83]

Potential for a distortion of competition from differences in licence terms regarding technology neutrality

8.76 As discussed in paragraphs 8.28-8.33, the conditions to be applied to any future spectrum licences were not stated during the 2000 3G licence auction. In addition, the existing 3G operators have a number of advantages over new entrants (such as existing customer bases, established brands, a UK-wide network and the ability to provide services at a lower frequency, which requires fewer base stations to cover the same area). Ofcom considers that the proposed application of technology neutrality in the 2.6GHz band is not likely to distort competition in the mobile market, and may lead to the introduction of innovative services which could otherwise not become available.

8.77 Ofcom notes that, should an existing licensee feel sufficiently strongly about the conditions in its existing 3G licence in this regard, it can submit a licence variation request and the relative merits of any such applications will be considered by Ofcom on a case by case basis.

8.78 Ofcom further notes that, as part of its promotion of spectrum liberalisation, it will be publishing a consultation document during 2007 covering, *inter alia*, technology and application neutrality for the 3G licences. Ofcom expects that this consultation document will provide additional information on this issue in advance of the auction of the 2.6GHz band.

Tradability, licence duration and tenure

Ofcom's current proposals

8.79 Ofcom proposed that the licences in the spectrum bands should be tradable, in order to provide additional scope for promoting efficiency and to respond to changes in markets over time. Ofcom also proposed that the licences should be of indefinite term with an initial period of 20 years in order that licensees should have a reasonable opportunity of recovering their investment for likely services.

Responses

8.80 There was broad agreement among respondents to the Consultation that the licences in the spectrum bands should be tradable. There was also broad agreement on the terms of tenure proposed by Ofcom.

[83] As discussed in Section 3, Ofcom is of the view that the impact of additional interference from the potential introduction of unpaired spectrum at the top of the 2.6 GHz band is likely to be lower than the benefits that would be foregone by not allowing the auction the flexibility to decide the amount of spectrum allocated to unpaired and paired uses.

8.81 However, T-Mobile and O2 argued that the 3G licensees would be at a disadvantage to licensees using 2.6GHz because of differences in tradability and tenure - the 3G licences are not tradable and are fixed in duration.[84]

Ofcom's current view

8.82 In respect of licence tenure, Ofcom recognises that insufficient certainty as to the status of the 3G licences beyond their fixed term could have a negative effect on investment, but reiterates that there are a number of ways in which greater certainty could be given besides altering the terms of 3G licences. For example, Ofcom could hold overlay auctions.

8.83 As mentioned earlier, as part of its commitment to promoting spectrum liberalisation, Ofcom will be consulting on, *inter alia*, the tenure and tradability of the 3G licences during 2007 and expects that this will provide additional information on this issue.

[84] Orange did not comment on the duration of the licence beyond the initial 20-year term. H3G reserved its position on tenure and duration, whilst Vodafone urged Ofcom to consider changing the 3G licence conditions to match the 2.6 GHz conditions post award, but did not place as much importance on this as T-Mobile and O2.

Section 9

Next steps

9.1 Subject to consideration of the responses to this Discussion Document, the proposed next steps for the award of the 2.6GHz and 2010MHz bands are set out below.

Engagement with stakeholders

9.2 Once stakeholders have considered Ofcom's updated views on the award, those interested are invited to share relevant evidence on technical and auction design issues ahead of the closing date for responses, in advance of sending their submissions.

9.3 We also plan to hold a seminar in September to present the proposals contained in this Discussion Document. Stakeholders interested in attending the seminar are invited to contact Ofcom to express their interest, using the details provided at Annex 1.

9.4 We also expect to organise one or more workshops, after the closing date for responses, specifically on auction design so that interested parties can familiarise themselves with the proposed format and processes.

Analysis of feedback, decisions and important publications

9.5 The closing date for responses to this Discussion Document is 28 September 2007. Ofcom will analyse all feedback received, in direct engagement with stakeholders, during the planned seminar and in responses to this Discussion Document.

9.6 We then plan to make decisions for the award by the end of 2007, resulting in the publication of a Statement on the December Consultation and this Discussion Document. If the decision in that Statement is to proceed with the award, we will publish-

a) an Information Memorandum, designed to give potential bidders as much information as possible so that they can decide whether to enter the auction and how to prepare for participation; and

b) draft Regulations for consultation.

9.7 The set of draft Regulations will include in particular the draft Regulations that define the award process. In order to give effect to a decision to proceed with an award of the spectrum, Ofcom must make Regulations under its powers contained in the WT Act. These Regulations will contain detailed and comprehensive rules and procedures for the running of the auction.

9.8 Other Regulations will be necessary to give effect to policies proposed in this document. These will include Regulations to:

a) allow spectrum trading for the 2.6GHz and 2010MHz bands; and

b) amend the order limiting the number of licences for certain categories.

9.9 The Regulations are made by means of statutory instruments. They must be published in draft with a minimum consultation period of one month for interested parties to comment. After this notice period has expired, Ofcom will consider all comments made on the draft Regulations and prepare a Statement on its decisions. Ofcom will then make the Regulations and state the date on which they will come into force. This is typically one month after the date the Regulations are made.

9.10 Ofcom will also publish other documents following its decisions for the award before the process starts, in particular the interface requirements for the bands (in accordance with the requirements of the R&TTE Directive[85]), to reflect the technical conditions to be adopted for the wireless telegraphy licences.

9.11 As discussed in Section 6, after the award, Ofcom will also consult on draft regulations to exempt terminals from licensing for their operation in connection with a licensed network, in the frequencies of licensees who request it.

Contributions to European regulatory processes

9.12 In the period leading up to the decisions for the award, Ofcom will continue to participate actively in the European regulatory discussions on WAPECS. This will include work in two main fora.

a) In CEPT's ECC, working group SE42 is due to consider further its response to the EC mandate on WAPECS, with meetings scheduled for 20-22 August and 25-27 September 2007. This will follow the adoption of an interim report in response to the EC's mandate at the ECC plenary meeting in early July 2007.

b) In the EU's RSC, Member States and the EC will consider the output of SE42's work, including ECC's July interim report to the EC and any developments in SE42 thereafter. The next RSC meetings are due to take place on 4-5 October and 12-13 December 2007.

9.13 The 2.6GHz band has already been the focus of work in the SE42 working group and the ECC interim report includes detailed options for the approach to least restrictive conditions for use of the band. Ofcom anticipates that further substantial progress should be achieved in these regulatory groups by the end of 2007, when Ofcom expects to make decisions for the award.

Start of the auction process

9.14 The auction process will start with the invitation of applications, with Ofcom specifying a date for the delivery of relevant application information. We expect that the date for delivery of applications would be a few days following the entry into force of the auction Regulations.

9.15 The various steps of the proposed auction process are described in detail in Annex 11. Ofcom anticipates that from the invitation of applications to the grant of licences, the auction process could last up to a few weeks.

Summary of proposed timeline

9.16 On the basis of the above, the next steps for the proposed award are as follows.

[85] Radio Equipment and Telecommunications Terminal Equipment Directive 1999/5/EC.

Table 15: Indicative timeline for the proposed award

To end September 2007	• Engagement with interested parties to receive evidence on technical and auction design issues
28 September 2007	• Closing date for responses to this Discussion Document
November/December 2007	• Workshops on auction rules
December 2007	• Decisions on the award. If the decision is taken to proceed, Ofcom will publish a Statement, Information Memorandum and draft Regulations • Start of the consultation period on the draft Regulations
January/February 2008	• Closing date for responses on draft Regulations
March/April 2008	• Decisions on the regulations with publication of a Statement and making of the regulations
April/May 2008	• Regulations come into force (after minimum statutory stay period). Auction process starts with the invitation of applications
After the award	• Consult on draft regulations for the exemption of terminals in relation to frequencies held by licensees who request the exemption

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on 28 September 2007**.

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://www.ofcom.org.uk/consult/condocs/2ghzdiscuss/, as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email 2GHzawardsconsult@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

A1.4 Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

Brice Le Cannu
Floor 3
Spectrum Policy Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Brice Le Cannu on 020 7783 4503.

Confidentiality

A1.8 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether

all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.9 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.10 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/about/accoun/disclaimer/

Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish a statement later in 2007.

A1.12 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/static/subscribe/select_list.htm

Ofcom's consultation processes

A1.13 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.14 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.15 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Vicki Nash, Director Scotland, who is Ofcom's consultation champion:

Vicki Nash
Ofcom
Sutherland House
149 St. Vincent Street
Glasgow G2 5NW

Tel: 0141 229 7401
Fax: 0141 229 7433

Email vicki.nash@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened version for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will normally allow ten weeks for responses to consultations on issues of general interest.

A2.6 There will be a person within Ofcom who will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organizations interested in the outcome of our decisions. This individual (who we call the consultation champion) will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why. This may be because a particular issue is urgent. If we need to reduce the amount of time we have set aside for a consultation, we will let those concerned know beforehand that this is a 'red flag consultation' which needs their urgent attention.

After the consultation

A2.8 We will look at each response carefully and with an open mind. We will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at www.ofcom.org.uk/consult/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing	☐	Name/contact details/job title	☐
Whole response	☐	Organisation	☐
Part of the response	☐	If there is no separate annex, which parts?	

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here. ☐

Name Signed (if hard copy)

Annex 4

Questions

A4.1 Ofcom would welcome comments or views on any aspect of this Discussion Document and in particular in response to the following questions.

Question 1: Do stakeholders agree with Ofcom's assessment of the blocking effect and of its implications for spectrum packaging?

Question 2: Do stakeholders agree with Ofcom's analysis of interference conditions that are relevant to the use of generic lots?

Question 3: Do stakeholders agree with Ofcom's updated proposals for technical conditions or have views on the possibility of
- extending the out-of-block masks out to an offset of ±20MHz from assigned blocks;
- placing additional restrictions on the use of restricted blocks between the FDD uplink and TDD; or
- a reduction in mobile station in-band power to 18dBm/MHz EIRP?

Question 4: Do stakeholders agree with the proposed changes to the auction design set out in the December 2006 consultation?

Annex 5

Impact Assessment

A5.1 The Impact Assessment contained in the December Consultation covered the following issues and options:

- how the available spectrum should be offered for use – through an auction, "first come, first served" or comparative selection processes;
- when the available spectrum should be offered for use – as soon as practicable or at some later date;
- what provisions there should be in respect of the technologies to be used – technology neutral or technology specific approach;
- how the available spectrum should be packaged to facilitate an efficient award process – relevant sizes and types of lots;
- whether the relevant licensing conditions should include rollout obligations;
- whether there should be a limit on the amount any one bidder could acquire licences for in the proposed awards;
- what auctions designs are appropriate for the available bands – sealed bid or open multi-round processes and detailed associated processes.

A5.2 This Impact Assessment only discusses areas where Ofcom is making new proposals in this Discussion Document or where substantive new issues have been raised in response to the December Consultation. Therefore, the issues which are considered in this Impact Assessment are as follows:

- whether to specify technical licence conditions in terms of spectrum usage rights (SURs) or block edge masks;
- changes in the proposed auction design
  - to take account of potential interference issues raised by stakeholders – in particular blocking between TDD and FDD terminals if unpaired spectrum is allocated in the top part of the band;
- whether to include a specific condition on inefficient hoarding in 2.6GHz licences;
- whether to proceed with an auction of the spectrum as soon as practicable
  - in particular whether certain potential bidders suffer greater private value uncertainty as a result of unresolved decisions under the control of Ofcom;
- whether relevant licensing conditions should include rollout obligations
  - in particular the argument that not imposing rollout obligations on new entrants would lead to a distortion of competition.

A5.3 These issues have been covered in detail in the main body of this Discussion Document. Therefore we present here a brief summary of our analysis and the reasons for the views which Ofcom draws from it.

Technical licence conditions

A5.4 The main options in specifying technical licence conditions were either to use SURs or transmitter spectrum masks. Although, in general, Ofcom considers that there are strong advantages to the SUR approach, Ofcom accepted the viewpoint put forward by many stakeholders that in the context of the 2.6GHz award, applying the SUR approach would require further engagement and work, which would not be consistent with the analysis relevant to the timing of the proposed award (see below). Ofcom also noted the general preference of stakeholders for a precedent of SUR implementation in a different band, given the importance of the 2.6GHz band and the view that they may not provide significant technical benefits over the use of transmitter spectrum masks in practice (since likely systems are technically similar). As a result Ofcom considers that the potential benefits of applying SURs in comparison to using transmitter spectrum masks is outweighed by the potential costs that could arise from implementing SURs at this specific time.

Changes to the auction design

Interference issues

A5.5 The chief interference issue raised by respondents to the December Consultation was the potential for blocking of FDD mobile terminals by TDD mobile terminals, if unpaired spectrum were allocated in the top part of the 2.6GHz band, to have a significant impact on the valuation of the rest of the band for paired use.

A5.6 In Section 5, Ofcom considered potential alternative options to those set out in the December Consultation for dealing with this issue were it likely to have an impact on bidders' valuations. The main alternative option Ofcom considered was to allow bidders for paired spectrum to make bids contingent on there being unpaired spectrum awarded in the top part of the band. This would have the benefit, in principle, of allowing the auction to determine the most efficient allocation of the spectrum given bidders' valuation of the blocking problem (in economic terms, an externality).

A5.7 However, this option also carries several risks. Allowing contingent bids in this context creates some disincentives for auction participants to bid their true values (for paired/FDD spectrum), and therefore it is possible that the outcome of the award might not be efficient. An important risk resulting from these disincentives is that the scope for the award to deliver innovation and new competition could be reduced (because of a reduced scope for unpaired/TDD users to access spectrum). It also introduces additional complexity for bidders which can also lead to inefficient outcomes of the award if bidders do not fully express their contingent preferences for packages in the award.

A5.8 The alternative to the above was to proceed with the auction design as proposed in the December Consultation, i.e. to allow bidding for unpaired spectrum in the top part of the band. The potential net benefits of this option depend on the potential scope of the blocking problem. Ofcom's analysis as reported in Section 3 of the main document is that, for separation distances below 8 metres, blocking can be a problem where both devices are in operation simultaneously (with the TDD mobile terminal transmitting and the FDD mobile terminal receiving). However, in most

situations it is unlikely that, in practice, all conditions necessary for interference to occur would be met in any significant measure. Ofcom's assessment also is that the size of the blocking effect on a paired/FDD network should not be greater than other sources of interference that would be present regardless of unpaired/TDD operation at the top of the 2.6GHz band, such as self-interference in the FDD network. In specific situations where the two types of mobile terminals may be likely to come into close proximity (e.g. conference centres, railway carriages, airports, sports stadia, etc.) the possible blocking effect could be mitigated in a number of ways.[86]

A5.9 Ofcom's assessment is, therefore, that blocking is unlikely to materially affect the valuation of the spectrum.

A5.10 Ofcom accepts that there is a balance to be drawn between the two alternatives approaches to auction design (with and without contingent bidding), on the basis of the risks associated with each in terms of auction efficiency and potential auction outcomes. We have identified the risk that contingent bidding may not help in eliciting any differences in value for paired spectrum (depending on whether TDD mobile use at the top of the 2.6GHz band is possible or not) and the impact that this would have on the scope for innovation and entry. As summarised above, the impact of blocking is likely to be modest technically and therefore in terms of bidder valuations. As a result, the risk of inefficiency without contingent bidding, with paired bidders receiving less spectrum than they would have without the possibility of TDD use in the upper band, seems low. In addition, the approach without contingent bidding modestly favours new entry and innovation (to the extent that the blocking effect could reduce the efficiency of the award), therefore Ofcom considers that the net benefits of this option are likely to be greater than a solution with contingent bidding.

Licence condition on inefficient hoarding

A5.11 Ofcom has considered whether or not to include a condition within the 2.6GHz licences that would prohibit inefficient hoarding. Including such a condition would in principle have the benefit of giving Ofcom a mechanism with which it was able to ensure that this potentially very valuable spectrum was put into effective use in a timely fashion. However, this potential benefit may not turn out to be of particular importance in practice because of the large amount spectrum which is being made available for award means that it is unlikely that potential users will not be able to get access to it.

A5.12 There may also be costs to including this type of licence condition. Firstly, it will increase regulatory risk for all bidders, due to the difficulty in defining precisely what type of behaviour the licence conditions was intended to prohibit. Secondly, it could prohibit entirely rational behaviour on the part of financial institutions which could improve the functioning of spectrum markets. Thirdly, it appears that some potential bidders (e.g. one or more MNOs) may wish to acquire spectrum in the auction, even though they may not want to use it immediately, and this behaviour would be entirely legitimate. Once again, regulatory risk would be increased, this time for a specific type of bidder.

A5.13 Ofcom's current view, therefore, is that the costs of including a licence condition prohibiting inefficient hoarding is likely to exceed the benefit.

[86] See Section 3 for further details on mitigating factors, including the use of dedicated micro- or pico-cells, the use of an alternative spectrum band, the use of tuneable filters in the FDD device, etc.

Timing of the award

A5.14 In the Impact Assessment in the December Consultation, Ofcom put forward its view that on the basis of research carried out for the consultation (for example the initial rollout of WiMAX networks in the US), there were potential service providers who could make use of the 2.6GHz spectrum immediately or in the very near term.

A5.15 On the other hand, Ofcom considered that the main benefits to delaying the award would arise from the greater certainty over the supply of potential substitute spectrum, in particular on liberalisation of 2G spectrum. However, Ofcom considered that the degree of uncertainty over 2G liberalisation and its potential impact on bidders' choice in the auction was limited because of prior statements made by Ofcom regarding the direction of its policy development on 2G liberalisation.

A5.16 Respondents to the December Consultation made a number of points regarding the benefits of delaying the award (as discussed in Section 7) emphasising the level of uncertainty they believed they faced, principally over 2G liberalisation, and questioning whether there was concrete demand for current access to the spectrum. Ofcom has reviewed these arguments carefully, and as set out in Section 7, presented more evidence to support its analysis of the options.

A5.17 With respect to the benefits of holding the award as soon as practicable, more evidence has emerged to support the contention that there is credible demand for current access to the spectrum: Ofcom has received confidential concrete expressions of interest for use of the band in bilateral meetings with stakeholders and international developments in both the award of 2.6GHz spectrum and the rollout of WiMAX networks in this band have gathered pace. In addition, there is a risk that, unless the award is held soon, the window of opportunity for WiMAX players to be able to supply mobile broadband services will close, and the UK could forego the benefits of increased innovation, new services, and greater competition that WiMAX and other TDD technologies could bring.

A5.18 There have also been developments which affect the costs of holding the award as soon as practicable. The European Union has published a Decision requiring the removal of restrictions preventing the use of 2G spectrum for UMTS, and the UK will have to implement this Decision within a reasonable time period. In line with this, Ofcom expects to issue a consultation in the near future on the subject of 2G liberalisation. This consultation will provide further clarity on supply of 2G spectrum and will allow all bidders to consider additional information on how the implementation of the EC Decision on 2G spectrum is likely to affect their specific position.

A5.19 Ofcom therefore remains of the view that the net benefits of holding the award as soon as practicable are likely to outweigh the net benefits of delaying the award.

Rollout obligations and other non-technical licence conditions

A5.20 In the December Consultation, Ofcom set out the view that its proposals on non-technical licence conditions, in particular not to include rollout obligations in 2.6GHz licences, were likely to be pro-competitive. Ofcom also argued that competitive distortion with respect to existing 3G MNOs were unlikely to arise, because auction participants would have taken their own (different) licence conditions into account when bidding for licences.

A5.21 Ofcom received several responses, as detailed in Section 8, raising further arguments that differences in licence conditions between new entrants using 2.6GHz and existing 3G operators were likely to lead to a distortion of competition.

A5.22 Ofcom set out its views on these responses concerning potential distortions to competition in Section 8 and because of the variety of issues and their detailed technical nature, we do not propose to summarise them here. However, Ofcom's updated assessment is that it does not consider that the arguments contending that its proposals would lead to a distortion of competition apply to the circumstances. In particular, 3G operators have a variety of ways to respond to new entry, e.g. by adjusting their tariffs, and, moreover, as incumbents, they had a number of advantages over new entrants such as greater economies of scale in a number of areas and an established brand presence. Ofcom's assessment, therefore, remains the same as in the December Consultation.

Annex 6

Blocking effect: a simulation of UMTS performance in the presence of WiMAX interference

Disclaimer

The technical studies described in this and subsequent annexes ("the Technical Studies") have been prepared by Ofcom and its advisers in connection with the award of wireless telegraphy licences to use the three spectrum bands at 2500-2690MHz, 2010MHz - 2025MHz and 2290-2300MHz (the “Spectrum Bands”).

The Technical Studies are intended for information purposes only. The Technical Studies are not intended to form any part of the basis of any investment decision or other evaluation or any decision to participate in the award process for the Spectrum Bands, and should not be considered as a recommendation by Ofcom or its advisers to any recipient of this Discussion Document to participate in the award process for the Spectrum Bands. Each recipient must make its own independent assessment of the potential value of a licence after making such investigation as it may deem necessary in order to determine whether to participate in the award process for the Spectrum Bands. All information contained in the Technical Studies is subject to updating and amendment.

The content of the Technical Studies, or any other communication by or on behalf of Ofcom or any of its advisers, should not be construed as technical, financial, legal, tax or any other advice or recommendation. Accordingly, any person considering participating in the award process for the Spectrum Bands (either directly or by investing in another enterprise) should consult its own advisers as to these and other matters or in respect of any other assignment of any radio spectrum.

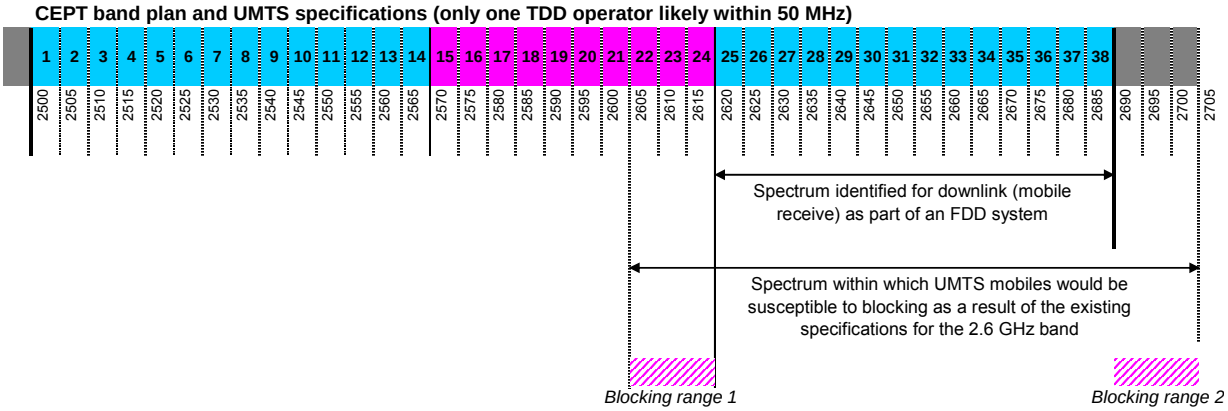
Introduction

A6.2 Under the award process considered in the rest of this Discussion Document, FDD downlink (i.e. transmissions from the base station to the mobile) is planned to take place in the 2620–2690MHz range.

A6.3 Under 3GPP specifications for UMTS user equipment, the in-band blocking specification extends for ±15MHz either side of the nominal downlink reception band (i.e. pass band of 2605–2705MHz in total). As shown in Figure 10 below, this 15MHz range includes the top part of the centre band (2570–2620MHz) where it is likely that TDD mobile terminals would be operating (blocking range 1 in the figure below). FDD mobiles could therefore encounter blocking interference from TDD mobiles operating in this range, even if the CEPT band

plan were not deviated from. This would be as a result of a choice made by those involved in the standardisation process for UMTS at 2.6GHz in 3GPP, since they have the option of defining a pass band range that is narrower.

Figure 10: Blocking of UMTS mobile under the CEPT band plan



A6.4 In practice, FDD mobile terminals will be fitted with a band pass filter. This filter will use the 15MHz of spectrum between 2605–2620MHz to roll-off (i.e. gradually change from allowing in-band emissions to pass through to filtering out-of-band emission). Therefore, interfering emissions from TDD mobile terminals in the range 2605–2620MHz should be attenuated somewhat, but not completely, by this band pass filter.

A6.5 It should be pointed out that the potential for mobile-to-mobile blocking is not just confined to the case described above. The reverse scenario (i.e. FDD mobile terminals blocking TDD mobile terminals when they are within the receive pass band of the TDD mobile terminals) is equally a potential problem. Considering WiMAX terminals, it is Ofcom's understanding that these are likely to have a receive pass band which encompasses the entire 2.6GHz band (or a significant part of it) and are therefore likely to suffer a potential blocking problem regardless of whether or not the result of the award is consistent with the CEPT band plan. It is interesting to note that this does not appear to be a concern for potential TDD bidders interested in using the spectrum for WiMAX. One possible reason for this may be a difference in perspective between FDD proponents (who are predominantly interested in UMTS (or LTE)) and the TDD/WiMAX community. The WiMAX community consider the band to be primarily of interest for data type services where intermittent disruptions in quality of service caused by blocking from FDD mobile terminals may not be regarded as a significant issue in itself (unless a real time data service is being used, a few delayed packets may not be noticed by a users). On the other hand, FDD proponents are largely represented by existing MNOs who are used to providing voice services as a significant part of their offering, and a blocked or dropped call is likely to be directly perceived by a user as poor quality of service. This difference in perception could explain, at least in part, the difference in positions between those interested in FDD use and those interested in TDD use.

A6.6 In order to provide an estimate of the level of risk associated with this performance issue, Ofcom has undertaken a simulation of UMTS performance in the presence of WiMAX interference. This simulation is primarily designed to

address the impact of mobile-mobile blocking where the centre-centre frequency separation is a minimum of 15MHz.

A6.7 The simulation considers UMTS devices and WiMAX interferers which are statistically distributed across a small scale UMTS network. Using this simulation, Ofcom has considered a number of different modelling scenarios which examined different assumptions on the distribution of the WiMAX mobiles, the proximity of a UMTS "victim" device and a chosen WiMAX interferer and the use of power control by the WiMAX devices. These variable assumptions were:

a) Distribution of WiMAX mobiles: choice between a uniform distribution[87] and a hot spot distribution[88]

b) Proximity of UMTS victim to WiMAX interferer: the simulation can be run in Interference Mode 0 or 1. In Interference Mode 0, the distributions of UMTS and WiMAX mobiles are left unaltered. In Interference Mode 1, the WiMAX mobiles are translated to place a randomly selected WiMAX mobile at a specified distance from a chosen UMTS mobile within the centre cell.[89]

c) WiMAX power control: choice between "on" or "off", with "on" implying that, on average, the WiMAX mobiles operate at a lower power.

A6.8 A Monte Carlo[90] simulation technique was used to model the effect of WiMAX mobile terminals on a UMTS network. This approach used a figure of 1000 iterations for each set of parameters to provide statistically valid results. Between iterations (and between scenarios) parameters concerning the UMTS network and UMTS and WiMAX devices were held constant, as were the propagation assumptions. Variation between the iterations was only from the distribution of the WiMAX devices within the network.

A6.9 The remainder of this Annex is structured as follows:

- **Simulation strategy and inputs**: provides a high-level summary of the simulation and its main inputs
- **Simulation process**: describes in detail the methodology adopted by the simulation
- **Simulation outputs**: summarises the outputs from the simulation
- **Discussion**: in light of the simulation outputs, considers potential mitigating factors for blocking as well as real-life situations in which the results of the technical study may imply that blocking is a substantial issue

[87] Where the probability of a mobile being at any location is equal to the probability of it being at any other location (i.e. the probability is uniformly distributed)
[88] Where the distribution of WiMAX mobiles within 25m of the central UMTS base station was assumed to have a different (higher) density than mobile beyond 25m of the central UMTS base station
[89] This allows examination of the expected deterioration of service for the selected UMTS mobile in close proximity to a WiMAX interferer.
[90] A Monte Carlo is a term used to describe solutions to mathematical problems which have many variables that cannot easily be solved. It involves randomly selecting a value (from a stated range) for the variables and then using these values for each individual calculation. This process is then repeated a finite number of times to build a statistical result.

A6.10 The sections of this annex covering the simulation focus on the technical study carried out and do not link the results to potential real-life uses of the spectrum by consumers (which would include consideration of user location and behavioural use of the devices, as well as potential alternatives to the 2.6GHz spectrum available to licence holders should blocking be an issue in limited cases). This is considered in detail in Section 3 of the Discussion Document.

Simulation strategy and inputs

A6.11 The study focused on the service implications for UMTS mobiles receiving UMTS downlink signals in the presence of WiMAX interferers.

A6.12 A Monte Carlo simulation technique was used to model the effect of WiMAX mobile terminals on a UMTS network. A figure of 1000 iterations for each set of parameters used to provide statistically valid results.

A6.13 The UMTS mobiles were modelled as if in a UMTS macro-cell network environment with power control[91] applied. This allowed the simulation to calculate the natural loss of service in the UMTS network to act as a comparison for the additional interference from WiMAX.

A6.14 UMTS mobiles were placed randomly in the cells with a uniform distribution across the network and the propagation path loss was modelled to represent the mobiles being indoors in an urban environment.

A6.15 The WiMAX mobiles were represented as stand-alone active interferers placed in the UMTS environment in accordance with a user defined distribution. At the outset the intention was not to model a WiMAX network (i.e. both mobiles and base stations) but to focus on the potential interference from WiMAX mobile devices.

A6.16 The study specifically addressed performance issues due to blocking by a set of interfering WiMAX mobiles, with the centre-centre channel separation between UMTS and WiMAX set to a minimum of 15MHz. All WiMAX mobiles modelled in the study were taken to lie in the upper part of the 2500 to 2690MHz band (which is consistent with potential outcomes from the 2.6GHz award).

A6.17 One of the key areas studied was the potential interference effect when a WiMAX mobile and a UMTS mobile are in close proximity.

A6.18 The remainder of this section summarises the simulation and parameters used for:

- the UMTS base station network and mobiles;
- the WiMAX interferers; and
- propagation modelling.

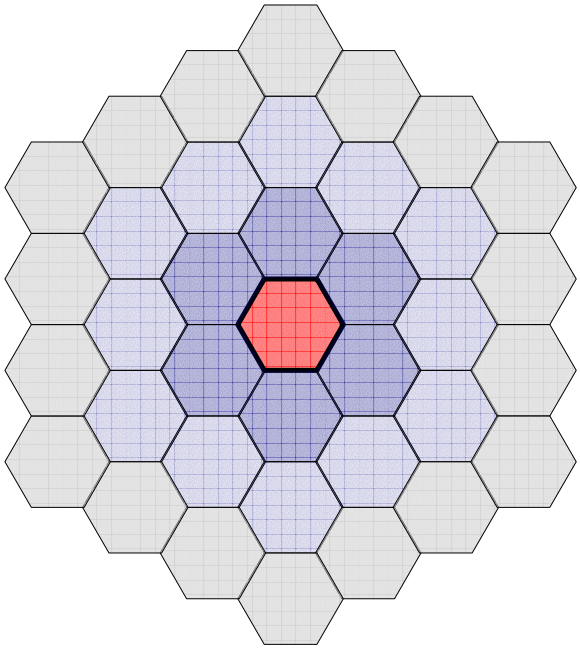
[91] Power control is the process where the network adjusts the power output (of the both base station and mobile) to optimize system performance. In general output power is kept to the minimum required to maintain overall optimal performance.

A6.19 Subsequently, we provide a detailed description of the simulation process itself.

The UMTS base station network and mobiles

A6.20 The UMTS network was modelled as a central hexagonal cell surrounded by three layers of hexagonal cells in a regular hexagonal array. The three layers of cells allow the simulation to model UMTS call rejection in the absence of WiMAX interferers. This layout gives a total of 37 cells and is shown in the diagram below. Each cell is tri-sectored, giving a total of 111 sectors.

Figure 11: UMTS macro-cell layout adopted in the simulation



A6.21 Base stations were all of a fixed height. While this may not represent the variation in a real network, the results in terms of the impact of WiMAX interference are considered to be meaningful.

A6.22 The antenna adopted while modelling the UMTS base stations has a narrow-angle pattern which is widely used in 3G networks. When using this pattern it is conventional that the antenna points directly at a neighbouring base station and this was used in the simulation. In comparison to a wide-angle pattern antenna (which would usually point between two neighbouring base stations) the narrow-angle antenna has reduced adjacent sector interference but has a larger geographic area at what might be termed the “cell edge”.

A6.23 A fixed set-up was adopted for the UMTS simulations and is representative of a stable network.

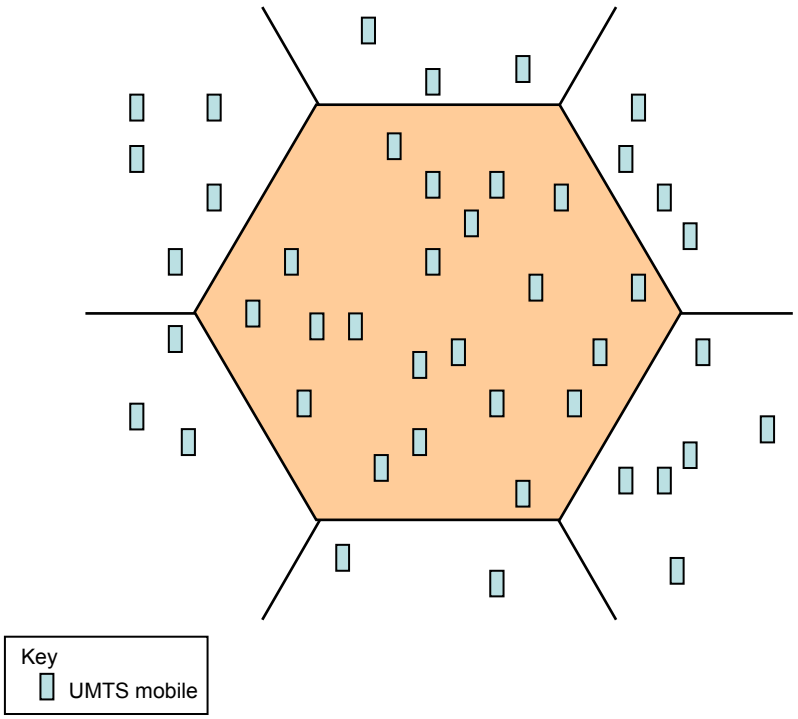
A6.24 A total of 4995 UMTS mobile terminals were considered for the simulation (an average of 45 per sector, which gives an average of 135 per cell). However, some proportion of these mobiles will be transmitting (and not subject to blocking from TDD transmissions) while the remainder will be receiving (and potentially subject to interference). An activity factor of 0.5 was applied to the UMTS mobiles to arrive at the average number of active (receiving) mobiles –

approximately 2500. For each iteration of the simulation, the Poisson approximation to the binomial distribution is applied to the average number of active mobiles across the network (2500) to yield the number of active receiving UMTS mobiles for that iteration.

A6.25 To put the use of a subscriber base of 5000 for UMTS into perspective – a typical user in the busy hour is likely to generate about 30 mErlangs of voice traffic. The population of 2500 active mobile terminals is equivalent to about 83,333 mobile terminals each generating 30 mErlangs of voice traffic (or 750 users per sector). A smaller number of terminals each operating for a larger percentage of the time was modelled in order to reduce the number of Monte Carlo calculations to a level that could be carried out in a reasonable period of time. The overall statistical probabilities of rejections are, however, likely to be reasonably representative of real situations.

A6.26 The active UMTS mobiles were then distributed across the UMTS network using a uniform probability distribution, an illustration of this in the centre cell given in the figure below.

Figure 12: Random distribution of UMTS mobile terminals in centre cell



Note: diagram is illustrative, with mobile device density not reflecting that in the simulation

A6.27 Table 16 below shows the UMTS parameters adopted for the simulation.

Table 16: UMTS parameters adopted for the simulation

Cell structure	Reference hexagonal centre cell and three outer layers of hexagonal cells.[92]
Cell radius	1 km
Downlink Frequency	2622.5MHz
Base station (BS) antenna height	30 m
BS antenna type	Thales 65º UMTS
BS antenna gain	14 dBi
Maximum BS power[93]	43dBm
Traffic Channel Power Control Range	25dB
Percent Parameter[94]	0.5 dB
UMTS soft handover margin	4 dB
Mobile station (MS) height	1.5 m
MS receiver noise floor	-100dBm
DTX Activity factor	0.5
Mean number of UMTS mobiles placed in each sector	45[95]

The WiMAX interferers

A6.28 The WiMAX interferers were modelled as a distribution of stand-alone mobiles not attached to a WiMAX network of base stations.[96] These mobiles were assumed to be in operation for 100% of the time. As for the UMTS case, these assumptions are not likely to be representative of real usage patterns (with a larger number of mobile terminals using the network for as smaller percentage of the time) but has been used to make the Monte Carlo simulations computationally manageable.

A6.29 IEEE 802.16e specifies closed loop power control as mandatory and, given modelling without power control would give a worst-case result, the simulation implemented an estimation of WiMAX power control. To test the sensitivity of results to the use of WiMAX power control, the simulation allowed power control for WiMAX mobiles to be set to “on” or “off”.

A6.30 One of the key aims of the simulation was to examine the effect of increasing WiMAX mobile density on the probability of UMTS blocking, as well as examining the potential impact of localised ‘hot spots’ of WiMAX mobiles (for

[92] Each cell is sectored giving 37 cells and 111 sectors.
[93] The maximum transmitted power of the UMTS base station. This is not the EIRP: antenna gain must be added to determine the EIRP.
[94] The maximum value of the difference between the converted E/I (E/I is the ratio of the energy per chip and the interference per chip generally referred to as E_c/I_{or}) for two consecutive iterations of the power control cycle for one terminal for the power control cycle for that terminal to be considered converged. Convergence must be achieved for all terminals before the overall power control cycle can be deemed complete.
[95] This figure is multiplied by the number of sectors (111) to yield the mean number of terminals across the network. The DTX activity factor is then applied to this to give the mean number of active terminals in any iteration of the model. The actual number of active terminals used in an iteration is determined by applying the Poisson approximation to the binomial distribution to the mean number of active terminals across the network.
[96] If the WiMAX terminals were attached to a WiMAX network it would be possible to model power control more accurately. It was felt that the potential for improved accuracy did not outweigh the additional complexity and computing time required.

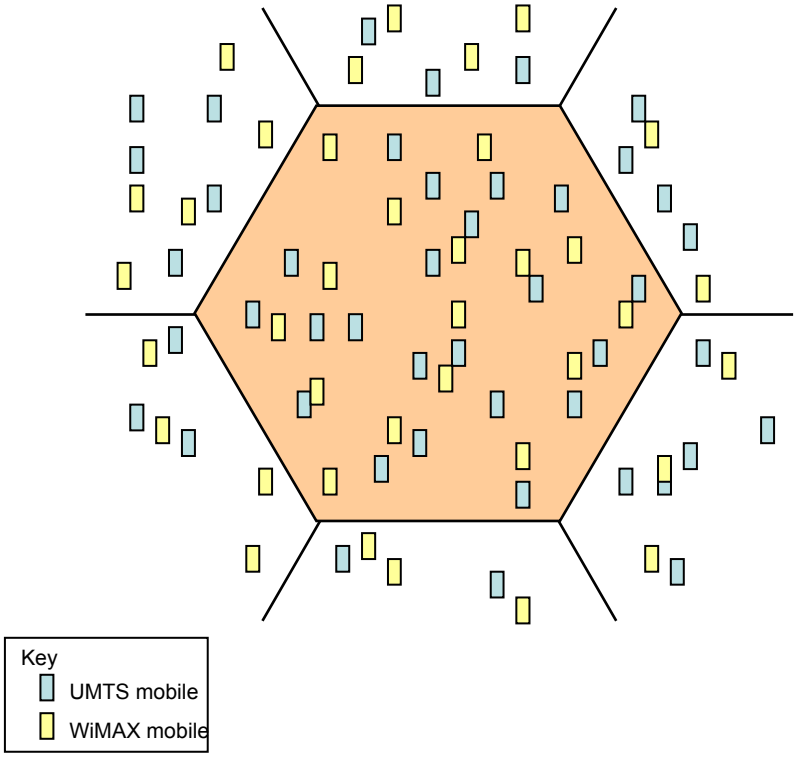
example, in airports, conference centres, train carriages, etc.) and of mobile UMTS and WiMAX devices being in close proximity.

A6.31 In order to examine the first two of these factors, the simulation allowed the user to choose from two options for the distribution of WiMAX mobiles:

- a uniform probability distribution, where the probability of a WiMAX mobile being in a given location is equal (uniform) across the network, with the user able to vary the density of WiMAX mobiles
- a hotspot distribution, where the density of WiMAX mobiles in a small radius (25m) within the centre of the centre cell was user-specified to a level higher than the background mobile WiMAX density outside of the hotspot

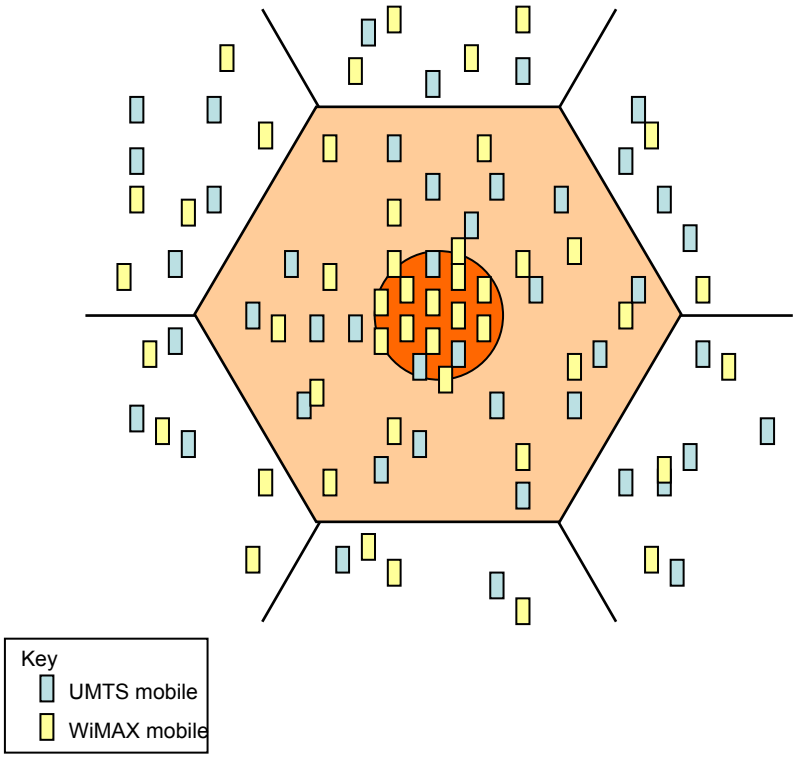
A6.32 The two figures below illustrate the uniform and hotspot distributions in the centre cell.

Figure 13: Uniform distribution of WiMAX mobile terminals in centre cell



Note: diagram is illustrative, with mobile device density not reflecting that in the simulation

Figure 14: Hotspot WiMAX distribution in centre cell



Note: diagram is illustrative, with mobile device density and hotspot radius not reflecting that in the simulation

A6.33 As mentioned above, the effect of the proximity of UMTS and WiMAX mobiles on UMTS blocking was also of primary interest for the study. The simulation considered two Interference Modes:

- Interference Mode 0: the WiMAX mobiles are left as specified by the chosen statistical distribution
- Interference Mode 1: the WiMAX mobiles are translated (moved) a certain distance with a randomly selected WiMAX mobile acting as an anchor point. This translation is achieved through:

  i) the random selection of a UMTS mobile within the central cell of the UMTS network.

  ii) the random selection of a WiMAX mobile within a pre-determined distance of the centre of the WiMAX distribution.

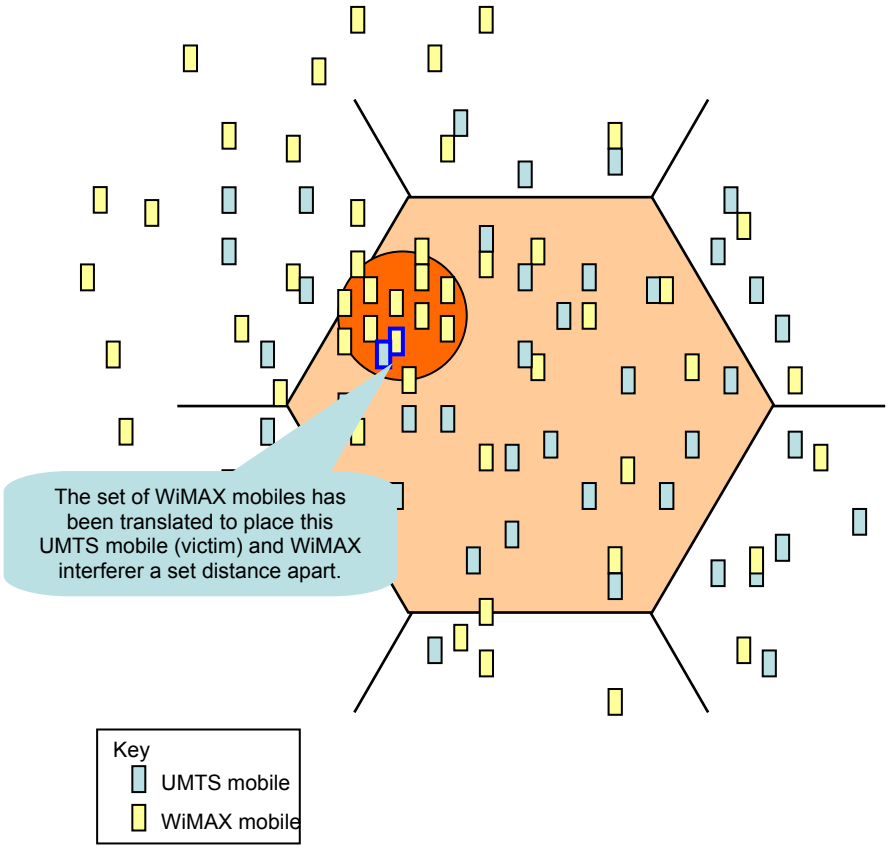
  iii) the movement of the whole set of WiMAX interferers to be such that the selected UMTS terminal and the anchor WiMAX terminal are a specified distance apart.

A6.34 This allows examination of the expected deterioration of service for the selected UMTS mobile in close proximity to a WiMAX interferer. It should be noted, however, that the impact of changing WiMAX interference resulting from this

translation will not necessarily just be experienced by the selected UMTS mobile.

A6.35 The figure below illustrates the use of Interference Mode 1 for a hotspot distribution of WiMAX mobiles.

Figure 15: WiMAX hotspot distribution using Interference Mode 1



Note: diagram is illustrative, with mobile device density and hotspot radius not reflecting that in the simulation

A6.36 The parameters used for the WiMAX interferers are shown in Table 17 below.

Table 17: WiMAX parameters

Maximum EIRP	Generally 23dBm[97]. For comparison purposes a number of simulation runs were also conducted at 30dBm and 16dBm.
WiMAX power control	A power distribution was applied to model closed loop power control.
Mobile station height	1.5m

A6.37 The number of WiMAX devices varies between the modelling scenarios (as the density of WiMAX devices affects the levels of interference) and is specified later in the discussion of the different scenarios.

[97] This is line with the assumptions of ITU working group 8F.

Propagation modelling

A6.38 The table below details the parameters used in the propagation modelling. The UMTS mobiles are modelled as being within an indoor environment served by macro-cells, and the WiMAX mobiles are also taken to be indoors. This provides a worst-case scenario – if the mobiles were outdoors then the likelihood of blocking would reduce.

Table 18: Features of the propagation modelling

Path loss between UMTS base stations and UMTS mobiles	CEPT SE21 HATA model
Clutter type	Urban (used in the CEPT SE21 HATA model)
Standard deviation associated with the path loss prediction from SE21 HATA.	13.45dB[98]
Building penetration loss for use in conjunction with SE21 HATA	12 dB
Minimum coupling loss for the link between the UMTS base station and the UMTS mobile	70 dB
Path loss between WiMAX mobiles and UMTS mobiles	Recommendation ITU-R P.1238 model. The floor penetration loss factor is not used (i.e. the mobiles are all assumed to be on one floor). A distance power coefficient of 29 is adopted.
Standard deviation for indoor path loss calculations	10 dB
Minimum coupling loss between a WiMAX mobile and a UMTS mobile.	35 dB

The simulation process

A6.39 As described earlier, the Monte Carlo simulation technique adopted here used 1000 iterations for each set of parameters used to provide statistically valid results. Each iteration involved the random placing of UMTS and WiMAX mobiles under the distributions described in the previous section. The UMTS base station configuration and parameters remain unchanged for each iteration, as did the majority of the parameters for the WiMAX and UMTS mobiles[99] and propagation modelling.

A6.40 In addition to the choice of WiMAX mobile distribution and Interference Mode, the user was able to specify parameters including:

- the density of WiMAX mobiles (in both the uniform and hotspot distributions)
- the separation distance when using Interference Mode 1

[98] Derived from the standard deviation external to buildings (9dB) and the standard deviation indoors (10dB). Calculated by taking the square root of the sum of the squares of these two values.
[99] A number of simulations were carried out with different power levels for the WiMAX mobiles to test the sensitivity of the results to this.

- the use (or not) of WiMAX power control

A6.41 The remainder of this section describes the modelling approach adopted in the simulation in further detail.

UMTS base stations

A6.42 A large array of sectored UMTS base stations is laid down based in a hexagonal cell layout, as described earlier. All base station antennae have the same height. The layout of the base stations is not changed between iterations of the model.

UMTS mobiles

A6.43 As discussed above, for each iteration of the model, the number of active UMTS mobiles for each iteration is calculated using the activity factor (of 0.5) and the Poisson approximation to the binomial distribution. These active terminals are then distributed across the UMTS network using a uniform probability distribution (with each mobile having a base station picked at random and then being randomly positioned within its hexagonal cell). The effect of this is that the number of active mobiles in a cell varies and the scatter across the entire array of UMTS cells is random.

A6.44 The path loss to each active UMTS mobile from every sector antenna is calculated. This allows the Pilot E/I[100] for every mobile from every transmitter to be calculated. The total interference is calculated as a linear sum of the interference powers. Each mobile is then assigned to a base station sector based on the highest E/I (i.e. the strongest signal).[101] However, if a mobile has another base station sector providing an E/I value lying within the soft handover margin of the highest E/I it is assumed to be in soft handover, with more than one base station sector serving that mobile.

UMTS power control

A6.45 The UMTS power control process uses information supplied by Lucent based on computer modelling of the channel and uses an iterative process.

- For each UMTS mobile the signal to noise ratio for the entire signal is calculated.[102]
- From this figure and a look-up table[103] the required traffic channel power is determined.
- The traffic channel power is summed by transmitter, including the control channels, to calculate the total required transmitter power.

[100] The Pilot E/I is the E/I calculated using the CPICH power, representing the mobile while it is not actively carrying traffic.
[101] In this process, the assigned base station sector may not necessarily be the base station antenna whose coverage area the mobile lies in.
[102] The signal is calculated from the base station sector the mobile is assigned to. The noise is the power sum of the signals from all of the other base station sectors
[103] Taken from data provided by Lucent for 1900 MHz. It is available within the ERO Seamcat tool (available at http://www.ero.dk/seamcat).

- The transmitter power is updated. If a UMTS mobile is suffering more interference from other UMTS mobiles following this update then more power must be dedicated to that mobile within the constraints of the maximum power that can be dedicated to a single terminal.

- The procedure returns to the calculation of the signal to noise ratio.

A6.46 This procedure continues for a number of iterations until the convergence rules are met or the maximum number of iterations are reached. If, during this process, a mobile requires more than the maximum traffic channel power to work, it is rejected. Similarly, if a mobile cannot achieve the required E/I it is also rejected.

A6.47 Following convergence of the UMTS power control process, the number of rejections in both the centre cell and over the whole network is available.

Addition of WiMAX mobiles

A6.48 Once the number of rejections of UMTS mobiles in the absence of WiMAX interferers ("background call rejections") has been calculated, the WiMAX interferers are introduced into the simulation as described earlier (i.e. using a uniform or hotspot distribution and Interference Mode 0 or 1, with WiMAX power control on or off).

A6.49 Once the WiMAX mobiles are positioned, the cumulative interference for each UMTS mobile is calculated from all WiMAX mobiles. For the WiMAX interference, the incoming WiMAX signal is attenuated by 56dB due to the presence of a filter in the receiver.[104]

A6.50 The UMTS power control process is then applied and, following convergence, the number of UMTS mobiles rejected in the central cell and over all cells is determined.

Consideration of power control in WiMAX

A6.51 IEEE 802.16e specifies closed loop power control as mandatory. It was therefore considered desirable to include WiMAX power control in the simulations, even if in the rudimentary form of a probability distribution.

A6.52 A WiMAX mobile must obey power change commands.. However, IEEE 802.16e does not specify update cycles nor provide any of the information necessary to permit an accurate model of the power profile to be derived. In order to estimate a power profile for inclusion in the simulation it was necessary to draw upon conventional assumptions associated with mobile technologies. These assumptions are as follows,

- The maximum cell size is defined by the ability of the mobile to receive the control channel with a high probability of success. A probability of success of 90% at the cell edge will yield a probability of coverage of 97% across the entire cell and this value of 90% coverage at the cell edge is used in our definition.

[104] 56dB is a calculated from the noise floor and the blocking power for the UMTS mobile.

- The control channel is assumed to operate at the slowest of the available data rates.

- WiMAX is optimised to transfer the user data at the maximum rate and this is achieved by varying the data rate to match the maximum which is available for the locally available C/I[105] ratio. It is therefore assumed that the power control process will not commence until the highest possible data rate has been achieved.

- The service environment is assumed to be in-building.

A6.53 Two of the assumptions govern the power at the cell edge: the assumption that the service will be used within a building and the requirement that there shall be 90% coverage at the cell edge. If the service is to be used within a building then the standard deviation of slow fading is higher than that used for services on the street. In this model a standard deviation of fading of 9dB has been used for the path to the street. This has been combined with a standard deviation of fading within the building of 10dB to yield an overall standard deviation of slow fading of 13.45dB.

Using standard cell planning criteria, in order to achieve 90% coverage at the cell edge it is necessary that there is an average power surplus at the cell edge of 1.3 times the standard deviation of slow fading, in this case 17.485dB. This means that, in effect, the average terminal at the cell edge will be using its power surplus to permit it to operate at a higher speed.

A6.54 The minimum C/I ratio required for a service to operate under static conditions in the laboratory is not sufficient for the same service to operate on the street. The difference between the C/I ratio required on the street and that required in the laboratory is the power control margin. This margin is necessary for two reasons: fast fading and the time delays in the power control update cycle. Ofcom have no information concerning the power control update process for mobile WiMAX and it would appear to be a factor which is established by the network operator. The figures selected for use in the simulation are therefore an estimation based on Ofcom's best judgement.

A6.55 It is possible to estimate an upper and lower bound through reference to other mobile technologies. The early GSM networks did not use closed loop power control and the power control set point was based on the received power. This may be described as a closed loop power control system in which the cycle time of the loop is infinite. Typical power control margins were 19 to 20dB. This is equivalent to a power control set point at 19 to 20dB above the sensitivity, typically -85dBm.

A6.56 3G systems have a dual power control loop in which the outer loop runs at 800 cycles per second and the inner loop runs at approximately one eighth of this figure. The power control margin is determinable from the required E/I ratios used in the computer models undertaken for the simulation considered in this annex. These figures vary considerably with the speed of operation, with 3G being more sensitive to fast fading at certain speeds. An average figure for the power control margin of 7 or 8dB might be encountered.

[105] C/I is the carrier to interference ratio.

A6.57 The power control margin for mobile WiMAX is likely to lie between these two extremes and the estimate adopted is the mean of 13dB.

A6.58 As a terminal moves from the outside of the cell towards the centre of the cell, the data rate will increase until it reaches the maximum. At this point, power control will start. The difference between the signal to noise ratio for the peak data rate and the signal to noise ratio for the slowest data rate is 17.55dB[106]. It can therefore be deduced that, if the slow fading margin at the cell edge is 17.485dB, then the average terminal will be operating at a relatively high data rate and that it would not need to move far into the cell before power control would start to operate. This model fails to take account of the inefficiencies of the power control cycle which have been mentioned above. If power control margin is 13dB then the mean path loss must be reduced by 13.1 dB (17.485 – 17.55 – 13) before power control comes into effect. If the path loss exponent is 3.522 (typical for HATA) then for each halving of the distance approximately 10 dB is gained[107]. Therefore if the radius of the cell is 1 kilometre, 10dB will have been gained by the time that the terminal is 0.5 kilometre from the base station and 13.1 will have been gained at 0.4 kilometres from the base station.

A6.59 If the cell radius is 1 kilometre then, assuming a uniform distribution across a circle, only 16% of terminals will be within 0.4 kilometres, with the remaining 84% of them will be at full power. At distances of less than 0.4 kilometres then power control will apply at a mean rate of 10dB for every halving of the distance.

A6.60 Therefore, a power control profile should be expected to have the form approximately as given in Table 19 below:[108]

Table 19: The adopted WiMAX power control profile

Cumulative Probability	Relative Transmit Power
0.0	0dB
0.84	0dB
0.96	-10dB
1.00	-20dB

A6.61 The cumulative probability profile in Table 19 above means that:

- 84% of WiMAX mobiles have maximum transmit power;

[106] This figure comes from the IEEE 802.16e standard: SNR for BPSK is 13.9 dB and 64QAM is 31.45 dB, 31.45-13.9=17.55 dB
[107] 3.522*10Log(1/2) ≈ 10 dB
[108] Recalling that a halving of distance equates to a reduction in area in a circle by a factor of four.

- 96% of WiMAX mobiles have a transmit power which is greater than or equal to -10 dB below maximum transmit power; and

- 100% of WiMAX mobiles have a transmit power which is greater than or equal to -20 dB below maximum transmit power.

A6.62 For the simulations WiMAX power control was generally "on". However some scenarios were conducted with WiMAX power control "off" in order to examine the sensitivity of the results to the inclusion of WiMAX power control profile.

WiMAX mobile distributions

A6.63 As described earlier, the UMTS network parameters were kept fixed across iterations and scenarios in order to explore the effect of different densities and distributions of WiMAX mobiles.

A6.64 As described earlier, the two different types of WIMAX mobile distribution that were available for use in the scenarios were: a uniform distribution; and a hot spot distribution

A6.65 We describe each of these distributions in detail in the rest of this section.

Uniform distribution

A6.66 It is not possible to estimate with any certainty what the density of WiMAX mobiles will be during the busy hour as this will depend partly upon how many (if any) unpaired channels there are in the upper part of the 2500 to 2690MHz band as a result of the award and partly upon whether any operators gaining this section of the spectrum are successful in terms of subscriber numbers. By adopting a variable density of WiMAX mobiles in the simulation, it is possible to interpolate the expected outcome for various values of WiMAX mobile density.

A6.67 For the uniform distribution, in order to assess the range of densities which can be achieved it is necessary to consider three factors:

- The number of WiMAX mobiles which may be supported per 10MHz –based on previous WiMAX network simulation studies Ofcom estimates that a maximum of 12 active WiMAX mobiles per sector may be supported at any one time.

- The number of 10MHz channels which may used for TDD WiMAX in the upper part of the band. At the maximum this could be 6 x 10MHz (5MHz Channels 27 – 38) with one 5MHz paired downlink channel at Channel 25 centred on 2622.5MHz.[109]

- A variety of cell sizes.

A6.68 Consideration of the above, and basing the calculations upon a 500m radius hexagonal cell,[110] implies that a maximum density of active WiMAX mobiles in

[109] In this case Channel 27 would not have a centre-centre offset of greater than or equal to 15 MHz. However, this is not critical for the purposes of this study where the focus is upon the effect of blocking due to various densities of WiMAX interferers.

[110] A 500m radius (rather than 1km) was used to provide an estimate of a reasonable maximum density.

the upper part of the 2.6GHz band should not be more than approximately 111 WiMAX mobiles per km^2. However, to explore the trend with increasing density we have examined some scenarios up to a density of 200 WiMAX mobiles per km^2.

A6.69 During the simulation the WiMAX mobiles are placed within a circular area surrounding the central UMTS base station using a uniform probability distribution. A Monte-Carlo randomisation is applied to both selection of angle and distance from the central UMTS base station.

A6.70 In order to compare our assumptions regarding WiMAX user densities to a potential real-life situation, we have carried out the following analysis (based on statistics for the City of London[111]).

Assumptions:

Business population of London (2004)	290,000
Area of the London Square Mile (km^2)	2.59
Density of business population ($1/km^2$)	112,000
% business population with a 2.6GHz device	20%

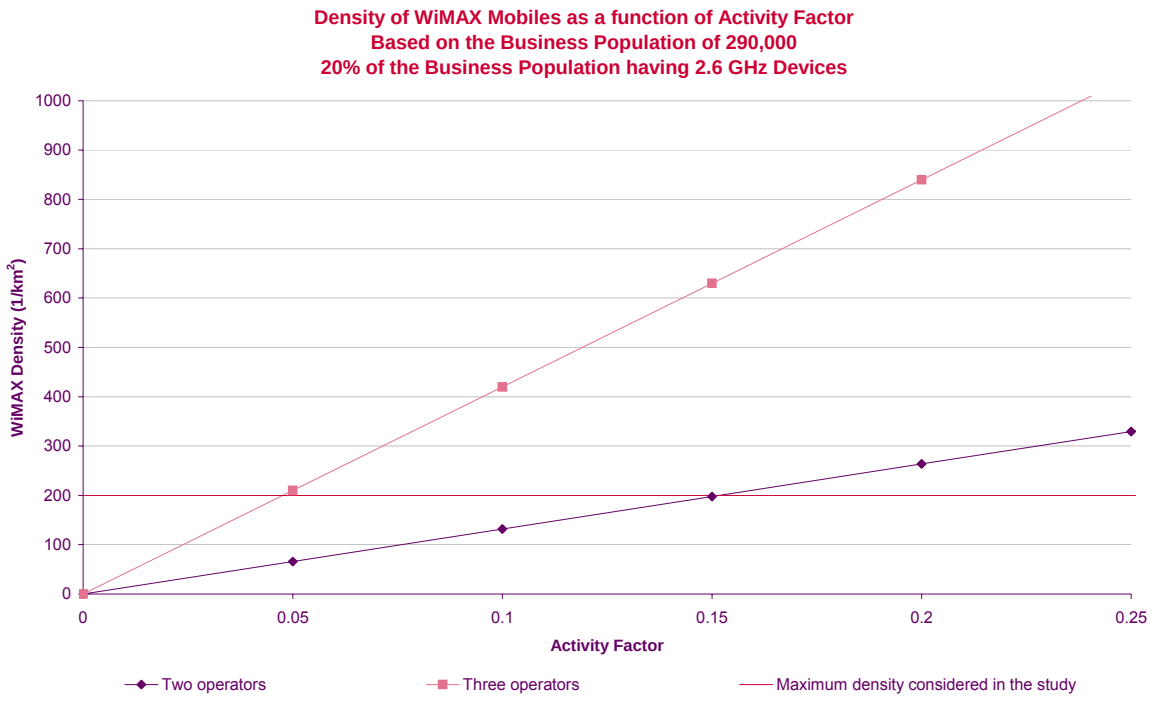
Number of TDD Operators	1	2	3
Unpaired spectrum in the top block as % of total 2.6GHz spectrum[112]	0%	6%	19%
Density of WiMAX users before applying an activity factor ($1/km^2$)[113]	0	1,350	4,200

A6.71 Whilst these assumptions are approximate, they provide an indication of the possible density of WiMAX devices in an area with a dense business population. Considering the application of an activity factor to the second table above, as shown in Figure 16 below, the maximum user WiMAX user density of 200 km^{-2} is equivalent to an activity factor of 15% for a two TDD operator scenario and 5% for a three TDD operator scenario under these assumptions.

A6.72 The chosen example location (the City of London) is one of the highest user density areas in the UK (excluding localised clusters of individuals in, for example, airports or conference centres). Therefore, a WiMAX user density of 200 per km^2 does not appear to be an unreasonable assumption for the maximum WiMAX mobile density considered for the uniform distribution.

[111] City Research Focus, 2006, Issue 1, page 7, 2004 Annual Business Inquiry
[112] Removing restricted blocks and unsold lots from the measure of 'total 2.6GHz spectrum'
[113] Assuming that devices using FDD and TDD are distributed evenly across the 2.6GHz band, which may not necessarily be the case

Figure 16: Illustrative example of density of WiMAX mobiles as a function of activity factor



Hot spot distribution

A6.73 Results have also been produced for a hot spot distribution. The hot spot consists of a circular area of radius 25m with a high uniform density of WiMAX mobiles surrounded by a lower uniform background density area delimited by a circular radius WOuterRad. As in the case of a completely uniform distribution of WiMAX mobiles, the cumulative distribution function (the inverse of which is used to randomly select distance from centre of the hot-spot) has a distance squared characteristic. It is simply modified to reflect the abrupt change in density at the hot-spot boundary and is given by:

$$P(r) = \frac{\rho_0 \pi r^2}{N} \quad \text{for} \quad r \le r_0$$

and

$$P(r) = \frac{(\rho_0 - \rho_B)\pi r_0^2 + \rho_B \pi r^2}{N} \quad \text{for} \quad r_0 < r \le WOuterRad$$

where ρ_0 is the hot-spot density, ρ_B is the background density, r_0 is the hot-spot radius and N is the total number of WiMAX interferers.[114]

[114] By definition, $P(WOuterRad) = 1$

A6.74 A fixed background WiMAX mobile density of 0.0000265 mobiles/m^2 (26.5 mobiles per km^2) was maintained for all the hot spot studies. Four different hot spot densities were used, ranging from the same level as the background density (for reference purposes) to 0.015 mobiles/m^2 (15000 mobiles per km^2). The higher figure was considered a realistic maximum to use for this study and implies a separation of less than 5m (assuming a circular area for each of the WiMAX mobiles). Within a hot-spot area of radius 25m this amounts to almost 30 active WiMAX mobiles in the upper portion of the 2.6GHz band. In a real-life situation with a high density of WiMAX mobiles, not all will be in the upper portion of the band and they will not all be active at the same time.

WiMAX distribution parameters

A6.75 The WiMAX distribution parameters are as given in Table 20 below:

Table 20: WiMAX distribution parameters

WOuterRad	6.0 km[115]
WFocusRad	25m[116]
WiMAX mobile density for the uniform distribution studies (all mobiles are active)	Various values adopted, ranging up to 111 WiMAX mobiles/km^2. A plot including results with up to 200 WiMAX mobiles/km^2 was also generated to explore the underlying trend.
Hot spot radius	25m
Background WiMAX mobile density for the hot-spot studies (ρ_B) (all mobiles are active)	26.5 mobiles/km^2
Hot spot WiMAX mobile density for the hot-spot studies (ρ_0) (all mobiles are active)	Four values: –26.5 mobiles/km^2 (equal to ρ_B for reference) – 5000 mobiles/km^2 – 10 000 mobiles/km^2 – 15 000 mobiles/km^2

Simulation outputs

A6.76 The key outputs from the simulation are outage statistics, and the prime focus is upon the centre cell results which have the most accurate interference background.

A6.77 For each set of inputs the following outputs are of interest:

[115] The WiMAX mobiles are distributed randomly within a circle centred on the central UMTS base station of the UMTS network, and WOuterRad defines the size of this circle. This figure compounds with the distribution profile of the WiMAX mobiles to create the distribution of the WiMAX terminals for each iteration.

[116] This is the distance from the central UMTS base station within which a random WiMAX terminal is selected for Interference Mode 1 in which a randomly selected WiMAX mobile is selected to lie a certain separation distance from a UMTS mobile randomly selected from within the central cell.

- ***Centre cell mean rejections (%)*** This figure gives the percentage of active UMTS mobiles that are rejected after the UMTS power control process has been applied and has converged. Two figures are available: without WiMAX interference and with WiMAX interference. In the absence of WiMAX interference the centre cell mean rejections figure is non-zero and indicates that the UMTS network cannot support all active UMTS mobiles, providing a useful reference for background call rejections in the UMTS network. The mean figures are derived by averaging the results over the 1000 iterations adopted for each scenario.

- ***Additional centre cell mean rejections (%)*** This gives the increase in centre cell mean rejections after WiMAX interference is applied and is simply the difference between the *centre cell mean rejection* figures before and after WiMAX interference is applied.

- ***Mean additional rejections applied to one terminal (%)*** Of prime interest is the effect of WiMAX interference on the UMTS mobile that is most badly affected by this interference. By use of Interference Mode 1 when conducting the simulations, the effect of a UMTS mobile and a WiMAX mobile being in close proximity can be investigated. The simulation itself does not provide the results on an individual mobile basis, however, in the situation where a UMTS mobile is close to a WiMAX mobile the size of the *additional centre cell mean rejections* percentage could be dominated by the fact that one UMTS mobile may lose service (due to WiMAX interference from the nearby WiMAX mobile) out of the set of active UMTS mobiles in the centre cell. If it is assumed that all additional rejections due to WiMAX are due to loss of service to one UMTS mobile in the centre cell (which would be a worst case, as in reality more than one UMTS mobile in the centre cell could lose service per iteration), then multiplication of the *additional centre cell mean rejections* percentage by the number of active UMTS mobiles in the centre cell gives the *mean additional rejections applied to one terminal*. It is a worst-case estimate of the effect of WiMAX interference projected upon the worst (randomly selected victim) UMTS mobile i.e. the probability of service loss due to WiMAX and must be interpreted carefully.

- ***Mean marginal rejections applied to one terminal (%)*** Use of the *mean additional rejections applied to one terminal* figure when running the simulation in Interference Mode 1 does not allow the separation of the effect of victim–interferer proximity from the effect of background WiMAX interference which will, in general, affect all UMTS mobiles in the centre cell equally. This is why use of the *mean additional rejections applied to one terminal* measure can be somewhat misleading. To determine the effect of UMTS–WiMAX proximity on the selected UMTS terminal, it is more useful to make an estimate of the effect of the background WiMAX interference and subtract this out of the calculation. Accordingly, in the case of Interference Mode 1, it is possible to use an additional result: the additional mean rejections over all cells (%) due to WiMAX interference, to give an indication of background effect of the WiMAX interference. Due to the absence of a fourth ring of cells around the outer third ring, the UMTS mobiles in the outer portion of the outer third ring will not be able to handover as easily and so are more likely to suffer rejection. Nevertheless, it is possible to make an estimate of the effect of proximal interference by subtracting the additional mean rejections over all cells from the additional mean rejections for the centre cell, and then multiplying the result by the number of active UMTS mobiles in the centre cell. This provides a figure referred to in this study as

mean marginal rejections applied to one terminal (%) and can be interpreted as the probability that a UMTS mobile in close proximity to a WiMAX mobile suffers loss of service as a result of the proximity of that WiMAX device.

Simulation results

A6.78 Results are presented here for the two types of WiMAX distribution considered (the uniform distribution and the hot spot distribution) as well as for the two different Interference Modes. A smaller limited set of scenarios was run using different power assumptions for the WiMAX mobiles and these are also presented in this section.

A6.79 Given the aims of this study (to analyse the effects of WiMAX interferers on UMTS mobiles), the results presented here examine the effect of variations in the density of WiMAX mobiles, as well as the effect of a decreasing the separation distance between a WiMAX interferer and a UMTS mobile (through the use of Interference Mode 1).[117]

Uniform distribution results using Interference Mode 0

A6.80 The results in this section are produced by leaving the UMTS mobiles and the WiMAX mobiles as they are randomly positioned using the uniform distribution. No adjustments are made to position a UMTS mobile and a WiMAX mobile any closer than is in the case from the distributions.

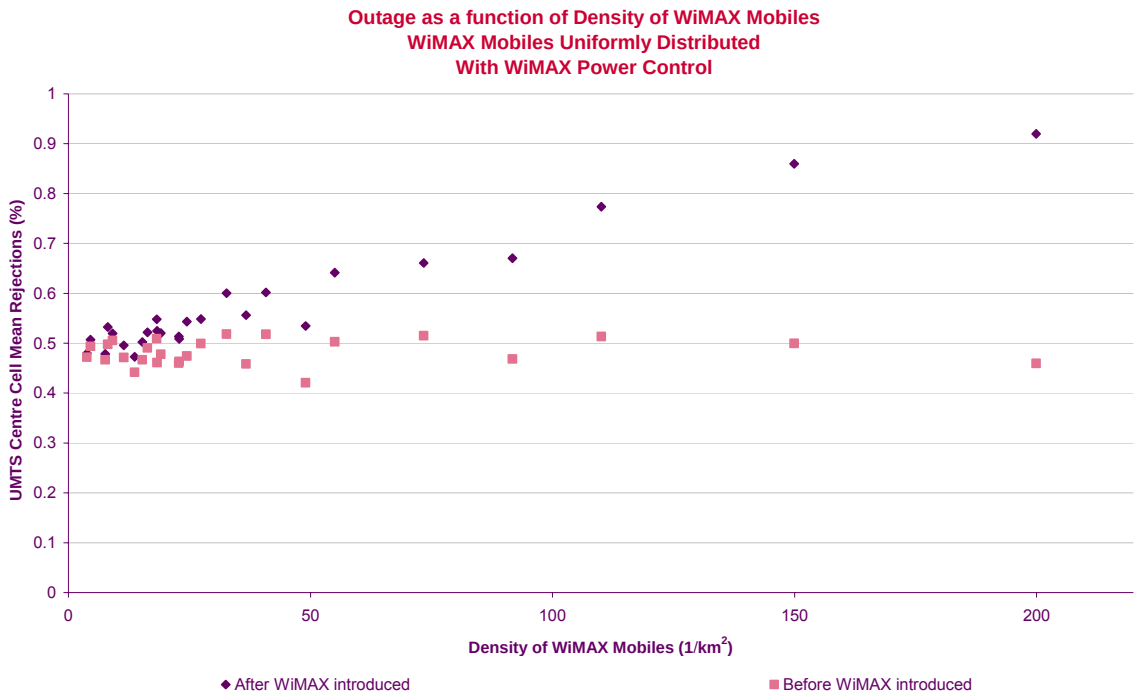
A6.81 All of the results in this section relate to WiMAX mobiles with a maximum EIRP of 23dBm.

A6.82 The chart below shows *centre cell mean rejections* as the density of active WiMAX mobiles in the upper part of the 2.6GHz band is increased. The WiMAX power control profile has been included in the simulation. There are two sets of points: the upper set shows the *centre cell mean rejections* after WiMAX interference has been applied in the simulation; and the lower set shows the *centre cell mean rejections* before WiMAX interference is applied. By definition, the lower set of results is independent of the density of WiMAX mobiles.

A6.83 It is useful to plot these results together to indicate the additional outage caused by WiMAX relative to the outage caused by background call rejections in the UMTS network. Furthermore, the lower set of figures show the repeatability of the results, with the centre cell mean rejection figures lying within approximately +0.05% of the average of the maximum and minimum values for the lower points.

[117] Changes in density and the separation distance both affect the distance between WiMAX interferers and UMTS mobiles, with a change in density affecting the *average* separation distance and the use of Interference Mode 1 affecting the distance for a single UMTS mobile.

Figure 17: Centre cell mean rejections: uniform WiMAX distribution with WiMAX power control

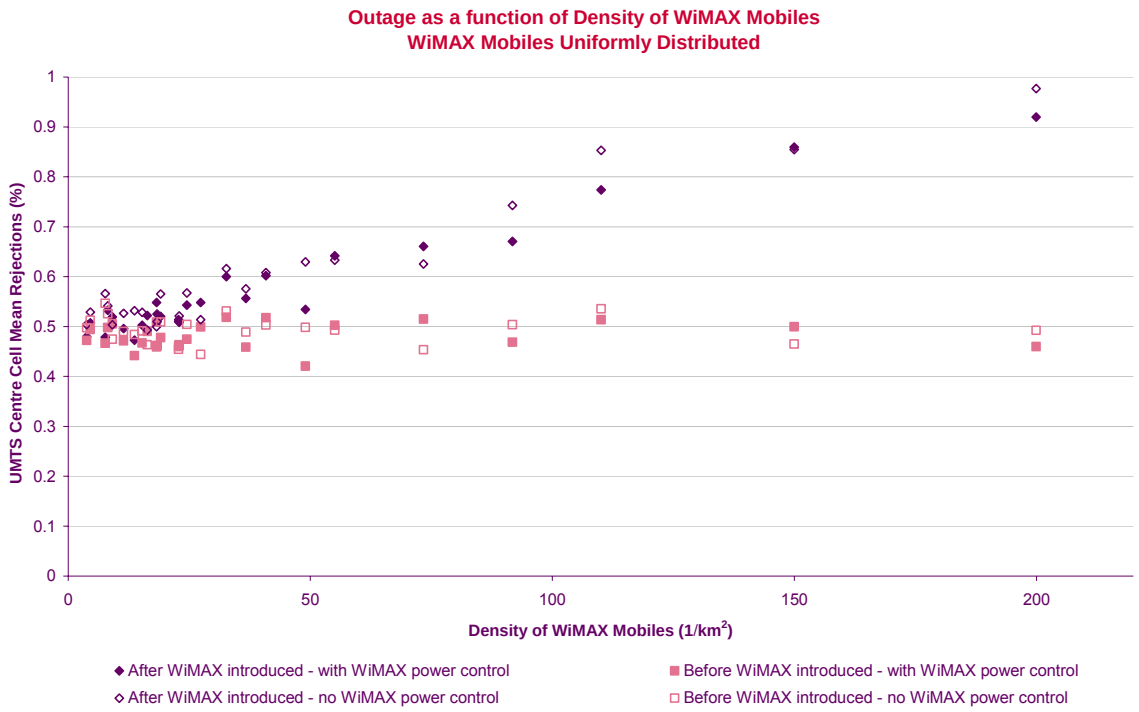


A6.84 The chart above shows that the *centre cell mean rejections* figure increases as the density of active WiMAX mobiles increases. However, it does not increase to greater than 1% even for a density of 200 WiMAX mobiles/km^2. C*entre cell mean rejections* in the absence of WiMAX are around 0.5% for this example UMTS network.

A6.85 In order to assess the effect of using a WiMAX power control profile (as compared to WiMAX mobiles operating at full power) the results were also generated without WiMAX power control applied. Both sets of results are shown in the chart below and suggest that the application of WiMAX power control does not have a significant impact on the results.

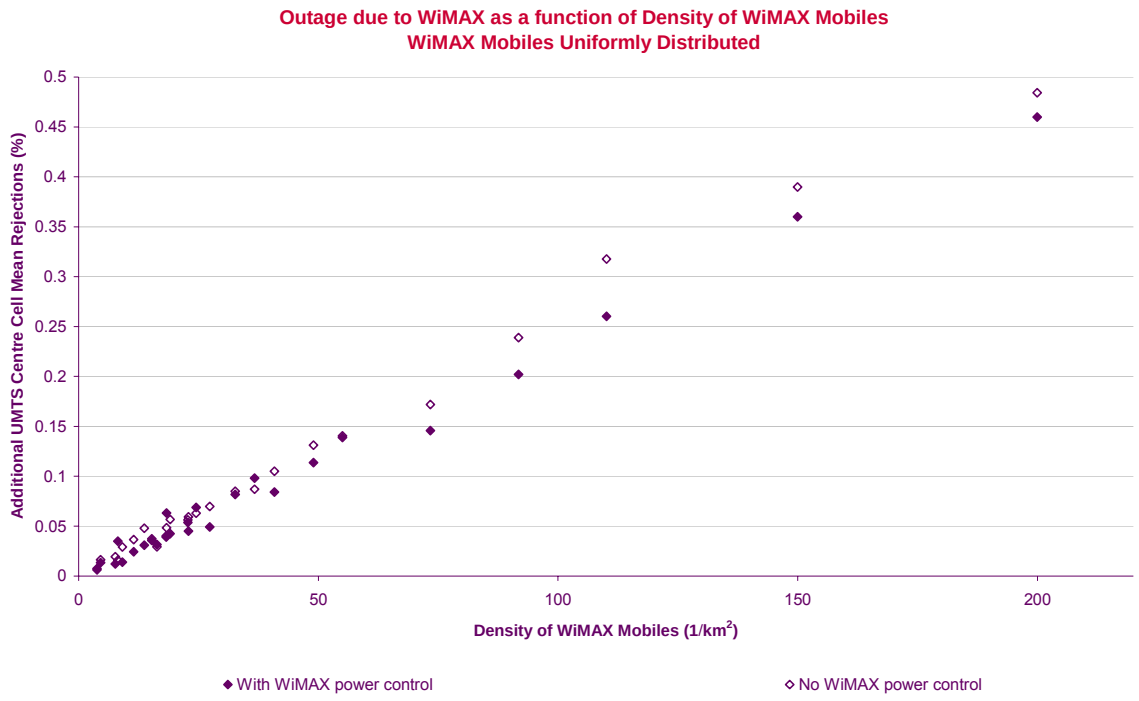
A6.86 In theory, the two series on the chart below which show background call rejections should exhibit the same behaviour (as the use of WiMAX power control is irrelevant when WiMAX mobiles are not present). The differences between these two series in the chart highlight the statistical basis of the simulation and the fact that the results presented here are subject to statistical variance.

Figure 18: Centre cell mean rejections: uniform WiMAX distribution with and without WiMAX power control



A6.87 The chart below shows the *additional centre cell mean rejections* (i.e. the difference between the upper and lower sets of results in the chart above). A uniform trend of increasing *additional centre cell mean rejections* is apparent as the density of active WiMAX mobiles increases and this trend is approximately linear.

Figure 19: Additional centre cell mean rejections: uniform WiMAX distribution with and without WiMAX power control



Uniform distribution results using Interference Mode 1

A6.88 In Interference Mode 1, a translation is applied to the set of WiMAX mobiles (initially positioned relative to the centre of the UMTS network) to ensure that a randomly selected UMTS mobile and a randomly selected WiMAX mobile are at a fixed separation distance from each other.

A6.89 All charts in this section relate to WiMAX mobiles with a maximum EIRP of 23dBm and the WiMAX power control profile is applied.

A6.90 When using Interference Mode 1, which considers effect of separation of a particular UMTS mobile from a WiMAX interferer, it is most appropriate to consider the final two measures as set out in the discussion of simulation outputs:

- *mean additional rejections applied to one terminal*;
- *mean marginal rejections applied to one terminal*.

A6.91 The use of these measures allows us to approximate real-life situations where it could be expected that we would see 'clusters' of devices in particular areas (such as airport lounges, trains, conference centres etc.), rather than following a uniform probability distribution.

A6.92 We have examined the variation of these measures under different separation distances and with a range of WiMAX mobile densities for the uniform probability distribution.

A6.93 In order to understand the implications of these separation distances it is useful to consider that the area per active WiMAX mobile is 1/ρ (where ρ is the density of WiMAX devices). Taking the area per WiMAX device to be circular we can calculate its radius, R, as the square root of 1/(πρ). For the densities used in this analysis, the calculated value of R as a function of ρ is given in the table below.

Table 21: Typical radii associated with the various densities of WiMAX mobiles

Density of active WiMAX mobiles, ρ (mobiles/km^2)	Radius, R (m)
8.2	197
16.3	140
24.5	114
32.7	99
40.8	88
49.0	81

A6.94 R is essentially the separation distance from a UMTS victim within which we would expect a minimum of one WiMAX interferer to lie.

A6.95 The two figures below show the *mean additional rejections applied to one terminal* and the *mean marginal rejections applied to one terminal* for the WiMAX mobile densities detailed above.

Figure 20: Mean additional rejections applied to a single UMTS terminal under Interference Mode 1: uniform WiMAX distribution with WiMAX power control

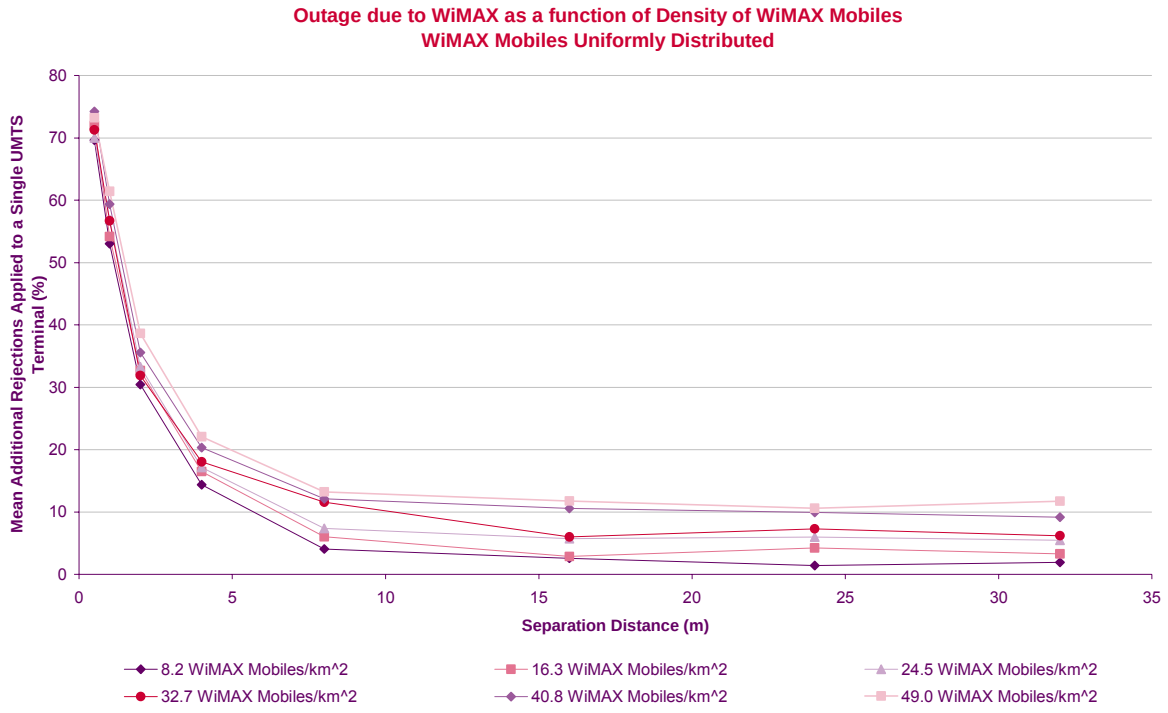
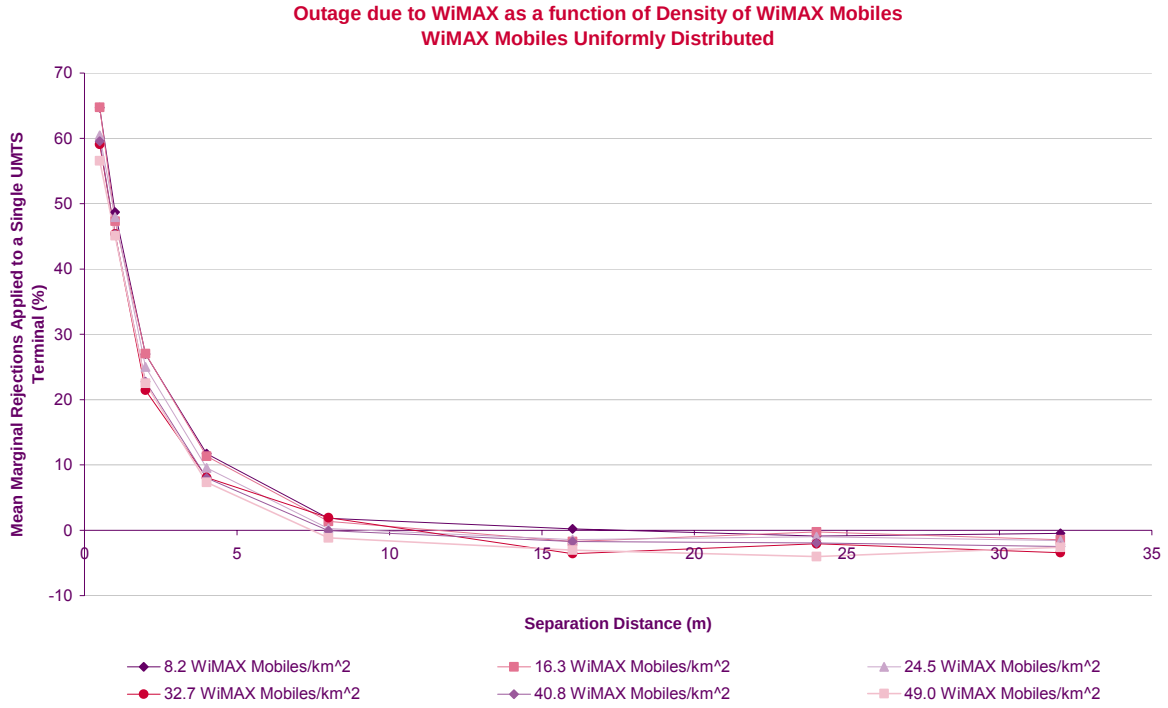


Figure 21: Mean marginal rejections applied to a single UMTS terminal under Interference Mode 1: uniform WiMAX distribution with WiMAX power control



A6.96 Comparison of the charts above shows that *mean marginal rejections as applied to a single terminal* is relatively insensitive to the density of WiMAX mobiles. This is as expected since the use of the *mean marginal rejections applied to a single terminal* is intended to indicate the additional outage suffered by an individual UMTS terminal purely due to the proximity of a WiMAX mobile rather than the effect of the background WiMAX interference which rises with increasing density. The higher background densities are reflected in the charts in Figure 20 which show the *mean additional rejections applied to a single terminal*.

A6.97 Use of the *centre cell mean rejections* over all cells to provide the background effect of the WiMAX interference leads to the *mean marginal rejections applied to one terminal* tending to a slightly negative number rather than to zero. This results in the background interference rate being slightly over-estimated. It is related to the lack of soft handover capability at the edge of the restricted UMTS network being modelled (so the percentage of rejections at the edge of the UMTS network through background call rejection is higher than in the centre cell). This effect is small relative to the high values of *mean marginal rejections applied to one terminal* which occur for small separation distances and does not invalidate the conclusions at small separation distances.

A6.98 Both charts indicate that, at small separation distances, the mean rejections applied to one terminal can be high (with values of up to around 75% in additional rejections and 65% in marginal rejections). As the results are based on a statistical analysis, the results could be subject to statistical variation but indicate that, should a UMTS mobile be in a particular set of circumstances (actively receiving in the 2.6GHz band when within 8 metres of an actively

transmitting WiMAX device also operating in the 2.6GHz band), there is a relatively high chance of the UMTS mobile being blocked.

Hot spot distribution results using Interference Mode 1

A6.99 In the case of the hot spot distribution of WiMAX mobiles, it is only appropriate to use Interference Mode 1 rather than Interference Mode 0. This is because the distribution of WiMAX mobiles is initially centred on the central base station in the central UMTS cell and UMTS mobiles in this region will be receiving a strong signal, lessening their susceptibility to blocking. Moving the hot spot (of 25m radius) to a more random position within the central UMTS area via use of Interference Mode 1 will more accurately reflect real-life situations.

A6.100 In the case of the hot spot, Interference Mode 1 involves the random selection of a UMTS mobile within the centre cell and then the random selection of a WiMAX mobile within the 25m hot spot area. The whole set of WiMAX mobiles is then translated, as is the case in the uniform distribution under Interference Mode 1. For short separation distances this means that the UMTS mobile is likely to be within the hot spot (following the translation).

A6.101 For all scenarios using the hot spot distribution, the density of WiMAX mobiles in the area around the hot spot is 26.5 mobiles/km^2. The densities within the hot spots are 26.5 mobiles/km^2 (equal to the density outside of the hot spot),[118] 5000 mobiles/km^2, 10 000 mobiles/km^2 and 15 000 mobiles/km^2.

A6.102 As summarised in paragraph A6.93, we can ascribe radii to the area associated with each WiMAX mobile for a given density, and these are given in the table below.

Table 22: Radii associated with the various hot spot densities

Density of active WiMAX mobiles, ρ (mobiles/km$^{2)}$	Radius, R (m)
26.5	109.5
5000	7.9
10 000	5.6
15 000	4.6

A6.103 These radii represent half the average distance between WiMAX mobiles in the hotspot. The smallest average distance between WiMAX mobiles using the densities given above is approximately 9m. Furthermore, these values are indicative of the distance from the randomly selected UMTS mobile within which it is expected that a WiMAX mobile will lie for a given randomly distributed set of WiMAX mobiles. This means that, once the separation distance of Interference Mode 1 increases to beyond the calculated value of R, it is likely that another WiMAX mobile will become the dominant interferer to the UMTS mobile rather than the randomly selected WiMAX mobile. It is therefore only appropriate to use separation distances up to the value of R as given in the table above.

A6.104 All charts in this section relate to WiMAX mobiles with a maximum EIRP of 23dBm.

[118] So a uniform density acting as a reference point.

A6.105 The charts below show the *mean additional rejections applied to one terminal* and the *mean marginal rejections applied to one terminal* for the WiMAX mobile hotspot densities as detailed above.

Figure 22: Mean additional rejections applied to a single UMTS terminal under Interference Mode 1: hotspot WiMAX distribution with WiMAX power control

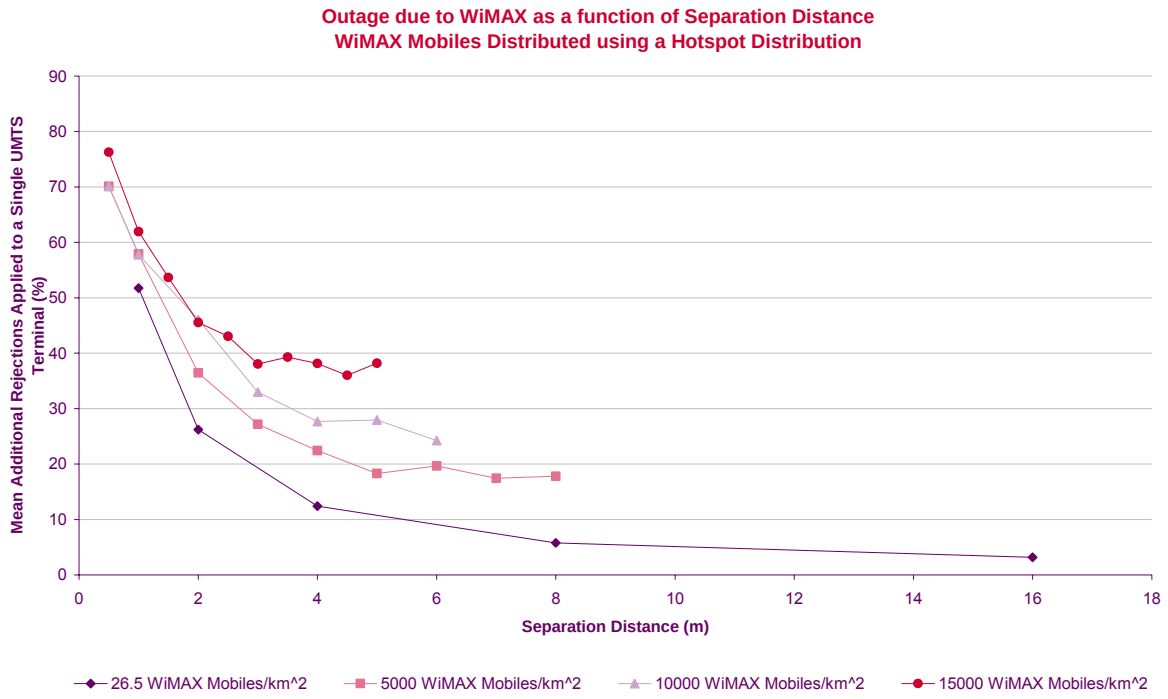
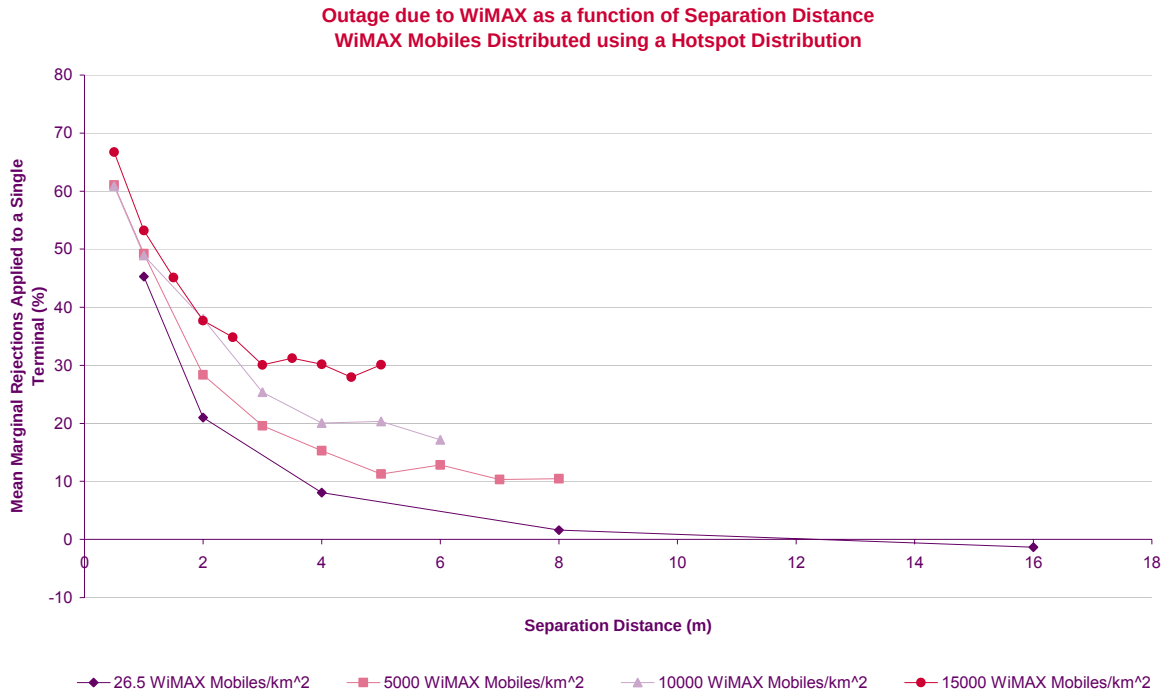


Figure 23: Mean marginal rejections applied to a single UMTS terminal under Interference Mode 1: hotspot WiMAX distribution with WiMAX power control



A6.106 The results for *mean additional rejections applied to one terminal* and *mean marginal rejections applied to one terminal* are consistent, with the charts showing a shift in the negative y-direction between additional and marginal, reflecting the removal of the effects of background WiMAX interference.

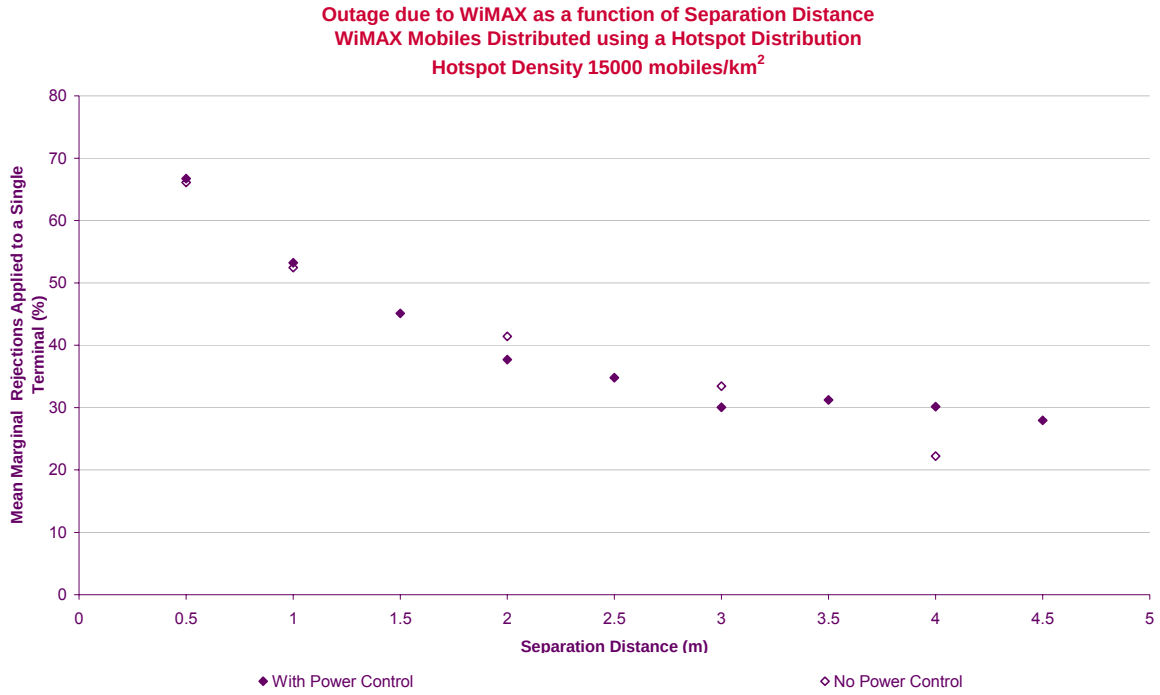
A6.107 As discussed earlier, *mean marginal rejections applied to one terminal* tends to a slightly negative value for the reason outlined in paragraph A1.97 above.

A6.108 As with the studies conducted with a uniform density of WiMAX interferers, it can be seen that *mean marginal rejections applied to one terminal* is high when the separation densities are small, rising to a value of around 67% for a separation distance of 0.5m (at 15 000 WiMAX mobiles/km^2). As the results are based on a statistical analysis, the results could be subject to statistical variation but indicate that there is a high probability that, should a UMTS mobile be in a particular set of circumstances (actively receiving in the 2.6GHz band when within 8 metres of an actively transmitting WiMAX device also operating in the 2.6GHz band), there is a relatively high chance of the UMTS mobile being blocked and that (as expected) this probability increases as the density of WiMAX mobiles increases.

A6.109 As the separation distance increases, there is an increasing probability that another WiMAX interferer will happen to lie in close proximity to the selected UMTS mobiles. For this reason, we have truncated the curves to show the case where the likelihood of blocking is dominated by the selected WiMAX interferer.

A6.110 The impact of no WiMAX power control being applied with a hot-spot density of 15 000 WiMAX mobiles/km^2 is shown in the chart below. It can be seen that application of power control has a relatively small impact on the results compared to (for example) varying WiMAX mobile density.

Figure 24: Mean marginal rejections applied to a single UMTS terminal under Interference Mode 1: hotspot WiMAX distribution with 15 000 mobiles/km^2, with and without WiMAX power control



Sensitivity of results to WiMAX mobile EIRP

A6.111 Some scenarios were carried out to assess the impact of WiMAX maximum EIRP upon the results. All of the simulations in this series have the WiMAX power control profile applied.

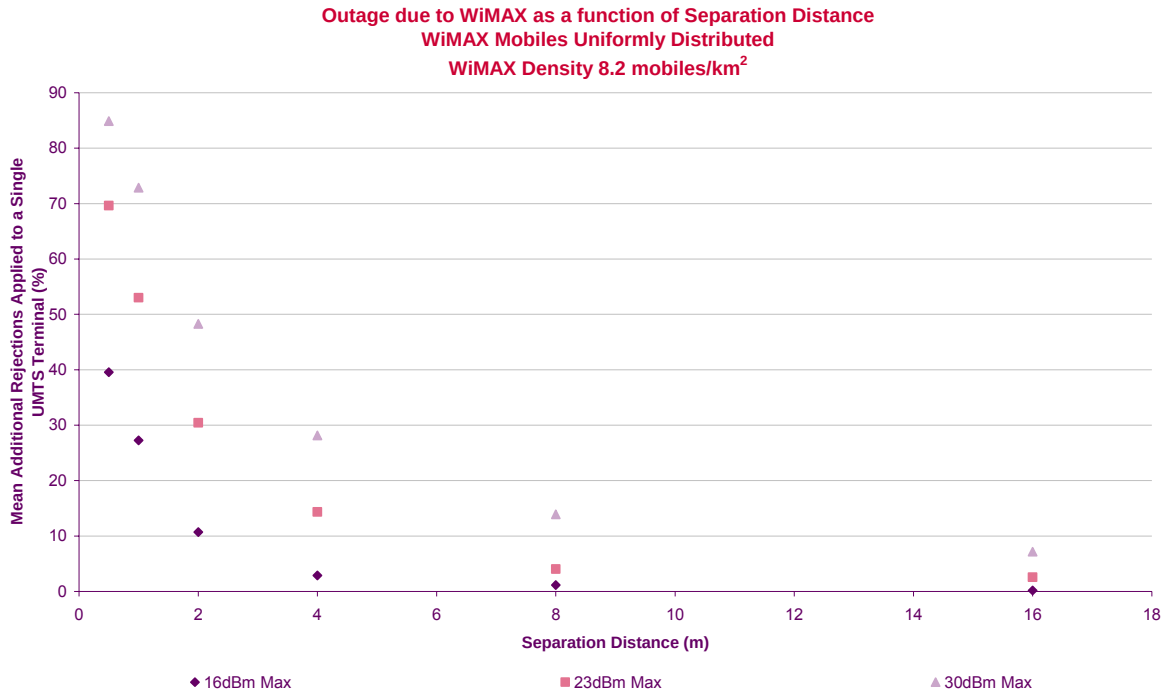
A6.112 The chart below shows *mean additional rejections applied to one terminal* due to the impact of WiMAX interference at different maximum EIRPs:

- 16dBm – representative of the average effect of band pass filters in the FDD mobile terminal in blocking range 1 in relation to the maximum WiMAX power (of 23dBm). This was chosen to help understand the impact of TDD terminals at the top end of the CEPT band plan centre gap which would exist regardless of whether the UK adheres to the CEPT band plan or not;

- 23dBm – the WiMAX terminal power used in ITU-R working party 8F sharing studies; and

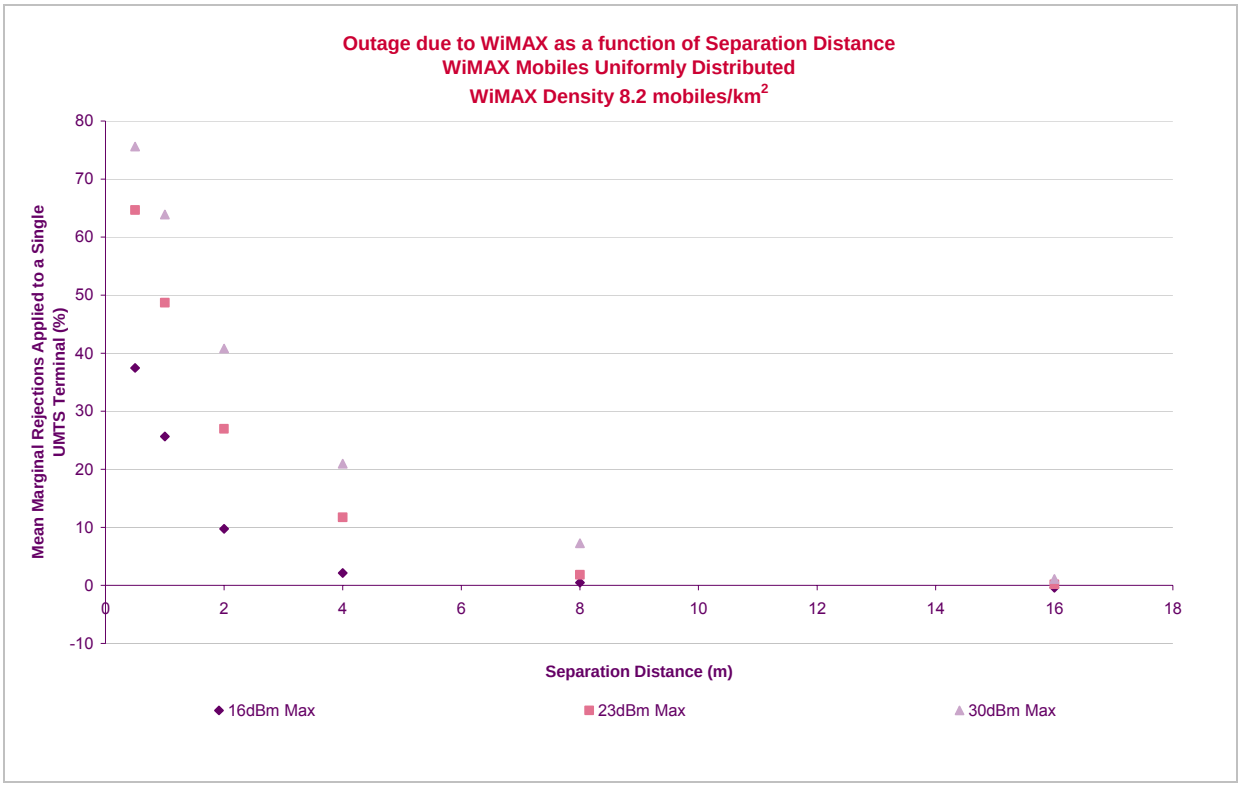
- 30dBm EIRP – the maximum power mobile terminal power contained in the December Consultation (unlikely to be seen in real-life personal WiMAX handsets).

Figure 25: Mean additional rejections applied to a single UMTS terminal under Interference Mode 1: uniform WiMAX distribution with 8.2 mobiles/km^2 with WiMAX power control – varying power levels



A6.113 *Mean marginal rejections applied to one terminal* for different maximum EIRPs are shown in the chart below. As expected, *mean marginal rejections applied to one terminal* reduces with reducing maximum EIRP. The maximum figure is 74%, seen when the EIRP is increased to 30dBm and separation is 0.5m.

Figure 26: Mean marginal rejections applied to a single UMTS terminal under Interference Mode 1: uniform WiMAX distribution with 8.2 mobiles/km^2 with WiMAX power control – varying power levels



Discussion

A6.114 As with any statistical simulation, the results are simply a snapshot of the various input scenarios and are subject to some statistical variance.

A6.115 The simulation addressed a wide range of WiMAX interferer densities both characterised by a uniform distribution and a hot-spot distribution. The impact of close proximity between a UMTS-WiMAX victim-interferer pair was also addressed.

A6.116 The results suggest that increasing the overall density of WiMAX devices increases the background outage associated with WiMAX interference. However this background increase in service outage is generally of no worse magnitude than the service outage which would be experienced by a UMTS network in its ability to support all UMTS active mobiles in the system.

A6.117 The service outage which develops when a UMTS mobile and a WiMAX mobile are in close proximity is reflective of the fact that one mobile is suffering a particularly high probability of interference. This is demonstrated in the calculation of the marginal rejection percentages applied to one terminal. Indications are that at close separation distances, normally at less than around 8m, the affected mobile is likely to experience increasingly severe service problems. Even an “average” UMTS mobile, rather than one at the limit of reception, is likely to experience a probability of loss of service of up to around 74% if the WiMAX mobile has a maximum EIRP of 30dBm and is at a distance of 0.5m.

A6.118 This proximity impact is quite severe, even if the WiMAX mobiles operating in the upper portion of the 2.6GHz band are distributed uniformly and at relatively low densities. This applies even if the WiMAX mobile transmit EIRP is only 16dBm. Nevertheless, once the separation-distance is higher than around 8m the impact of blocking essentially reduces to the background level and is unlikely to be noticeable. This is a significantly smaller distance than the minimum coupling loss calculation distances of 43m for a 30dBm EIRP interferer or 21m for a 23dBm interferer (assuming free space loss).

A6.119 In terms of relating the impact of this to the real world it is necessary to be aware of the limitations of the simulation. Firstly, blocking will only occur if the UMTS mobile is actively receiving in the 2.6GHz band and the nearby WiMAX device is transmitting in the 2.6GHz band and this will limit the likelihood of a single user encountering recurring problems. In addition, there are a number of potential mitigating factors which could substantially lessen the impact of blocking of FDD devices when TDD devices are in close proximity. These factors include:

- the potential presence of indoor micro- or pico-cells for UMTS or WiMAX (or both);
- the potential availability of alternative methods of service provision for UMTS operators (e.g. other spectrum bands being available) in the case of interference from WiMAX;
- the relative impact of blocking on the quality of service of voice communications and data communications.

A6.120 In addition to the factors identified above for potential mitigation, it should be noted that other European regulators consider allowing TDD operation within 2620-2690 MHz. For example, both Norway and the Netherlands have published plans to award the 2.6GHz band that include potential TDD operation in the pass band of UMTS mobile. It is possible that other regulators within Europe could similarly allow TDD mobiles to operate in the upper part of the band. The European landscape is therefore likely to be rather complex as far as the split between TDD and FDD is concerned. In some countries the CEPT band plan will probably be used, whilst in others, a different band plan including TDD use within 2620-2690MHz may be preferred.

A6.121 Given this, it is possible that FDD terminal manufacturers could consider this flexibility in their handset designs to ensure that these have as large a market as possible in Europe while offering the greatest protection possible from harmful interference.

A6.122 Further, it has been put to Ofcom that a practical and cost-effective way of achieving such a flexible design is to incorporate tuneable filters into terminals. These filters could allow the handset to narrow its effective receiver pass band to the subset of frequencies assigned to the particular operator to whose network the equipment is connected. Filters require some frequency range to roll off but the use of this technique could significantly improve the blocking performance of terminals in the presence of in-band TDD.

A6.123 There is also the issue of how well a simulation can reflect reality. The modelling process in the simulation does not exactly mirror the operation of CDMA systems. The time delays in the real power control process will tend to

damp down oscillations and this is not reflected in the modelling. In addition the modelling does not include potential recovery through coding or error correction. It is possible that more UMTS mobiles could maintain service in a real network environment.

A6.124 In addition, a comparison has not been explicitly conducted against what reference performance that may be achieved in the presence of adhering to the CEPT band plan. However, the results of the simulation with a WiMAX EIRP of 16dBm can be used to infer the effect of WiMAX terminals in the upper portion of the centre gap (2605 – 2620MHz).

A6.125 Depending upon the outcome of the auction and the success of any operators using unpaired spectrum in the upper part of the 2.6GHz band, such high densities as have been modelled may not be realised leading to a low impact upon the additional outage expected from the operation of, say, WiMAX.

A6.126 Finally, if it is assumed that the WiMAX mobiles are distributed uniformly and randomly without the fixed separation distance constraint then it can be expected that on average a WiMAX mobile will not be close to a UMTS mobile. This means that even though the results show a high impact upon the performance when the separation distances are short, such distances are represented by only a relatively small area around the victim UMTS mobile unless the density of interferers is high.

Annex 7

Adjacent Channel Interference - FDD/TDD

A7.1 This Annex describes a study carried out by Ofcom to better understand the relative trade-offs in cost of deploying a network in the presence of different levels of adjacent channel interference (ACI).

A7.2 Of specific interest in the 2500-2690MHz band is the effect of ACI on a FDD licensed operator (using paired spectrum) in the presence of either a second FDD licensed operator in the adjacent spectrum or a TDD licensed operator (using unpaired frequencies) also in the adjacent spectrum.

Scope of study

A7.3 In order to inform the design of the technical licence conditions and the award process, Ofcom has endeavoured to understand more about the relative cost to deploy a network under different adjacent channel interference (ACI) conditions that might arise as a consequence of our original award proposals.

A7.4 The study looked in detail at the network requirements of a licensed operator of paired spectrum deploying an FDD system to provide a consistent quality of service in the presence of different types of ACI.

A7.5 The main focus has been to compare the cost of any mitigating measures required by a national network operator to counter the effects of ACI given the presence of another national operator in the adjacent channel. Specifically, the impact of a TDD neighbour has been compared with that of a FDD neighbour assuming that both are compliant with the spectrum masks proposed in the December Consultation. However, this methodology would allow other types of ACI to be assessed quickly in a similar manner and it is the case that a TDD network operator would see interference from neighbouring FDD systems and other TDD systems.

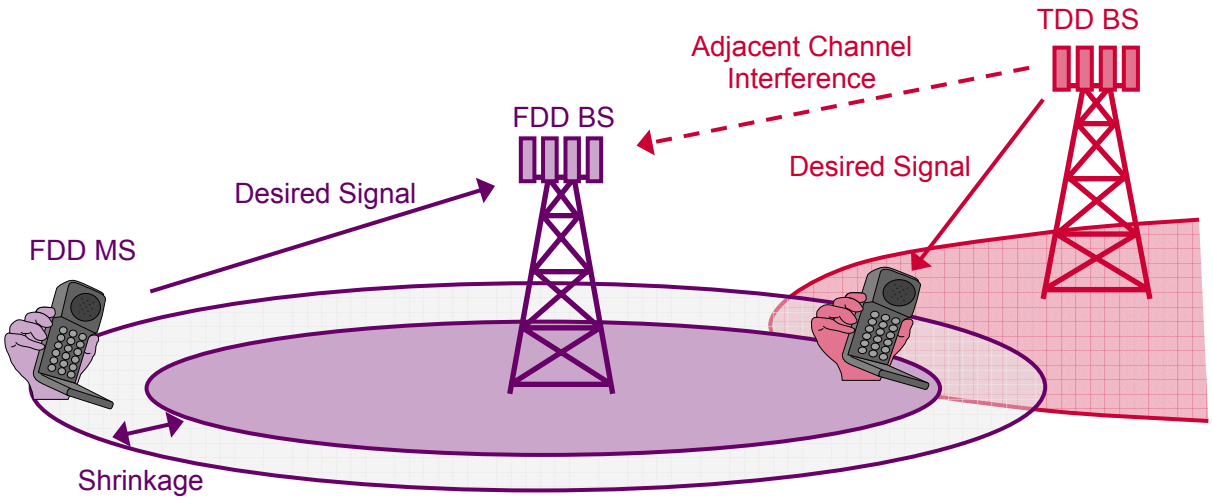
A7.6 Given a victim system, in this case the FDD operator, there are generally 4 sources of adjacent channel interference that can have a detrimental effect on the performance of the network. These are:

- Cell shrinkage through base station to base station uplink interference;
- Cell shrinkage through mobile to base station uplink interference;
- Dead zones due to base station to mobile downlink interference; and
- Dead zones due to mobile to mobile interference.

Case A: Cell shrinkage through base station to base station uplink interference

A7.7 An example situation is shown in Figure 27 where a victim base station receives interference from an interfering base station nearby. The interference appears as noise on the front end of the victim base station and this has the effect of desensitising the victim receiver. The result is that the victim can no longer ‘hear’ its own mobiles at the cell edge and so effectively the individual cell coverage is diminished (i.e. the cell shrinks).

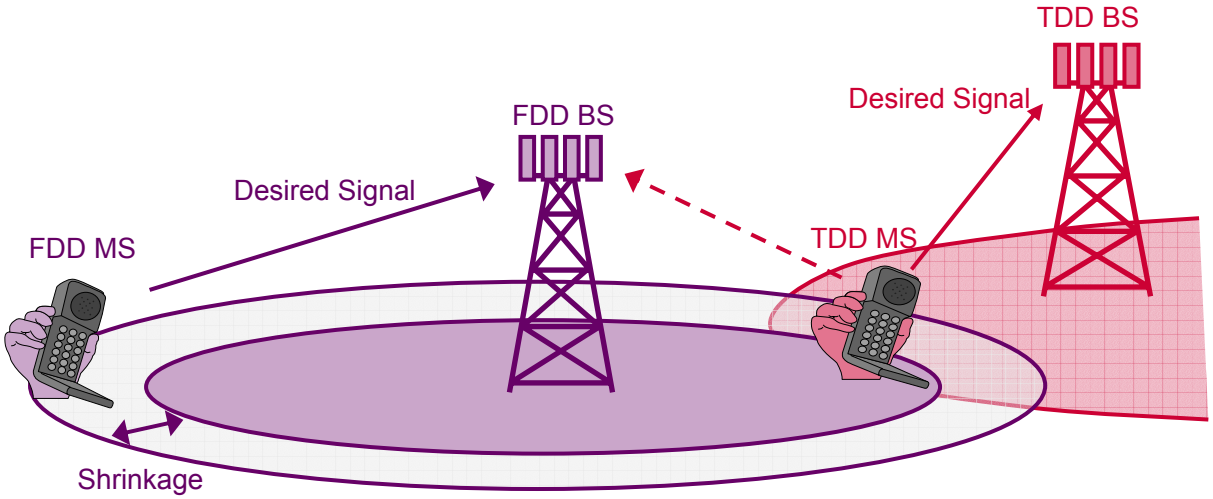
Figure 27: Base station to base station ACI uplink cell shrinkage



Case B: Cell shrinkage through mobile to base station uplink interference

A7.8 This situation is similar to that described above and is illustrated in Figure 28 below. In this case the interference is from a TDD mobile on an adjacent carrier operating within the coverage area (or even beyond in extreme cases) of a victim base station site. Again, the interference appears as noise on the front end of the victim desensitising the receiver and shrinking the effective coverage.

Figure 28: Mobile to base station ACI uplink cell shrinkage

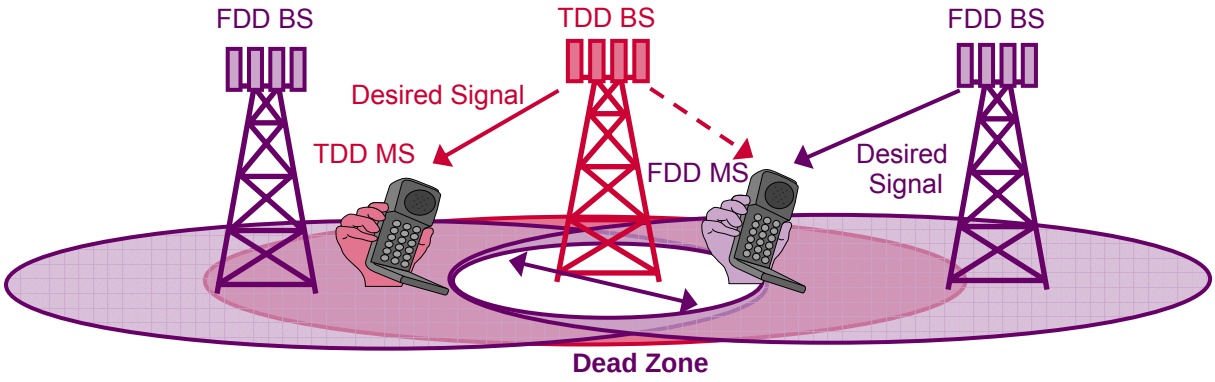


Case C: Dead zones due to base station to mobile downlink interference

A7.9 Dead zones are another effect of ACI and are manifest on the downlink to the mobile stations in the network. An example situation is shown in Figure 29 below. Here, the victim FDD mobile, in attempting to 'listen' to its own base is interfered by the ACI from (in general) a much closer base station. If the mobile is at the limit of its own coverage area then it is unable to demand more power from the base station to overcome the interference and therefore suffers outage. As the victim moves away from the interferer and towards its

base transmitter the interference diminishes and service is restored. The result is that there is an area of restricted or no coverage around the interfering base station known as a dead zone.

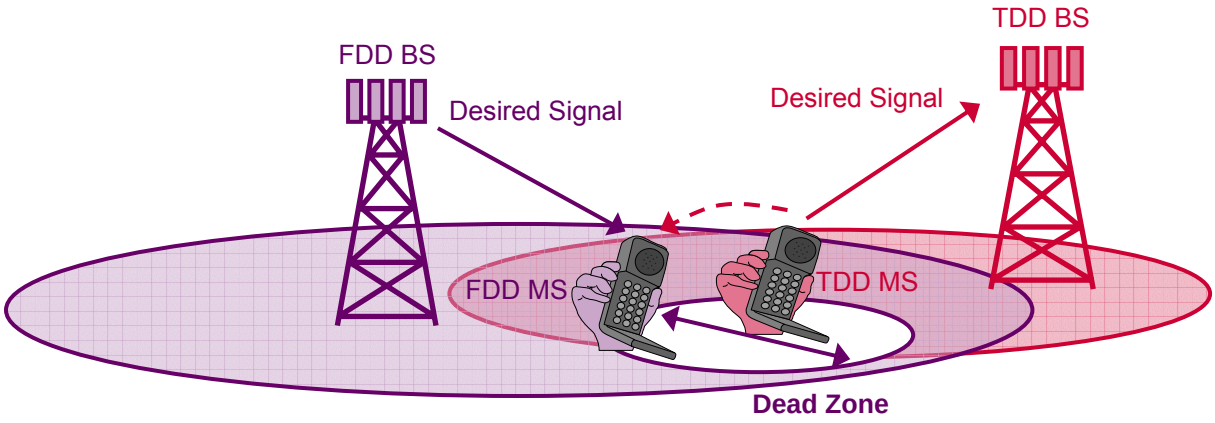
Figure 29: Base station to mobile ACI downlink dead zone



Case D: Dead zones due to mobile to mobile interference

A7.10 This situation is similar to that described above and is illustrated in Figure 30 below. In this case the interference is from a TDD mobile on an adjacent carrier operating in proximity to a victim FDD mobile location. Again, if the victim is operating at the limits of its downlink coverage area then the interfering mobile swamps the victim creating a dead zone around the interferer. This is a particularly challenging situation as both the interferer and the victim are mobile making it difficult to control the problem.

Figure 30: Mobile to mobile ACI downlink dead zone



Focus of the study

A7.11 This study has focused on the impact of ACI on network infrastructure (i.e. base stations). Dead Zones are the result of interference into mobiles and it is not realistic to impose specific requirements on mobiles to counter the effects of ACI.

A7.12 It is possible to apply various countermeasures to base station systems that will reduce the effects of ACI. These countermeasures come at a cost and it is

the aim of this study to understand how that cost differs under different ACI conditions for Cases A & B above.

Comparison to the FDD/FDD case

A7.13 In FDD systems the problem of ACI is rendered negligible in most cases. In such systems the uplink and downlink signals are separated in frequency by a "duplex spacing" which is normally at least several times greater than the bandwidth of the system. This means that sensitive receivers are separated from potentially hostile transmitters by a significant amount of spectrum. ACI produced by a transmitter can be reduced enormously over a large bandwidth using standard filtering techniques thereby avoiding the need for expensive, high performance equipment.

A7.14 On the other hand, TDD systems by their nature transmit and receive in the same band. Therefore, there exists the possibility that a network element (base station or mobile) could be attempting to receive a relatively weak signal whilst another element nearby is transmitting at high power. If the two systems are in adjacent channels then the interference can be significant and degrade system performance. Traditionally in TDD systems this can be resolved by synchronising uplink and downlink transmissions across networks in the band.

A7.15 In the case of the spectrum in the 2.6GHz band, the main problem is that the spectrum contains sub-bands of paired and unpaired frequencies that will likely be used to deploy FDD and TDD systems respectively. Where these bands meet there is the possibility to have an FDD system in one channel and a TDD system in the adjacent channel (though, with Ofcom's proposals for a restricted channel the immediately adjacent TDD carrier could only be used at a low power). In this case there is no duplex spacing or synchronisation to reduce the effects of ACI and hence other measures must be found to prevent a degradation of system performance.

The FDD/TDD case

A7.16 This study is concerned with interference caused by a TDD system into a victim FDD base station network. The band plan proposed by Ofcom in the December Consultation is a flexible one. It is possible that more of the spectrum may be allocated to TDD operators than is currently proposed by CEPT[119]. Under Ofcom's current proposals, the spectrum at the bottom of the 2.6GHz band is allocated to FDD uplink operation (the receive band of the FDD base station equipment). The point in the spectrum band at which an FDD operator has spectrum next to a TDD operator is where the effects of ACI will be most detrimental to the FDD base station network.

A7.17 Prior to the issue of the December Consultation, Ofcom commissioned a study by Mason Communications Ltd[120] to look at ACI issues. On the basis of this study, Ofcom developed a set of spectrum masks to minimise the out-of-

[119] ELECTRONIC COMMUNICATIONS COMMITTEE, ECC Decision of 18 March 2005 on harmonised utilisation of spectrum for IMT-2000/UMTS systems operating within the band 2500 – 2690 MHz (ECC/DEC/(05)05)

[120] '2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz Spectrum Awards – Engineering Study (Phase 2)', Mason Communications Limited, November 2006.

band emissions (OOBE) of transmitters deployed in the band into receivers in adjacent channels.

A7.18 The analysis by Mason Communications was conducted using OOBE specifications based on existing equipment standards. This annex considers whether the spectrum masks developed by Ofcom offer sufficient protection to FDD operators from adjacent TDD interferers.

A7.19 The first step in this process is to assess the extent of the problem without mitigation measures and to quantify the reduction in interference required (if any) that will allow normal network operation. The next step is to analyse the mitigation measures available and assess whether they can provide sufficient isolation between systems to prevent ACI from adversely affecting the system performance. Where there is insufficient isolation then there will be an impact on network performance that will affect the overall network coverage. The final step is to quantify this impact (if any) and assess how it affects the cost of deploying a network in the presence of ACI.

Methodology used in the study

A7.20 The methodology adopted for the study is as follows.

a) Calculate link budgets for the candidate technologies deployed in the different bands.

b) Conduct a baseline dimensioning exercise for green-field networks (i.e. with no adjacent channel interference).

c) Calculate Adjacent Channel Protection ratios based on proposed spectrum masks and equipment specification standards.

d) Use the technique of Minimum Coupling Loss (MCL) to establish the isolation required between systems and how this translates to minimum site-to-site distances needed to prevent interference.

e) Assess mitigation measures and recalculate the minimum separation distances.

f) Where ACI is still an issue, the final step is to relate the resulting cell shrinkage to site density and hence relative network cost.

A7.21 A report by the European Radiocommunications Committee (ERC) within the European Conference of Postal and Telecommunications Administrations (CEPT)[121] contains a thorough description of the MCL technique. The methodology described in the report has been used in this analysis.

A7.22 The Monte Carlo analysis technique, which is also described in the ERC report, is generally considered to be more thorough and more reflective of real-world network analysis. However, this technique requires complex computer simulations and can be time consuming. MCL is regarded as a worst case analysis for individual transmitter receiver pairs. However, the technique can be applied across a single cell and then scaled to give an overall impression of the impact of ACI across the whole network.

[121] "A Comparison of the minimum Coupling Loss Method, Enhanced Minimum Coupling Loss Method, and the Monte-Carlo Simulation", ERC Report 101, Menton, France May 1999.

Assumptions

A7.23 This study is concerned with ACI at the boundary between FDD and TDD spectrum within the band 2500 – 2690MHz and interference *into* the FDD band *from* the TDD band. However, the same methodology could be applied to investigate other scenarios where ACI may be problematic. In the case of the 2.6GHz award there is the potential for ACI to exist between the FDD and TDD networks and existing radar and PMSE systems in the adjacent bands. There is also the possibility of ACI and co-channel interference (CCI) from systems in neighbouring countries, particularly France and the Republic of Ireland.

A7.24 The assumptions used in this part of the study are listed below.

i) 3GPP WCDMA in 5MHz channels is deployed in the victim FDD band.

ii) All other FDD licensed operators have also deployed 3GPP WCDMA in the neighbouring FDD spectrum.

iii) IEEE 802.16e (Mobile WiMAX) is deployed in the interfering TDD band with 5MHz channels in restricted blocks and 10MHz channels in all other cases.

iv) All deployed systems conform to the spectrum masks proposed in Section 9 of the December Consultation.

v) Other system parameters are based on industry standards (e.g. 3GPP, ETSI (BRAN)) and also on the work of CEPT ECC.

vi) The FDD networks have been dimensioned to provide contiguous coverage for voice services only. The TDD network has been dimensioned to provide the maximum possible coverage at minimum service levels (i.e. to provide maximum coverage with the minimum of infrastructure).

vii) Coverage was designed for outdoor (on-street) level rather than for indoors. It is assumed that indoor coverage will be provided by separate, dedicated networks. Such networks could be deployed on adjacent channels; however they have not been modelled as part of this study.

viii) The geography of the UK has been broken down into 3 geotypes: rural, suburban and urban. ACI has only been analysed between sites in the same geotype in order to minimise the number of interfering combinations and to reduce the complexity of the analysis.

ix) A frequency re-use factor of 1 as been assumed in each network i.e. each frequency is used in every cell. This is possible for both types of network and represents the worst case scenario in terms of ACI. A frequency re-use greater than 1 in either network will reduce the probability of a site suffering ACI.

A7.25 The breakdown of the UK into geotypes has used the figures given in Table 23 below. These are based upon the UK population coverage data provided by Mason Communications in their report[120].

Table 23: Assumed UK demographics

Network cell type	% population	Coverage area (km^2)
Urban	10	1236
Suburban	60	26 448
Rural	30	95 660
Totals	**100**	**123 344**

A7.26 Additionally, figures regarding transport arteries are also taken into account[122][123] and these are presented in Table 24. Major transport arteries are covered by 'rural' type cells with two antennas aligned parallel to the route, one in each direction.

Table 24: Main UK transport arteries

Transportation links	Length (km)
Major rail routes	12 591
Motorways	3400
National 'A' Roads	48 200
Totals	**64 191**

Baseline analysis

A7.27 For the purposes of establishing a baseline against which to compare the effects of ACI a basic network was planned to provide coverage across the whole of the UK for each technology.

A7.28 Link budgets have been prepared for each of the three geotypes and each technology.

A7.29 A key factor in planning network coverage is whether to provide for in-building coverage or not. At 2.6GHz, building penetration losses are significant and require a large portion of the available link power to overcome them. As a consequence there is a reduction in the power available to provide wide area coverage and hence the cell sizes are drastically reduced.

A7.30 It has been assumed for this exercise that, in the first instance, networks will be deployed to provide outdoor coverage and the requirement for indoor coverage will be met using dedicated indoor solutions which have a negligible effect on outdoor networks.

A7.31 However, one case that has been modelled is that of an indoor WiMAX system deployed on the restricted adjacent TDD channel.

A7.32 The results of the initial dimensioning exercise for on-street coverage only are presented in the following two tables. From these results it is evident that the calculated cell sizes and the site count for each network are reasonably

[122] 'European Road Statistics 2006', International Road Federation, Brussels 2006.
[123] 'Railways Database', World Bank Group, http://www.worldbank.org/transport/rail/rdb.htm

similar. In other words, the networks will have similar site densities. This is important for the interference analysis as it aids in the estimation of the number of likely interferers into a victim site.

Table 25: UK WCDMA network dimensions for on-street coverage only

Network cell type	Cell size (on street)	% population	Coverage area (km^2)	Sites required (on street)
Urban	0.79	10	1236	759
Suburban	2.35	60	26 448	1848
Rural	7.77	30	95 660	611
Road/rail (rural)	7.77	n/a	64 191	4133
Totals		**100**		**7351**

Table 26: UK WiMAX network dimensions for on-street coverage only

Network cell type	Cell size (on street)	% population	Coverage area (km^2)	Sites required (on street)
Urban	0.99	10	1236	487
Suburban	2.42	60	26 448	1733
Rural	8.02	30	95 660	573
Road/rail (rural)	8.02	n/a	64 191	4001
Totals		**100**		**6794**

Adjacent channel protection analysis

Calculation of adjacent channel protection (ACP)

A7.33 The next step in the analysis is to examine the ACI performance of the interfering system based upon the spectrum masks proposed in the consultation document.

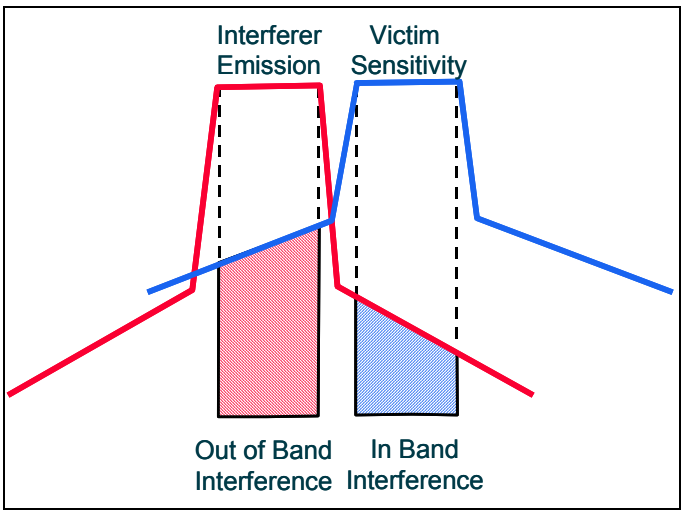
A7.34 The basic methodology for this exercise is presented in a report by the European Radiocommunications Committee (ERC) within the European Conference of Postal and Telecommunications Administrations (CEPT)[124] and the same definitions apply.

A7.35 Figure 31 below illustrates the basic concept of ACI. On the one hand, interference is caused to the victim receiver by out-of-band emissions from the adjacent system (blue shaded area on the right of Figure 31). The degree to which this takes place is quantified by the Adjacent Channel Leakage Ratio (ACLR).

A7.36 A second source of interference is the victim receiver's ability to reject signals in the adjacent channel otherwise known as the Adjacent Channel Selectivity (ACS). This is illustrated by the red shaded area (left hand shaded area) in Figure 31.

[124] "A Comparison of the minimum Coupling Loss Method, Enhanced Minimum Coupling Loss Method, and the Monte-Carlo Simulation", ERC Report 101, Menton, France May 1999.

Figure 31: Adjacent channel interference



A7.37 When considering the adjacent channel interference between two adjacent systems the ACLR of the interferer and the ACS of the victim receiver should be combined to give the overall Adjacent Channel Interference Ratio (ACIR) using the formula below:

Equation 1: Adjacent Channel Interference Ratio

$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}}.$$

A7.38 ACIR is a measure of the combined interference due to the out-of-band emissions of a transmitter and the non-ideal selectivity of the receiver. It is a measure of the degree of isolation between adjacent systems and represents the degree of protection afforded to the receiver.

A7.39 The formula clearly shows that where one of the factors in the equation is much less than the other then it will tend to limit the overall ACIR performance of the system. This is also evident from Figure 31 where it is clear that the total interfering power is the combination of the two shaded areas. If one is very much greater than the other then it will dominate the ACI performance between the two systems. If, for example, the ACLR is 10dB lower than the ACS, then the overall ACIR will only be 0.4dB worse than the ACLR.

A7.40 The ACS specification of the victim FDD system used in this study has been taken from an ITU report[125] which considers sharing in the 2500 – 2690MHz band and is based upon 3GPP standards. These are given in the table below:

[125] 'Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2 600 MHz operating in adjacent bands and in the same geographical area', REPORT ITU-R M.2030

Table 27: FDD Base Station Adjacent Channel Selectivity

Carrier separation	FDD BS ACS (dB)
@2.5MHz	46
@7.5MHz	58
@12.5MHz	66

A7.41 The standards are not clear on the values of ACLR that should be followed for the interfering TDD WiMAX system. Values have therefore been calculated using the spectrum masks specified in the December Consultation. If these spectrum masks are adopted then all equipment will be expected to at least meet the specification for out-of-band emissions. If it transpires that the IEEE 802.16e standards specify a more rigorous requirement then the eventual performance will be more favourable than that described here.

A7.42 The ACLR of a transmitter is defined in 3GPP[126] as the ratio of the filtered mean power centred on the assigned channel to the filtered mean power centred on an adjacent channel frequency.

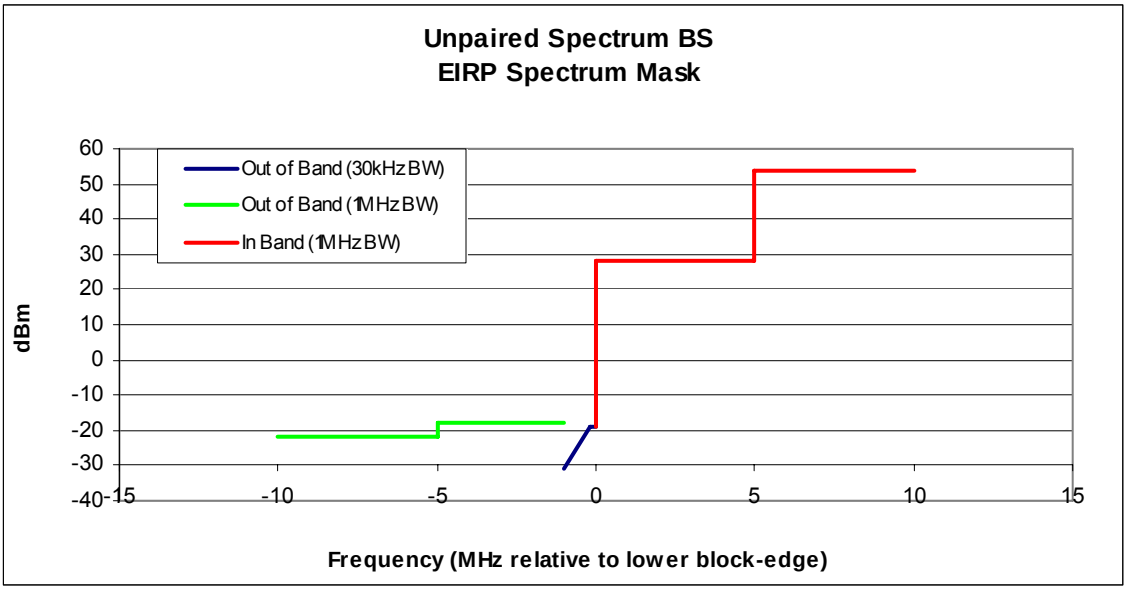
A7.43 The first step in the calculation was to establish the maximum possible mean power allowed by the proposed spectrum masks. Regardless of the equipment specification, the most challenging ACLR requirement will be when the transmitter is operating at maximum power.

A7.44 We consider the WiMAX base station interferer first. The same methodology has been applied to the analysis of a WiMAX mobile interferer and the results of this are presented in a separate section.

A7.45 The spectrum mask specification for the TDD system has two possible levels depending upon the frequency spacing from the lower band edge. At up to 5MHz spacing the band is restricted to 28dBm/MHz and from 5MHz to 10MHz spacing and beyond, the limit is 54dBm/MHz, as shown in Figure 32 below.

[126] "3GPP TS 25.104 V7.5.0 (2006-12) Technical Specification, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Base Station (BS) radio transmission and reception (FDD) (Release 7)", 3GPP, December 2006.

Figure 32: TDD spectrum mask lower block edge



A7.46 The TDD system is assumed to be transmitting on 5MHz or 10MHz wide channels which occupy a physical bandwidth of 4.5MHz or 9MHz (i.e. after filtering). The narrower channel being used for the restricted band. The maximum transmit power in the assigned channel is therefore:

Equation 2: TDD in-band EIRP

$$\text{EIRP (Restricted band)} = 28 \text{ dBm} + 10 \log (4.5 \times 10^6 \text{Hz}) = 34.5 \text{ dBm}$$

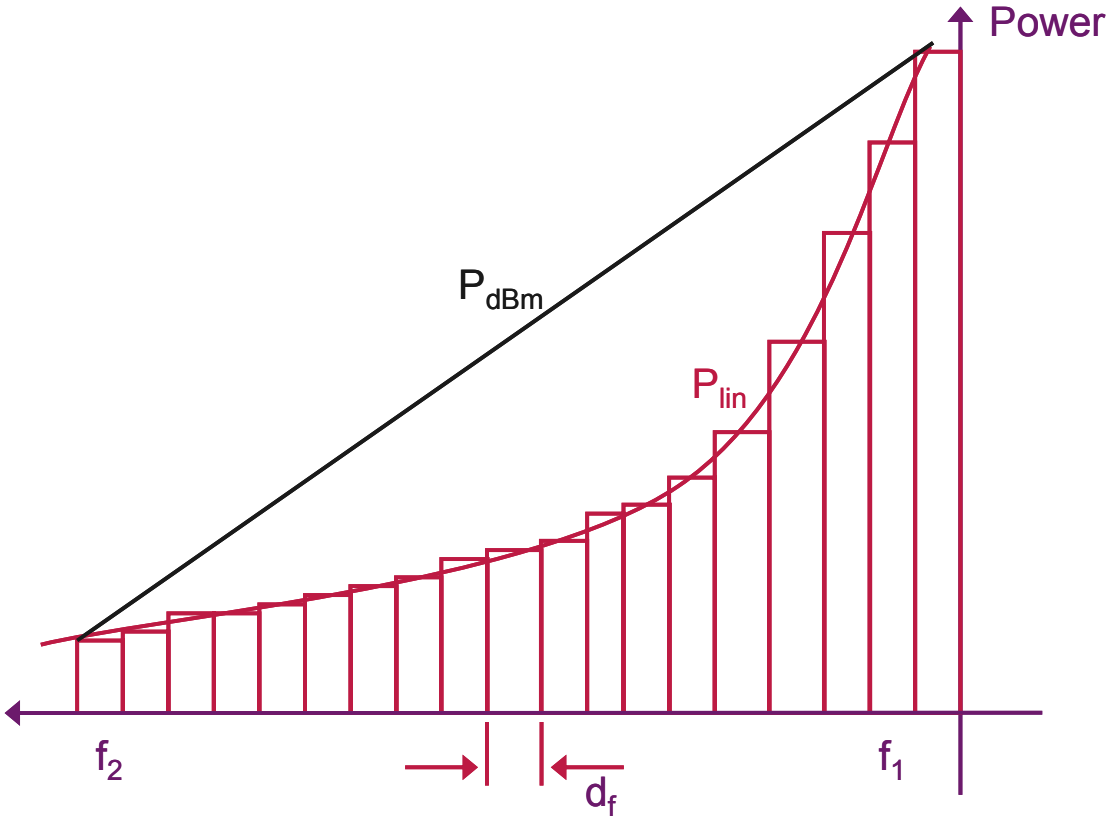
$$\text{EIRP (Unrestricted band)} = 54 \text{ dBm} + 10 \log (9 \times 10^6 \text{Hz}) = 63.5 \text{ dBm}$$

A7.47 The maximum power allowed into the adjacent channels is also specified by the spectrum mask. The Ofcom specifications are defined in steps and in different reference bandwidths. In order to calculate the total power received it is necessary to convert each stage into an absolute value, sum over the channel width and then apply filtering. In this case the FDD system is on a 5MHz channel raster with the power into the receiver limited by a standard 3.84MHz WCDMA channel filter.

A7.48 Where the mask specifies a gradual change between two values (e.g. the 30kHz portion in Figure 32 which increases from -19dBm to -31dBm over 800kHz) it is not sufficient to take the middle value as the average between the two extremes of the step. The mask is specified in dBm which is a logarithmic scale so the midpoint expressed in dB will not reflect the mean power over the band.

A7.49 In order to accurately calculate the average power the value must be obtained first in Watts and then converted back into dB. This was calculated in a piecemeal fashion by dividing each step of the mask into numerous small ‘strips’, calculating the power in each and then summing over the interval. In this way a very close approximation may be obtained provided sufficient strips are taken. In this case for each variable step in the mask 100 points were calculated. The process is illustrated in Figure 33 below.

Figure 33: Establishing the out-of-band power



A7.50 For the lower edge spectrum mask of Figure 32 the maximum allowed adjacent channel power for each adjacent 5MHz band (up to 15MHz from the lower block edge) is given in Table 28 below.

Table 28: Maximum allowable adjacent channel power from Ofcom spectrum mask

Frequency range	Emission range	Specification BW	Total power (dBm)	Segment size
0.0 to –0.2MHz	–19 to –19	dBm/30kHz	–10.76	200kHz
–0.2 to –1.0MHz	–19 to –25	dBm/30kHz	–9.44	800kHz
–1.0 to –5.0MHz	–18 to –18	dBm/MHz	–11.98	4MHz
		Sum of above:	–5.83	5MHz
–5.0 to –10.0MHz	–22	dBm/MHz	–15.01	5MHz
–10.0 to –15.0MHz	–22	dBm/MHz min	–15.01	5MHz

A7.51 The resultant adjacent channel power as seen by the victim is finally obtained by calculating the power in the received filter bandwidth i.e. 3.84MHz.

A7.52 The ACLR of the system is then calculated as the difference of the in-band power radiated by the interferer and the adjacent channel power as received by the victim. The results for the 5MHz and10MHz TDD interferers into the 5MHz FDD victim are given in Table 29. The first column is the minimum separation from the lower TDD block edge to the victim carrier.

A7.53 Three values are given for each offset. The first represents the ‘unrestricted’ in-band power which, according to the spectrum mask, is a maximum of

54dBm/MHz or 63.5dBm EIRP (according to Equation 2). A 'typical' value is also quoted based on link budgets presented by the WiMAX Forum[127] which states a base station transmit power of 10W per channel giving an EIRP of 56.3dBm. The final figure is the ACLR of a transmitter in the restricted channel which according to Equation 2 has a maximum EIRP of 34.5dBm

A7.54 The first two entries are greyed out as it is not possible under the mask restrictions to allow an unrestricted transmitter at 2.5MHz offset from the band edge.

Table 29: TDD BS ACLR according to Ofcom spectrum mask proposal

ACLR (dB)	Unrestricted	Typical	Restricted
@2.5MHz			41.51
@7.5MHz	79.70	72.45	50.69
@12.5MHz	79.70	72.45	50.69

A7.55 The level of protection afforded to the victim system by the adjacent channel specification of both the mask and the equipment standard is calculated from Equation 1 above. The results are shown in Table 30.

Table 30: 10MHz TDD BS to 5MHz FDD BS adjacent channel protection

ACP (dB)	Unrestricted	Typical	Restricted
@2.5MHz			40.19
@7.5MHz	57.97	57.85	49.95
@12.5MHz	65.82	65.11	50.56

Minimum Coupling Loss

A7.56 The Minimum Coupling Loss (MCL) calculation is used to work out how much isolation is required to protect a victim receiver from interference. It is generally assumed that a system is designed to cope with interference which is no stronger than the system noise floor (i.e. interference plus thermal noise increases the overall noise floor by 3dB).

A7.57 The question is therefore, given that the interference into the victim receiver can be no more than the thermal noise limit and given the interference experienced by the victim from an adjacent channel is defined by the ACIR, how much additional isolation is required in order to ensure there is no degradation in system performance.

A7.58 The theory of MCL analysis is described further in a report from the European Radiocommunications Committee (ERC)[128]. However, the technique has its limits. It is mainly valid for looking at specific victim/interferer pairs. In order to build up a picture of the system performance over an entire network it is necessary to employ more advanced techniques such as Enhanced MCL or Monte Carlo. These techniques average the effects of multiple victims and

[127] 'Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation', WiMAX Forum, August, 2006

[128] "A Comparison of the minimum Coupling Loss Method, Enhanced Minimum Coupling Loss Method, and the Monte-Carlo Simulation", ERC Report 101, Menton, France May 1999.

interferers by randomly varying some of the network parameters over their likely range during normal operation.

A7.59 Nevertheless, MCL is very useful in examining worst-case interference scenarios under typical operating conditions. If a system can be designed to overcome worst-case interference under these conditions then it can be confidently assumed that the network will not suffer degradation in its performance. Hence, the MCL approach is always a useful first step to understand the potential scale of any problem.

A7.60 MCL is calculated according to the following equation:

Equation 3: Minimum coupling loss:

$$\text{Isolation} = P_{INT} + dB_{BW} + MC_{INT} + G_{VICT} + G_{INT} - (S_{VICT} - C/I_{VICT}) + f(dBc_{INT},P_{INT})$$

Where:

- P_{INT} is the maximum transmit power of the interferer.
- dB_{BW} is the bandwidth conversion factor between interferer and victim.
- MC_{INT} is the multiple carrier margin to account for when the interferer is a base site and has more than a single carrier being transmitted.
- G_{VICT} is the gain of the victim antenna (inc. cable loss).
- G_{INT} is the gain of the interferer antenna (inc. cable loss).
- S_{VICT} is the sensitivity of the victim.
- C/I_{VICT} is the protection ratio of the victim.
- $f(dBc_{INT},,P_{INT})$ is a function defining the power of the wideband noise at the frequency offset being considered relative to the interferer's carrier power.

A7.61 In the case of 5MHz and 10MHz TDD interferers (5MHz for restricted carriers and 10MHz for unrestricted and typical carriers) and 5MHz FDD victim at 2.6GHz, the parameter values that have been assumed are consistent with the link budget analyses set out in the 'Baseline analysis' section. The assumptions are as follows:

- P_{INT} is variable to allow checking of the maximum value (unrestricted spectrum mask), minimum (restricted spectrum mask) and typical (based on the WiMAX Forum link budget.[129]
- dB_{BW} is assumed to be 0dB. The bandwidth conversion is incorporated into the derivation of the ACP as described in the previous section.
- MC_{INT} is also assumed to be 0dB. It is assumed that in cases where the interfering BS has more than one carrier only one carrier will be adjacent to the victim band and hence will dominate the interfering signal strength.

[129] 'Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation', WiMAX Forum, August, 2006

- G_{VICT} is assumed to be 20dBi gain – 3dB losses = 17dB.
- G_{INT} is assumed to be:
  - 17dB for unrestricted and typical 10MHz carriers.
  - 3db for restricted 5MHz carriers.
- S_{VICT} is taken from the link budget and includes the noise figure and any own system interference.
- C/I_{VICT} also taken from the link budget and includes the processing gain and the Eb/No of the victim service.
- $f(dBc_{INT},,P_{INT})$ in this case is the Adjacent Channel Interference Ratio as calculated in Table 30.

A7.62 It should be noted that this analysis is only valid for victim/interferer pairs that are in the far field region from each other's antenna. The isolation requirements of co-located systems can be analysed by removing the antenna gains from Equation 3.

A7.63 Note also that this model assumes that both the interfering antenna and the victim antenna are co-aligned (i.e. the worst case).

A7.64 Given the different interfering powers and the different ACIR values at the alternative band separations, the results obtained are show in Table 31 & Table 32 below. Note again that the interfering power in the directly adjacent TDD band is limited and so only values for the restricted levels are shown.

Table 31: Required isolation from TDD base station (far field region)

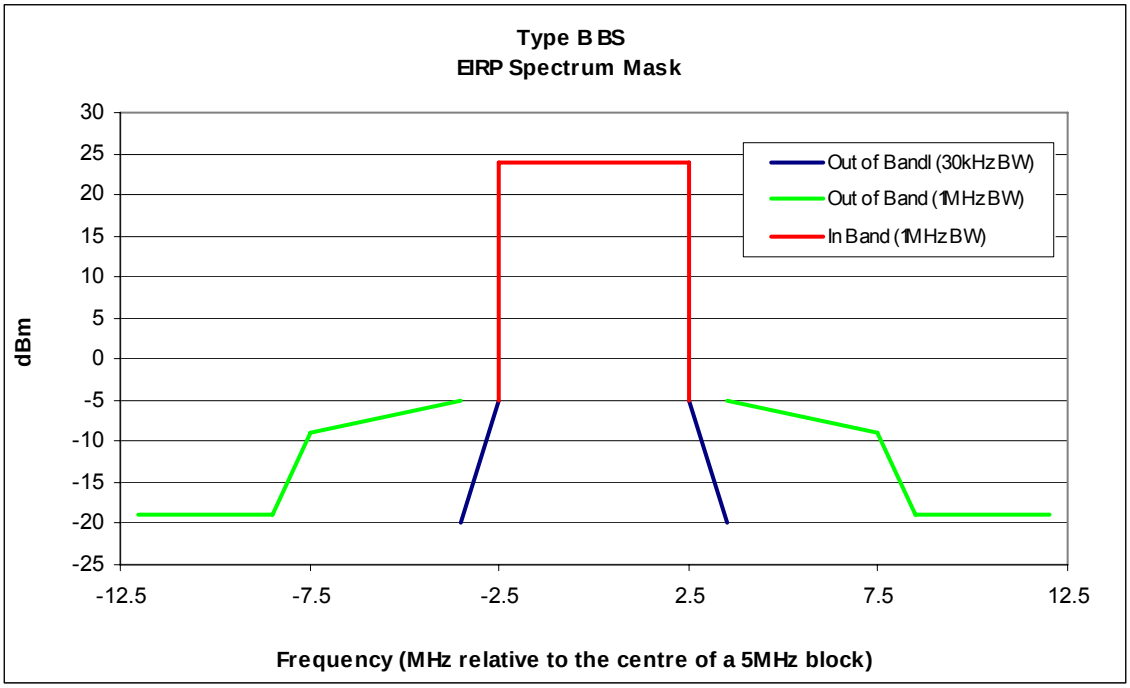
Isolation required for 3dB rise (dB)	Far field		
	Unrestricted	Typical	Restricted
@2.5MHz			112.50
@7.5MHz	123.73	116.60	102.74
@12.5MHz	115.88	109.33	102.13

Table 32: Required isolation from TDD base station (co-located)

Isolation required for 3dB rise (dB)	Far field		
	Unrestricted	Typical	Restricted
@2.5MHz			89.50
@7.5MHz	83.73	76.60	79.74
@12.5MHz	75.88	69.33	79.13

A7.65 The exercise has been repeated in order to determine the required isolation from a TDD mobile interferers operating. The spectrum mask specified for the mobile terminals is different from the base station mask and is shown in Figure 34 below.

Figure 34: Mobile equipment spectrum mask (FDD & TDD)



A7.66 The results are shown in the table below (a co-location table has not been included as this is not relevant to mobile interferers).

Table 33: Required isolation from TDD mobile station (far field region)

Isolation required for 3dB rise (dB)	Far field	
	Unrestricted	Typical
@2.5MHz	122.83	115.31
@7.5MHz	105.63	95.10
@12.5MHz	105.05	94.52

Probability of being interfered

A7.67 The next step in the analysis of the effect of ACI is to assess the probability of interference for a victim receiver in a network.

A7.68 Four cases have been analysed :

a) Interfering TDD base station on a separate mast (far field conditions).

b) Interfering TDD base station indoors on the restricted channel (far field conditions).

c) Interfering TDD base station on the same mast (co-located).

d) Interfering TDD mobile at ground level.

A7.69 In the first case it is assumed that no additional isolation is provided between interferer and victim other than that provided by physical separation.

A7.70 Case a) is considered in detail in the following sections.

a) Interfering TDD base station

A7.71 The first step is to translate the required MCL isolation into a minimum separation distance at which the interference is at the maximum level without causing degradation of system performance.

A7.72 For this a propagation model is required to calculate the path loss between the victim and interfering base stations.

A7.73 For this specific scenario none of the standard propagation models are valid. Also Free Space Loss is considered too pessimistic over longer distances. It was therefore decided to continue to follow the approach set out in Annex 12 of the December Consultation. This is a simple dual-slope model which has a breakpoint at 200m for propagation between 'high' sites below which free space is assumed. Beyond that the path loss falls off at an increased rate (a coefficient of 3 rather than 2 for free space).

A7.74 The model is defined in the December Consultation as:

Equation 4

$$L_{DS} = L_{FS}(d) + L_N(B) \qquad \text{for } d \le d_0$$

Equation 5

$$L_{DS} = L_{FS}(d_0) + A.10.\log_{10}\left(\frac{d}{d_0}\right) + L_N(B) \qquad \text{for } d > d_0$$

where:

$$L_{FS} = 32.45 + 20\log_{10}(f_{MHz}) + 20.\log_{10}(d_{km})$$

$L_N(B)$ = log-normal distribution mean zero & standard deviation B

A7.75 The introduction of a log-normal term can lead to very low path losses close to the transmitter – much less than free space path loss. As this is unrealistic the loss is capped at free space path loss.

A7.76 In this analysis only the *mean* path loss was calculated i.e. $L_N(B)$=0dB.

A7.77 For the case where the interferer is either an indoor base site, a pico site or a mobile device the extended HATA model described by CEPT in SE21 was used.[130]

A7.78 The equations were rearranged to allow the calculation of *d* from a given path loss. Path loss values were entered equivalent to the required isolation levels calculated in the previous section in order to determine the minimum

[130] CEPT SE21(97)81 'Monte Carlo Radio Compatibility Tool. Propagation model between 30MHz and 3GHz'. Sub-annex B.a.

separation distance required between the victim and receiver at different frequency offsets from the block edge.

A7.79 Note that this propagation model is applied across all geotypes (urban, suburban and rural).

A7.80 The results are presented in the table below.

Table 34: Minimum site to site distance between WCDMA & WiMAX base stations

Min. site to site distance required (km)	Far field		
	Unrestricted	Typical	Restricted
@2.5MHz			1.44
@7.5MHz	3.41	1.97	0.68
@12.5MHz	1.87	1.13	0.65

A7.81 In order to establish the probability of a victim receiver being interfered it is necessary to establish the likelihood of a TDD interferer being closer than the distances calculated above.

A7.82 Given that the relative site densities of the 3G WCDMA and WiMAX systems are similar it is reasonable to assume that each WCDMA site will have at least one WiMAX site within its coverage area.

A7.83 There will be situations in real networks where more than one interfering site will be present however it is not unreasonable to assume that only one interfering site will be dominant.

A7.84 It has also been assumed that there is an even probability of an interfering site being located at any point within the victim coverage area which corresponds with the case where there is no coordination between operators. The probability of a site being within a particular radius will therefore be based on the area covered by that radius.

A7.85 Figure 35 illustrates the breakdown of a cell site coverage area into concentric rings. The area of a hexagon is given as $(3\sqrt{3})/2*r^2$, where r is the radius. For a hexagon of radius 1 the area is 2.6 units^2.

A7.86 The probability of a point lying within a hexagon of radius a, where $0 \leq a \leq r$ is simply the area of the hexagon at a over the area of the hexagon at $a = r$.

A7.87 The approach taken here was to normalise the minimum site to site distances to the radii of the various cell types for WCDMA i.e. urban, suburban and rural. The area was then calculated and divided by 2.6 (the area of a hexagon of radius 1) to give the probability of an interferer lying within the minimum site to site distance and hence the probability that a site would be interfered.

A7.88 For road and rail coverage it is assumed that sites are located on a line parallel to the route. It is also assumed that there is an even chance that a single, dominant interferer will be located at a point along the line covered by an interferer. The probability that the interferer is located at a distance from the victim (or less) is simply the ratio of that distance to the maximum coverage radius of the victim site.

A7.89 The results for each case of an unrestricted power interferer, a typical power interferer and a restricted power interferer are shown in Table 35, Table 36 and Table 37.

Figure 35: Division of site coverage area into concentric rings

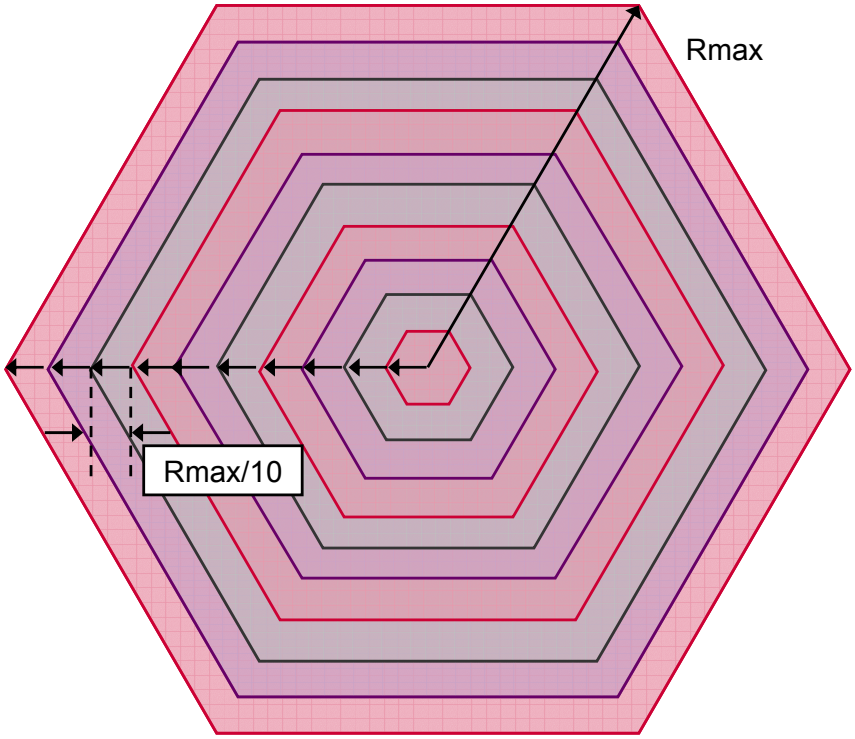


Table 35: Probability of interference from a TDD base station at unrestricted power

Probability of interference: unrestricted	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban		100.0%	100.0%
Suburban		100.0%	63.3%
Rural		19.3%	5.8%
Road/rail		43.9%	24.0%

Table 36: Probability of interference from a TDD base station at typical power

Probability of interference: typical	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban		100.0%	100.0%
Suburban		70.7%	23.2%
Rural		6.5%	2.1%
Road/rail		25.4%	14.6%

Table 37: Probability of interference from a TDD base station at restricted power

Probability of interference: restricted	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban	100.0%	74.0%	67.4%
Suburban	37.7%	8.4%	7.7%
Rural	3.4%	0.8%	0.7%
Road/rail	18.6%	8.8%	8.4%

A7.90 From the above results it is clear that in all but the more sparsely populated areas (i.e. rural and at significant band offset such as 12.5MHz from the block edge), the probability of interference is significant. The probability of interference decreases with the reduction in interferer power as expected and as the victim moves away (in frequency) from the interfering band.

A7.91 The interference suffered by the victim site is not however catastrophic. As the interferer moves closer to the victim site the effect is to raise the noise floor and effectively shrink the coverage area of the cell.

A7.92 It is possible to analyse the effect of reducing this cell size and how it impacts on the site density; however, the first step is to consider ways of implementing additional isolation between the victim and interferer that are less costly than the acquisition and building of additional sites.

A7.93 In practice several measures can be implemented to mitigate against ACI and these have been covered extensively in the report by Mason Communications.[131] However, it has been raised in the various responses to the December Consultation that the values chosen in that report were towards the limit of what is achievable and in some cases (e.g. antenna azimuth alignment) not practical.

A7.94 Where network deployment is uncoordinated it is almost impossible to say in advance which sites will suffer from ACI. Mitigation techniques will therefore be needed to be applied to all sites to avoid the time and expense of reconfiguring sites on an individual basis unless the predicted number of interfered sites is very low.

A7.95 In this study only basic mitigation techniques have been considered. Additionally, more pessimistic values have been used in order to better reflect what will be readily achievable in practice and hence less costly to implement. If network operators coordinate their network deployments it should be possible to easily improve on these figures.

A7.96 The main source of additional isolation to counter ACI is from additional filtering on the victim receive chain. The ability to implement the value of 60dB proposed in Mason's report was not contested in any of the consultation responses, however there were comments that such filters would be costly. Some respondents suggested a figure closer to 50dB may be more practical. A value of 45dB has been assumed here with only 10dB at 2.5MHz offset from the band edge to allow for a more gradual roll-off.

[131] '2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz Spectrum Awards – Engineering Study (Phase 2)', Mason Communications Limited, November 2006.

A7.97 For co-located antennas it is generally accepted that an isolation of 30dB may be assumed[132]. In this study a value of 25dB has been used.

A7.98 For antennas in the far field it is reasonable to assume it to be generally unlikely that the interfering antenna and victim antenna will be directly aligned along their bore-sights. Hence an additional 1dB isolation has been factored in due to downtilting with a further 2dB due to non-alignment in the azimuth plane.

A7.99 Finally, it has been assumed that systems using the restricted band shall only be deployed indoors or at outdoor pico-sites. Hence a building penetration loss of 10dB has been added to the isolation at 2.5MHz spacing for indoor systems and no additional isolation is assumed from non-aligned antennas since the indoor and pico-antennas are assumed to be omnidirectional.

A7.100 Although unlikely, a co-located system has been considered at 2.5MHz offset where the only isolation is due to antenna separation and additional filtering.

A7.101 Table 38 below shows the assumed values of additional isolation that may be implemented before an operator would consider acquiring more sites.

Table 38: Additional isolation from base station to base station ACI mitigation

Mitigation: conservative estimates (dB)	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Co-lo antenna separation	25	25	25	25
Building penetration loss	10	0	0	0
Antenna downtilt	0	0	1	1
Antenna azimuth	0	0	2	2
Antenna filtering	10	10	45	45
Total co-located	**35**	**35**	**70**	**70**
Total far field	**20**	**10**	**48**	**48**

A7.102 The effect of implementing the above mitigation techniques and thereby gaining additional isolation is that less isolation is required to be achieved by site to site separation.

A7.103 When considering interfering *mobile* equipment these figures are still valid as they are all measures that are applied to the receiver base station. However as for indoor and pico base sites, additional isolation due to antenna alignment cannot be assumed.

A7.104 In order to gauge the effect of the additional isolation due to the countermeasures described above the total figures are subtracted from the isolation requirements detailed in Table 31, Table 32 and Table 33. The remainder will be the additional isolation that will be required to be provided by separation of the sites in the case of far field antennas or by other means i.e. additional mitigation, in the case of co-located antennas.

[132] 'Co-siting solutions' Kenth Höglund and Björn Ternby, Ericsson Review No 2, 2003

A7.105 The same exercise as before (see A7.87) was carried out to determine the probability of interference with the mitigation measures in place. The results are given in the following tables.

Table 39: Additional isolation required after mitigation techniques (co-located sites)

Isolation required with mitigation (dB)	Co-located		
	Unrestricted	Typical	Restricted
@2.5MHz (indoor)			54.50
@2.5MHz (street)			54.50
@7.5MHz	13.73	6.60	9.74
@12.5MHz	5.88	–0.67	9.13

Table 40: Additional isolation required after mitigation techniques (far field sites)

Isolation required with mitigation (dB)	Far field		
	Unrestricted	Typical	Restricted
@2.5MHz (indoor)			92.50
@2.5MHz (street)			102.50
@7.5MHz	75.73	68.60	54.74
@12.5MHz	67.88	61.33	54.13

A7.106 For sites in the far field the minimum required separation distance was calculated as before using the relevant propagation model.

Table 41: Minimum site to site distance with ACI mitigation (far field)

Min site to site distance required (km)	Far field		
	Unrestricted	Typical	Restricted
@2.5MHz (indoor)[133]			0.11
@2.5MHz (street)[133]			0.31
@7.5MHz[134]	0.06	0.02	0.01
@12.5MHz[134]	0.02	0.01	0.00

A7.107 Once again, these distances were normalised to the particular cell radius of the corresponding geotypes and the probability of interference calculated. The results for the different interferer power levels (unrestricted, typical and restricted) are presented in the tables below.

[133] SE21 model
[134] High to high model

Table 42: Probability of interference with ACI mitigation (unrestricted interferer power)

Probability of interference: unrestricted	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban		0.5%	0.1%
Suburban		0.1%	0.0%
Rural		0.0%	0.0%
Road/rail		0.7%	0.3%

Table 43: Probability of interference with ACI mitigation (typical interferer power)

Probability of interference: typical	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban		0.1%	0.0%
Suburban		0.0%	0.0%
Rural		0.0%	0.0%
Road/rail		0.3%	0.1%

Table 44: Probability of interference with ACI mitigation (restricted interferer power)

Probability of interference: restricted	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	1.8%	15.1%	0.0%	0.0%
Suburban	0.2%	1.7%	0.0%	0.0%
Rural	0.0%	0.2%	0.0%	0.0%
Road/rail	1.4%	4.0%	0.1%	0.1%

A7.108 The figures presented in the tables above clearly show a significant reduction in the probability that a site will experience interference from the results without mitigation. In the worst case 15.1% of urban sites will experience service degradation due to ACI if the interferers are outdoor pico cells deployed at 2.5MHz offset in a completely random fashion. It is not anticipated that restricted transmitters at 2.5MHz offset would be deployed in a road or rail environment and, except for this, the likelihood of interference in the other deployment scenarios is probably acceptable.

A7.109 The results for 2.5MHz offset in a street urban environment reflect the fact that there is no frequency separation between the edge of the victim FDD base station and the interfering TDD base station and that building penetration loss is not available as a mitigating factor.

A7.110 Any improvement in the mitigation figures presented here would improve the situation even further. It is likely also that by coordinating with the interfering operator any remaining interference situations could be resolved.

b) Interfering TDD mobile

A7.111 The analysis presented above was repeated for interfering TDD WiMAX mobiles, again with 5MHz channels in restricted blocks and 10MHz in other cases.

A7.112 The propagation model used was the extended HATA model mentioned previously.[135] Base site heights of 20m for rural / open environments, 25m for suburban and 30m for urban have been assumed. The mobiles were assumed to be at street level at a height of 1.5m.

A7.113 Only two power levels have been considered, unrestricted and typical. There is no requirement in the Ofcom spectrum mask (see Figure 34) to have a restricted power in the mobile.

A7.114 From the Ofcom mask description and equipment specification the isolation between an interfering mobile and base site required for normal operation is given in Table 45 below.

Table 45: Required isolation from TDD mobile station

Isolation required for 3dB rise (dB)	Far field	
	Unrestricted	Typical
@2.5MHz	122.83	115.31
@7.5MHz	105.63	95.10
@12.5MHz	105.05	94.52

A7.115 For victim/interferer pairs in the far field this translates into the following minimum separation distances using the extended HATA model. Tables are provided for unrestricted and typical interferer powers.

Table 46: Minimum site to site distance between unrestricted TDD mobile and FDD base station (no mitigation)

Min site to site distance required: unrestricted (km)	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban	0.35	0.11	0.11
Suburban	0.70	0.23	0.22
Rural	2.33	0.76	0.73
Road/rail	2.33	0.76	0.73

[135] CEPT SE21(97)81 'Monte Carlo Radio Compatibility Tool. Propagation model between 30MHz and 3GHz'. Sub-annex B.a.

Table 47: Minimum site to site distance between typical TDD mobile and FDD base station (no mitigation)

Min site to site distance required: typical (km)	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban	0.21	0.08	0.08
Suburban	0.43	0.12	0.11
Rural	1.43	0.38	0.37
Road/rail	1.43	0.38	0.37

A7.116 Once again, these values were normalised to the appropriate cell radius and the probability of interference calculated. The results without mitigation against ACI are as follows.

Table 48: Probability of interference from unrestricted TDD mobile station

Probability of interference: unrestricted	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban	19.6%	2.1%	1.9%
Suburban	9.0%	1.0%	0.9%
Rural	9.0%	1.0%	0.9%
Road/rail	30.0%	9.8%	9.4%

Table 49: Probability of interference from typical 10MHz TDD mobile station

Probability of interference: typical	Offset from block edge		
	2.5MHz	7.5MHz	12.5MHz
Urban	7.3%	0.9%	0.9%
Suburban	3.4%	0.2%	0.2%
Rural	3.4%	0.2%	0.2%
Road/rail	18.4%	4.9%	4.7%

A7.117 The figures are generally better than for base station to base station interference since the interferer power is generally lower and the mobiles are relatively more isolated at street level than base sites on masts.

A7.118 The mitigation measures implemented for the mobile to base station interference scenario are presented in Table 50 below.

Table 50: Additional isolation from mobile to base station ACI mitigation

Mitigation: conservative estimates (dB)	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Co-lo antenna separation	25	25	25	25
Building penetration loss	10	0	0	0
Antenna downtilt	0	0	0	1
Antenna azimuth	0	0	0	2
Antenna filtering	10	10	45	45
Total co-located	**35**	**35**	**70**	**70**
Total far field	**20**	**10**	**48**	**48**

A7.119 This results in a reduction in the isolation required from other means (i.e. site separation for the far field case). The additional isolation required with countermeasures in place is therefore those values given in Table 51 below.

Table 51: Additional isolation required for mobile to base station operation

Isolation required with mitigation (dB)	Far field		Co-located	
	Unrestricted	Typical	Unrestricted	Typical
@2.5MHz (indoor)	102.83	95.31	67.83	60.31
@2.5MHz (street)	112.83	105.31	67.83	60.31
@7.5MHz	60.63	50.10	15.63	5.10
@12.5MHz	60.05	49.52	15.05	4.52

A7.120 Once again, these have been converted to a minimum separation distance for the far field case from which the probability of a base site being interfered can be calculated.

Table 52: Minimum site to site distance between unrestricted TDD mobile and FDD base station

Min site to site distance required: unrestricted (km)	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	0.10	0.18	0.00	0.00
Suburban	0.19	0.37	0.00	0.00
Rural	0.63	1.21	0.00	0.00
Road/rail	0.63	1.21	0.00	0.00

Table 53: Minimum site to site distance between typical TDD mobile and FDD base station

Min site to site distance required: typical (km)	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	0.08	0.11	0.00	0.00
Suburban	0.12	0.22	0.00	0.00
Rural	0.39	0.74	0.00	0.00
Road/rail	0.39	0.74	0.00	0.00

A7.121 This results in the following probability of interference.

Table 54: Probability of interference with ACI mitigation (unrestricted mobile power)

Probability of interference: unrestricted	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	1.5%	5.3%	0.0%	0.0%
Suburban	0.7%	2.4%	0.0%	0.0%
Rural	0.7%	2.4%	0.0%	0.0%
Road/rail	8.1%	15.6%	0.0%	0.0%

Table 55: Probability of interference with ACI mitigation (typical mobile power)

Probability of interference: typical	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	0.9%	2.0%	0.0%	0.0%
Suburban	0.2%	0.9%	0.0%	0.0%
Rural	0.2%	0.9%	0.0%	0.0%
Road/rail	5.0%	9.6%	0.0%	0.0%

A7.122 As for the base station to base station case the worst case interference occurs for the 2.5MHz offset outdoors case. However, here the worst case occurs for the road/rail scenario rather than the urban scenario that occurred in the base station to base station case above. The reason that, for TDD mobile to FDD base station, the road/rail case is the worst is that mobiles are typically restricted to one dimension (i.e. along the road or railway line) rather than to an area – the probability of interferers being within a certain distance (r) of a victim base station is proportional to 1/r rather than $1/r^2$ (as would be the case for an area distribution). As 1/r falls off much less rapidly than $1/r^2$ with increasing r then a probability of interference based on a linear distribution of interferers is likely to be higher than one based on an area distribution (as interference is more likely to occur the nearer to the FDD base station a TDD mobile is located).

A7.123 As shown below, assuming an additional 15dB of mitigation, it is evident that a significant reduction in the probability of interference is possible with only a modest amount of additional isolation.

Table 56: Probability of interference with additional 15dB ACI mitigation (unrestricted mobile power)

Probability of interference: unrestricted	Offset from block edge			
	2.5MHz (indoor)	2.5MHz (street)	7.5MHz	12.5MHz
Urban	0.6%	1.1%	0.0%	0.0%
Suburban	0.1%	0.3%	0.0%	0.0%
Rural	0.1%	0.3%	0.0%	0.0%
Road/rail	3.0%	5.9%	0.0%	0.0%

Summary

A7.124 Care should be taken when interpreting the results of this analysis. For interference between base sites, given that the locations of the sites are fixed, it is possible to interpret the interference probability into the probability that a certain percentage of all sites will be interfered. This implies that some will be interfered and some will not.

A7.125 For mobile interferers, on the other hand, locations are not fixed and so there is the possibility that every base site can be interfered. The probability therefore represents the percentage of time that a mobile is in a location that, if it is transmitting, will cause the base site to experience interference.

TDD WiMAX base station interferer

A7.126 From the analysis of ACI for the particular case of a WCDMA FDD base station being interfered by a TDD WiMAX system in the adjacent channel, the following observations can be made.

A7.127 Interference from WiMAX base sites will cause unacceptable levels of interference to WCDMA base sites in most cases without mitigation techniques being employed. In rural locations, where the probability is 6.5% at 7.5MHz offset from the block edge for a typical interferer (Table 36), it could be possible to deploy a network. However coordination would be required between operators to ensure that the minimum site separation distance of 1.97Km (Table 34) is adhered to.

A7.128 Co located WiMAX and WCDMA base sites would not work without additional isolation at all channel offsets.

A7.129 However, with reasonable measures in place to provide additional isolation the situation is greatly improved. WCDMA systems should be at least 7.5MHz offset from the block edge of unrestricted TDD base sites and under these circumstances the greatest probability of interference is 0.5% in urban environments and 0.7% in road/rail deployments. This is for unrestricted interferers which are unlikely to be deployed in reality. For a realistic transmitter power the probabilities reduce to 0.1% and 0.3% respectively. Also, given the relatively pessimistic values adopted for the ACI countermeasures any improvement in these figures would improve the situation further.

A7.130 Co location however could still be problematic unless an additional 5.88dB of isolation could be provided between 'typical' systems (Table 39). Again, however, fairly pessimistic figures were considered here and it should be possible to achieve the extra degree of isolation required in a real deployment.

A7.131 The main potential problem is in the use of the restricted band at 2.5MHz offset. With the countermeasures in place an acceptable performance may be achieved in the rural and suburban environments. However, in the urban environment there remains a 15.1% chance of being interfered if the WiMAX systems are deployed as on-street pico cells. If, however, the restricted band is used solely for indoor systems then the risk of interference drops to 1.8% due to propagation losses through building materials. However, care would have to be taken to ensure that in high rise buildings (for example) the isolation is still sufficient when indoor systems are deployed within range of WCDMA sites on top of nearby buildings.

TDD WiMAX mobile station interferer

A7.132 On the face of it, the case of interfering mobile WiMAX equipment is not as potentially problematic as the ACI from adjacent WiMAX base equipment. For an unrestricted mobile operating at least 7.5MHz from the WCDMA carrier in an urban environment there is only a 2.1% probability of causing interference to the WCDMA base station (Table 48). However, this applies to every site.

A7.133 Additionally, there will be many more mobiles per cell hence this probability will increase in line with the number of interferers. For example, if there are 20 WiMAX users within the coverage area of the WCDMA site then there is a 20*2.1%=42% chance that one of them will be in a location that will cause interference if they were transmitting. This situation is improved if it is considered that mobiles, unlike base stations, are not transmitting continuously. As a coarse estimate it is assumed that a WiMAX user is only active 5% of the time hence the probability of interference becomes 20*2.1%*5% = 2.1%. It should be noted that this is a coarse estimate of the usage pattern of a WiMAX subscriber and more work would be required to understand these effects in further detail.

A7.134 As with the interference from the base sites it is shown that a significant improvement can be achieved if basic measures are taken to counteract the ACI at the WCDMA base receiver. For WCDMA systems at 7.5MHz or more from the band edge there is 0% probability (to one decimal place) of interference even for an unrestricted mobile (Table 54). In reality, there may be a small risk of interference if several mobiles are simultaneously transmitting in close proximity to the WCDMA base site however the risk is minimal.

A7.135 As expected, the most significant interference is from mobiles that are in the adjacent band at 2.5MHz separation from the WCDMA carrier, particularly where they are located on-street with no building penetration loss to provide additional isolation. Based on pessimistic levels of isolation obtained from countermeasures to ACI, we find a probability of 2.0% that a base site will be interfered. However, if a further 15dB of filtering could be achieved then the probability of interference reduces to 1.1% (Table 56) which is a more acceptable figure to an operator wishing to deploy a WCDMA network using FDD in the 2.6GHz band.

Road and rail coverage

A7.136 Figures for the interference probability to sites providing coverage to road and rail services are also included in the above tables. In line with the rest of the study, adequate mitigation reduces the likelihood of interference to an acceptable level for WCDMA systems deployed at 7.5MHz from the band edge of an unrestricted WiMAX interferer.

A7.137 As expected, the performance of the WCDMA system in the presence of restricted sites at 2.5MHz offset is worse. However, it is highly unlikely that this type of site would be used to provide outdoor road or rail coverage.

A7.138 One example of potential for interference could be if a restricted WiMAX carrier was deployed onboard a train. However, this is a special case and would require further investigation.

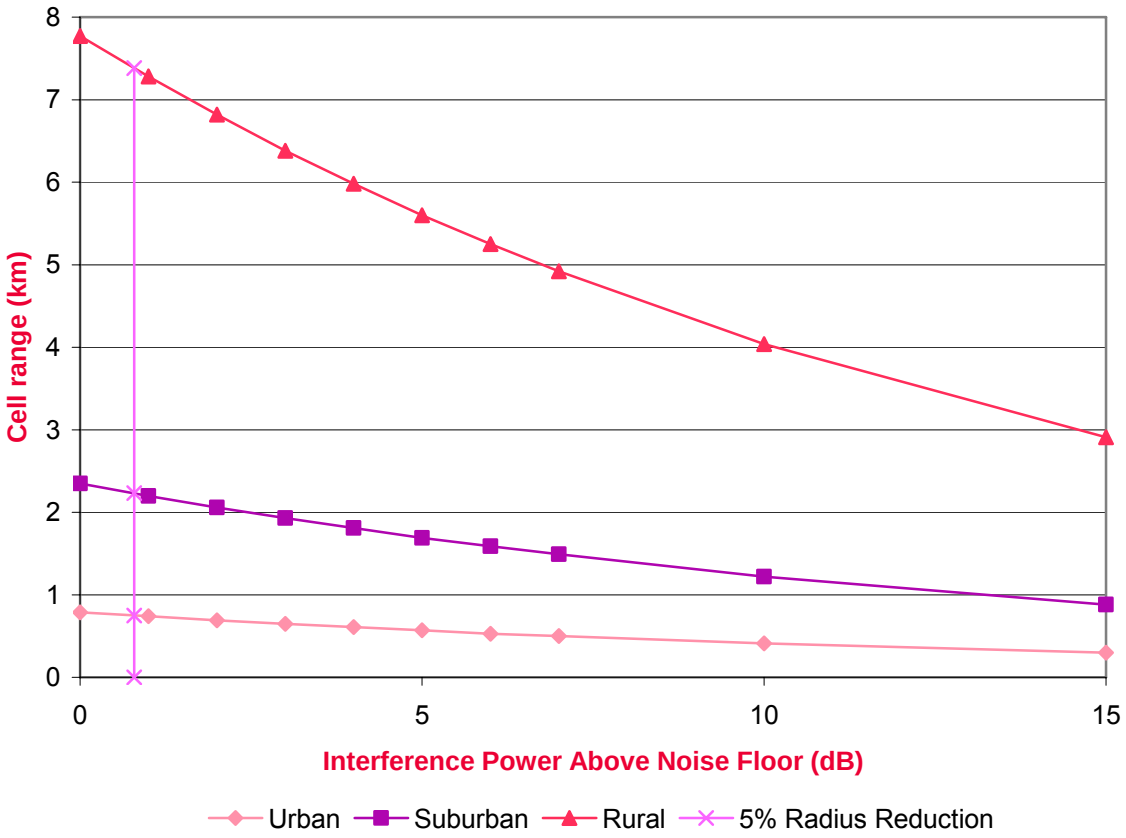
Implications for network dimensioning

A7.139 Given the high cost of site acquisition and build (including equipment purchase) it is highly likely that an operator would implement measures to mitigate against adjacent channel interference rather than deploy more sites in order to increase the network density. Such an approach would likely result in increased interference from the FDD network back into the TDD system and if the TDD operator increased the density of their network in response the situation could escalate out of control.

A7.140 In an exercise to understand the implication of increased interference in the network the WCMDA link budgets were used to analyse the variation in cell range with interference power.

A7.141 The curves in Figure 36 show the expected reduction in cell size as the interference increases above the noise floor of the WCDMA receiver.

Figure 36: Cell shrinkage due to noise rise from interference



A7.142 On average across the three geotypes a 0.79dB increase in interference is enough to cause a 5% reduction in the cell range. This translates to a 9.75% reduction in cell area which has a corresponding impact on the number of cells required to recover the lost coverage area. In this case an additional 8% of the original number of cell sites would be required.

A7.143 This clearly illustrates the sensitivity of the system to changes in the interference levels from an adjacent network. It also serves to illustrate that it is generally preferable to provide isolation by means of additional filtering or other isolation techniques rather than attempt to fill coverage holes with extra sites.

A7.144 It is worth reiterating at this point that the analysis presented here has not considered a frequency re-use greater than 1 in the interfering WiMAX network. If frequencies were re-used then the interference across the WCDMA network would be reduced.

A7.145 Frequency re-use could be a straightforward means of solving any ACI problems if and when they arise during network roll-out involving minimal effort on the part of the WiMAX operator and minimal cost which could be shared between both operators.

Costs

A7.146 For an operator wishing to deploy a WCDMA network in the FDD spectrum adjacent to the TDD band where a WiMAX system is deployed, the main additional cost will be from additional filtering to mitigate against the effects of ACI.

A7.147 As a coarse estimate a filter will cost of the order of £500. Assuming 2 TRxs per sector on a 3-sector site equates to 6x£500 = £3000 per site.

A7.148 Site acquisition and build costs are generally of the order of £40 to £50k per site, thus additional filtering would represent a small fraction of the overall cost to deploy a network.

A7.149 For a national roll-out of say 7000 sites, this would represent an additional cost of approximately £20 million (compared to site costs of £280–350 million).

Conclusions

A7.150 The main conclusions to be drawn from the analysis presented in this study are as follows.

- Without taking measures to counter the effects of ACI, it would be difficult to deploy a WCDMA network in the FDD spectrum adjacent to a WiMAX TDD network (even at an offset of 12.5MHz from the lower band edge of the FDD spectrum the ACI would be considerable in all but the rural environment, with ACI dominated by the adjacent channel selectivity of the receiver equipment).

  Acceptable levels of performance can be readily achieved by implementing a relatively modest level of mitigation between the systems in the form of additional filtering applied to the WCDMA base station receiver.

- It should be possible to achieve greater isolation than the mitigation figures presented imply which will result in even better performance.

  The spectrum masks proposed in the December Consultation are adequate to limit interference to adjacent channels from the TDD band. The limiting factor on the adjacent channel performance is the specification of the receiver equipment.

  Implementation of additional receiver filtering will be a significant cost to a network operator in the band adjacent to TDD systems. However, compared with site acquisition and deployment costs it is likely to be a relatively small fraction of total wireless network costs.

- However, use of TDD in the restricted channel adjacent to the FDD uplink can still cause ACI problems in some scenarios.

Annex 8

Adjacencies with Programme Making and Special Events use

A8.1 This Annex sets out results of further analysis carried out by Ofcom since the December Consultation on coexistence of likely mobile services for the available bands and PMSE use in adjacent bands.

A8.2 This includes empirical work commissioned by Ofcom from ERA to characterise the Adjacent Channel Selectivity (ACS) performance of two digital wireless camera receivers operating within the 2.0 – 2.5GHz range, and the improvement that may result in the PMSE receiver ACS performance through use of suitable pass band filters.

A8.3 The Annex also presents a revised compatibility analysis of the potential for interference into PMSE receivers from candidate FDD and TDD systems operating in the 2010 and 2600MHz award bands.

ERA Study Results

Adjacent Channel Selectivity

A8.4 The ERA study report is published alongside this Discussion Document on the Ofcom website, see: http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/.

A8.5 The ERA results show that for one of the PMSE receivers (Receiver A), the measured ACS value based on the ratio of adjacent channel interference to an equivalent co-channel noise power ('I/N') definition was found to be 50.5 dB for interference from adjacent channel UMTS signals and 48.6 dB for interference from adjacent channel WiMAX signals. This value is around 20 dB lower than the value assumed in the Engineering Study Phase 2 Report by Mason (which was based on an estimate), but is consistent with the figure quoted by JFMG in their consultation response of a suggested value of around 46 dB.

A8.6 Results for the other PMSE receiver characterised by the ERA (Receiver B) were found to be significantly worse in performance of ACS. It is noted that such a receiver may well experience significant amounts of adjacent channel interference from other PMSE users. ERA attributed the poor PMSE receiver selectivity performance to the apparent lack of any front end filtering employed. Use of an external pass band filter will significantly improve the ACS performance of such receivers.

A8.7 It should be noted that it is not clear to Ofcom whether the out-of-band emissions that are present for UMTS and WiMAX signal generation within the ERA study had a material (i.e., distorting) effect on the ACS measurement. ERA have attempted to factor out this effect as indicated in Section 5.0 of their report. However, in many of the cases the out-of-band emissions from the UMTS and WiMAX signal generation is considered by Ofcom to be of a similar level to the maximum receiver system noise power – such that the degradation in PMSE link performance caused by out-of-band emissions may well dominate over the degradation caused by poor receiver

selectivity. If this is indeed the case then the ACS estimates (based on 'I/N') should have been significantly higher. Further studies would be required to resolve this matter (which is not planned).

Nonetheless, the ERA results clearly quantify the degradation in PMSE link performance due to adjacent channel interference in terms of simultaneous in-band and out-of-band interference mechanisms. As such, the ERA results are still considered to be useful by Ofcom but require careful interpretation.

Channel Filter

A8.8 On the issue of use of a pass band filter to improve the PMSE receiver selectivity, ERA managed to procure two independent prototype pass band filters from separate specialist filter manufacturers for the study. The objective here was to determine whether it is feasible to design a suitable pass band filter that may be deployed by PMSE users that provides a 30 dB or greater rejection at a frequency of 2502.5MHz relative to an 8MHz PMSE pass-band centred at 2495MHz.

A8.9 From results of the filter characterisation the ERA found one of the prototype channel filters (Filter B) met this design goal thereby demonstrating the feasibility of designing and deploying such pass band filters. Deployment of filters similar in performance to Filter A will result in a significant improvement in the PMSE receiver ACS performance. The cost and physical dimensions of the filters procured by ERA are indicated in Section 4.1 of their report.

A8.10 However, it is clear from the results that use of the filter does not equate to a corresponding 30 dB improvement in ACS for the directly adjacent channel, since sufficient adjacent channel energy is still passed through in the filter roll-off region in the band 2500 – 2502.5MHz (see Figure 12 and 13 of the ERA report).

ERA found the use of filtering improved the PMSE receiver ACS performance by 11 – 16 dB for adjacent channel interference (UMTS interferer at 2502.5MHz). This improvement is better than the typical channel filter response of no more than 6 dB rejection at 10MHz and 30 dB for 20MHz indicated by JFMG in their consultation response. The rejection at the second adjacent award channel (centred at 2507.5MHz) was found by the ERA to be around 40db for filter A and greater than 50dB for filter B.

A8.11 It should be noted that some of the results presented by ERA for ACS performance improvement through use of filtering (such as that measured in the presence of WiMAX interference or for further separated channels) is considered by Ofcom to be inconsistent. On closer examination of the ERA results, similar to comments made in paragraph A8.7 above, Ofcom considers the filter results are biased by the impact of out-of-band emissions from the adjacent channel signal generation.

A8.12 Nonetheless sufficient information is available from the ERA results to infer that the use of a mitigation filter at a PMSE receiver can improve the receiver ACS by a minimum of 11 dB for a directly adjacent channel (7.5MHz offset from the PMSE carrier centre frequency). This applies for both WiMAX and UMTS type interfering signals. For the second adjacent channels (12.5MHz offset from the PMSE carrier centre frequency), from ERA Figures 10 and 11, it is reasonable to assume a minimum improvement of 40 dB in receiver ACS may be afforded.

This improvement may well be higher. From Section 4.0, Table 8 of the ERA report, based on the attenuation afforded by the Filter-B, and subtracting a 3dB

factor to account for insertion and random losses, the receiver ACS improvement ('I/N') could well be as high as around 21 dB for a 5MHz UMTS signal and 24dB for a WiMAX signal. Therefore the assumption of an 11dB improvement in receiver ACS for a directly adjacent interferer may well be considered as conservative.

Revised coupling results

A8.13 This section provides a revised estimate of the potential for interference into PMSE receivers. In general the PMSE and mobile system parameters selected are those specified by Mason within the Engineering Study Phase 2 Report, but with the PMSE ACS and mitigation filter values revised accordingly. Additionally, the values for out-of-band emissions for UMTS and WiMAX signals were increased over that assumed in the Mason report.

A8.14 The method adopted for the analysis is described in Appendix A of the Mason report. In summary, the analysis first calculates an Adjacent Channel Interference Ratio (ACIR) parameter. This is based on the power addition of the noise degradation caused by poor receiver Adjacent Channel Selectivity (ACS based on the 'I/N' definition) with the out-of-band emissions produced by the interferer that is received co-channel at a receiver (quantified by the Adjacent Channel Leakage Ratio (ACLR)).

A8.15 Once the ACIR interference power is known, the 'additional isolation' of a communications link is calculated from the summation (in dB) of: Tx Power + Tx Gain – ACIR – Propagation Loss + Rx Gain – Interference Limit.

A8.16 The revised analysis includes consideration of a small bandwidth conversion factor (of approximately 2 dB) to account for differences in PMSE receiver bandwidth (of 8MHz) and ACLR bandwidths (of 5MHz). Also, the ACLR parameter are adjusted from the 10MHz offset as assumed in Engineering Study Phase 2 Report to a 7.5MHz offset in order to account for the closest separation between the centre frequency of the PMSE channel and the first 5MHz award channel. The effect of these two factors increases the level of interference that is assumed at the input of a PMSE receiver.

A8.17 Scenario 1. Mason check calculation. PMSE ACS = 70 dB; interference into adjacent PMSE channel (i.e. centred at 2495MHz)

As a check to ensure the coupling loss calculations are replicated correctly, the results indicated in Table B3 of the Mason study are derived and compared against the results presented in Table 60 below. No difference in the results is found.

The system parameters assumed in the analysis for the comparison check are listed in Table 57 to Table 59 below. The results are presented in Table 60 and estimate the additional isolation (or margin) between a PMSE receiver and a FDD/TDD mobile interferer.

Table 57: PMSE receiver parameters (Mason Check)

Receiver Parameters	Antenna Rx Gain (dBi)	Inteference Level (dBm)	Adjacent Channel Selectivity @ 7.5MHz - ACS (dB)
Radio Camera 1W	0.0	-107	70
Portable/Mobile links	8.0	-107	70
Airborne links	8.0	-107	70
Temporary point to point	20.0	-107	70

Table 58: UMTS/WiMAX transmitter parameters (Mason Check)

Transmitter Parameters	Tx Power (dBm)	Antenna Tx Gain (dBi)	Adjacent Channel leakage Radio @ 10MHz offset (dB)	Adjacent Channel leakage Radio @ 15MHz (dB)
TDD Base Station	36.0	18.0	66.0	70.0
TDD Fixed Sub	24.0	8.0	51.0	54.1
TDD Mobile	20.0	3.0	51.0	54.1
FDD Mobile	21.0	0.0	43.0	57.6

Table 59: Propagation Models and associated losses (Frequency 2600MHz)

Propagation Loss Model	losses(dB) for distance(m)				
	10	50	100	500	1000
ITU-R M.1225 Pedestrian	71.4	99.4	111.4	139.4	151.4
Free Space Path	60.7	74.7	80.7	94.7	100.7

Table 60: Check calculation comparing results with that presented in the Eng. Phase 2 Report. Additional coupling loss or margin to meet PMSE interference criterion. PMSE ACS = 70 dB, Frequency = 2600MHz

Interference Path		Additional Isolation or Margin at 7.5MHz offset between carriers (dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	25.0	-3.0	-15.0	-43.0	-55.0	42
TDD Base Station	Portable/Mobile links	33.0	5.0	-7.0	-35.0	-47.0	67
TDD Base Station	Airborne links	43.7	29.7	23.7	9.7	3.7	Note 1
TDD Base Station	Temporary point to point	45.0	17.0	5.0	-23.0	-35.0	133
TDD Fixed Sub	Radio Camera 1W	16.6	-11.4	-23.4	-51.4	-63.4	26
TDD Fixed Sub	Portable/Mobile links	24.6	-3.4	-15.4	-43.4	-55.4	41
TDD Fixed Sub	Airborne links	35.3	21.3	15.3	1.3	-4.7	Note 1
TDD Fixed Sub	Temporary point to point	36.6	8.6	-3.4	-31.4	-43.4	82
TDD Mobile	Radio Camera 1W	7.6	-20.4	-32.4	-60.4	-72.4	15
TDD Mobile	Portable/Mobile links	15.6	-12.4	-24.4	-52.4	-64.4	25
TDD Mobile	Airborne links	26.3	12.3	6.3	-7.7	-13.7	Note 1
TDD Mobile	Temporary point to point	27.6	-0.4	-12.4	-40.4	-52.4	49
FDD Mobile	Radio Camera 1W	13.6	-14.4	-26.4	-54.4	-66.4	22
FDD Mobile	Portable/Mobile links	21.6	-6.4	-18.4	-46.4	-58.4	35
FDD Mobile	Airborne links	32.3	18.3	12.3	-1.7	-7.7	Note 1
FDD Mobile	Temporary point to point	33.6	5.6	-6.4	-34.4	-46.4	69

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.18 Scenario 2. Baseline calculation based on revised parameters.
PMSE ACS = 46 dB; interference into an adjacent PMSE channel (i.e. centred at

2495MHz).

The following revisions to system parameters are made to the Mason check calculation presented in Scenario 1: a PMSE receiver ACS parameter of 46 dB instead of 70 dB; scaling of the frequency to 2500MHz from 2600MHz; and increasing the FDD & TDD ACLR values to account for the two factors listed in paragraph A8.16.

The parameters used in the revised analysis are as follows below (termed the baseline revised parameters).

A8.19 Note the ACLR parameters for TDD Base Stations assumed within the revised analysis below do not take into consideration the restrictions that will apply to base station transmissions in the bottom two 5MHz lots at 2500-2505 and 2505-2510MHz. This is in order to permit the estimation of the interference from TDD base station transmissions at the 2010MHz band award adjacency. Base station transmitters are only likely to be deployed adjacent PMSE channels at 2500MHz if all lots in the 2.6GHz band were to be used for unpaired use. In such cases, the restrictions in the base station out-of-band emissions at 2500MHz will further serve to protect PMSE use at this adjacency.

Table 61: Revised PMSE receiver parameters – "Baseline"

Receiver Parameters	Antenna Rx Gain (dBi)	Interference Level (dBm)	Adjacent Channel Selectivity @ 7.5MHz - ACS (dB)
Radio Camera 1W	0.0	-107	46
Portable/Mobile links	8.0	-107	46
Airborne links	8.0	-107	46
Temporary point to point	20.0	-107	46

Table 62: Revised UMTS/WiMAX transmitter parameters – "Baseline". Estimated ACLR into 8MHz bandwidth

Transmitter Parameters	Tx Power (dBm)	Antenna Tx Gain (dBi)	ACLR @ 7.5MHz offset (dB)	ACLR @ 17.5MHz offset (dB)
TDD Base Station	36.0	18.0	54.3	70.0
TDD Fixed Sub	24.0	8.0	37.8	54.1
TDD Mobile	20.0	3.0	33.9	54.1
FDD Mobile	21.0	0.0	33.6	57.6

Table 63: Propagation Models and associated Losses (Frequency 2500MHz) – "Baseline"

Propagation Loss Model	losses(dB) for distance(m)				
	10	50	100	500	1000
ITU-R M.1225 Pedestrian	70.9	98.9	110.9	138.9	150.9
Free Space Path	60.4	74.4	80.4	94.4	100.4

Table 64: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 1st adjacent PMSE channel (7.5MHz separation). PMSE ACS = 46 dB

Interference Path		Additional Isolation or Margin at 7.5MHz offset between carriers (dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	44.7	16.7	4.7	-23.3	-35.3	131
TDD Base Station	Portable/Mobile links	52.7	24.7	12.7	-15.3	-27.3	207
TDD Base Station	Airborne links	63.2	49.2	43.2	29.2	23.2	Note 1
TDD Base Station	Temporary point to point	64.7	36.7	24.7	-3.3	-15.3	414
TDD Fixed Sub	Radio Camera 1W	30.8	2.9	-9.2	-37.1	-49.2	59
TDD Fixed Sub	Portable/Mobile links	38.8	10.9	-1.2	-29.1	-41.2	94
TDD Fixed Sub	Airborne links	49.4	35.4	29.4	15.4	9.4	Note 1
TDD Fixed Sub	Temporary point to point	50.8	22.9	10.8	-17.1	-29.2	187
TDD Mobile	Radio Camera 1W	25.4	-2.6	-14.6	-42.6	-54.6	43
TDD Mobile	Portable/Mobile links	33.4	5.4	-6.6	-34.6	-46.6	68
TDD Mobile	Airborne links	43.9	29.9	23.9	9.9	3.9	Note 1
TDD Mobile	Temporary point to point	45.4	17.4	5.4	-22.6	-34.6	136
FDD Mobile	Radio Camera 1W	23.7	-4.3	-16.3	-44.3	-56.3	39
FDD Mobile	Portable/Mobile links	31.7	3.7	-8.3	-36.3	-48.3	62
FDD Mobile	Airborne links	42.2	28.3	22.2	8.3	2.2	Note 1
FDD Mobile	Temporary point to point	43.7	15.7	3.7	-24.3	-36.3	124

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.20 The results presented in Table 64 above adopt the format presented in Mason's Engineering Study Phase 2 Report. They shows the additional isolation (or margin) calculated to be required to avoid interference from a range of separation distances between different PMSE systems and adjacent channel FDD/TDD systems. Results are shown for a 7.5MHz offset between centre frequencies of an award channel at 2500 – 2505MHz, and the PMSE channels at 2490 – 2500MHz.

A8.21 Where the result is negative, the value represents an excess margin that exists between interferer and victim. For convenience, the colour red is used to highlight a requirement for additional isolation and green to indicate an excess margin.

A8.22 Scenario 3. PMSE ACS = 46 dB, Mitigation filter = 11 dB; interference into an adjacent PMSE channel (i.e. centred at 2495MHz).

If a suitable pass band filter is employed, then the PMSE ACS can be considered to be improved by a minimum of 11 dB over the baseline results presented in Scenario 2. The coupling results are as follows.

Table 65: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 1st adjacent PMSE channel (7.5MHz separation). PMSE ACS of 46 dB + PMSE mitigation filter of 11 dB (Total ACS = 57 dB)

Interference Path		Additional Isolation or Margin at 7.5MHz offset between carriers (dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	37.6	9.7	-2.4	-30.3	-42.4	87
TDD Base Station	Portable/Mobile links	45.6	17.7	5.6	-22.3	-34.4	138
TDD Base Station	Airborne links	56.2	42.2	36.2	22.2	16.2	Note 1
TDD Base Station	Temporary point to point	57.6	29.7	17.6	-10.3	-22.4	276
TDD Fixed Sub	Radio Camera 1W	30.3	2.3	-9.7	-37.7	-49.7	57
TDD Fixed Sub	Portable/Mobile links	38.3	10.3	-1.7	-29.7	-41.7	91
TDD Fixed Sub	Airborne links	48.8	34.8	28.8	14.8	8.8	Note 1
TDD Fixed Sub	Temporary point to point	50.3	22.3	10.3	-17.7	-29.7	181
TDD Mobile	Radio Camera 1W	25.1	-2.8	-14.9	-42.8	-54.9	43
TDD Mobile	Portable/Mobile links	33.1	5.2	-6.9	-34.8	-46.9	67
TDD Mobile	Airborne links	43.7	29.7	23.7	9.7	3.7	Note 1
TDD Mobile	Temporary point to point	45.1	17.2	5.1	-22.8	-34.9	134
FDD Mobile	Radio Camera 1W	23.5	-4.5	-16.5	-44.5	-56.5	39
FDD Mobile	Portable/Mobile links	31.5	3.5	-8.5	-36.5	-48.5	61
FDD Mobile	Airborne links	42.0	28.0	22.0	8.0	2.0	Note 1
FDD Mobile	Temporary point to point	43.5	15.5	3.5	-24.5	-36.5	122

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.23 Scenario 4. PMSE ACS = 46 dB, PMSE interference level = +10 dB improvement; interference into an adjacent PMSE channel (i.e. 2495MHz).

If the PMSE interference level for the link is considered to be able to tolerate a 10 dB additional interference (i.e., assuming an interference power of -97dBm instead of -107dBm at the input of the receiver), then the coupling results based on a revised PMSE receiver ACS figure of 46 dB are as follows below.

Table 66: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 1st adjacent PMSE channel (7.5MHz separation). PMSE ACS of 46 dB + 10 dB increase in PMSE interference level

Interference Path		Additional Isolation or Margin at 7.5MHz offset between carriers (dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	34.7	6.7	-5.3	-33.3	-45.3	74
TDD Base Station	Portable/Mobile links	42.7	14.7	2.7	-25.3	-37.3	117
TDD Base Station	Airborne links	53.2	39.2	33.2	19.2	13.2	Note 1
TDD Base Station	Temporary point to point	54.7	26.7	14.7	-13.3	-25.3	233
TDD Fixed Sub	Radio Camera 1W	20.8	-7.1	-19.2	-47.1	-59.2	33
TDD Fixed Sub	Portable/Mobile links	28.8	0.9	-11.2	-39.1	-51.2	53
TDD Fixed Sub	Airborne links	39.4	25.4	19.4	5.4	-0.6	Note 1
TDD Fixed Sub	Temporary point to point	40.8	12.9	0.8	-27.1	-39.2	105
TDD Mobile	Radio Camera 1W	15.4	-12.6	-24.6	-52.6	-64.6	24
TDD Mobile	Portable/Mobile links	23.4	-4.6	-16.6	-44.6	-56.6	38
TDD Mobile	Airborne links	33.9	19.9	13.9	-0.1	-6.1	Note 1
TDD Mobile	Temporary point to point	35.4	7.4	-4.6	-32.6	-44.6	77
FDD Mobile	Radio Camera 1W	13.7	-14.3	-26.3	-54.3	-66.3	22
FDD Mobile	Portable/Mobile links	21.7	-6.3	-18.3	-46.3	-58.3	35
FDD Mobile	Airborne links	32.2	18.3	12.2	-1.7	-7.8	Note 1
FDD Mobile	Temporary point to point	33.7	5.7	-6.3	-34.3	-46.3	70

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.24 It is noted a 10 dB increase in the tolerable interference level can arise from either an increase in PMSE received signal power of 10 dB or from a different target C/N requirement , or a higher system interference threshold consideration, or a combination of these factors.

The 10 dB increase in receiver signal power can arise from use of more directional receive antenna and/or not operating at the edge of coverage.

While a 10dB increase in the interference threshold can arise from a different target C/N and system noise attribution as follows: if a 25% allowance of system noise for interference can be considered instead of 10% (estimated as basis of -107dBm limit), this will result in a 4 dB increase in the interference threshold. While if a lower target C/N is selected, e.g. QPSK or 16QAM modulation use instead of 64QAM (see Table 1 of the ERA report), this will allow a 6 dB increase the link margin. A combination of two above factors will equate to a 10 dB increase in the interference allowance.

A8.25 <u>Scenario 5. PMSE ACS = 46 dB, mitigation filter = +11 dB, PMSE level = +10 dB improvement; interference into an adjacent PMSE channel (i.e. centred at 2945MHz).</u>

This scenario considers use of a suitable pass band filter (increasing the PMSE ACS by a minimum of 11 dB) and a 10dB increase in the interference level, over the baseline results presented in Scenario 2.

Table 67: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 1st adjacent PMSE channel (7.5MHz separation). PMSE ACS of 46 dB + 11 dB mitigation filter + 10 dB increase in PMSE interference level

Interference Path		Additional Isolation or Margin at 7.5MHz offset between carriers (dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	27.6	-0.3	-12.4	-40.3	-52.4	49
TDD Base Station	Portable/Mobile links	35.6	7.7	-4.4	-32.3	-44.4	78
TDD Base Station	Airborne links	46.2	32.2	26.2	12.2	6.2	Note 1
TDD Base Station	Temporary point to point	47.6	19.7	7.6	-20.3	-32.4	155
TDD Fixed Sub	Radio Camera 1W	20.3	-7.7	-19.7	-47.7	-59.7	32
TDD Fixed Sub	Portable/Mobile links	28.3	0.3	-11.7	-39.7	-51.7	51
TDD Fixed Sub	Airborne links	38.8	24.8	18.8	4.8	-1.2	Note 1
TDD Fixed Sub	Temporary point to point	40.3	12.3	0.3	-27.7	-39.7	102
TDD Mobile	Radio Camera 1W	15.1	-12.8	-24.9	-52.8	-64.9	24
TDD Mobile	Portable/Mobile links	23.1	-4.8	-16.9	-44.8	-56.9	38
TDD Mobile	Airborne links	33.7	19.7	13.7	-0.3	-6.3	Note 1
TDD Mobile	Temporary point to point	35.1	7.2	-4.9	-32.8	-44.9	76
FDD Mobile	Radio Camera 1W	13.5	-14.5	-26.5	-54.5	-66.5	22
FDD Mobile	Portable/Mobile links	21.5	-6.5	-18.5	-46.5	-58.5	34
FDD Mobile	Airborne links	32.0	18.0	12.0	-2.0	-8.0	Note 1
FDD Mobile	Temporary point to point	33.5	5.5	-6.5	-34.5	-46.5	69

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.26 Scenario 6. PMSE ACS = 61 dB; interference into a second adjacent PMSE channel (i.e. centred at 2485MHz).

This scenario estimates the interference into a 2nd adjacent PMSE channel at 2485MHz, from interference at 2502.5MHz, i.e., 17.5MHz offset.

From the ERA results, the PMSE receiver ACS for 17.5MHz separation between PMSE and UMTS carrier centre frequencies is estimated to be around 61 dB (without use of mitigation filter). It is noted that the value is lower than the corresponding ACS value for an FDD base-station of 66dB assumed by Mason.

The revised analysis for interference into the 2480 - 2490MHz PMSE channel, through use of a PMSE ACS of 61 dB and transmitter ALCR values of 17.5MHz separation, from the baseline results presented in Scenario 2 is as follows.

Table 68: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 2nd adjacent PMSE channel (17.5MHz separation). PMSE ACS = 61 dB. Transmitter out-of-band emissions (ACLR @ 17.5MHz.

Interference Path		Additional Isolation or Margin at 17.5MHz offset between carriers(dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	29.6	1.6	-10.4	-38.4	-50.4	55
TDD Base Station	Portable/Mobile links	37.6	9.6	-2.4	-30.4	-42.4	87
TDD Base Station	Airborne links	48.1	34.1	28.1	14.1	8.1	Note 1
TDD Base Station	Temporary point to point	49.6	21.6	9.6	-18.4	-30.4	174
TDD Fixed Sub	Radio Camera 1W	14.8	-13.2	-25.2	-53.2	-65.2	23
TDD Fixed Sub	Portable/Mobile links	22.8	-5.2	-17.2	-45.2	-57.2	37
TDD Fixed Sub	Airborne links	33.3	19.3	13.3	-0.7	-6.7	Note 1
TDD Fixed Sub	Temporary point to point	34.8	6.8	-5.2	-33.2	-45.2	74
TDD Mobile	Radio Camera 1W	5.8	-22.2	-34.2	-62.2	-74.2	14
TDD Mobile	Portable/Mobile links	13.8	-14.2	-26.2	-54.2	-66.2	22
TDD Mobile	Airborne links	24.3	10.3	4.3	-9.7	-15.7	Note 1
TDD Mobile	Temporary point to point	25.8	-2.2	-14.2	-42.2	-54.2	44
FDD Mobile	Radio Camera 1W	1.1	-26.9	-38.9	-66.9	-78.9	11
FDD Mobile	Portable/Mobile links	9.1	-18.9	-30.9	-58.9	-70.9	17
FDD Mobile	Airborne links	19.6	5.7	-0.4	-14.3	-20.4	Note 1
FDD Mobile	Temporary point to point	21.1	-6.9	-18.9	-46.9	-58.9	34

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.27 Scenario 7. PMSE ACS = 61 dB, relaxed mitigation filter = 30 dB; interference into a second adjacent PMSE channel (i.e. centred at 2485MHz).

This scenario estimates interference into the 2480 - 2490MHz channel with use of a pass band filter for that channel. A relaxed performance for the filter can be considered as adjacent channel interference is not the dominate interference mechanism within the calculation.

The revised analysis through use of a PMSE ACS of 61 dB, transmitter ALCR values of 17.5MHz separation and relaxed pass band filter of 30 dB filter, from the baseline results presented in Scenario 2 is as follows.

Table 69: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 2nd adjacent PMSE channel (17.5MHz separation). PMSE ACS of 61 dB, + relaxed PMSE mitigation filter of 30 dB (ACS = 91 dB), Transmitter out-of-band emissions (ACLR) @ 17.5MHz

Interference Path		Additional Isolation or Margin at 17.5MHz offset between carriers(dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	20.1	-7.9	-19.9	-47.9	-59.9	32
TDD Base Station	Portable/Mobile links	28.1	0.1	-11.9	-39.9	-51.9	50
TDD Base Station	Airborne links	38.6	24.7	18.6	4.7	-1.4	Note 1
TDD Base Station	Temporary point to point	40.1	12.1	0.1	-27.9	-39.9	101
TDD Fixed Sub	Radio Camera 1W	14.0	-14.0	-26.0	-54.0	-66.0	22
TDD Fixed Sub	Portable/Mobile links	22.0	-6.0	-18.0	-46.0	-58.0	35
TDD Fixed Sub	Airborne links	32.5	18.5	12.5	-1.5	-7.5	Note 1
TDD Fixed Sub	Temporary point to point	34.0	6.0	-6.0	-34.0	-46.0	71
TDD Mobile	Radio Camera 1W	5.0	-23.0	-35.0	-63.0	-75.0	13
TDD Mobile	Portable/Mobile links	13.0	-15.0	-27.0	-55.0	-67.0	21
TDD Mobile	Airborne links	23.5	9.5	3.5	-10.5	-16.5	Note 1
TDD Mobile	Temporary point to point	25.0	-3.0	-15.0	-43.0	-55.0	42
FDD Mobile	Radio Camera 1W	-0.5	-28.5	-40.5	-68.5	-80.5	10
FDD Mobile	Portable/Mobile links	7.5	-20.5	-32.5	-60.5	-72.5	15
FDD Mobile	Airborne links	18.0	4.0	-2.0	-16.0	-22.0	Note 1
FDD Mobile	Temporary point to point	19.5	-8.5	-20.5	-48.5	-60.5	31

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.28 Scenario 8. PMSE ACS = 61 dB, PMSE interference level = +10 dB improvement; interference into a second adjacent PMSE channel (i.e. centred at 2485MHz).

This scenario presents interference analysis into the 2480 - 2490MHz channel with +10 dB increase in interference level.

The revised analysis through use of a PMSE ACS of 61 dB, transmitter ALCR values of 17.5MHz separation and PMSE interference level at -97 dB, from the baseline results presented in Scenario 2 is as follows.

Table 70: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 2nd adjacent PMSE channel (17.5MHz separation). PMSE ACS of 61 dB, + 10 dB increase in PMSE interference level, Transmitter out-of-band emissions (ACLR) @ 17.5MHz

Interference Path		Additional Isolation or Margin at 17.5MHz offset between carriers(dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	19.6	-8.4	-20.4	-48.4	-60.4	31
TDD Base Station	Portable/Mobile links	27.6	-0.4	-12.4	-40.4	-52.4	49
TDD Base Station	Airborne links	38.1	24.1	18.1	4.1	-1.9	Note 1
TDD Base Station	Temporary point to point	39.6	11.6	-0.4	-28.4	-40.4	98
TDD Fixed Sub	Radio Camera 1W	4.8	-23.2	-35.2	-63.2	-75.2	13
TDD Fixed Sub	Portable/Mobile links	12.8	-15.2	-27.2	-55.2	-67.2	21
TDD Fixed Sub	Airborne links	23.3	9.3	3.3	-10.7	-16.7	Note 1
TDD Fixed Sub	Temporary point to point	24.8	-3.2	-15.2	-43.2	-55.2	42
TDD Mobile	Radio Camera 1W	-4.2	-32.2	-44.2	-72.2	-84.2	8
TDD Mobile	Portable/Mobile links	3.8	-24.2	-36.2	-64.2	-76.2	12
TDD Mobile	Airborne links	14.3	0.3	-5.7	-19.7	-25.7	Note 1
TDD Mobile	Temporary point to point	15.8	-12.2	-24.2	-52.2	-64.2	25
FDD Mobile	Radio Camera 1W	-8.9	-36.9	-48.9	-76.9	-88.9	6
FDD Mobile	Portable/Mobile links	-0.9	-28.9	-40.9	-68.9	-80.9	9
FDD Mobile	Airborne links	9.6	-4.3	-10.4	-24.3	-30.4	Note 1
FDD Mobile	Temporary point to point	11.1	-16.9	-28.9	-56.9	-68.9	19

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

A8.29 Scenario 9. PMSE ACS = 61 dB, relaxed mitigation filter = 30 dB, PMSE interference level = +10 dB improvement; interference into a second adjacent PMSE channel (i.e. centred at 2485MHz).

This scenario presents interference analysis into the 2480 - 2490MHz channel with pass band filter and +10 dB increase in interference level.

The revised analysis through use of a PMSE ACS of 61 dB, transmitter ALCR values of 17.5MHz separation, relaxed pass band filter of +30dB rejection and PMSE interference level at -97 dB, from the baseline results presented in Scenario 2 is as follows.

Table 71: Additional coupling loss or margin to meet PMSE interference criterion. Estimated unwanted emissions in 2nd adjacent PMSE channel (17.5MHz separation). PMSE ACS of 61 dB, + relaxed PMSE mitigation filter of 30 dB , + 10 dB increase in PMSE interference level, + Transmitter out-of-band emissions (ACLR) @ 17.5MHz

Interference Path		Additional Isolation or Margin at 17.5MHz offset between carriers(dB)					Indicative Separation distance ITU-R M1225 (m)
Interferer	Victim	10	50	100	500	1000	
TDD Base Station	Radio Camera 1W	10.1	-17.9	-29.9	-57.9	-69.9	18
TDD Base Station	Portable/Mobile links	18.1	-9.9	-21.9	-49.9	-61.9	28
TDD Base Station	Airborne links	28.6	14.7	8.6	-5.3	-11.4	Note 1
TDD Base Station	Temporary point to point	30.1	2.1	-9.9	-37.9	-49.9	57
TDD Fixed Sub	Radio Camera 1W	4.0	-24.0	-36.0	-64.0	-76.0	13
TDD Fixed Sub	Portable/Mobile links	12.0	-16.0	-28.0	-56.0	-68.0	20
TDD Fixed Sub	Airborne links	22.5	8.5	2.5	-11.5	-17.5	Note 1
TDD Fixed Sub	Temporary point to point	24.0	-4.0	-16.0	-44.0	-56.0	40
TDD Mobile	Radio Camera 1W	-5.0	-33.0	-45.0	-73.0	-85.0	7
TDD Mobile	Portable/Mobile links	3.0	-25.0	-37.0	-65.0	-77.0	12
TDD Mobile	Airborne links	13.5	-0.5	-6.5	-20.5	-26.5	Note 1
TDD Mobile	Temporary point to point	15.0	-13.0	-25.0	-53.0	-65.0	24
FDD Mobile	Radio Camera 1W	-10.5	-38.5	-50.5	-78.5	-90.5	5
FDD Mobile	Portable/Mobile links	-2.5	-30.5	-42.5	-70.5	-82.5	Note 1
FDD Mobile	Airborne links	8.0	-6.0	-12.0	-26.0	-32.0	9
FDD Mobile	Temporary point to point	9.5	-18.5	-30.5	-58.5	-70.5	17

Note 1: Calculation does not account for typical pattern losses between base station and airborne PMSE receivers, as considered further in the Engineering Study Phase 2 Report.

Annex 9

Emissions from Aeronautical Radionavigation and Radiolocation at 2700-2900MHz

A9.1 In the December Consultation, Ofcom provided information about the use of civil radars in the band 2700-2900MHz. This Annex provides information about military radars which also operate in this band.

In-band PFD

A9.2 Table 72 below contains the general transmission and operational parameters of 'S-band' aeronautical primary surveillance radar that are considered to be in use within the UK. The table has been directly replicated from Table 3.1.2-3 of the Alenia Marconi Systems Limited report for Ofcom[136]. The table was compiled for civil ATC (airport approach) usage, but the parameters can also be considered as representative of military ATC surveillance radars.

[136] See http://www.ofcom.org.uk/static/archive/ra/topics/research/topics/s-studies/civil-radio-systems.pdf

Table 72: Typical system parameters for ground based radars operating in the 2700-2900MHz band

TYPICAL CHARACTERISTICS	Solid State	TWT	Magnetron
Tuning range (GHz)	2.7 to 2.9	2.7 to 3.1	2.7 to 2.9
Operational Frequencies Used	4	2 or 4	1 or 2
Frequency Accuracy	≈ 50 kHz	≈ 50 kHz	≈ 10MHz
Frequency Stability	≈ 25 kHz	≈ 25 kHz	≈ 20MHz
Modulation	Un-modulated Pulse / Non-linear FM	Un-modulated Pulse / Non-linear FM	Un-modulated Pulse
Transmitter Power into Antenna (kW)	15 or 30	75	625
Pulse width (μs)	1 & 100	0.4 & 20	1
Pulse rise/Fall time (μs)	0.169	0.08	0.06
Pulse repetition rate (Hz)	825	1100	700
Duty cycle (%)	8.25	2.75	0.7
Chirp bandwidthMHz	1	0 & 2.5	0
Compression ratio	100:1	50:1	NA
RF emission BW (-3 dB)MHz	0.8 & 0.8	2.5 & 2.5	1
RF emission BW (-20 dB)MHz	2 & 1.4	16.8 & 3.6	6.0
RF emission BW (-40 dB)MHz	4 & 2	45 & 10	45
Antenna pattern type	Cosec-squared	Cosec-squared	Cosec-squared
Antenna type	Reflector	Reflector	Reflector
Antenna Horizontal beamwidth -3dB (degrees)	1.4	1.5	1.4
Antenna polarisation	Linear/Circular	Circular	Linear /Circular
Antenna mainbeam gain (dBi)	35	33	32
Antenna Vertical beamwidth -3dB (degrees)	4.5	5	5
Antenna horizontal scan rate (degrees/sec)	90	90	90
Antenna horizontal scan type	360 degrees, Continuous	360 degrees, Continuous	360degrees, Continuous
Antenna side-lobe levels (1st SLs and remote SLs) dB wrt main beam	≈ -26 / -40	≈ -26 / -40	≈ -26 / -40
Antenna height (m) above ground	8 to 15	8 to 15	12

A9.3 Figure 37 shows the area over which the out-of-band (OOB) emissions from military ground based ATC surveillance radar is expected by Ofcom to exceed a field strength of 21 dB(μV/m) into Channel 38 (2685 – 2690MHz). This threshold level equates to a minimum received signal power of -125dBm (which is derived on the basis of an interference level of 110dBm into a base station receiver having a 15dBi gain antenna and located at a height of 15m above local ground). Results are also presented for areas where the field strength threshold level is estimated to exceed 51 dB(μV/m). This higher level has been used to simulate the effect of unwanted interference originating from radar side-lobes, as detailed in the December Ofcom Technical Study. An average figure of -30dB for radar side-lobes relative to the main beam has been assumed.

A9.4 Figure 38 shows the area over which the OOB emissions from military ground-based ATC surveillance radar is expected by Ofcom to exceed a field strength of 40 dB(μV/m). This threshold equates to a minimum received signal power of -106dBm into a mobile station receiver having a 0dBi gain antenna located at a height of

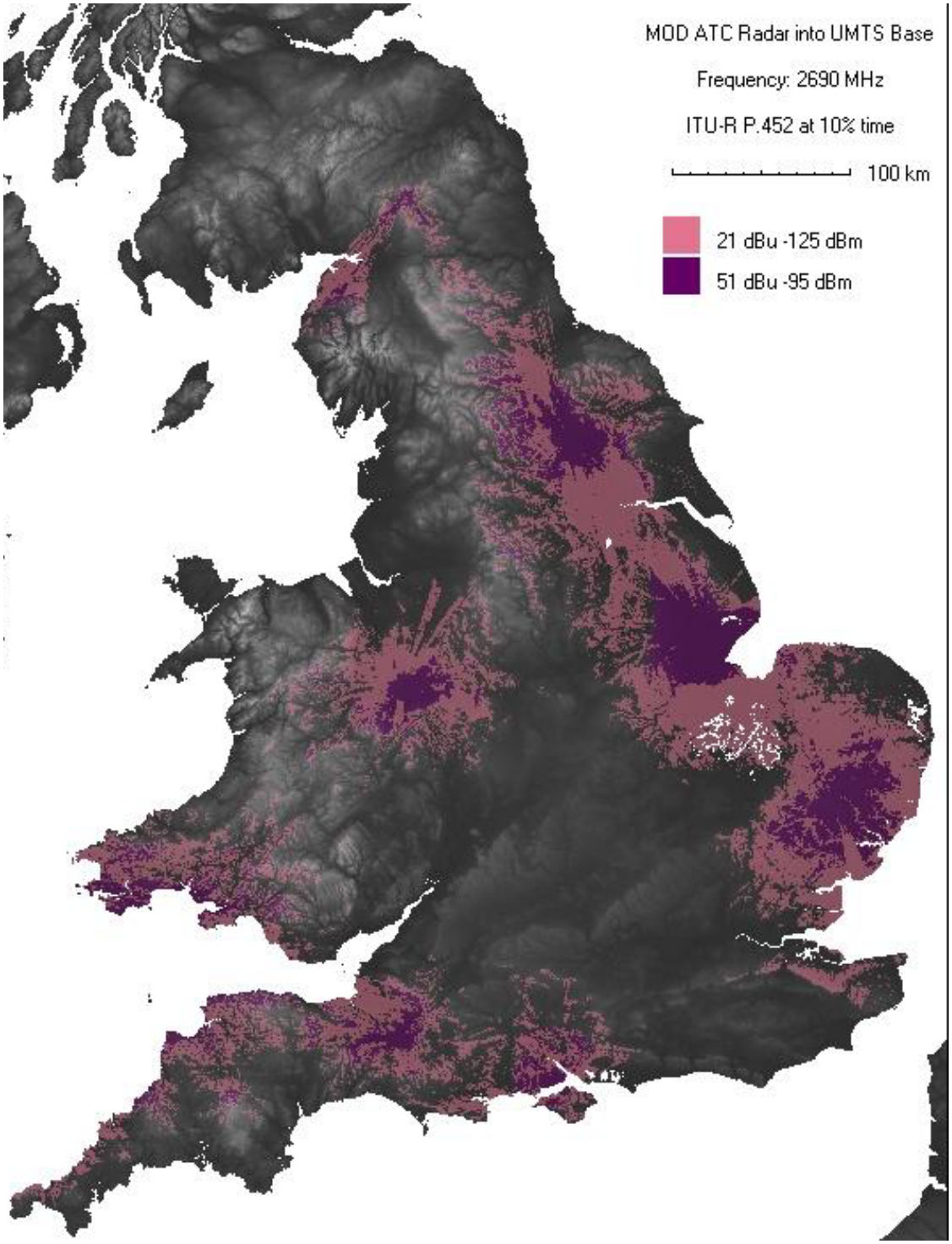
1.5m above local ground. Results are also presented for areas where the field strength threshold level is estimated to exceed 70 dB(μV/m), estimating areas where interference results from radar side-lobes.

A9.5 Figure 39 and Figure 40 indicate similar areas to the above but for estimates of unwanted emissions into Channel 30 (2645 – 2650MHz) instead of Channel 38. Figure 41 and Figure 42 provide an estimate of the unwanted emissions into Channel 22 (2605 – 2610MHz).

A9.6 The coverage maps presented in Figure 37 to Figure 42 are based on certain assumptions made by Ofcom on the location of the MoD ATC radars, their assigned frequencies, the estimated out-of-band emissions and other key RF parameters. Ofcom considers some of these assumptions as conservative (for example, the assumed level of out-of-band emissions from radar transmitters, on the reduction in OOB emissions that will result when the interference originates from the side-lobes compared to the main-beam and on the level of permissible interference that may be tolerated by candidate mobile systems. As such, Ofcom believes these predicted coverage areas may well be viewed as pessimistic (a 'worst case'). Additionally, the predictions do not attempt to capture mitigation to impulsive interference which can be achieved with forward error correction coding and data interleaving schemes employed by candidate mobile systems.

A9.7 For MoD AD radar usage, it has not been possible for Ofcom to provide an accurate assessment of the likely coverage areas estimating interference from MoD AD radar OOB emissions since such radars may operate anywhere in the band 2700 – 3100MHz and from any of the sites identified in Figure 43, or other UK sites subject to operational requirements. The individual frequency assignments, the likely numbers of radars operating simultaneously, their particularly locations and durations are not known to Ofcom. However, it is noted that the frequency assignments are coordinated at the time of deployment amongst the various other MoD AD radars, and also amongst other Civil or MoD ATC radars within certain distances and/or frequencies. Also, MoD AD radars are typically operated on an intermittent basis.

Figure 37: Estimated areas around military ATC Radar where threshold levels identified by Ofcom for base-station usage are likely to be exceeded in Channel 38



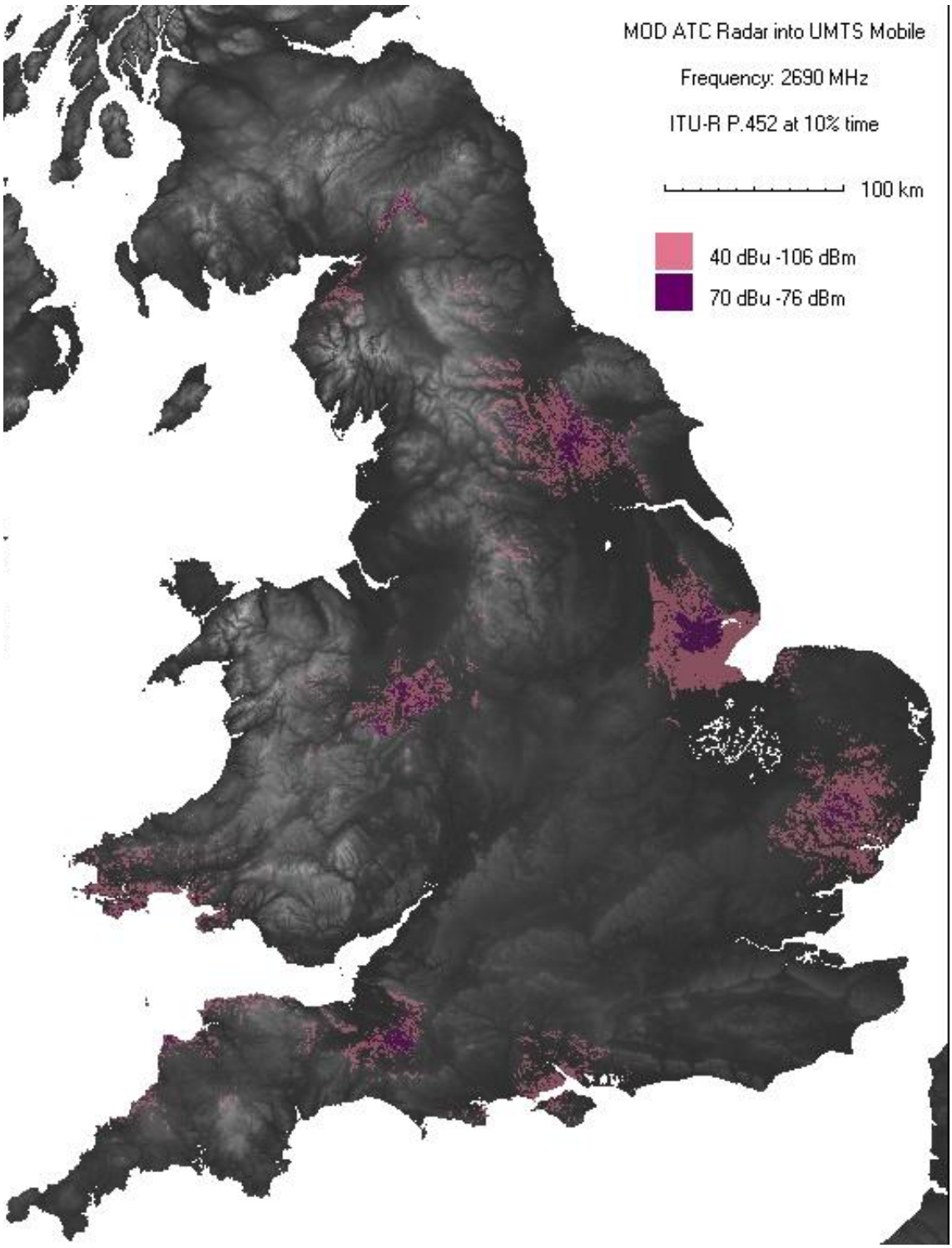
Key:

swept main-beam zone (estimated areas exceeding field strength of 21dB(μV/m))

side-lobe zone (estimated areas exceeding field strength of 51dB(μV/m))

See Figure 44 for the propagation and clutter models employed.

Figure 38: Estimated areas around military ATC Radar where threshold levels identified by Ofcom for mobile-station usage are likely to be exceeded in Channel 38



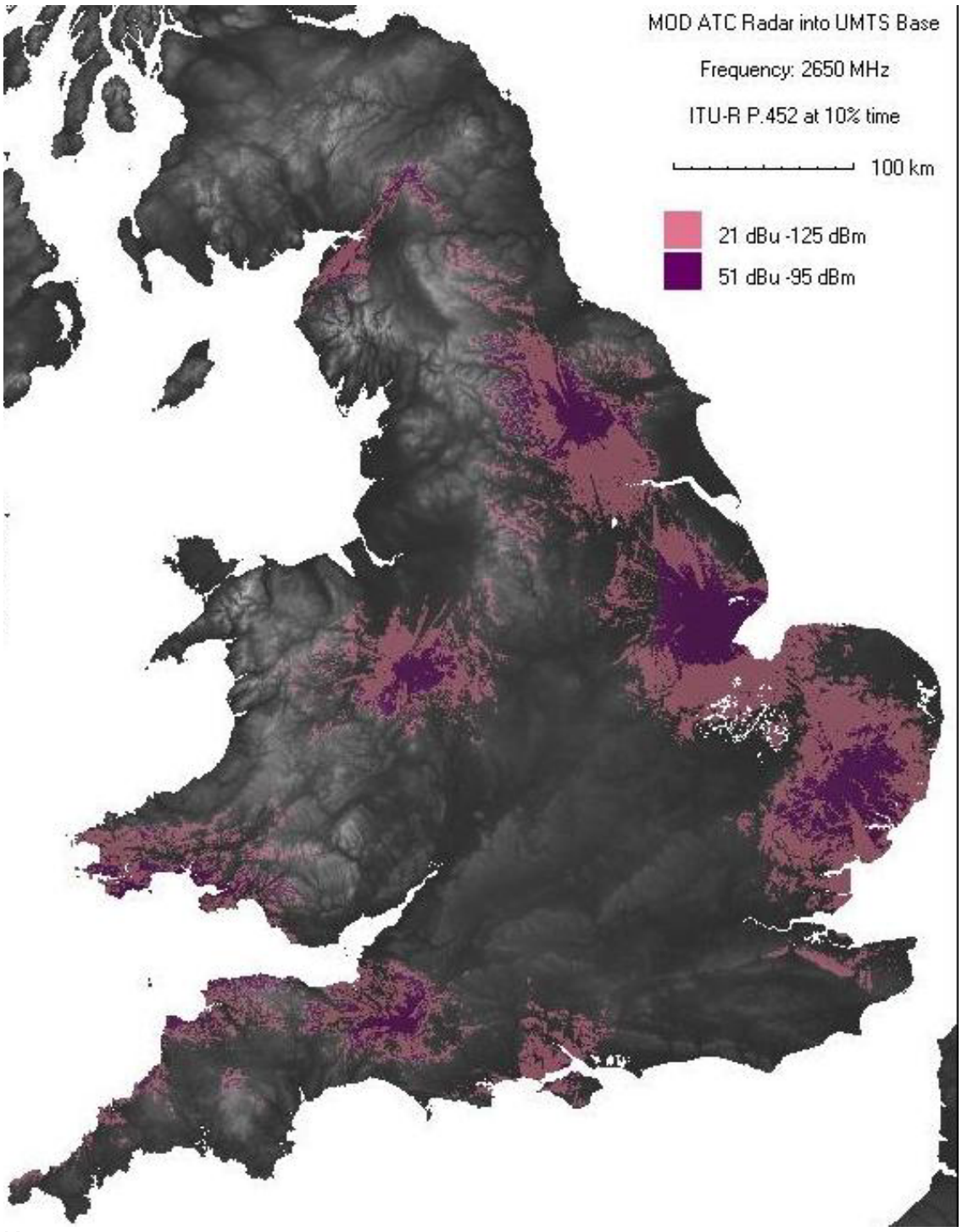
Key:

swept main-beam zone (estimated areas exceeding field strength of 40dB(μV/m))

side-lobe zone (estimated areas exceeding field strength of 70dB(μV/m))

See Figure 44 for the propagation and clutter models employed.

Figure 39: Estimated areas around military ATC Radar where threshold levels identified by Ofcom for base-station usage are likely to be exceeded in Channel 30



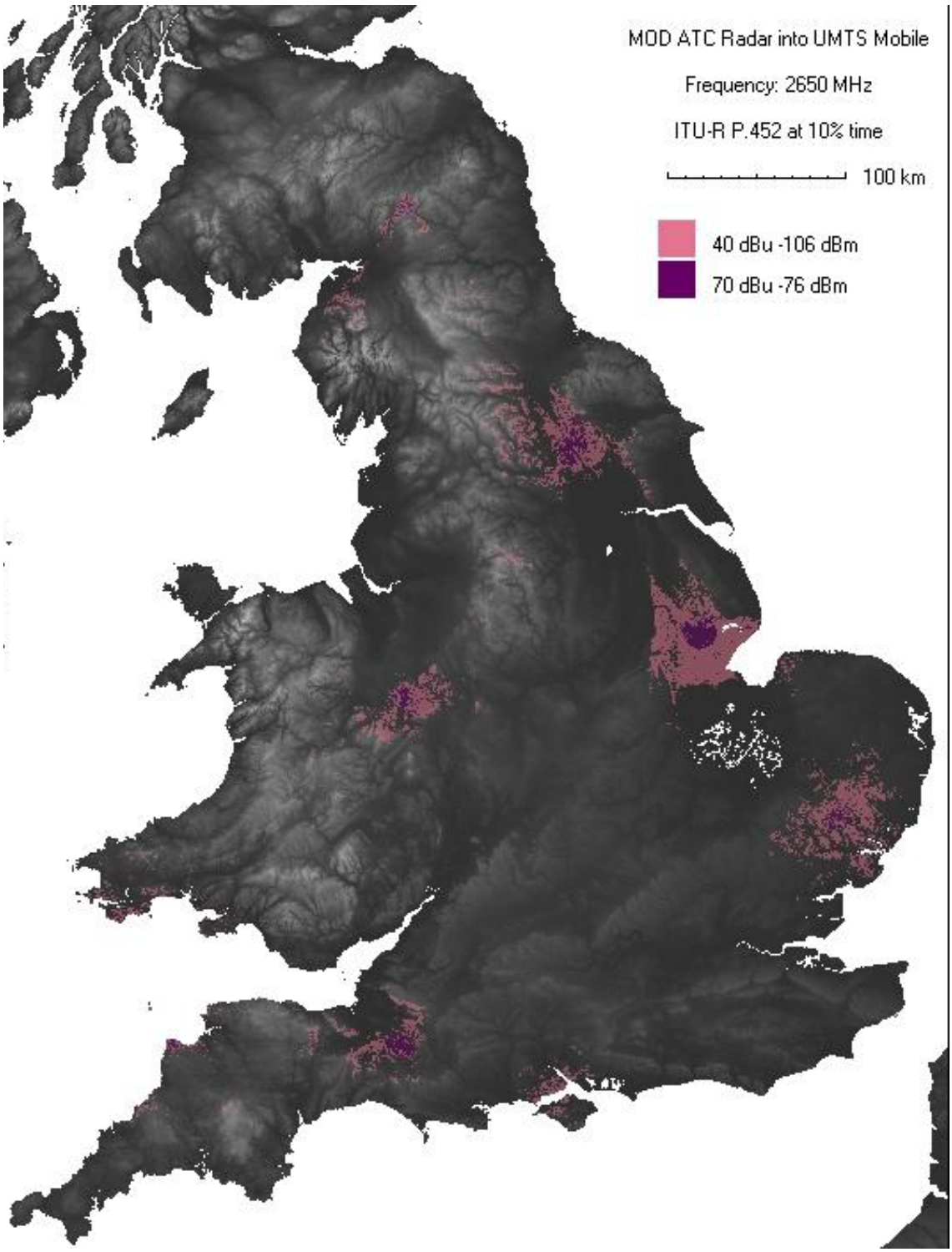
Key:

swept main-beam zone (estimated areas exceeding field strength of 21dB(μV/m))

side-lobe zone (estimated areas exceeding field strength of 51dB(μV/m))

See Figure 44 for the propagation and clutter models employed.

Figure 40: Estimated areas around military ATC Radar where threshold levels identified by Ofcom for mobile-station usage are likely to be exceeded in Channel 30



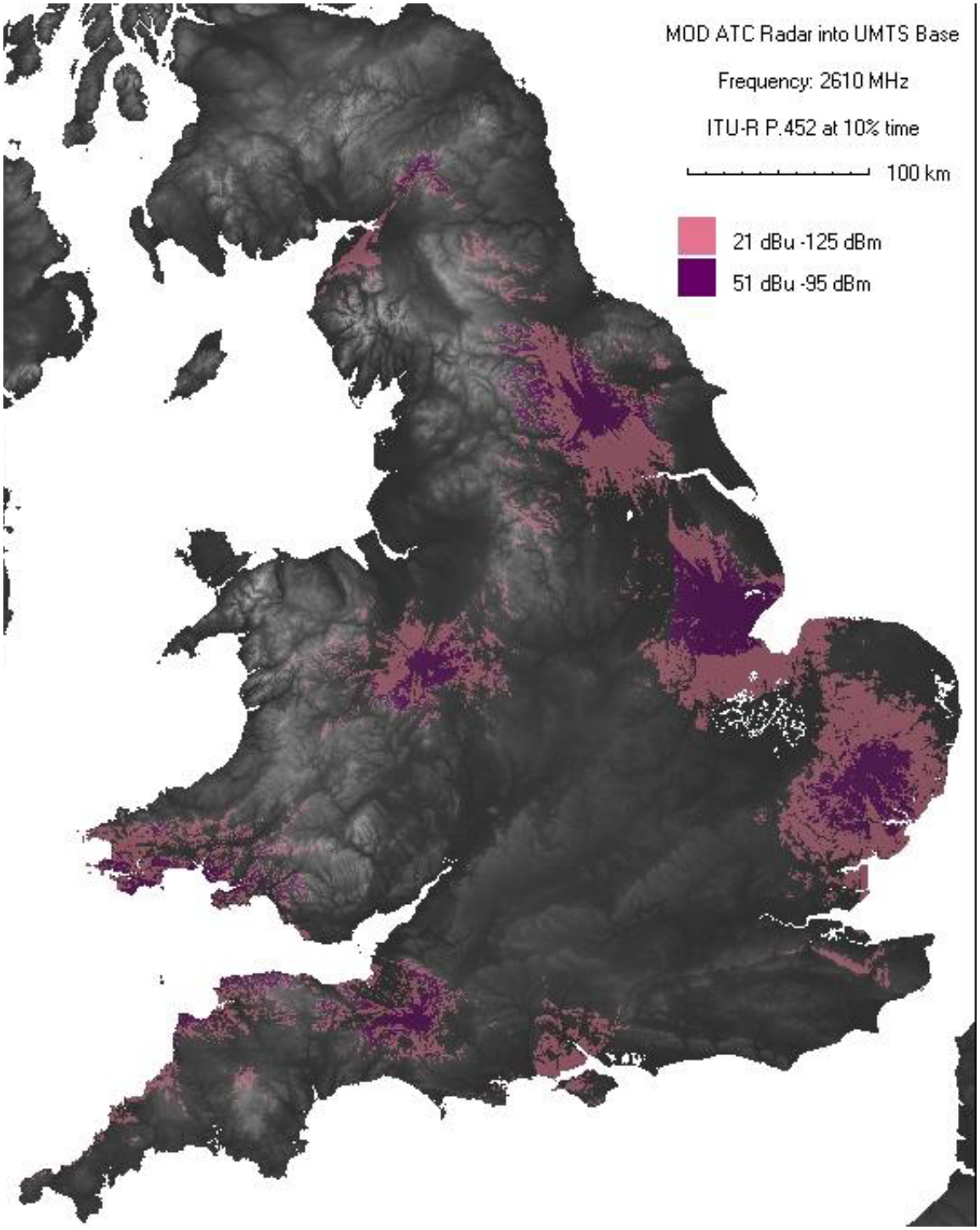
Key:

swept main-beam zone (estimated areas exceeding field strength of 40dB(μV/m))

side-lobe zone (estimated areas exceeding field strength of 70dB(μV/m)).

See Figure 44 for the propagation and clutter models employed.

Figure 41: Estimated areas around military ATC Radar where threshold levels identified by Ofcom for base station usage are likely to be exceeded in Channel 22



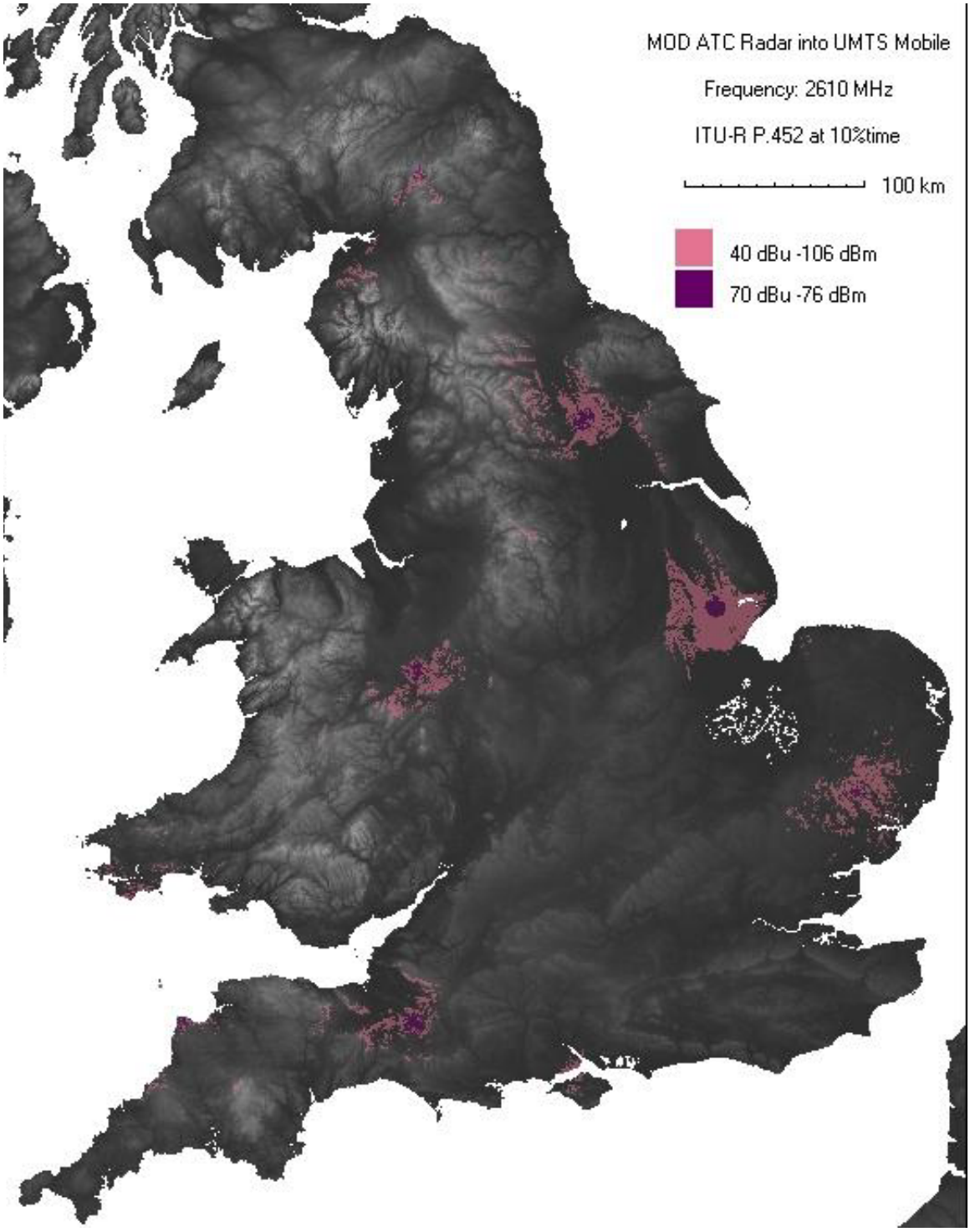
Key:

swept main-beam zone (estimated areas exceeding field strength of 21dB(μV/m))

side-lobe zone (estimated areas exceeding field strength of 51dB(μV/m)).

See Figure 44 for the propagation and clutter models employed.

Figure 42: Estimated areas around military ATC Radar where threshold levels identified by Ofcom for mobile station usage are likely to be exceeded in Channel 22



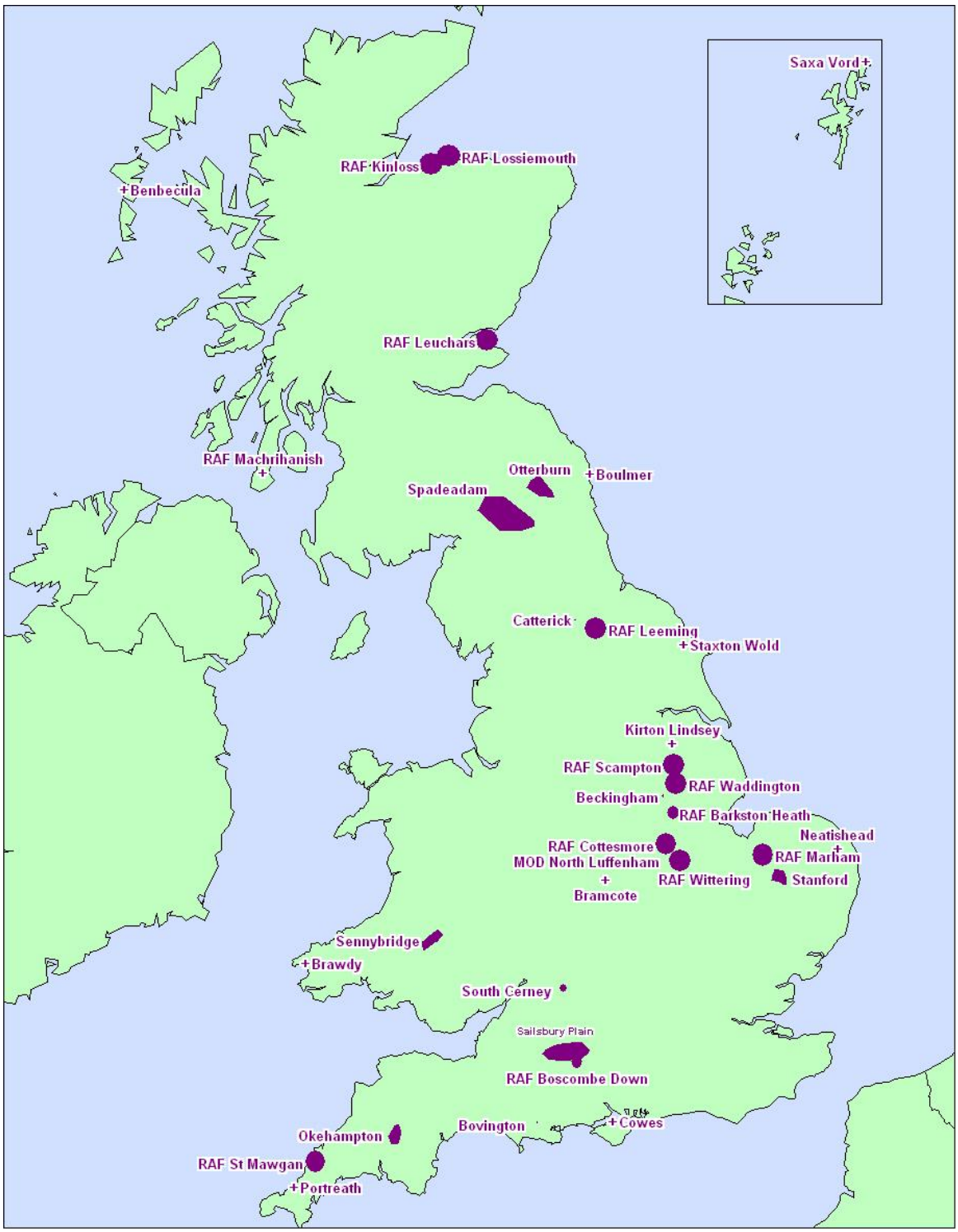
Key:

swept main-beam zone (estimated areas exceeding field strength of 40dB(μV/m))

side-lobe zone (estimated areas exceeding field strength of 70dB(μV/m))

See Figure 44 for the propagation and clutter models employed.

Figure 43: Likely areas[137] where mobile MoD AD Radars may be deployed and where fixed AD radars are currently deployed



[137] These areas are subject to change based on operational requirements.

Parameters used in ICS Telecom modelling

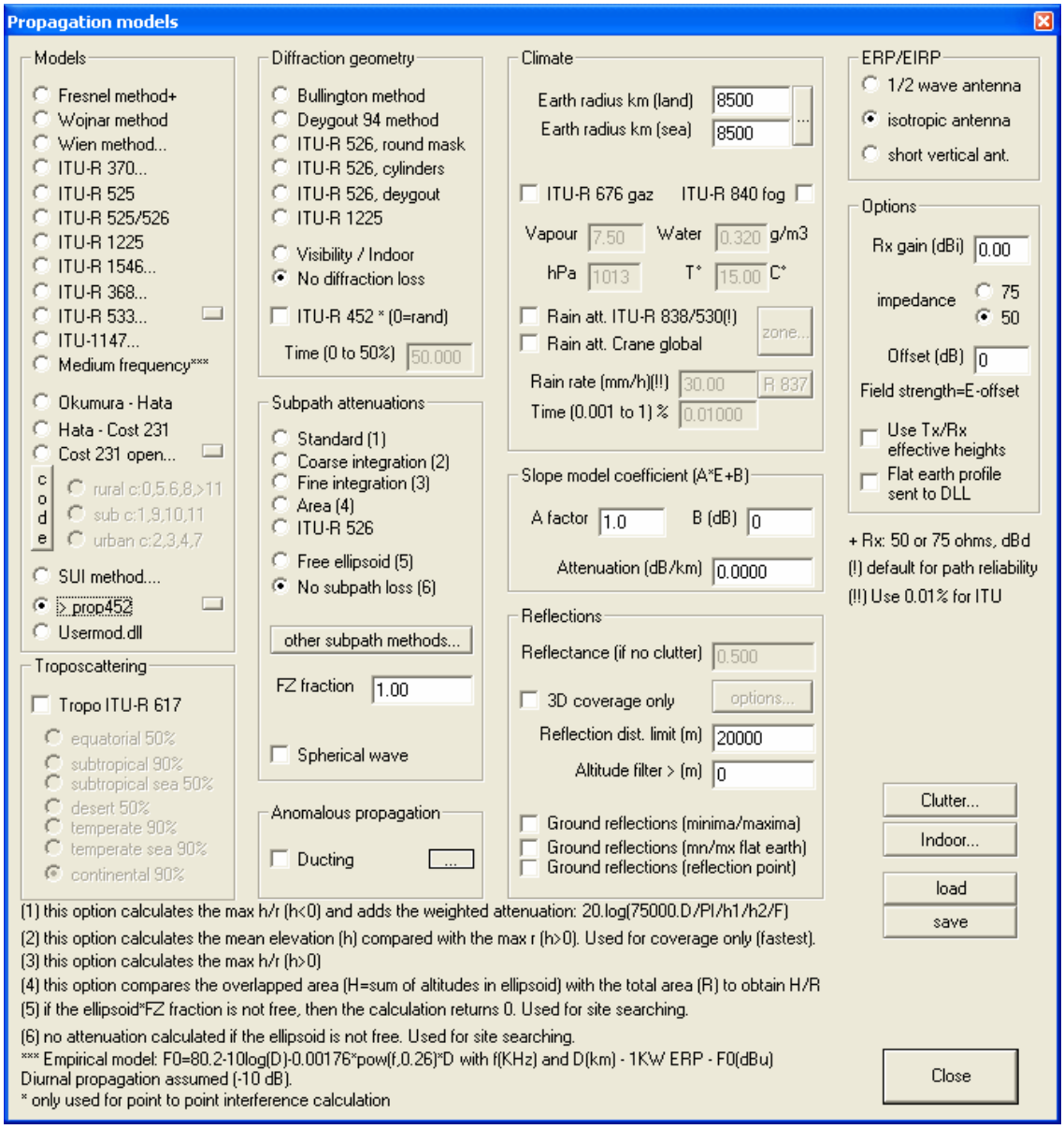
Propagation and clutter models employed in deriving radar OOB emissions coverage plots.

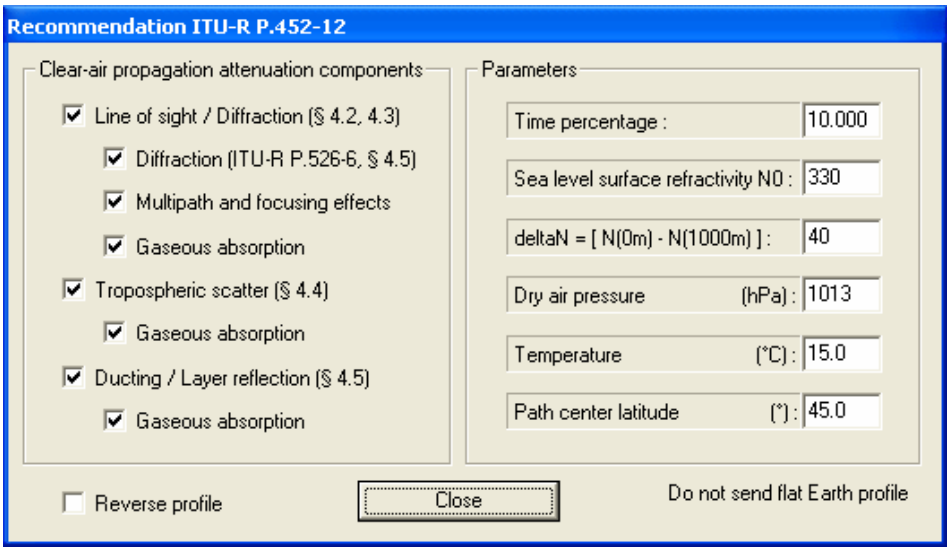
a) Software: ICS Telecom – version 8.2.3 with 200m resolution digital terrain.

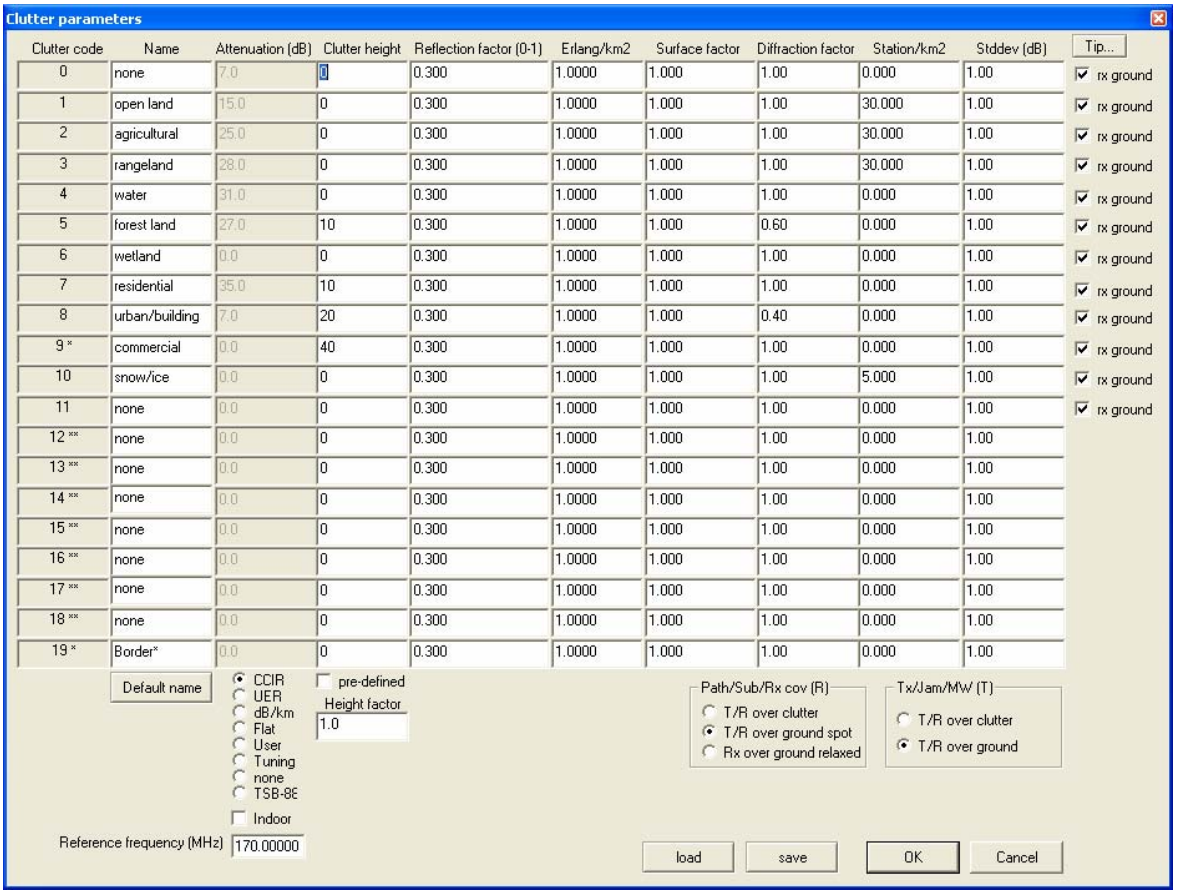
b) Propagation model: ITU-R Rec P 452 @ 10% probability of time, with terrain and clutter enabled.

c) Unless otherwise specified, default ICS Telecom settings were used.

Figure 44: Propagation and clutter models used to estimate MoD ATC interference coverage areas with ICS Telecom




Recommendation ITU-R P.452-12
Clear-air propagation attenuation components
Line of sight / Diffraction (§ 4.2, 4.3)
Diffraction (ITU-R P.526-6, § 4.5)
Multipath and focusing effects
Gaseous absorption
Tropospheric scatter (§ 4.4)
Gaseous absorption
Ducting / Layer reflection (§ 4.5)
Gaseous absorption
Parameters
Time percentage : 10.000
Sea level surface refractivity N0 : 330
deltaN = [N(0m) - N(1000m)] : 40
Dry air pressure (hPa) : 1013
Temperature (°C) : 15.0
Path center latitude (°) : 45.0
Reverse profile
Close
Do not send flat Earth profile


Clutter parameters
Clutter code | Name | Attenuation (dB) | Clutter height | Reflection factor (0-1) | Erlang/km2 | Surface factor | Diffraction factor | Station/km2 | Stddev (dB) | Tip... | rx ground
0 | none | 7.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00 | rx ground
1 | open land | 15.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 30.000 | 1.00 | rx ground
2 | agricultural | 25.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 30.000 | 1.00 | rx ground
3 | rangeland | 28.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 30.000 | 1.00 | rx ground
4 | water | 31.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00 | rx ground
5 | forest land | 27.0 | 10 | 0.300 | 1.0000 | 1.000 | 0.60 | 0.000 | 1.00 | rx ground
6 | wetland | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00 | rx ground
7 | residential | 35.0 | 10 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00 | rx ground
8 | urban/building | 7.0 | 20 | 0.300 | 1.0000 | 1.000 | 0.40 | 0.000 | 1.00 | rx ground
9 * | commercial | 0.0 | 40 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00 | rx ground
10 | snow/ice | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 5.000 | 1.00 | rx ground
11 | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00 | rx ground
12 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
13 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
14 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
15 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
16 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
17 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
18 ** | none | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
19 * | Border* | 0.0 | 0 | 0.300 | 1.0000 | 1.000 | 1.00 | 0.000 | 1.00
Default name
CCIR
UER
dB/km
Flat
User
Tuning
none
TSB-8
pre-defined
Height factor
1.0
Indoor
Reference frequency (MHz) 170.00000
Path/Sub/Rx cov (R)
T/R over clutter
T/R over ground spot
Rx over ground relaxed
Tx/Jam/MW (T)
T/R over clutter
T/R over ground
load
save
OK
Cancel

Annex 10

Co-ordination of services with France and Ireland

A10.1 Where appropriate, Ofcom, acting on behalf of HM Government, negotiates agreements with the Radio Regulatory Authorities of neighbour countries in the form of a Memoranda of Understanding (MoUs) relating to cross-border coordination for the management of interference. These MoUs normally define the signal power, in a specified frequency band, that may be received in a neighbour country from a station in the home country. Stations that exceed the defined power levels are coordinated directly between the administrations on behalf of the operators.

A10.2 MoUs do not give an absolute assurance of no interference into stations close to a border or set an absolute limit on the signal strength that may be received in one administration from a transmitter in another. They specify a trigger level, which is used to initiate a formal coordination procedure so that an administration may have knowledge of, and an opportunity to express concern about, transmitters in a neighbouring country.

A10.3 Where they are available, recommendations published by the European Conference of Postal and Telecommunications (CEPT) typically provide a basis for assessing interference from transmitters in neighbour countries and the negotiation of MoUs by neighbouring European administrations. CEPT Recommendation 01-01[138] in particular gives recommended coordination trigger levels for IMT2000-like services in the 2100 and 2500MHz frequency bands.

A10.4 Ofcom is in the early stages of negotiating cross-border co-ordination agreements with both France and the Republic of Ireland in respect of the Spectrum Bands. Licensees will be required to observe current and any future agreements that Ofcom negotiates with neighbouring countries. Where spectrum users in neighbouring countries are operating within the terms of the cross-border coordination agreements, Ofcom cannot offer any protection from transmissions by licensees in neighbouring countries to a UK licensee operating in border areas.

A10.5 In the absence of an MoU, the process defined by the ITU for registering transmitters in a neighbouring country would apply in accordance with articles 9 and 11 of the ITU Radio Regulations

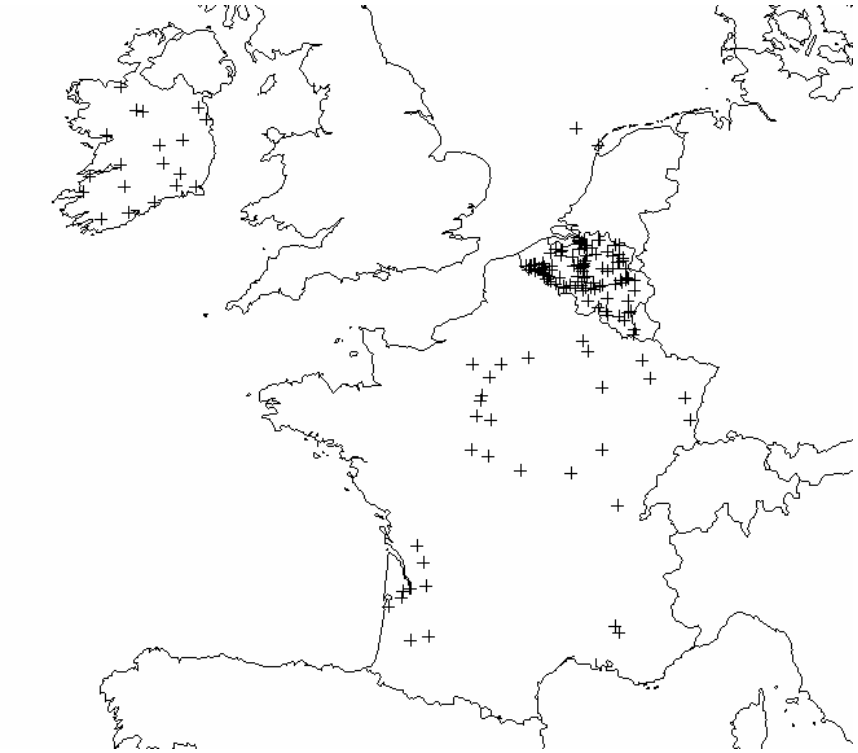
A10.6 It should be noted that a number of transmitter assignments in the frequency band 2500-2690MHz already exist in neighbouring countries. These assignments and their technical characteristics have been notified under Article 11 of the Radio Regulations by their respective country's administrations, with the International Telecommunications Union (ITU). This records the assignments in the terrestrial section of the International Master Frequency Register to obtain international recognition and protection from harmful interference. The Master Register is maintained by the Radiocommunications Bureau of the ITU. Information about the BRIFIC may be found on the ITU website at http://www.itu.int/ITU-

[138] ERC Recommendation 01-01. Border coordination of UMTS, available at http://www.ero.dk/documentation/docs/docfiles.asp?docid=1587&wd=N.

R/publications/brific-ter/index.html and the register is available from the ITU at http://www.itu.int/pub/R-SP-LN.IT-2007.

The figure below shows the location of these entries in the frequency register.

Figure 45: Location of entries in the 2.6GHz band in the ITU frequency register



France

A10.7 In France, the 2.6GHz band is used mainly by the Gendarmerie Nationale (part of the French MoD) for fixed and tactical (point-to-point) radio.

A10.8 ANFR has advised Ofcom that:

a) According to ANFR's assessment, there are 40 fixed links near to the coast whose performance may be adversely affected by UMTS like services in the UK as well as an indeterminate number of tactical radio relay links.

b) ANFR do not expect the use of the 2.6GHz band to change in France from fixed and tactical links to mobile uses (e.g. IMT-2000) until after 2010.

c) When they licence the 2.6GHz band for new uses, France plan to seek protection of services in France (and trigger levels for co-ordination) in accordance with the CEPT channel plan in ECC Decision (05)05[139] and CEPT Rec. 01-01

A10.9 The lower portion of the band (2500-2570MHz) is designated in ECC Decision (05)05 for uplink as part of FDD use, i.e. for mobile User Equipment (UE)

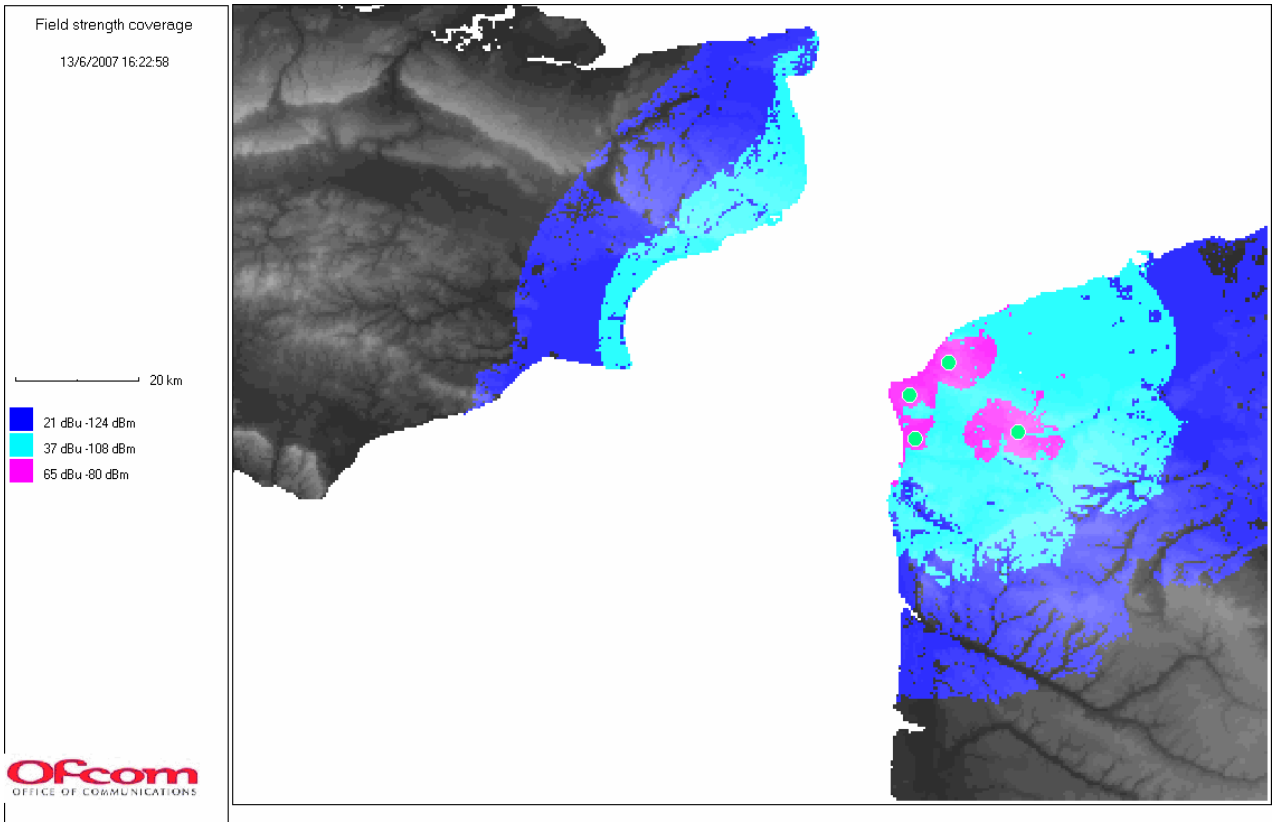
[139] See ECC decision of 18 March 2005 on harmonised utilisation of spectrum for IMT-2000 UMTS systems operating within the band 2500-2690MHz, ECC/DEC/(05)05, available at http://www.ero.dk/documentation/docs/docfiles.asp?docid=2056&wd=N.

transmission and base station reception. Such uplink frequencies are generally not subject to international coordination because the power of a UE is relatively low and administrations have no control over the location of mobile UEs used by network customers. However, given the flexibility in terms of relative amounts of spectrum for paired and unpaired use in the award proposed by Ofcom, there may be base stations transmitters operating within the range 2500-2570MHz at relatively high powers and at fixed locations in the UK in future. In its discussions with ANFR on a MoU for the 2.6GHz band, Ofcom plans to include provisions for a trigger level appropriate for the protection of base station receivers in France which may operate in the range 2500-2570MHz, depending on the outcome of the award of the 2.6GHz band in the UK.

A10.10 The upper portion of the band (2620-2670MHz) is designated in ECC Decision (05)05 for downlink as part of FDD use, i.e. for base station transmission and mobile UE reception. Figure 46 below shows the regions in the UK where certain levels of emissions may be expected to be exceeded due to the operation of UMTS base stations in France; assuming a representative cluster of four stations in France with: 1000W[140] EIRP, 20m high, average propagation to Rec 1546, 50% of time and a 3m receiver in the UK, as described for coordination in CEPT Rec. 01-01. We also used the recommended coordination trigger levels for FDD systems (65dBuv/m), for TDD systems (37dBuv/m, also applicable for FDD systems at 6km inland) and for TDD systems not using preferential codes (21dBuv/m).

[140] Average power for UMTS transmitters recorded on the UK Sitefinder database (see http://www.sitefinder.ofcom.org.uk/) + one standard deviation of the powers

Figure 46: Area of the UK may be impacted by interference from base stations in France



A10.11 The field strengths in Figure 46 give an indication of the UK regions in which UK users of the 2.6GHz band may be impacted by interference from base stations in France. The field strengths can be compared to the standard thermal noise level of -204dBw/Hz. For practical purposes we estimate that the 37dBuv/m contour, broadly equivalent to the standard thermal noise floor (as illustrated in Table 73 below), is likely to represent the region where interference from a mature UMTS like network in France may have an impact on UK services.

Table 73: Relationship between field strength, power received by an isotropic antenna and thermal noise level

Relationship between Field strength and power received by an isotropic antenna

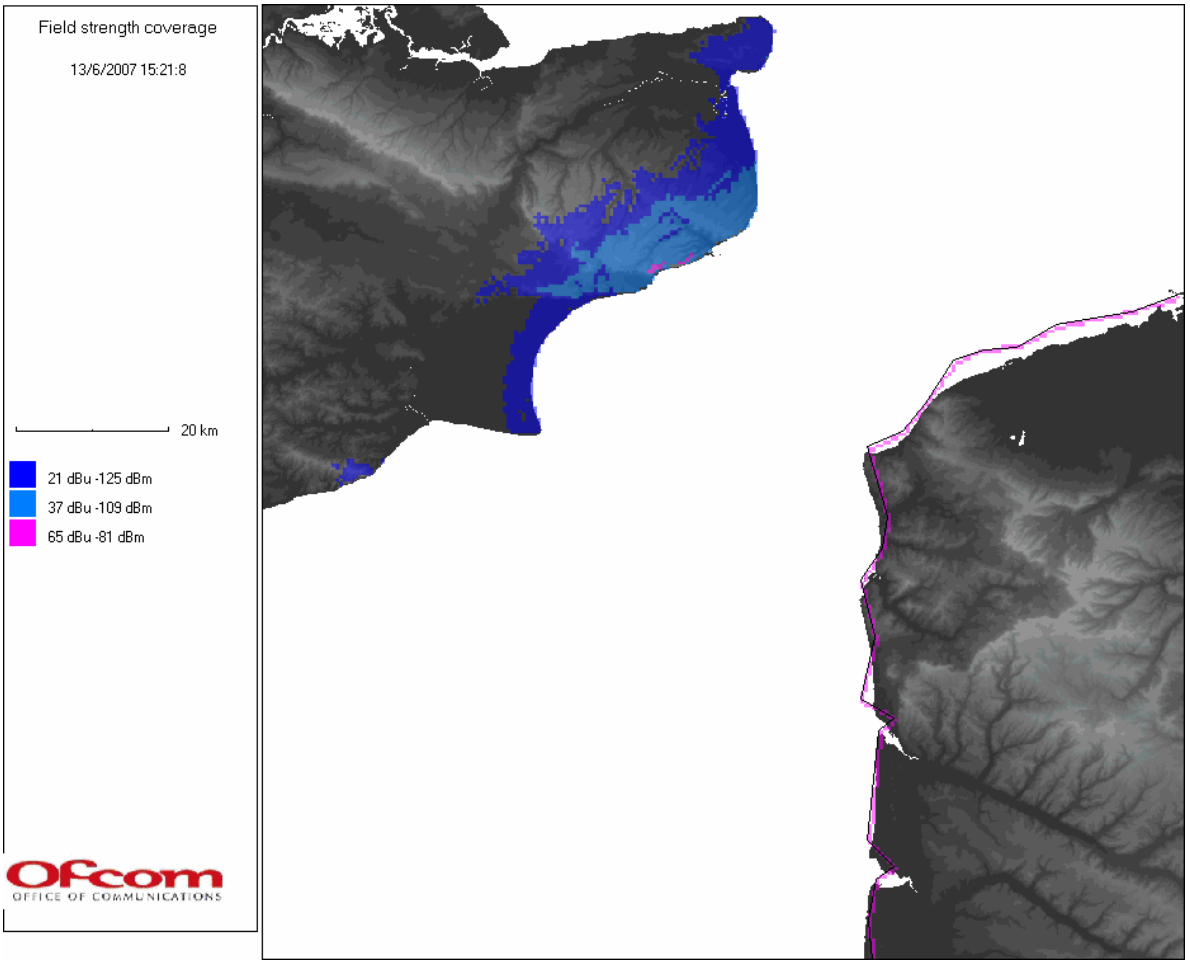
Field Strength (dBuv/m/5MHz)	*Equivalent power received by an isotropic antenna (dBW/Hz)*	*Comment*
65	-177.6	
37	-205.6	Broadly equivalent to thermal noise level of -204 dBW/Hz
21	-221.6	Broadly equivalent to thermal noise level of -204 dBW/Hz for an 16dBi gain receive antenna

A10.12 For example from paragraph 4.2.1, scenario 1, presented in the Ofcom Technical Study [141] we can estimate that, if base station receivers are planned in the UK for the upper band 2570-2690MHz (which may be used in France for TDD base transmit or FDD base transmit); and if the receiver height is 20m above local ground with a receive path gain of 18dBi; and the UK operator is seeking an interference level not exceeding -110dBm (equivalent to -207dBw/Hz for a 5MHz wide channel) for 1% of time, then interference from French operations at 2.6GHz may have an impact over much of South East England. Alternatively from Figure 46 and the discussion in paragraph A10.11 we can estimate that, if mobile station receivers are planned in the UK for the upper band 2570-2690MHz, and if the receivers' height is 3m above local ground and if the receiver path gain is 0dBi and the operator is seeking an interference level of 37dBuv/m (equivalent to -205dBw/Hz for a 5MHz wide channel) for 50% of time, then interference from French operations at 2.6GHz may have an impact over a small corner of SE England.

A10.13 Figure 47 below shows the estimated area where future coordination with France may be anticipated for UK base stations. This plot shows the areas where locating a UK base station (operating at 1000W EIRP, 20m AGL and 2600MHz), is expected to result in signal strengths at any point on the French coast greater than 21, 37 and 65 dBuv/m for receivers at a height of 3m AGL in France (based on propagation to ITU Rec 1546, 50% time, in line with CEPT Recommendation 01-01). For practical purposes the contour of 37dBuv/m (the TDD trigger level), represents the region of the UK where co-ordination of stations may be required.

[141] 2010-2025 MHz, 2290-2300 MHz, 2500-2690 MHz Spectrum Awards, Technical Study, Adjacent and In-Band Compatibility Assessment for 2500-2690MHz
Ofcom Consultation published: 11|12|2006

Figure 47: Areas where UK base stations are likely to require coordination



A10.14 The Ofcom Technical study presented an initial assessment of the potential for mobile networks in France to cause interference into UK networks. A 'worst case' base station to base station scenario was presented (Scenario 1 of paragraph 4.2.1); this may be compared with the plots given in Figure 46 above. Whilst the scenarios presented in the Ofcom Technical study remain valid, for the purpose of a 'worst case' assessment, the approach adopted here, based on ERC Recommendation 01-01 for the coordination of UMTS services, suggests that the impact of mobile services in France (based on UMTS) on services in the UK may be less that originally assessed, particularly if base station to base station transmissions in the lower portion of the band (2500-2570MHz) are avoided.

A10.15 Further to this model-based analysis, Ofcom has also undertaken measurements of field strengths in the 2.6GHz band near Dover, Hythe and Hastings[142]: In general there was little interference observed at the times when the measurements where conducted. This supports our understanding that currently the 2.6GHz band is lightly used in France. The measurements probably also reflects the nature of the current use in France for point to point transmissions.

A10.16 In the short term, while existing point-to-point services continue to operate in France, Ofcom expects that, overall, interference from France in the 2.6GHz band

[142] Ofcom Report ML2/004/05 Republic of Ireland MMDS Field Strengths measurements in the 2.5 – 2.69 GHz band.

is unlikely to be significant in the UK. During that period, international coordination between France and the UK would take place in accordance with the ITU procedures defined in the Radio Regulations (see in particular articles 9 and 11) However, Ofcom is in discussions with ANFR to determine the best way to manage the co-ordination of services in the 2.6GHz band between UK and France for the case of current point to point and future mobile services in France. It is likely that such discussions could conclude after completion of the award of the 2.6GHz band, given the indications from France that any change in use is unlikely to take place before 2010. In future, Ofcom expects to discuss the details of a MoU with France based on CEPT Rec. 01-01.

Ireland

A10.17 In Ireland, the 2500-2686MHz-frequency band is used for the Multichannel Multipoint Distribution Service (MMDS) service.[143,144,145,146,147] The MMDS network is currently operated by UPC Ireland B.V.[148] and ComReg have advised us that the licences issued to UPC run to 2014 with options for extension. UPC operates both analogue and digital distribution services at present but is currently undertaking a programme to convert the analogue services to digital.

A10.18 Individual MMDS channels are distributed evenly across the band at all transmit locations. According to technical information published by ComReg [145, 146] ("the Technical Information"), the available pool of 22 channels in the range 2500 to 2676MHz is divided into 2 sets of 11 channels, each of 8MHz width, as per the table below. Each station is assigned to channel group A or B which may be operated in horizontal or vertical polarisation in order to reduce interference. The technical information also states that the channels in the range 2500-2524MHz and 2668 to 2676MHz should not have been available from 1 January 2005. However we understand (from ComReg) that this change has will not be implemented as a consequence of the decision in Europe not to use the bands 2500 – 2520MHz and 2670 – 2690MHz for mobile satellite use – see ECC Decision(05)05). Measurements made by Ofcom's Baldock Monitoring team confirm that in May 2007 signals were detected in Newry across the full range from 2500MHz.

[143] Television Transmission Licensing For Cable and MMDS Systems Report on the Consultation Document No. ODTR 98/63 23 December 1998
[144] MMDS TV Licence, Wireless Telegraphy Act, 1926, amended programme services distribution licence issued pursuant to the Wireless Telegraphy Act, 1926, and the Wireless Telegraphy (programme services distribution) Regulations, 1999. ODTR 99/81 July 1999 (effective from 19/04/99)
[145] Technical Conditions for the operation of analogue programme services distribution systems in the frequency band 2500-2686MHz. ComReg 98/65R2, 9 June 2004.
[146] Technical Conditions for the operation of digital programme services distribution systems in the frequency band 2500-2686MHz. ComReg 98/67R2, 9 June 2004
[147] Future Strategy for MMDS in the 2.5GHz band
[148] Proposed Acquisition by UPC Ireland B.V. of MS Irish Cable Holdings B.V., M/05/024 UGC (Chorus) / NTL, Determination of the (Republic of Ireland) Competition Authority, 4th November 2005

Table 74: Summary of MMDS channels in Ireland

Channel Number	*Channel Frequencies (MHz)*	*Channel Group*
4	2524 - 2532	B
5	2532 - 2540	A
6	2540 - 2548	B
7	2548 - 2556	A
8	2556 - 2564	B
9	2564 - 2572	A
10	2572 - 2580	B
11	2580 - 2588	A
12	2588 - 2596	B
13	2596 - 2604	A
14	2604 - 2612	B
15	2612 - 2620	A
16	2620 - 2628	B
17	2628 - 2636	A
18	2636 - 2644	B
19	2644 - 2652	A
20	2652 - 2660	B
21	2660 - 2668	A

A10.19 Since the Ofcom Technical study published alongside the December Consultation, we have obtained two further sources of information about the MMDS transmissions.

a) Ofcom's monitoring team have undertaken a series of measurements of MMDS signal levels around Northern Ireland, West Wales and North West England.

b) ComReg have provided us with up to date information about the location and characteristics of the MMDS transmit stations.

A10.20 The Ofcom monitoring team made observations of MMDS signal strengths at: Newry, Armagh and Enniskillen in Northern Ireland and at South Stack (near Holyhead), Capel Engedi (10 miles inland from South Stack), Southport Esplanade, Blackpool North Parade and Parbold Hill (10 miles inland).

Figure 48: Map of MMDS measurement locations

A10.21 Measurements were undertaken in May and June 2007 during normal meteorological conditions and relate to average propagation. The results are given in the Ofcom report Number ML2/004/05,[149] available on Ofcom's website, see: http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/ and show plots of received signal strength at these locations at frequencies across the 2.6GHz band. The average field strengths across the band are summarised in the table below. For reference, the background noise floor in this band is around 31 dBuv/m/MHz. The main points of note are that:

- No signals from MMDS transmitters were detected at all at the locations in North West England (Southport Esplanade, Blackpool North Parade, Parbold Hill).
- Signals were detected on the most westerly part of Angelsey (South Stack), with a weaker signal 10 miles inland at Capel Engedi.
- In Northern Ireland, strong signals were detected in Newry and Enniskillen, although no signal at all was detected in Armagh.

[149] Ofcom Report Number: ML2/004/05, Field Strength measurements in the 2.5 – 2.69 GHz band from emissions in the Republic of Ireland and France

Table 75: Summary of MMDS measurements

Location	*Estimated signal level in a 1MHz bandwidth (dBuv/m/MHz)*	*Other activity*
Newry	Analogue: 54 Digital 73	None
Armagh	None	
Enniskillen	Analogue 49.8	None
South Stack	Digital 35	None
Capel Engedi	Digital 27.38	Radar spurious
Southport Esplanade	None	Radar spurious
Blackpool North Parade	None	None
Parbold Hill	None	Ignition noise

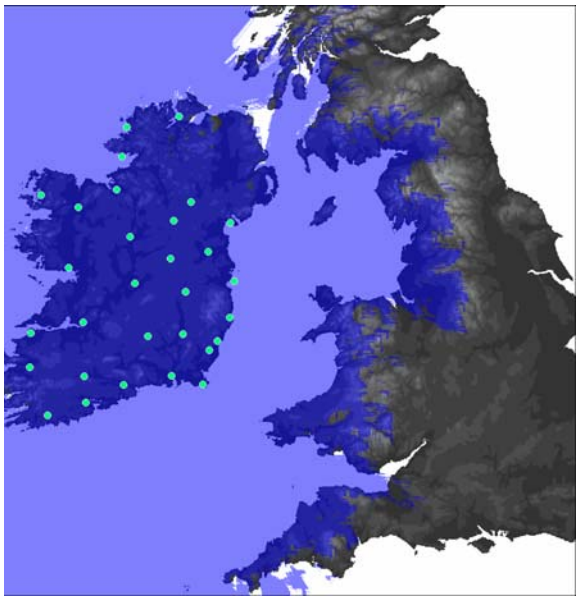
A10.22 To illustrate the implications of the more up to date information about the location and characteristics of the MMDS transmit stations we have replicated some plots of predicted signal levels that were included in the Ofcom Technical Study published in December 2006 and shown at the 8 February Ofcom seminar.

A10.23 The Ofcom Technical Study published in December 2006 presented some plots of the predicted signal levels in the UK from MMDS transmitters in Ireland using transmitter data (height and power) that was constructed from the technical information published by ComReg.[145, 146] A plot was presented on the basis of worst case assumption (1% propagation time and a high receiver gain antenna) in order to indicate the maximum footprint of locations where MMDS signals might be detected. The plot showed the power contour for a receiver power of 110dBm, equivalent to signal level of 20dBuv/m at the antenna face, for a receive antenna gain of 15dBi, (scenario 1 and scenario 2 in paragraph 4.2.3 of the Ofcom Technical study). However, as noted below, this is an extreme scenario when considering the scope for adverse impact of the MMDS network on any new UK network.

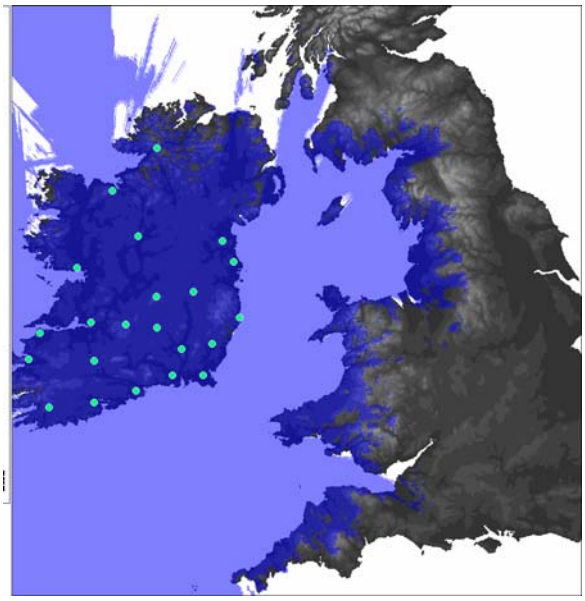
A10.24 Ofcom has replicated of these calculations using the up to date transmitter data and antenna characteristics supplied by ComReg. We note that certain stations are fitted with directional antennas, which reduce the signal levels in the direction of the UK. The comparison of the plots is shown below. It can be seen that use of the up to date transmitter data results in predictions of slightly less signal level around Northern Ireland and North West England.

Figure 49: Signal coverage from MMDS transmitters into the UK (Propagation Rec 452, 1% of time, 20m high receiver)

From Ofcom Technical Study



Using transmitter data from ComReg



A10.25 As noted above, these plots are included to represent the maximum footprint of received signal. When considering the possible impact of MMDS signals on potential systems operating in the 2.6GHz band in the UK, the main source of concern will relate to the scope for the MMDS signals to degrade reception of user terminal transmissions into the base station receive. Relevant considerations will relate to:

a) The receiver path gain and sensitivity, noting that base stations are normally more sensitive than user terminals;

b) The height of the base stations;

c) The strength of the unwanted MMDS signal compared with the wanted signal strength from the user terminal (which will be lower if the terminal is at the edge of the cell and higher if it is nearer to the base station);

d) The percentage of time for which the interfering signal exceeds a threshold at which interference might start to be a consideration.

e) The application of various mitigation techniques by the operator of the 2.6GHz systems.

A10.26 A full analysis of the extent to which a service might suffer degradation would clearly depend on the design and intended coverage of that service. However, when considering the areas where users of services in the 2.6GHz band might suffer material degradation of service for more than a minimal percent of time it might be more informative to consider the areas where the receiver noise from MMDS is predicted to exceed background interference for 10% propagation time.

A10.27 Figure 50 below shows the areas where the unwanted signal strength exceeds 20 and 37dBuv/m for 10% of the time. The power contour 20dbuv/m is representative

of the area where interference may be a design consideration for base station receivers and the contour 37dBuv/m represents the area where interference may be a design consideration for mobile station receivers. As indicated from Table 76 below.

Figure 50: Signal Coverage from MMDS transmitters into the UK (Propagation Rec 452, 10% of time, 20m high receiver)

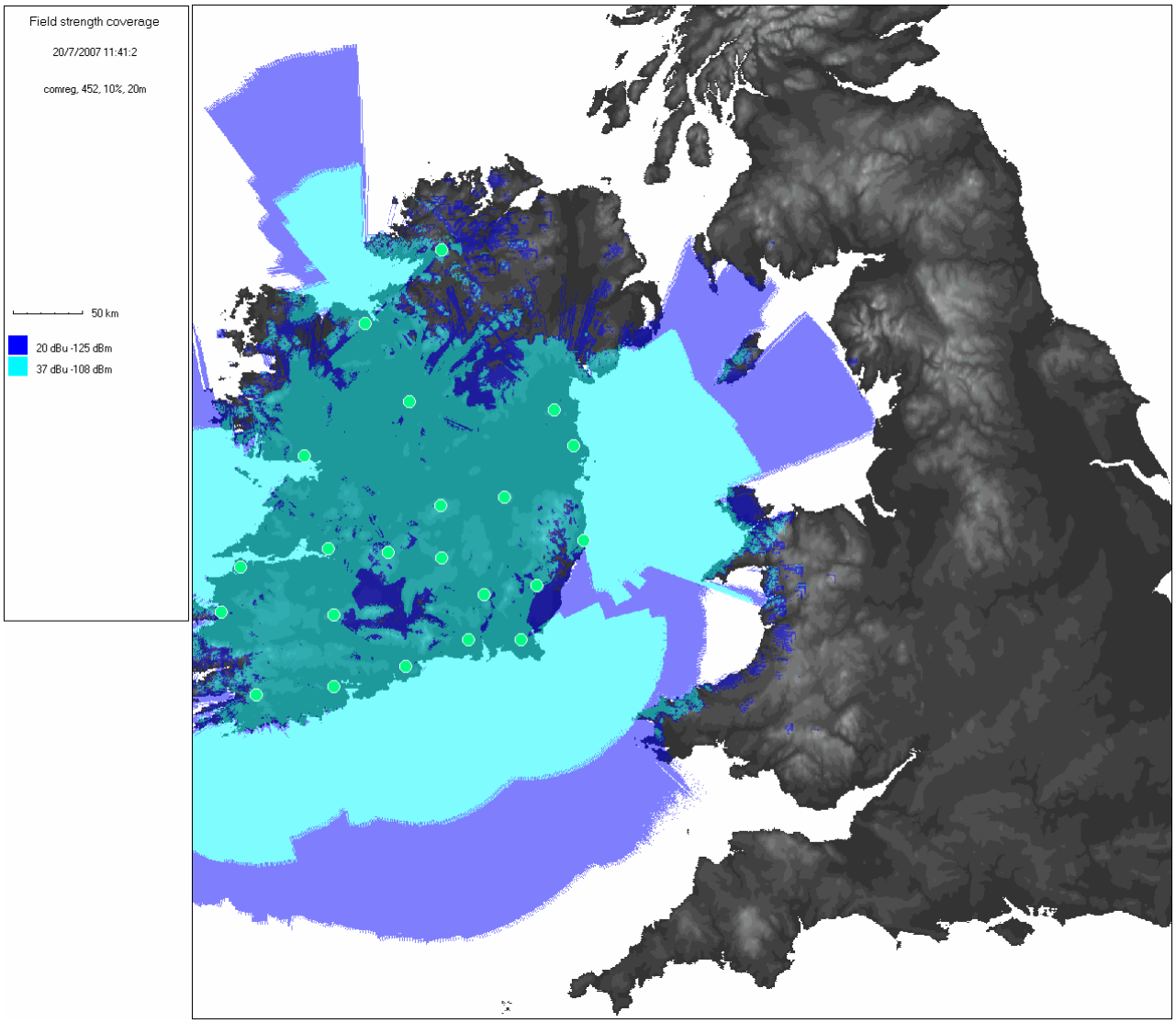


Table 76: Relationship between signal level and receiver noise power

Field strength at antenna face (dBuv/m)	*Frequency (MHz)*	*Antenna gain (dBi)*	*Power density at receiver input for a 5MHz wide signal (dBW/Hz)*
20	2595	18	-204
37	2595	0	-205

A10.28 The above plot suggests that the areas where the parameters are exceeded are limited to parts of Northern Ireland and the extreme West of Wales.

A10.29 In consideration of these field strength calculations and the field measurements undertaken by Ofcom's monitoring team, we do not think that MMDS services should have a material impact on the value of the 2.6GHz spectrum.

A10.30 Whilst these plots and measurements provide guidance; stakeholders that are interested in bidding for the spectrum should make their own assessments of the potential of the spectrum to support service.

A10.31 Ofcom is continuing to discuss with ComReg the best way to manage the co-ordination of services in the 2.6GHz band between UK and Ireland based on the setting of a trigger level which will enable the continuing operation of MMDS services in Ireland.

A10.32 It is possible that Ireland may look to a change of use at some time in the future and this would provide an opportunity to establish coordination along the lines of CEPT recommendation 01-01. If a non-MMDS type technology is introduced in the frequency band 2500-2690MHz, Ofcom will renegotiate the frequency co-ordination MoU.

Annex 11

Rules and procedures for the 2.6GHz and 2010MHz auction

A11.1 This annex provides a description of the proposed rules and procedures for Ofcom's combined auction of spectrum in the 2.6GHz and 2010-2025MHz bands under our base case assumption that it is not necessary to provide a bid option to bidders for paired lots for excluding unpaired uplink above 2620MHz. These rules are currently work in progress and may change. They are presented at this stage to assist stakeholders in understanding the preferred format. In accordance with its normal practice, Ofcom will consult on the rules for the auction when it publishes the relevant draft Statutory Instrument.

Overview

A11.2 There are 38 blocks of 5MHz available in the 2.6GHz band, which will be awarded as paired or unpaired spectrum, or as unpaired guard blocks. The number of lots in each category will be determined in the auction. There is also one lot of unpaired spectrum at 2010-2025MHz. A description of the lots available in the auction is provided in Table 77.

Table 77: Description of lots available in the auction

Band and category	*Number of lots*	*Spectrum endowment*	*Eligibility pts per lot*	*Reserve price per lot*	*Minimum bid size (in lots)*
2010-2025MHz – Unpaired	1	1 x 15MHz	2	£100,000	1
2.6GHz – Paired	Between 0 & 14	2 x 5MHz	2	£100,000	1
2.6GHz – Unpaired	Between 9 & 38	1 x 5MHz	1	£50,000	2
2.6GHz – Guard blocks†	Between 0 & 2	1 x 5MHz	NA	NA	NA

† Bidders do not bid for guard blocks in the Principal Stage of the auction; rather the number of guard blocks is determined by the outcome of bidding for the other three categories of lots. Guard blocks are made available to bidders in the Assignment Stage.

A11.3 The auction proceeds in five stages:

- **Application Stage.** Prospective bidders submit their applications to participate in the award process, including initial deposit.
- **Qualification Stage.** Ofcom determines which applicants are qualified to bid. The determination is based on a check of the applications and initial deposits, and assessment of bidder groups. Ofcom announces the number and identity of the qualified applicants. If there is only one bidder, the bidder will be entitled to

select the frequency lots it wishes to purchase and the award will then progress directly to the Grant Stage. If there is more than one bidder, then a bidding process is required.

- **Principal Stage.** There are two phases of bidding, which determine the identity of the winning bidders, the number and type of spectrum lots that they will receive, the allocation of spectrum between paired and unpaired lots within the 2.6GHz band.

  - **Primary bid rounds.** The first phase is the primary bid rounds, which follow a clock auction format. Bidders top up their deposits and the amount determines their eligibility to bid in the auction. Bidders make a single bid each round for a package of lots across the three categories in response to a set of prices notified to them by Ofcom (one price-per-lot for each category of spectrum). Note that guard blocks do not count as a category for the purpose of bidding in the Principal Stage.

    In the primary bid rounds, all bids for packages containing unpaired lots within the 2.6GHz band are contingent on all unpaired lots being contiguous. This has the implication that if such a bid was successful, any unpaired lots awarded must be located either in the lower unpaired area (i.e. below lot 24) or the upper paired area (i.e. from lot 38 downwards), and not split across the two areas.

    For unpaired 2.6GHz lots, prices are increased in the next primary bid round if there is excess demand for the 2.6GHz band as a whole and demand for unpaired 2.6GHz lots exceeds nine. For paired 2.6GHz lots, prices increase whenever there is excess demand for the 2.6GHz band as a whole or demand for paired 2.6GHz lots exceeds 14. For the unpaired 2010-2025MHz lot, the price increases whenever there is excess demand for this lot. The primary bid rounds continue until (a) there is no excess demand in any category and (b) it would be possible to accommodate all demand for unpaired lots without a split award.

  - **Supplementary bids round.** The second phase is the supplementary bids round, which always follows the primary bid rounds. This is a single round sealed bid process, in which bidders have the opportunity to make multiple, mutually exclusive bids for packages of lots across categories, subject to constraints created by their primary round bids. In the case that bidders have submitted a primary bid that included unpaired lots or intend to submit a supplementary bid that contains unpaired lots, they will also be allowed to submit further bids for the same packages contingent on unpaired spectrum being split between the upper and lower areas.

    Ofcom then identifies the highest value combination of bids that can be accommodated, drawing on all valid bids from the primary and supplementary bids rounds and taking at most one bid from each bidder in that combination. A ‘base price’ for each winning bid is also identified. The outcome determines the allocation of lots between paired and unpaired in the 2.6GHz band, whether there is a split award for unpaired lots and the number of guard blocks, if required.

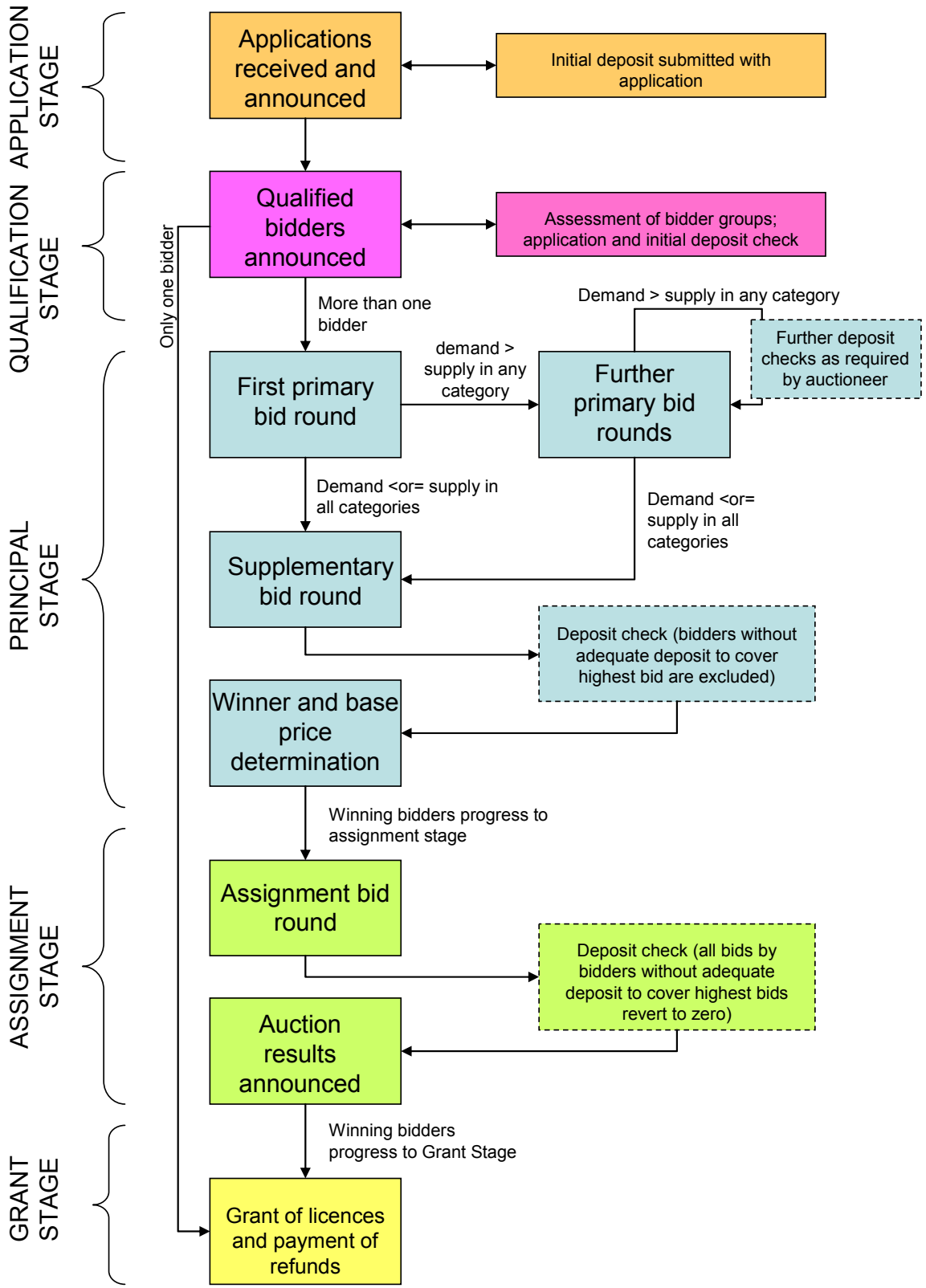
- **Assignment Stage.** This stage determines how the available frequencies within the 2.6GHz band that are assigned to paired, unpaired and guard blocks are distributed amongst the winning bidders from the Principal Stage (the winner of

the 2010-2025MHz lot having already been determined). Bidders participate in two parallel, sealed bid auctions for the paired lots and unpaired lots, and make 'assignment round bids' for particular ranges of frequencies compatible with the number of lots that they won in the Principal Stage. The guard blocks are included in selected bid options. Ofcom then identifies the highest value combination of bids that can be accommodated, subject to all bidders being assigned contiguous paired and contiguous unpaired frequencies (or two blocks of contiguous unpaired frequencies in the case of a split award). A final price for each bidder is also identified, which combines the base price and any additional prices arising from the Assignment Stage.

- **Grant Stage.** After the conclusion of the Assignment Stage, the award progresses to the Grant Stage, in which payments are finalised, licences are granted and the auction results are published.

A11.4 The flow chart in Figure 51 provides an overview of the whole process. In the following sections, we explain how the usage rights in the 2.6GHz band are determined, and describe the auction rules and procedures for each stage in detail.

Figure 51: Flow chart showing key stages in the auction process



Usage rights in the 2.6GHz band

A11.5 All lots in the 2.6GHz band are available for award. Depending on the outcome of the Principal Stage, each lot could be allocated for paired use ('paired 2.6GHz lot'), for unpaired use ('unpaired 2.6GHz lot') or as a guard block.

A11.6 Table 78 shows the feasible trade-offs between paired 2.6GHz lots, unpaired 2.6GHz lots and guard blocks in the 2.6GHz band.

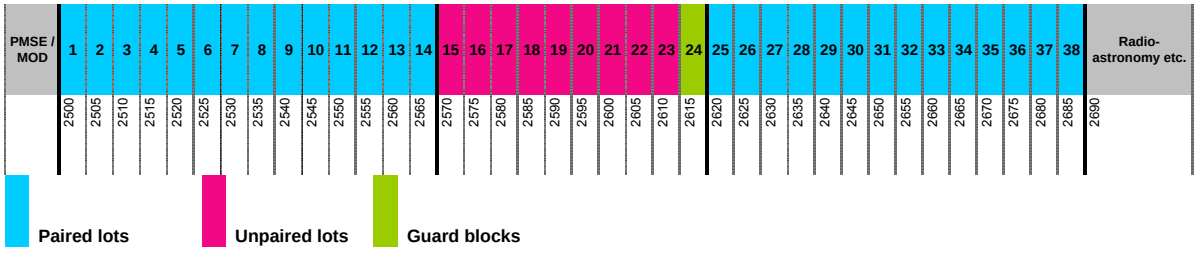
Table 78: Trade off between unpaired and paired lots in the 2.6GHz band

Outcome	*Unpaired lots (1x5MHz)*					*Paired lots (2x5MHz)*			*Guard blocks (1x5MHz)*
	Total no. of lots	Lower area		Upper area		Total no. of lots	Uplink	Downlink	No. of lots
		No. of lots	Frequencies	No. of lots	Frequencies				
1	9	9	2570-2615	0	-	14	2500-2570	2620-2690	1
2	10	10	2565-2615	0	-	13	2500-2565	2620-2685	2
3	13*	11	2560-2615	2*	2680-2690	12	2500-2560	2620-2680	1‡
4	15*	12	2555-2615	3*	2675-2690	11	2500-2555	2620-2675	1‡
5	17*	13	2550-2615	4*	2670-2690	10	2500-2550	2620-2670	1‡
6	19*	14	2545-2615	5*	2665-2690	9	2500-2545	2620-2665	1‡
7	21*	15	2540-2615	6*	2660-2690	8	2500-2540	2620-2660	1‡
8	23*	16	2535-2615	7*	2655-2690	7	2500-2535	2620-2655	1‡
9	25*	17	2530-2615	8*	2650-2690	6	2500-2530	2620-2650	1‡
10	27*	18	2525-2615	9*	2645-2690	5	2500-2525	2620-2645	1‡
11	29*	19	2520-2615	10*	2640-2690	4	2500-2520	2620-2640	1‡
12	31*	20	2515-2615	11*	2635-2690	3	2500-2515	2620-2635	1‡
13	33*	21	2510-2615	12*	2630-2690	2	2500-2510	2620-2630	1‡
14	35*	22	2505-2615	13*	2625-2690	1	2500-2505	2620-2625	1‡
15	38	24	2500-2620	14	2620-2690	0	-	-	0

* The actual number of unpaired lots would be 1 less than this in the event that there is an unpaired bidder that receives a split assignment (see further discussion for more detail).
‡ The actual number of guard blocks would be 1 more than this in the event that an unpaired bidder receives a split assignment.

A11.7 For example, Figure 52 illustrates outcome 1 from Table 78 in which the spectrum is split into nine unpaired 2.6GHz lots (lots 15-23), 14 paired 2.6GHz lots (uplink lots 1-14 and downlink lots 25-38) and one guard block (lot 24).

Figure 52: Outcome 1 from Table 78 (9 unpaired lots and 14 paired lots)



A11.8 If demand for unpaired 2.6GHz lots in the auction is sufficient to displace some of the paired lots, the lower boundary between paired and unpaired 2.6GHz lots shifts downwards. Additional unpaired spectrum is created at the expense of paired uplink spectrum. This also frees up the corresponding paired downlink spectrum at the top of the band, which creates further unpaired spectrum.

A11.9 Typically, for each paired 2.6GHz lot (uplink and downlink) that is removed, an additional two unpaired 2.6GHz lots can be created, one in the lower area and one in the upper area. There are two exceptions to this rule:

- In the case that 13 paired lots are allocated (lots 1-13 paired with lots 25-37), only one additional unpaired lot will be created (lot 14) since there is insufficient spectrum at the top of the band to create the required 5MHz separation between paired and unpaired use (see below). In this case, lot 38 will also be designated as a guard block.

- In the case that all spectrum is allocated as unpaired lots, then there is no longer a requirement for a guard block between paired and unpaired 2.6GHz lots. In this case, an additional unpaired 2.6GHz lot (lot 24) can be allocated.

A11.10 In order to prevent undue interference between adjacent unpaired applications, and between adjacent unpaired and paired applications, it is necessary to have a 5MHz separation in each of these cases. This is achieved in two ways:

- For each unpaired winner, the lowest frequency lot that they are awarded will be subject to specific usage restrictions designed to protect adjacent unpaired or paired use.

- Either one or two of the 38 lots will be designated as guard blocks and will be not be available in the principal stage of the auction:

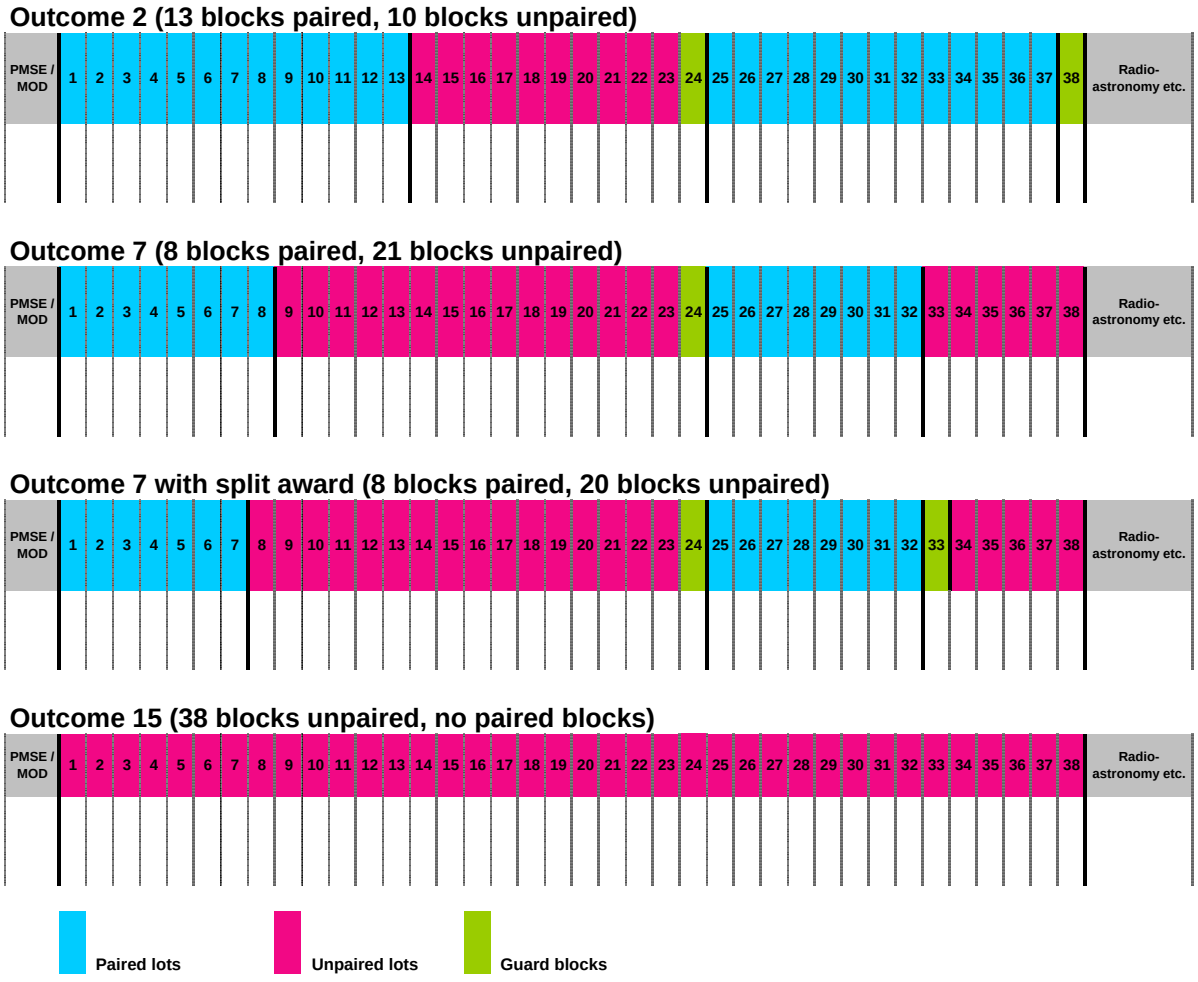
    - Lot 24 (in all cases, except where all spectrum is awarded as unpaired lots);

    - Lot 38 (only in the case that exactly one paired lot is converted to unpaired use and 10 unpaired lots are awarded); and

    - one further lot between lots 26 and 37 inclusive (only in the case that there is a winning bidder for unpaired spectrum that receives a split award of lots, as described later).

A11.11 For example, Figure 53 illustrates selected outcomes from Table 78. Outcome 2 illustrates the case that there are 13 paired 2.6GHz lots and 10 unpaired 2.6GHz lots, in which case a guard block is required in lot 38. The two band plans for outcome 7 illustrate the cases that there are 8 paired 2.6GHz lots and either 20 or 21 unpaired 2.6GHz lots, depending on whether or not there is a split award for one winner of unpaired 2.6GHz lots. In the case of a split award, an extra guard block is required that is awarded to the bidder receiving the split award; this is located in spectrum immediately below and adjacent to their assignment in the upper unpaired area, which in this illustration is lot 33. Finally, outcome 15 illustrates the case that all 38 lots are allocated to unpaired 2.6GHz use.

Figure 53: Selected outcomes from Table 78



Application and Qualification Stages

A11.12 The application and qualification stages determine the participants in the auction.

Application Stage

A11.13 Ofcom will publish on its website the day and time by which applications to participate in the auction must be submitted. Applications will only be accepted from bodies corporate. On the application day applicants must pay into Ofcom's bank account an initial deposit of £100,000.[150]

A11.14 Each applicant must provide details of its associates and members of its bidder group who are not associates. An associate is a person who has a material interest in the applicant. A bidder group includes the applicant, its associates and other persons who have access to confidential information. Applicants may add members to or remove members from their bidder groups by notifying Ofcom.

A11.15 Confidential information is information about an applicant or bidder which is not in the public domain and which if disclosed to another applicant or bidder would be

[150] The proposed initial deposit has been set at a level that corresponds to the minimum deposit necessary to submit a bid in the first round, based on proposed reserve prices.

likely to affect their decisions in relation to the award process. Disclosure of confidential information by a member of a bidder group outside the bidder group may result in an applicant not being qualified to bid or to a bidder being excluded from the award process and losing its deposit.

Qualification Stage

A11.16 Ofcom will notify each applicant of the names and associates of all other applicants and set a date by which applicants must notify whether any members of their bidder group are also associates of another applicant. Ofcom will itself consider whether any members of one bidder group are also members of another bidder group.

A11.17 Where Ofcom identifies such common membership it will notify the applicants concerned and specify a date by which all the common memberships must be resolved.

A11.18 Ofcom will next determine which applicants are qualified to bid in the auction. An applicant may not qualify if a member of its bidder group is also a member of another bidder group. Ofcom will also take into account a number of other matters, i.e. whether:

- the grant of a licence to an applicant would be likely to prejudice national security;
- the applicant is a fit and proper person to hold a Licence;
- the applicant has submitted false or misleading information;
- the applicant or any member of its bidder group has colluded or attempted to collude or is colluding or attempting to collude with any other person to distort the outcome of the award process, or has acted or is acting to distort the outcome of the award process;
- the applicant or any member of its bidder group, or any person to whom confidential information has been disclosed, has disclosed, or is disclosing or attempting to disclose or has incited or is inciting another person to disclose confidential information to anyone other than to a member of its bidder group, Ofcom, a provider of finance (where the disclosure was for the purpose of raising finance for the application), or a person considering whether to join the bidder group of the applicant;
- the applicant or any member of its bidder group has received or is obtaining or attempting to obtain confidential information relating to another applicant;
- the applicant or any member of its bidder group is receiving or attempting to receive services in relation to the award process from anyone who has provided or is providing services to Ofcom in relation to the award process (for these purposes the advisers are Allen & Overy LLP, DotEcon Ltd, Professor Peter Cramton of the University of Maryland and Dr Ian Jewitt of Nuffield College); or
- any member, or director or employee of a member of the applicant's bidder group who is also a director or employee of a member of another applicant's bidder group is taking part in the preparation of both bidder groups for participation in the award process or receiving confidential information relating to both bidder groups.

A11.19 Ofcom will notify each applicant of whether it has qualified to bid in the auction and of the last day on which applicants who have qualified may withdraw their application without forfeiting their initial deposit.

A11.20 After the last day for withdrawal, Ofcom will publish on its website the names of all applicants qualified to participate in the auction who have not withdrawn and announce the procedure it will follow for award of the licences (depending on the number of bidders).

If there are no bidders

A11.21 If there are no bidders, there will be no auction and Ofcom will consider an alternative award process.

If there is only one bidder

A11.22 If there is only one bidder, there will be no auction and the bidder will be entitled to select the frequency lots it wishes to purchase. Ofcom will send the bidder a licence selection menu and notify the date and time by which the completed menu must be returned.

A11.23 In the completed menu the bidder must indicate the number of frequency lots it wishes to purchase in each of the three categories. Its menu may comprise:

- one unpaired lot covering the frequencies 2010-2025MHz; and/or
- between one and nine contiguous paired 2.6GHz lots immediately above 2500MHz (and corresponding blocks immediately above 2620MHz); and/or
- between two and eighteen unpaired 2.6GHz lots immediately below 2615MHz (and possibly immediately below 2690MHz).

A11.24 The total amount of lots selected across all three categories must have an associated number of eligibility points between 2 and 18 points inclusive. If the bidder selects paired 2.6GHz lots, it will be awarded the contiguous frequencies immediately above 2500MHz corresponding to the number of lots that it selected. If the bidder selects between two and eleven unpaired 2.6GHz lots, it will be awarded the contiguous frequencies immediately below 2615MHz corresponding to the number of lots that it selected. If the bidder selects between twelve and thirteen unpaired 2.6GHz lots, it will be allocated the following frequencies:

- if 12 lots, the frequencies 2560-2615MHz and 2685-90MHz and a guard block at 2680-2685MHz;
- if 13 lots, the frequencies 2555-2615MHz and 2685-90MHz and a guard block at 2680-2685MHz;
- if 14 lots, the frequencies 2555-2615MHz and 2680-90MHz and a guard block at 2675-2680MHz;
- if 15 lots, the frequencies 2550-2615MHz and 2680-90MHz and a guard block at 2675-2680MHz;
- if 16 lots, the frequencies 2550-2615MHz and 2675-90MHz and a guard block at 2670-2675MHz;

- if 17 lots, the frequencies 2545-2615MHz and 2675-90MHz and a guard block at 2670-2675MHz; or

- if 18 lots, the frequencies 2545-2615MHz and 2670-90MHz and a guard block at 2665-2670MHz.

A11.25 The licence fee will be the sum of the reserve prices for each frequency lot comprised in the licence.

A11.26 The bidder must pay the licence fee into Ofcom's bank account and return the completed licence selection menu by the date and times notified. Where the bidder has not forfeited its initial deposit this will be offset against the licence fee.

A11.27 After Ofcom receives the completed licence selection menu and relevant licence fee, it will grant the bidder a licence for the frequency lot or lots selected. If the selection menu has not been completed in accordance with the paragraphs above or is unclear or illegible Ofcom will ask the bidder for confirmation of the bidder's intentions.

A11.28 If the bidder fails, by the date and the times specified, to return the completed licence selection menu to Ofcom or to pay the licence fee, it will forfeit its initial deposit and not be entitled to the grant of a licence.

If there is more than one bidder

A11.29 In the case that there are two or more bidders the award progresses to the Principal Stage.

A11.30 Prior to the Principal Stage, Ofcom will supply bidders with the digital certificates, usernames and passwords necessary to access the electronic auction system (described below). Bidders will be supplied with a user manual for the electronic auction system. Bidders will also receive a set of one-time passwords for authenticating any communication they may initiate with Ofcom during the auction (see later).

The Principal Stage

A11.31 The Principal Stage consists of one or more primary bid rounds followed by a supplementary bids round.

The primary bid rounds

A11.32 The primary bid rounds follow a clock auction format. The auction proceeds in discrete rounds, with all bidders making bids within the same fixed time window (subject to the provisions for extensions, described further below). In any given primary bid round, a single bid for a single package of lots can be made by each bidder, at the prevailing round prices. Bids for packages containing unpaired 2.6GHz lots are contingent on these lots being fully contiguous in either the lower or upper unpaired areas. Bidders complete an electronic bid form specifying the number of lots they demand in each category at these prices (which cannot exceed the total available). This bid is for a package of lots; it will only be considered in its entirety and will not be subdivided.

A11.33 In the first round, bidders must bid for at least the one 2010-2025MHz lot or one paired 2.6GHz lot or two unpaired 2.6GHz lots. If, in any subsequent primary bid

round, a bidder decides that it does not wish to continue bidding it should submit a bid for zero lots in each category; this will avoid the bidder being given an unnecessary extension by the electronic auction system (see further details below).

Scheduling primary bid rounds

A11.34 Primary bid rounds are scheduled at Ofcom's discretion. There is no minimum or maximum round length. However, Ofcom does not anticipate running primary bid rounds of less than 10 minutes or greater than 2 hours. The rounds will be scheduled between 10am and 5pm on UK business days. There is no upper bound on the number of rounds per day, although Ofcom does not anticipate running more than 12 rounds in a single day.

A11.35 Bidders must be notified of the start time of a round at least 15 minutes before it starts. (In practice, the auction software will require that rounds be scheduled at least 16 minutes into the future to allow for network latency.) With the next round start time, each bidder will also be given information about:

- the duration of the round;
- the round prices that will apply to lots in each category;
- their eligibility to bid in the round (expressed as a number of eligibility points); and
- their number of remaining extension rights.

Primary bid round prices and price increases

A11.36 In the first primary bid round, the price per lot for each category will be set equal to the reserve price for that category. In subsequent rounds:

- For unpaired 2.6GHz lots, the primary round price per lot will be increased if there is both (a) excess demand for the 2.6GHz band as a whole and (b) demand for unpaired lots exceeds nine. If either of these conditions does not hold, the round price will remain unchanged.
- For paired lots, the primary round price per lot will be increased if there is excess demand for the 2.6GHz band as a whole or if demand for paired lots exceeds 14. If neither of these conditions hold, the round price will remain unchanged.
- For the unpaired 2010-2025MHz lot, the primary round price per lot will be increased if there is excess demand for that lot. If this condition does not hold, the round price will remain unchanged.

A11.37 For the 2.6GHz band as a whole, excess demand means a combined demand for paired 2.6GHz and unpaired 2.6GHz lots that exceeds the total supply of lots in the case that no split award of unpaired lots is possible.

A11.38 It is not possible for the price of lots in any category to fall during the primary bid rounds.

A11.39 The amount by which prices increase from round to round for each category, subject to paragraph A10.36, will be at Ofcom's discretion. A maximum increase of 100% of the previous round price shall apply for each category, with one exception described below.

A11.40 In practice, we expect to use this discretion to set larger price increases for categories where there is a greater level of excess demand. In judging this, excess demand as a proportion of the number of available lots is likely to be a useful metric.

A11.41 If the demand for unpaired 2.6GHz lots is less than or equal to nine, then no bid increment will apply to this category, so the price ratio of paired to unpaired lots may rise above 2:1. The exception referred to above applies if, in a later round of the auction, demand for unpaired 2.6GHz lots rises above nine, because then a sufficient price increase will be applied in the subsequent round to restore the 2:1 price ratio; in this case, the price increase could, if necessary, exceed 100% of the previous round price. These rules are designed to ensure that whenever demand for unpaired 2.6GHz lots exceeds nine, the primary round price for a paired 2.6GHz lot is always twice the price of an unpaired 2.6GHz lot.

Activity rule and eligibility points

A11.42 Each category of lots in the auction has an associated number of eligibility points per lot. Any bid for a package of lots also has an associated number of eligibility points which is determined by the sum of the eligibility points associated with all the lots in that package.

A11.43 Ofcom will determine the initial eligibility for each bidder based on the size of their deposit at a fixed date and time prior to the first round of the auction. Each bidder receives 1 eligibility point per whole £50,000 of deposit. For example, a bidder with a deposit of £500,000 would have an initial eligibility of 10 points.

A11.44 The minimum initial eligibility is 2 points, which corresponds to a deposit of at least £100,000 and less than £150,000. Qualified applicants with less than £100,000 deposit at the specified time and date will be excluded from the auction.[151]

A11.45 The maximum initial eligibility is 18 points, regardless of the level of a bidder's deposit. Thus, a bidder with a deposit of £900,000 or any amount larger than this would have an initial eligibility of 18 points. This maximum will apply throughout the auction.

A11.46 From the second primary bid round onwards, each bidder's eligibility is determined by their activity in the previous round. Specifically, each bidder's eligibility in any round from round 2 onwards is equal to the number of eligibility points associated with their bid in the previous round. For example, assume that Fred had an eligibility of twelve in round 8. He bids for a package consisting of two paired 2.6GHz lots, four unpaired 2.6GHz lots and the 2010-2025MHz lot. The number of eligibility points associated with his package bid is ten (four + four + two), so his eligibility in round 9 would fall to ten.

A11.47 In any primary bid round of the auction, bidders can only bid for a package of lots with an associated number of eligibility points that is less than or equal to their eligibility in that round. Thus, over successive primary bid rounds, a bidder's eligibility can stay the same or fall, but can never increase.

A11.48 As the primary bid rounds progress, bidders may switch eligibility between categories of lots. Therefore, it is possible that a bidder's activity in one or two

[151] As the initial deposit is set at £100,000, it is only possible for a bidder to be excluded for having inadequate deposit in the case that it has forfeit all or part of its initial deposit.

categories may increase, provided that the bidder's activity in other categories is sufficiently reduced.

A11.49 Any package bid specifying demand for unpaired 2.6GHz lots must contain at least two lots in this category. This means that the minimum number of eligibility points associated with any package bid is two points.

Deposits and eligibility

A11.50 During the primary bid rounds, Ofcom may at any point and on any number of occasions, announce a deadline by which time bidders must have raised their deposit to a level that is at least equal to their highest primary round bid submitted prior to the announcement that deposits had to be raised. If the announcement is made before 2pm on a business day, then the deposit deadline will be no earlier than midnight on the following business day (e.g. if the announcement was made at 1pm on Tuesday, the deadline for increasing deposits would be no earlier than midnight on Wednesday). If the announcement is made at any other time, the deadline will be no earlier than midnight on the next business day after the following business day (e.g. if the announcement was made at 3pm on Thursday, the deadline would be no earlier than midnight on Monday).

A11.51 If a bidder does not meet a deadline for increasing its deposit, its eligibility will be reduced to zero in the next round after the deadline and it will in consequence not be able to submit any further primary round bids. Such a bidder will, however, still be able to participate in the supplementary bids round, subject to the constraints on bids implied by its eligibility dropping to zero in the relevant primary bid round (see below for further explanation on supplementary bids) and subject to meeting the rules on making bid deposits to support its supplementary bids.

A11.52 For example, consider a bidder that had eligibility of 12 points in round 8 but then did not raise its deposit as required by Ofcom. Its eligibility would drop to zero in round 9, that being the next round after the deadline for increasing deposits. In the supplementary bids round, the bidder would still be able to make bids for packages with eligibility between 1 and 12 points inclusive, but its maximum bids for such packages would be capped on the basis of the prices for each category of lots that applied in round 9. For the avoidance of doubt, the bidder's bids in round 8 would be valid for the purpose of determining bid totals, i.e. the bids are taken into account in determining whether there should be another primary bid round and, if there is another round, whether the round price should be raised in a particular category.

Submitting primary bid rounds

A11.53 Primary round bids are submitted using the electronic auction system (save in exceptional circumstances, as described below). There is a two-step process for submitting bids:

- in the first step, bidders input their bid for checking by the electronic auction system; and
- in the second step, a valid bid is formally submitted.

A11.54 To make a bid, bidders select the number of lots in each category that they wish to include in their package. Within the electronic bid form, bidders will be presented with drop-down boxes to select the number of lots to be included in their package;

the choices available within these down-boxes will be subject to the following constraints:

- the number of paired 2.6GHz lots must be between zero and nine;
- the number of unpaired 2.6GHz lots must be either zero or between two and 18; and
- the number of unpaired 2010-2025MHz lots must be either zero or one.

A11.55 Note that each bid will also be subject to an eligibility cap of 90MHz across all categories, as described in section 6. Where a bidder does not wish to include any lots from a particular category in its package, the bidder should set the number of lots for that category to zero. It is not possible to include a single unpaired 2.6GHz lot in a package; if any unpaired 2.6GHz lots are included, then at least two must be included.

A11.56 The amount of a primary round bid is determined by (a) for each category, multiplying the number of lots selected in that category by the relevant current round price; and (b) adding these values together. It is not possible for bidders to choose the amount of a primary round bid, only the package that will be subject to a primary round bid.

A11.57 Once a bidder has selected the package to be subject to a primary round bid, it must input this for checking by the electronic auction system. The electronic auction system will not allow bidders to submit a primary bid for a package that has associated eligibility points in excess of a bidder's eligibility. It will also warn bidders if a proposed bid would meet this requirement but would result in that bidder having lower eligibility in the next round. In either case, bidders will be able to return to the bid entry form to revise their bid.

A11.58 Once a bid has been checked and has been confirmed as meeting the eligibility requirements, the screen will display the 'bid submission form', which provides a statement of the bid. A bidder can then formally submit this bid. Alternatively, the bidder could return to the bid entry form to revise its bid (in which case the bidder would need to check its bid once more before it could be submitted).

Extensions

A11.59 An extension right allows a bidder additional time in which to submit a primary round bid. In the event that a bidder with non-zero eligibility and one or more remaining extension rights fails to submit a bid during a primary bid round, the round will automatically be extended for that particular bidder and one of its remaining extension rights deducted. The electronic auction system will give that bidder a revised deadline for submitting a primary round bid 30 minutes later than the original round deadline.

A11.60 The extension period lasts at most 30 minutes, but may terminate earlier once all bidders using extensions have successfully submitted their bids. The extension period only applies to bidders that failed to submit their bid during the normal round time, have one or more available extension rights and non-zero eligibility. Bidders who have submitted a decision already during the round cannot take any further action during the extension period; they will be told that the round has been extended and should wait for the announcement that the extension period has ended. Bidders who have not submitted a bid during the primary bid round and

have no remaining extension rights will not be able to enter a bid during the extension period; such bidders will lose all eligibility to bid in further primary bid rounds.

A11.61 Each bidder starts the auction with two extension rights. Each time the bidder fails to submit a bid in a primary bid round before the deadline and an extension period is triggered for that bidder, the number of extension rights available for that bidder in subsequent primary bid rounds is reduced by one.

A11.62 Additional extension rights may be granted either to all bidders or to individual bidders at Ofcom's absolute discretion. Additional extension rights can ONLY be granted in the periods between primary bid rounds. They cannot be granted during a primary bid round.

A11.63 Extension rights are provided to bidders as an emergency tool in case, owing to unforeseen circumstances, they are unable to submit a bid during a primary bid round. The overall intention of extension rights is to provide a backup against technical failures, rather than to provide bidders with extra time to consider their decisions. For example, if a bidder has problems with its Internet connection and cannot access the auction system, it can use an extension right. In the event of significant problems that prevented a number of bidders accessing the electronic auction system, we would envisage using our exceptional powers to reschedule or re-run a primary bid round, rather than relying on extension rights.

A11.64 A bidder may notify Ofcom that it is unable to submit a bid during a primary bid round and is likely to require an extension period; notification is not mandatory but would assist administration of the process, especially where the bidder might be having problems accessing the electronic auction system and needs to make use of the procedures described in the following section.

Submission of primary round bids in exceptional circumstances

A11.65 Where a bidder is unable to submit a primary round bid using the electronic auction system, it should seek in advance Ofcom's permission to submit a bid using either fax or email. A bidder may seek such permission before the start of a round or during a round or during an extension period. Where Ofcom grants permission, the bidder must submit its bid using the agreed mechanism, i.e. either fax or email (in these circumstances bids submitted by the electronic auction system will not be accepted unless Ofcom has expressly agreed) and within the deadline specified by Ofcom. Ofcom may grant such permission for a single round or for all rounds during a day or for a specified period.

A11.66 In the event that a bidder submits multiple bids by fax or email, only the first bid received will be accepted. A bid must specify the number of lots in each category that the bidder offers to purchase at the primary bid round prices prevailing in that round. Any bid made by fax or email will be subject to password verification.

A11.67 If a bid submitted by fax or email exceeds the bidder's eligibility, is illegible or unclear, the bid will be invalid and the bidder's eligibility in the following round will fall to zero and, as a consequence, it will not be able to submit any further primary round bids. However, the bidder will be able to participate in the supplementary bids round, subject to the constraints on bids implied by its eligibility dropping to zero in the relevant primary bid round and subject to meeting the rules on making bid deposits to support its supplementary bids.

Information available during the primary bid rounds

A11.68 Before the start of the first primary bid round, each bidder will be notified of their own initial eligibility. This information will not be provided to other bidders. Further, Ofcom proposes not to announce the aggregate level of initial eligibility across all bidders.

A11.69 At the end of each primary bid round, Ofcom will reveal to each bidder:

- aggregate demand for lots in each category; and
- information about their own bids, their eligibility in the next round, the amount of that bidder's highest bid in the auction to date, and how many extension rights the bidder has remaining.

A11.70 In addition, Ofcom may also reveal details of the number of lots each bidder requested in each category, but on an anonymous basis, subject to further consideration of the implications for bidder behaviour.

A11.71 The electronic auction system includes a history function that will allow bidders to monitor and download information about aggregate demand in previous rounds and about their own bids.

End of the primary bid rounds

A11.72 The primary bid rounds end when there is a round in which there is no excess demand for the 2010-2025MHz lot AND no excess demand for lots in the 2.6GHz band as a whole subject to the condition that all remaining demand for contiguous unpaired lots could be met without resort to a split award AND no excess demand for paired lots. At this point, Ofcom will announce that the primary bid rounds have finished and that the auction will progress to the supplementary bids round.

A11.73 In addition, following the close of a primary bid round, Ofcom may announce that it is terminating the primary rounds early (i.e. while demand is still above supply in one or more categories). In this case, the auction will proceed directly to the supplementary bids round, as described further below, and there will be no further primary bid rounds. Ofcom will only terminate the primary rounds early if it believes that proceeding directly to the supplementary bids round at this time is in the general interest of running an efficient award process.

The supplementary bids round

A11.74 In the supplementary bids round, bidders may submit a number of bids for packages of lots, subject to respecting the eligibility restrictions resulting from their bids in the primary bid rounds. This round provides an opportunity for bidders to bid for packages of lots that they were eligible to bid on in the primary bid rounds but that they did not bid for, and also to express the maximum amount they are willing to pay for packages that they bid on in a primary bid round, subject to their eligibility constraints. It also provides an opportunity for bidders to make bids for the same packages of lots contingent on any unpaired 2.6GHz lots being subject to split awards in specific configurations.

A11.75 All bids received from bidders in both the primary bid rounds and the supplementary bids round are then considered together to determine the winners of the Principal Stage and whether a split award will be part of the winning combination of bids.

A11.76 Unlike the primary bid rounds, bidders must choose the amount of any supplementary bids they make. These amounts are subject to a minimum and in some cases a maximum as described below.

Scheduling the supplementary bid round

A11.77 The start time and duration of the supplementary bids round will be announced by Ofcom after the completion of the primary bid rounds. There will be at least one clear business day in between the last primary round and the supplementary bids round. Ofcom has discretion over the time and duration of the round. However, Ofcom anticipates that the round will take place between 10am and 5pm on a single business day, and last for at least 2 hours and no more than 7 hours.

Restrictions on supplementary bids

A11.78 All supplementary bids are bids for distinct packages or configurations of lots from one or more of the three categories of lots. There are two types of supplementary bids that a bidder can submit:

- **Standard supplementary bids** – These are bids that either contain no unpaired 2.6GHz lots or include unpaired 2.6GHz lots contingent on there being no split award. Each standard supplementary bid must be for a distinct package of lots. These may be packages for which the bidder has already submitted a primary bid.

- **Split supplementary bids** – For every package bid made in the primary and supplementary bid rounds that contains 3 or more unpaired 2.6GHz lots, a bidder will also be eligible to make 'split supplementary bids' for the same package of lots, contingent on it receiving a particular pattern of split award. A split award is an assignment of unpaired spectrum split into two contiguous blocks, one in the lower unpaired area and one in the upper unpaired area. Note that any bidder that receives a split award will receive an additional guard block, located in spectrum immediately below and adjacent to their spectrum in the upper area spectrum.

A11.79 The maximum number of standard supplementary bids is 190, i.e. every possible combination of lots with a number of eligibility points of 18 or less (in accordance with the safeguard cap of 90MHz).

A11.80 We are not proposing to limit the number of split supplementary bids that a bidder could submit. The number of split supplementary bids that can be made for each package depends of the number of unpaired lots in the corresponding primary or standard supplementary bid. For example, a bidder that bid for a package containing seven contiguous unpaired lots, could also bid for the following split award options (including the additional guard block for split awards):

- 4 lots in one area and 4 lots in the other area;

- 5 lots in one area and 3 lots in the other area; and/or

- 6 lots in the lower area and 2 lots in the upper area.

A11.81 Similarly, a bidder that bid for a package containing ten contiguous unpaired lots, could also bid for the following split award options (including the additional guard block for split awards):

- 6 lots in one area and 5 lots in the other area;
- 7 lots in one area and 4 lots in the other area;
- 8 lots in one area and 3 lots in the other area; and/or
- 9 lots in one area and 2 lots in the other area.

A11.82 As with primary bids, the bidder is not allowed to specify which lots will be in the lower area and which lots will be in the upper area. However, in the case that they make a bid that specifies just 2 lots in one area and more than two in the other area, then the two–lot block must be located in the upper area (with one lot being the additional guard block for the split award). As the bids must include the additional guard block, it is not possible to make a bid that specifies just one lot in either area.

A11.83 All supplementary bids must exceed the sum of the reserve prices for the component lots within the package.

A11.84 Some standard supplementary bids are subject to an upper bound on the amount bid. For the purposes of determining whether upper bound restrictions apply to a bid made by a particular bidder, a distinction is made between:

- bids for packages that have associated eligibility points which are less than or equal to the bidder's activity in the final primary bid round; and
- bids for packages that have associated eligibility points that exceed the bidder's activity in the final primary bid round.

A11.85 For standard supplementary bids for packages with eligibility points equal to or below the bidder's activity in the final primary bid round, there is no restriction on the maximum amount bid.

A11.86 For standard supplementary bids for packages with eligibility points above the bidder's activity in the final primary bid round, the bid amount cannot exceed the aggregate sum of the primary bid round prices in the round where the bidder was last eligible to bid on that package.

A11.87 A simple example makes this clear.

- Suppose that in round 8, the price per unpaired 2.6GHz lot was £150,000, the price per paired 2.6GHz lot was £300,000, and the price for the 2010-2025MHz lot was £250,000. Suppose that a bidder submitted a bid for a package of six unpaired 2.6GHz lots and two paired 2.6GHz lots. Thus, its total activity in round 8 was ten points.
- Now suppose that in round 9, the price per unpaired 2.6GHz lot is increased to £160,000, the price per paired 2.6GHz lot is increased to £320,000 but the price for the 2010-2025MHz lot remains unchanged at £250,000. Then consider two cases according to the bids made from round 9 onwards:

  i) The bidder continues to bid on six unpaired 2.6GHz lots and two paired 2.6GHz lots until the end of the primary bid rounds;

ii) The bidder reduces its demand to four unpaired 2.6GHz lots and 2 paired 2.6GHz lots in round 9.

- In the first case, activity was maintained at ten points throughout the primary bid rounds, so there is no limit on the amount of a standard supplementary bid that the bidder could make for packages of lots with associated eligibility points less than or equal to ten points.

- In the second case, activity declined from ten points to eight points in round 9, so the bidder's eligibility from round 10 onwards was reduced to eight points. Any standard supplementary bids for packages of lots with an aggregate eligibility of nine or ten points would be capped according to the prices in round 9, as this is the last round when the bidder was eligible to bid on packages with these eligibilities. For example, the bidder could submit supplementary bids for packages such as:

  i) Ten unpaired 2.6GHz lots at a price not exceeding £1,600,000 (10*£160,000);

  ii) Five paired 2.6GHz lots at a price not exceeding £1,600,000 (5*£320,000);

  iii) Four paired 2.6GHz lots and the 2010-2025MHz lot at a price not exceeding £1,530,000 (4*£320,000 + £250,000);

  iv) Three unpaired 2.6GHz lots, two paired 2.6GHz lots and the 2010-2025MHz lot at a price not exceeding £1,370,000 (3*£160,000 + 2*£320,000 + £250,000); and

  v) Seven unpaired 2.6GHz lots and the 2010-2025MHz lot at a price not exceeding £1,370,000 (7*£160,000 + £250,000)

A11.88 For split supplementary bids, the maximum bid is set at the amount bid for the corresponding standard supplementary bid, or if there was no standard supplementary bid, the corresponding primary bid.

A11.89 For example, suppose that the bidder in the previous example intends to make a standard supplementary bid for seven unpaired 2.6GHz lots and the 2010-2025MHz lot at a price of £1,370,000. In this case, the bidder could also submit the following split supplementary bids for this package (including the additional guard block for split awards):

- four unpaired 2.6GHz lots in one area and four in the other area, plus the 2010-2025MHz lot at a price not exceeding £1,370,000;

- five unpaired 2.6GHz lots in one area and three in the other area, plus the 2010-2025MHz lot at a price not exceeding £1,370,000; and/or

- six unpaired 2.6GHz lots in the lower area, two in the upper area, plus the 2010-2025MHz lot at a price not exceeding £1,370,000.

Preparing supplementary bids

A11.90 The electronic auction system includes a supplementary bids management tool that bidders can use to maintain and revise a list of provisional supplementary bids (including both standard supplementary bids and split supplementary bids) throughout the primary and supplementary bids rounds. This system also provides

information about all primary round bids submitted by the bidder and the constraints on supplementary bids deriving from these bids.

A11.91 The management tool is provided purely for the convenience of bidders. No provisional bids entered into the system will be visible to Ofcom or any other bidder.

Submitting supplementary bids

A11.92 Supplementary bids are submitted using the electronic auction system within the specified timing for the supplementary bids round. The submission procedure is a two-step process, which is similar to that for the primary bid rounds:

- in the first step, bidders may prepare a list of supplementary bids (including both standard supplementary bids and split supplementary bids) which they enter for checking by the electronic auction system; and
- in the second step, bids are displayed on a 'bid submission form', which should be formally submitted.

A11.93 Any provisional supplementary bids stored by a bidder using the management tool, together with the bids they made for packages in the primary bid rounds, will be available as a starting point for compiling a list of supplementary bids during the supplementary bid round. A bidder may add, revise or delete its bids as required; though it cannot delete any primary round bids, only increase the amount of such bids, if it wishes (subject to constraints created by its bids in subsequent primary rounds). Bidders are also provided with details of any constraints on their maximum bids for packages with particular eligibility levels. All bids must be in whole pounds sterling.

A11.94 Once a bidder has finalised its first list of supplementary bids, it must input these for checking by the electronic auction system. Any errors (such as: a bid below the minimum; or a bid above the maximum) will result in this entire first set of supplementary bids being rejected by the checking system. In this case, bidders will be able to revise their supplementary bids and re-enter them for checking.

A11.95 Once this list of supplementary bids has been checked and has been confirmed as meeting the requisite criteria, a statement of these bids will be displayed on a bid submission form. A bidder can then formally submit these bids. Alternatively, it could revise its bids and re-enter them for checking. As in the Principal Stage, submitting bids is a two-step process; supplementary bids are not considered to have been made until they have been submitted; entering bids for checking is not sufficient.

A11.96 An extension right will be available to bidders in the supplementary bids round. The process for submission of supplementary bids in exceptional circumstances will be similar to that described above for the submission of primary round bids in exceptional circumstances.

Deposit rule for supplementary bids round

A11.97 Before the end of the day on which the supplementary bids round closes, bidders must have on deposit with Ofcom an amount at least equal to their highest bid made across both the primary bid rounds and the supplementary bids round.

A11.98 If a bidder does not meet this deposit obligation, all its bids from the primary and supplementary bids stages will be void and excluded from consideration in the determination of Principal Stage winners and prices. Such a bidder will also forfeit any deposit that it has submitted.

Winner determination

A11.99 Following the close of the supplementary bids round and completion of the deposit checks, Ofcom will proceed to determine the winning bids. These are the combination of valid primary and supplementary bids of greatest total value amongst all valid bids submitted, subject to the conditions that:

- no more lots are awarded than are available;
- at most one bid is accepted from each bidder; and
- assignments are contiguous except for those corresponding to split supplementary bids.

A11.100 A software algorithm will be used to determine the combination of bids that meets these criteria. It is possible that there could be more than one set of bids having the equal highest value. In this case, the tie will be resolved in the following way:

- The combination of bids with the highest number of associated eligibility points will be selected.
- If there is still a tie, with a number of possible allocations having the same total value of winning bids and the same number of eligibility points, then a process of random selection will be used to select the winning set of bids.

Base price determination

A11.101 Each winning bid has an associated base price. A base price is an overall price for the entire package of lots subject to a winning bid. A separate base price is determined for each winning bidder. (Notice that we do not determine a price per lot for each category of lot.) There is no base price for a bidder who does not win any lots in the Principal Stage.

A11.102 Base prices are calculated using a second price rule. This is a single calculation that jointly determines a set of base prices – one for each winning bidder. We describe the second price rule in terms of a set of conditions that the base prices must satisfy. There is a unique set of base prices that satisfy these conditions.

A11.103 First, the base price of a winning bid must be greater than or equal to the total reserve prices of the lots within the package associated with that winning bid.

A11.104 Second, base prices are required to satisfy a condition that there is no alternative bidder or bidders prepared to pay more than any winner or group of winners. We describe this second condition as a process for checking that the condition is satisfied:

- calculate the total amount of the winning bids (call this the “winning bid total”, W);

- for each winning bid, find the difference between the amount of that winning bid and the corresponding base price (call this the “price difference” for that winning bidder);

- calculate the total of the price differences for all winning bidders (call this the “total price difference”, P);

- take all of the winning bidders’ Principal Stage bids, and subtract the corresponding price difference for each winner from *all* bids made by that winner (call these the “modified bids”);

- re-run the determination of winning bids using the method described above (see Winner determination), but using (a) the non-winning bidders’ Principal Stage bids; and (b) the winning bidders’ modified bids as reduced by the price differences (call this the “modified winner determination”);

- calculate the total of the winning bids found in the modified winner determination (call this the “modified winning bid total”, MW);

- the condition is satisfied when the sum of the modified winning bid total (MW) and the total price difference (P) is equal to the winning bid total (W).

A11.105 There are typically many sets of base prices that satisfy these two conditions. To select amongst all these various sets of base prices, we require a third condition that the sum of the base prices across winning bidders is minimised.

A11.106 All base prices satisfying the first, second and third conditions have the property that the base price of a winning bid is not more than the amount of that winning bid.

A11.107 Where there is only one set of base prices (one base price for each winner) satisfying these three conditions, this determines the base prices for the Principal Stage. In the case where there are many sets of base prices satisfying these three conditions, we impose a fourth condition that selects a unique set of base prices. We can describe this condition in terms of a process for checking that it is satisfied.

- Calculate the opportunity cost for a particular winning bidder which is defined to be:

  i) the amount of the winning bid of that bidder; less

  ii) the total of all winning bids in the winning combination; plus

  iii) the greatest possible total of bids subject to: (a) accepting at most one bid from each bidder; (b) accepting no bids from that winning bidder; (c) allocating each lot at most once; and (d) bidder may only receive a split award of unpaired 2.6GHz spectrum if they made a winning bid for the corresponding split award;

- Calculate the sum across winning bidders of the squares of the differences between the base price and the corresponding opportunity cost;

- The fourth condition is satisfied if there is no other set of base prices satisfying the first, second and third conditions with a strictly smaller sum of squares of differences between the base price for each winner and the opportunity cost for that winner.

A11.108 These conditions characterise a unique base price for each winning bidder that is no more than their winning bid and is at least the reserve price for that package. Finally, if these base prices are not amounts in whole pounds, they are rounded up to the nearest whole pound.

End of the Principal Stage

A11.109 Once Ofcom has determined the winning bids and the base prices, the outcome of the principal stage will be announced to bidders. The following information will be released to all bidders:

- the identity of the winning bidders;
- the number of lots won in each category by each winning bidder;
- the division of lots between unpaired and paired spectrum in the 2.6GHz band and whether a split award is part of the winning combination; and
- the number of guard blocks.

A11.110 In addition, each winning bidder will be told the base price that applies to their own winning bid. This information will not be released to other bidders at this stage.

A11.111 Losing bidders and applicants who did not qualify and applicants who withdrew before the last day for withdrawal will be refunded their deposits, unless these have been forfeit.

The Assignment Stage

A11.112 The purpose of the Assignment Stage is to determine how the available frequencies in the 2.6GHz band are distributed amongst the winning bidders from the Principal Stage, and the final price to be paid by each winning bidder. The Principal Stage will have already determined how much spectrum bidders will receive, whether a split award will be part of the outcome and if so, who will receive this split award (having specifically bid for it), but not the frequency ranges to be assigned (except in the case of the 2010-2025MHz lot).

A11.113 There is a separate assignment procedure for the paired 2.6GHz lots and for the unpaired 2.6GHz lots, although bidding and frequency selection will take place simultaneously for both categories. The exact procedure for each category will vary depending on whether there is only one or more than one winner of lots in that category. For categories where there are two or more winning bidders, a further round of bidding – the assignment bid round – is always required for both categories of lots (except in the case where there are two unpaired winners for non-split awards whose bids can be exactly accommodated in the upper and lower unpaired areas; then the assignment bid round only concerns paired spectrum). For categories where there is only one winning bidder, then no further bidding is required.

A11.114 It is possible that some or all lots in some categories may be unassigned at the end of the Principal Stage. If there are unassigned lots in the 2.6GHz band, this will have an impact on the frequency selection options for winning bidders in this band. Unsold spectrum in each category will be contiguous and unsold lots may not be lots that fall between sold lots within a category. Assignments of paired lots will receive contiguous lots immediately above 2500MHz (and corresponding blocks

immediately above 2620MHz). Assignments of unpaired lots will receive contiguous lots immediately below 2615MHz and possibly immediately below 2690MHz if there are more than 11 unpaired lots in total but depending on how unpaired assignments can be arranged given winning bidders' split supplementary bids.

A11.115 In the case of the 2010-2025MHz lot, there can only be one winning bidder from the Principal Stage. Therefore, no bidding round will be required. The final price for this lot will equal the base price if it is awarded on its own. If it is allocated as part of a package with 2.6GHz spectrum, the final package price will be determined at the end of the Assignment Stage (see below).

Procedure for assigning lots in categories with only one winning bidder

A11.116 If there is only one winning bidder in a category and there are no unallocated lots, then no further bidding is required. The bidder will be assigned all the available frequencies in the relevant parts of the 2.6GHz band. A single winner of unpaired 2.6GHz spectrum would also be awarded the guard block at lot 24 and, in the case that this is a split award, also the additional guard block created in the upper unpaired area.

A11.117 It is possible that some lots may be unallocated. If this is the case, the following rules apply:

- *There is one winner of paired 2.6GHz lots and some lots suitable for paired use are unsold.* In this case, the bidder will be awarded the contiguous frequencies immediately above 2500MHz corresponding to the number of lots that it won.

- *There is one winner of unpaired 2.6GHz spectrum, which has won between two and eleven lots.* In this case, the bidder will be awarded the contiguous frequencies immediately below 2615MHz corresponding to the number of lots that it won.

- *There is one winner of unpaired 2.6GHz spectrum, which has won more than eleven lots, and its winning bid was conditional on there being no split award*. In this case, the bidder will be awarded the contiguous frequencies immediately below 2615MHz corresponding to the number of lots that it won. For example, if the bidder won 14 lots, it would be awarded the frequencies 2545-2615MHz.

- *There is one winner of unpaired 2.6GHz spectrum, which has won more than eleven lots, and its winning bid was a split award.* In this case, the bidder will be awarded two blocks of contiguous frequencies immediately below 2615MHz and immediately below 2690MHz. The larger block will always be the one containing frequencies immediately below 2615MHz.

A11.118 In all these cases, the relevant bidder is not required to participate in any further bidding process for the lot category where it is the only bidder and no additional fee will be due for the frequencies in this category that it is assigned.

Scheduling the assignment bid round

A11.119 For all categories where there is more than one winning bidder, an assignment bid round is generally required (this is always true for paired lots when there are several paired winning bidders; this may not be the case for unpaired lots in the case that licences are awarded in both the lower and upper areas). A separate bidding

process is required for each category, but these will be conducted simultaneously using the electronic auction system. Each bidder will be presented with a single bid form that contains the bid options for all the categories where they are eligible to bid for lots in the Assignment Stage.

A11.120 The start time and duration of the assignment bid round will be announced by Ofcom after the completion of the Principal Stage. There will be at least one clear business day between the supplementary bid round and the assignment bid round (if required). Ofcom has discretion over the time and duration of the round. However, Ofcom anticipates that the round (if required) will take place between 10am and 5pm on a single business day, and last for at least 2 hours and no more than 7 hours.

Determining the bid options for the assignment bid round

A11.121 Winning a certain number of lots within a category in the Principal Stage entails both a right and an obligation to purchase one of the corresponding frequency range options presented to that bidder in the assignment bid round. For example, if a bidder won three unpaired 2.6GHz lots contingent on a non-split award in the first stage, this entails a commitment in the second stage to accept any available contiguous packages of three lots (15MHz) at specific frequencies in either the lower unpaired area or the upper unpaired area in the 2.6GHz band.

A11.122 Bidders are not permitted to bid for smaller packages of lots than they won in the Principal Stage. They are also not permitted to bid for larger packages of lots, except in the case that their frequency bid options include an adjacent guard block, as follows:

- Any option for unpaired 2.6GHz spectrum that includes lot 23 (2610-2615MHz) will additionally include the guard block at lot 24 (2615-2620MHz);
- Any option that involves a split award of unpaired spectrum will include an additional guard block which is immediately adjacent and below the spectrum that they are awarded in the upper unpaired spectrum;
- In the case that lot 38 (2685-2690MHz) is designated as a guard block (outcome 2 in Table 78), this lot will be included in any option for paired spectrum that includes the adjacent lot 37 (2680-2685MHz).

A11.123 For each category where there are two or more winning bidders, Ofcom will determine a set of frequency range options available to each bidder. For each bidder for paired spectrum, Ofcom will identify an exhaustive list of packages of contiguous frequencies which are consistent with the number of lots that they won in the first stage and may also allow all other winners to receive contiguous assignments. There will be a relatively small number of such frequency range options given the requirement for contiguity. For each bidder for unpaired spectrum, the same rules apply, although if a split award is part of the winning combination, the corresponding bidder will be presented with bid option(s) for two blocks of contiguous unpaired spectrum, one each in the lower and upper unpaired areas, consistent with their winning bid from the Principal Stage.

A11.124 In the case of the unpaired 2.6GHz lots, it is possible that there will be only one package of contiguous frequencies consistent with the conditions at paragraphs A11.112 to A11.115 and A11.146 that is available for one or at most two bidders. In

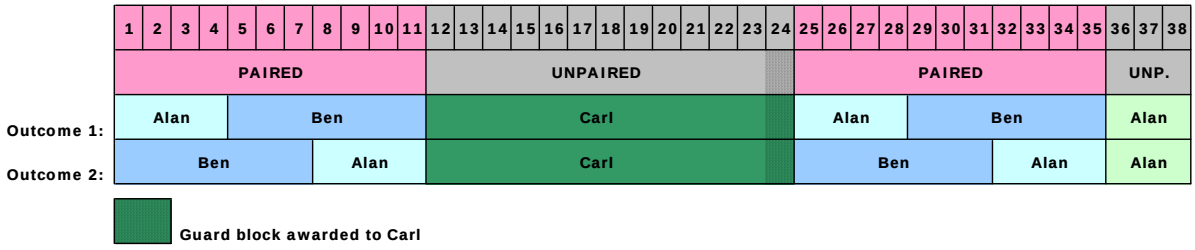
this case, such bidders will not participate in the assignment bid round and will be awarded the relevant frequencies.

A11.125 Some simple examples illustrate. Suppose that in the Principal Stage, there were four winning bidders: Alan won 4 paired 2.6GHz lots and 3 unpaired non-split 2.6GHz lots; Ben won 7 paired 2.6GHz lots; and Carl won 12 unpaired non-split 2.6GHz lots. For the paired 2.6GHz lots, the bid options are as follows:

- Alan: lots 1-4 paired with lots 25-28; or lots 9-11 paired with lots 32-35.
- Ben: lots 1-7 paired with lots 25-31; or lots 5-11 paired with lots 29-35.

A11.126 For unpaired 2.6GHz lots, there is only one way of configuring the spectrum that ensures both Alan and Carl receive contiguous assignments: Alan must receive lots 36-38 and Carl must receive lots 13-23 (plus the guard block at lot 24). The possible outcomes are illustrated in Figure 54.

Figure 54: Example of possible award outcomes I

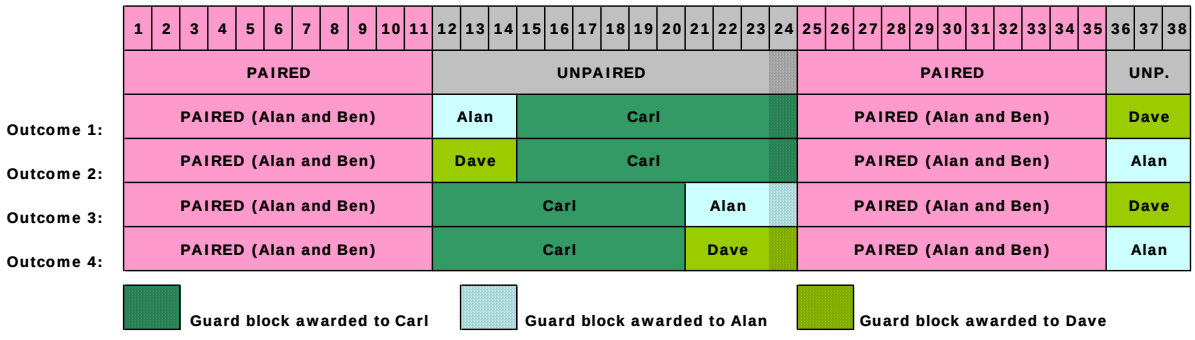


A11.127 Now consider the same example, but suppose that Carl won 9 unpaired non-split 2.6GHz lots instead of 12, and there was another winning bidder, Dave, who won 3 unpaired non-split 2.6GHz lots. The bid options for paired 2.6GHz lots are unchanged, but now there are a number of bid options for each winner of unpaired 2.6GHz lots:

- Alan: lots 12-14; 21-23 (plus the guard block at lot 24); or 36-38.
- Carl: lots 12-20; or 15-23 (plus the guard block at lot 24).
- Dave: the same bid options as Alan.

A11.128 The possible outcomes are illustrated in Figure 55.

Figure 55: Example of possible award outcomes II



A11.129 It is possible that there could be two or more winners of paired 2.6GHz lots and some lots suitable for paired spectrum that are unallocated. In this case, Ofcom will

identify an exhaustive list of adjacent packages of contiguous frequencies, such that one of the packages always occupies the frequencies immediately above 2500MHz. In all cases, the options presented to each bidder will be consistent with the number of paired 2.6GHz lots that they won in the Principal Stage.

A11.130 It is possible that there could be two or more winners of unpaired 2.6GHz lots and some lots suitable for unpaired spectrum that are unallocated. If this is the case, then the options available will depend on the aggregate number of unpaired 2.6GHz lots awarded:

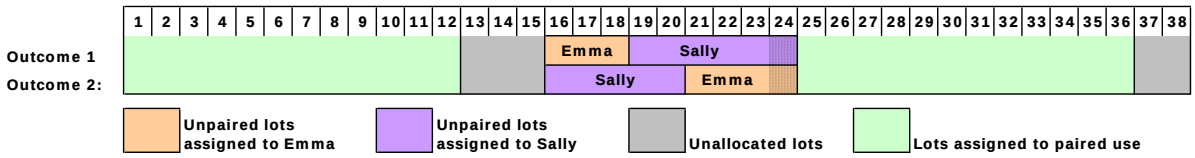
- *If this is eleven or less*: Ofcom will identify an exhaustive list of adjacent packages of contiguous frequencies, such that one of the packages always occupies the frequencies immediately below 2615MHz.
- *If this is twelve or more*: Ofcom will identify an exhaustive list of adjacent packages of contiguous frequencies in the lower and the upper unpaired areas, such that:
  - in the lower unpaired area, one of the packages always occupies the frequencies immediately below 2615MHz; and
  - in the upper unpaired area, one of the packages always occupies the frequencies immediately below 2690MHz.

A11.131 In all cases, the options presented to each bidder will be consistent with the number and structure of unpaired 2.6GHz lots that they won in the Principal Stage.

A11.132 A simple example illustrates. Suppose that in the Principal Stage, there were four winning bidders: Emma won 4 paired 2.6GHz lots and 3 unpaired non-split 2.6GHz lots; Kay won 6 paired 2.6GHz lots; Pam won two paired 2.6GHz lots; and Sally won 5 unpaired non-split 2.6GHz lots. Thus, there are only 12 paired lots and 8 unpaired non-split lots sold; lot 24 is designated as a guard block and 5 lots are unallocated.

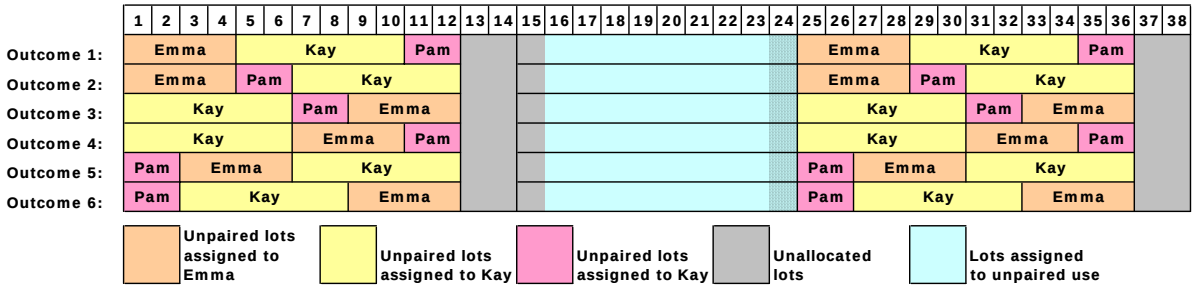
A11.133 For the unpaired 2.6GHz lots, Emma and Sally's awards must be contiguous and adjacent to each other, and one of them must receive frequencies immediately below 2615MHz. There are two possible configurations of Emma and Sally's lots, and both have two bid options each, as illustrated in Figure 56:

Figure 56: An example of bid options for unpaired spectrum in the case of unallocated lots



A11.134 For the paired 2.6GHz lots, Emma, Kay and Pam's awards must be in two paired contiguous blocks and adjacent to each other, and one of them must receive frequencies immediately above 2500MHz. There are six possible configurations of Emma, Kay and Pam's lots, and each has four bid options, as illustrated in Figure 57:

Figure 57: An example of bid options for paired spectrum in the case of unallocated lots



Split assignment of unpaired spectrum

A11.135 A bidder for unpaired spectrum will only receive a split award if it has placed a corresponding split supplementary bid that is part of the winning combination.

A11.136 Any bidder that receives a split award will also receive an additional lot as a guard block, which will be in spectrum immediately below their assignment in the upper unpaired area.

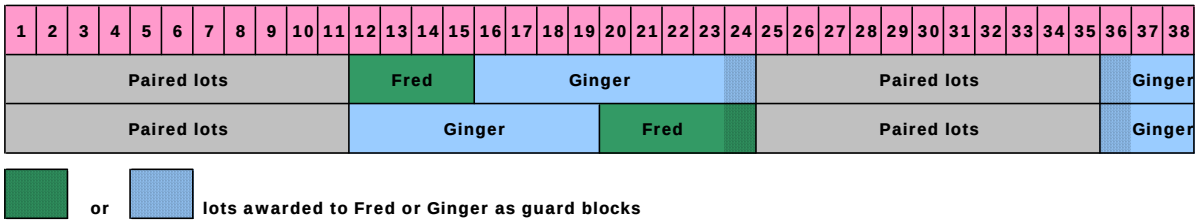
A11.137 A simple example illustrates. Suppose that in the Principal Stage, Ginger won ten unpaired 2.6GHz lots, contingent on a split of eight lots in one area and three lots in the other area (one of which includes the additional guard block), and Fred won four unpaired 2.6GHz lots contingent on a non-split award. Further, assume that all other lots are allocated as paired spectrum or guard blocks. With 14 unpaired lots awarded, the unpaired spectrum must be split into two parts: 12 lots in the lower unpaired area and three in the upper area. On this basis, Ginger's block of eight contiguous lots must be located in the lower area and her block of three contiguous lots must be in the upper area. Similarly, Fred's block of four contiguous lots must be in the lower area. Figure 58 illustrates the possible outcomes, given these constraints. Ginger's bid options are as follows:

- lots 12-19 & lots 37-38, plus a guard block at lot 36; and
- lots 16-23 & lots 37-38, plus guard blocks at lots 24 and 36,

and Fred's bid options are:

- lots 12-15; and
- lots 20-23, plus a guard block at lot 24.

Figure 58: Illustration of bid options in the case of a split award of unpaired 2.6GHz lots



Submitting assignment round bids

A11.138 Assignment round bids are submitted using the electronic auction system during the specified round time. The submission procedure is a two-step process, which is similar to that in the Principal Stage:

- in the first step, bidders input their bids for every available frequency range option in every category where they are eligible to bid, and enter them for checking by the electronic auction system; and
- in the second step, a 'bid submission form' displaying their bids is formally submitted.

A11.139 Assignment round bids must be in whole pounds sterling. The minimum bid for each frequency range option is zero. There is no upper limit.

A11.140 If a bidder fails to submit a bid in the available time, then it will be deemed to have made a bid of zero for every frequency range option in every category where it was eligible to bid.

A11.141 Note that all bidders eligible to participate in the assignment round are guaranteed to win at least the same amount of spectrum in each category that they won in the Principal Stage (in addition, they may be eligible to win one or two guard blocks). Only the relative bids made on different outcomes will affect the outcome selected and the additional prices to be paid. Therefore, it is recommended (but not obligatory) that bidders submit a bid of zero for their least favoured option in every category where they are eligible to bid. A bidder not submitting a bid will be deemed to have bid zero.

A11.142 An extension right will be available to bidders in the assignment bid round. The process for submission of assignment bids in exceptional circumstances will be similar to that described above for the submission of primary round bids in exceptional circumstances. If the bidder fails to submit a bid for one or more available packages, it will be deemed to have submitted a bid of zero for all such packages.

Deposit rule for the assignment bid round

A11.143 Before the end of the day on which the assignment bid round closes, bidders must ensure that they have on deposit with Ofcom an amount no less than the aggregate sum of their base price and their highest assignment round bids for each of the categories where they have submitted such bids.

A11.144 If a bidder does not meet this deposit requirement, all the bids it submitted in the assignment round will be void and it will be deemed to have submitted bids of zero for all frequency range options. These zero bids will be used for the purposes of determining what frequencies are awarded to the winning bidders in each category. No deposit will be forfeit for failing to meet this deposit rule.

Winner determination

A11.145 Following the close of the assignment bid round and completion of the deposit checks, Ofcom will proceed to determine the winning bids for each category.

A11.146 For each category, the winning assignment bids are the combination of valid assignment round bids of greatest total value amongst all valid assignment bids submitted, subject to the conditions that:

- at most one bid is accepted from each bidder;
- each bidder is assigned the same amount of spectrum in each band as they won in the Principal Stage, plus guard blocks if applicable;
- each bidder for paired 2.6GHz lots receives contiguous frequencies;
- each bidder for unpaired 2.6GHz lots is awarded a single block of contiguous frequencies, unless their winning bid was for a split award;
- if a bidder won a split award of unpaired 2.6GHz spectrum (having bid for it), then they will be awarded two blocks of contiguous frequencies, one each in the lower and upper unpaired areas, with the split of lots across the two areas being consistent with their winning Principal Stage bid;
- any bidder that receives a split award will receive an additional guard block, located in spectrum immediately below and adjacent to their spectrum in the upper area spectrum; and
- the frequency ranges included in the winning assignment bids do not overlap.

A11.147 A software algorithm will be used to determine the combination of bids that meets these criteria. Each bidder will have one winning assignment bid in each category where they won lots in the Principal Stage. This is a consequence of (i) bidders only being presented with assignment bid options that are consistent with all bidders receiving blocks of contiguous spectrum and (ii) all bidders making assignment bids (even if of amount zero) for all options. It is possible that there could be more than one combination of bids having equal highest value. In this case, the tie will be resolved by the electronic auction system using a process of random selection.

Determining additional prices and the licence fee

A11.148 In each category where there were two or more winning bidders, additional prices will be determined. The additional prices are determined using a second price rule in an analogous manner to the Principal Stage. As with the Principal Stage, we can describe the second price rule as a set of conditions that the additional prices must satisfy. There is a unique set of additional prices that satisfy these conditions.

A11.149 First, additional prices are required to be positive or zero.

A11.150 Second, additional prices must satisfy a condition that there is no alternative bidder or bidders prepared to pay more than any winner or group of winners. We describe this second condition as a process for checking that the condition is satisfied:

- calculate the total amount of the winning assignment bids (call this the “winning assignment bid total”, AW);
- for each winning assignment bid, find the difference between the amount of that winning assignment bid and the corresponding additional price (call this the “price difference” for that winning bidder);

- calculate the total of the price differences for all winning bidders (call this the "total price difference", AP);

- take all of the winning bidders' assignment bids, and subtract the corresponding price difference for each winner from *all* assignment stage bids made by that winner (call these the "modified assignment bids");

- re-run the determination of winning assignment bids using the method described above (see Winner determination), but using the winning bidders' modified assignment bids as reduced by the price differences (call this the "modified assignment winner determination");

- calculate the total of the winning assignment bids found in the modified assignment winner determination (call this the "modified winning assignment bid total", MAW);

- the condition is satisfied when the sum of the modified winning assignment bid total (MAW) and the total price difference (AP) is equal to the winning assignment bid total (AW).

A11.151 As with the Principal Stage, there are typically many sets of additional prices that satisfy these two conditions. To select amongst all these various sets of additional prices, we require a third condition that the sum of the additional prices is minimised.

A11.152 Where there is only one set of additional prices satisfying these three conditions, this determines the additional prices for the Assignment Stage. In the case that there are many sets of additional prices satisfying these three conditions, we impose a fourth condition that selects a unique set of additional prices. We can describe this condition in terms of a process for checking that it is satisfied.

- Calculate the opportunity cost for a particular winning bidder which is defined to be:

  - the amount of the winning assignment bid of that bidder; less

  - the total of all winning assignment bids; plus

  - the sum of winning assignment bids in a modified winner determination as described earlier in which that winner's assignment bids are excluded;

- Calculate the sum across winning bidders of the squares of the differences between the additional price and the corresponding opportunity cost;

- The fourth condition is satisfied if there in no other set of additional prices satisfying the first, second and third conditions with a strictly smaller sum of squares of differences between the additional price for each winner and the opportunity cost for that winner.

A11.153 These conditions characterise a unique price for each winning bidder in each category that is no more than their winning Assignment Stage bid. Finally if these additional prices are not amounts in whole pounds, they are rounded up to the nearest whole pound.

A11.154 The licence fee for each bidder will be the sum of their base price (from the Principal Stage) and any additional prices for the specific frequency ranges assigned to them (from the Assignment Stage).

End of the assignment stage

A11.155 Once Ofcom has determined the winning bids and the additional prices for the assignment stage, the results of the auction will be announced to all bidders. The following information will be released to all bidders:

- the identity of the winning bidders;
- the frequency ranges awarded to winning bidders in each category; and
- the licence fee to be paid by each winning bidder, including a breakdown of the base price and any additional prices applicable to that bidder.

The Grant Stage

A11.156 In the Grant Stage, winning bidders are granted licences for the frequencies corresponding to the lots that they won in the Assignment Stage, including any guard blocks if applicable.

A11.157 Winning bidders will be refunded the amount of their deposit less the price for their winning bid, as determined according to the rules described above for determining additional prices and the licence fee, less any amount that has been forfeit.

Other Auction Rules

Exceptional circumstances

A11.158 In the case of exceptional circumstances (e.g. widespread technical failure) during the Principal Stage or the Assignment Stage, Ofcom has the discretion to:

- postpone the deadline for a round in progress;
- postpone the scheduling of further rounds;
- cancel a round that is either underway or for which round results have not yet been released, and re-schedule the round again; or
- void all bids received in the auction, and either cancel the auction or start the auction again.

A11.159 In the event that an individual bidder breaches the activity rules, as defined in the regulations, the bidder will either be fined but permitted to continue in the auction, or be expelled from the auction, depending on the severity of the breach. If a bidder is expelled from the auction, all its bids will become void, but for the avoidance of doubt there will be no retrospective change made to the process of the auction up to that point so far as it affects other bidders.

Unassigned lots

A11.160 It is possible that at the end of the supplementary stage, the number of lots allocated to bidders in some categories may be less than supply, either due to

deficient demand or because the winner determination produces a set of winning bids whose aggregate demand for lots is less than supply.

A11.161 If there are unallocated lots in the 2.6GHz band at the end of the supplementary stage (excluding lots set aside as guard blocks), there will be a corresponding number of unassigned lots at the end of the award. Ofcom will retain such unassigned lots for future award as appropriate. In the final assignment outcome, all unassigned lots will be positioned according to the rules set out earlier.

Information policy

A11.162 Information policy determines the information released to bidders and the general public.

A11.163 All bidders will receive the same information (other than details of their own bids which are private up to the conclusion of the auction). Even if a bidder drops its eligibility to zero, it will continue to be able to monitor the progress of the auction (unless it is excluded from the award process, and locked out of the electronic auction system by Ofcom, for transgressing the rules). The information that will be released in each stage of the auction is described in the relevant section of the rules above.

A11.164 Before the auction, Ofcom will publish on its website the number and identity of the bidders. Upon completion of the Assignment Stage, Ofcom will publish on its website the identity of the winning bidders, the frequencies that they have won and their licence fees.

A11.165 After the award process is concluded, Ofcom intends to publish on its website details of all valid primary, supplementary and assignment bids.

Breach of activity rules

A11.166 Any breach of the activity rules that would materially affect the outcome of the award process may result in a bidder or applicant forfeiting its deposit and may also result in that bidder or applicant being excluded from the award process. If a bidder has been issued a licence and is later found to have breached the activity rules, the licence may be revoked. The activity rules apply to all bidders and all applicants who have qualified to bid and they continue to apply until the licences have been awarded.

A11.167 Events that may lead to exclusion from the award process and/or to an initial deposit or bid deposit being forfeited include:

- an applicant or bidder has submitted false or misleading information to Ofcom;
- an applicant or bidder or any member of its bidder group is colluding or attempting to collude with any other person to distort the outcome of the award process, or is acting in a way which is likely to distort the outcome of the award process;
- the applicant or bidder or any member of its bidder group, or any person to whom confidential information has been disclosed, is disclosing, attempting to disclose or inciting another person to disclose confidential information to anyone other than to a member of its bidder group, Ofcom, a provider of finance (where the

disclosure was for the purpose of raising finance for the bid) or to a person considering whether to join the bidder group of the applicant or bidder;

- the applicant or bidder or any member of its bidder group is obtaining or attempting to obtain confidential information in relation to any other applicant or bidder;

- the applicant or bidder or any member of its bidder group is receiving or attempting to receive services in relation to the award process from any person who has provided or is providing services to Ofcom in relation to the award process (for these purposes the advisers are Allen & Overy LLP, DotEcon Ltd, Professor Peter Cramton of the University of Maryland and Dr Ian Jewitt of Nuffield College);

- any member, director or employee of a member of the applicant's or bidder's bidder group, who is also a director or employee of a member of another bidder group, is taking part in the preparation of both bidder groups for participation in the award process or is receiving confidential information relating to both bidder groups;

- a member of an applicant's or bidder's bidder group is or becomes a member of another bidder group; and

- a change is occurring in the membership of an applicant's or bidder's bidder group subsequent to the application day except where a person ceases to be a member of the bidder group, a person has been added to the bidder group in accordance with the regulations, or where a person becomes an associate through merger and acquisition activity provided that such activity is not for a purpose related to the award process (and provided that the addition will not result in a member of one applicant or bidder's bidder group also being a member of another bidder group).

A11.168 Where any changes occur to the membership of an applicant's or bidder's bidder group, that applicant or bidder must notify Ofcom as soon as practicable.

Electronic Auction System

A11.169 Both the Principal Stage and the Assignment stage will be conducted using an electronic auction system. Bidders will be able to access the system over the public Internet using a standard web-browser. The minimum requirements in terms of hardware and software will be described in a user manual that will be distributed to Bidders prior to the auction. However, these requirements will not be onerous – a typical PC running Windows and using Internet Explorer or Firefox or an Apple Mac using Safari or Firefox should usually be sufficient. Java will need to be installed on the bidder's computer to access the electronic auction system (if not already available, this can be downloaded from www.java.com and easily installed).

A11.170 Bidders will need to have a reliable Internet connection (128Kbit/s download speed or better, so a typical ADSL or E1/T1 connection will suffice). We recommend that bidders consider having a backup computer and backup Internet connection.

A11.171 Internet addresses for primary and backup auction servers will be communicated to Bidders prior to the auction. In order to access these servers, Bidders will need to install digital certificates on the computers they intend to use to access the electronic auction system. This is a simple process and instructions will be provided

in the user manual. Digital certificates will be distributed to bidders by Ofcom and are specific to each bidder. A password will be required to install the certificates, which will be distributed separately.

A11.172 Bidders will be able to log in to the auction system only from computers on which they have installed the necessary digital certificates. A further login username and password is required to access the electronic auction system, which Ofcom will communicate to Bidders prior to the auction.

A11.173 Bidders will be identified by the electronic auction system through their digital certificates and their username and login password. Bidders will need to ensure that these are not disclosed to third parties. In the event of any breach of security, bidders should contact Ofcom at the soonest opportunity.

A11.174 The electronic auction system only allows a bidder to be logged in from one computer at any one time. However, should there be a failure of the bidder's computer or network connection, the electronic auction system will automatically log out the bidder, who can then log in from a different computer on which the necessary digital certificates are installed. The bidder will be able to continue using the electronic auction system from the point he or she left off.

A11.175 The electronic auction system allows bidders to enter bids and to observe the progress of the auction. It provides a display of the key aspects of the auction state, such as the number of completed primary bid rounds, whether a round is currently running and a countdown timer for submitting decisions when deadlines are in force. It also displays a clock synchronised with the auction server to aid bidders in submitting bids. However, bidders should note that deadlines apply according to the time that bids are received at the server, not the time that they are sent from the bidder's computer. Therefore, it is prudent for bids to be submitted in good time prior to the end of rounds to allow for network delays. Bids are not processed by the electronic auction system and results are not released until after the end of the round, so there is no strategic advantage to bidders from delaying submission of their bids.

A11.176 Submitting a bid into the electronic auction system involves a two-step checking and confirmation process (regardless of whether these are primary round bids, supplementary bids or assignment stage bids). Bidders will first need to enter their bid (or bids) and send these for checking by the electronic auction system. The system will check that that the bid (or bids) is consistent with the auction rules. If not, the bidder will be given an explanation of the problem and be returned to the relevant screen to allow further editing of the bid (or bids). If the bid (or bids) is consistent with the auction rules, the electronic auction system will return a summary of the bid (or bids), which can then be submitted. Only bids that have been submitted will be considered to be valid bids. If a bidder checks a bid, but then fails to submit it, this will be treated as if no bid was made.

A11.177 Throughout the primary bid rounds, bidders will be able to use the electronic auction system to store and update a list of supplementary bids on a provisional basis. This list of provisional supplementary bids can then be edited, checked and submitted during the supplementary bids round. The facility to check and submit supplementary bids will be disabled until the start of the supplementary bids rounds.

A11.178 The electronic auction system will provide summaries of each bidder's own bids and also a history of round prices and excess demand. Downloadable files of own bids and the auction history will be provided for transferring data to other applications.

These will be available in comma separated value (.CSV) and tab delimited (.TXT) formats. Either format can be easily read into programs such as Microsoft Excel.

A11.179 The electronic auction system provides a one-way messaging system that allows Ofcom to send notices to bidders. Ofcom envisages this being the primary means of communicating with bidders about round schedules, deposit increase deadlines and other aspects of the auction process. If bidders need to contact Ofcom, they will need to use telephone and fax numbers supplied to them by Ofcom.

Miscellaneous

A11.180 Ofcom has a general power to exclude an applicant or bidder where it considers the grant of a licence to that applicant or bidder would be prejudicial to the interests of national security or where the applicant or bidder is not a fit and proper person to hold a licence.

A11.181 Ofcom has a general power to alter the date, time, or place of delivery of any documents or the completion of any action in relation to the award process.

A11.182 Ofcom has a general discretion to refund any sums paid to it.

Annex 12

Evidence of demand for use of the 2.6GHz band

A12.1 In Section 7, Ofcom considers the timing of any award process for the 2.6GHz band, taking into account comments from stakeholders received following the December Consultation.

A12.2 Some stakeholders (including H3G, O2 and T-Mobile) argued that demand for use of the 2.6GHz band was unproven, or that the December Consultation did not provide sufficiently prove that demand exists. Other respondents (including BT, Intel, Siemens, Sprint Nextel, the WiMAX Forum and the UMTS Forum) were of the view that significant and sufficient demand exists for use of the 2.6GHz band in the immediate future.

A12.3 As part of the bilateral discussions held with stakeholders following the December Consultation, Ofcom received a number of concrete expressions of interest in using the band in the immediate future.

A12.4 Ofcom appreciates that those stakeholders who have expressed doubt regarding the existence of demand from potential service providers do not have the benefit of being privy to the bilateral discussions to which we refer. Therefore, in order to set the potential scale of the consumer benefits which could be generated from competition, innovation and cost savings into context, Ofcom has considered further evidence on potential demand for use of the 2.6GHz spectrum drawing on third party forecasts, as well as publicly available data and announcements from operators and equipment vendors.

A12.5 The evidence of demand for services which can be offered using the 2.6GHz band (primarily mobile data services) is considered regardless of whether it is served through the 2.6GHz band or through other spectrum bands (such as those currently held by the 3G MNOs).

A12.6 Ofcom notes that forecasts for end-user demand are, by their nature, uncertain and should be treated with some degree of caution as they are based on a set of forecasted assumptions including, *inter alia*, pricing, availability, quality of service and end-user interest. However, in Ofcom's view, the evidence set out herein for potential demand for use of the 2.6GHz band is such that the consumer benefit which could be generated through the satisfaction of previously un-served demand for mobile data services is significant.

A12.7 As such, this annex provides supporting evidence for Ofcom's assessment of:

- end-user demand for mobile data services
- current and emerging global use of the 2.6GHz band for mobile data services

End-user demand for use of the 2.6GHz band

A12.8 As set out in the December Consultation, there are four main categories of services which have been identified as being of interest to prospective bidders and for which there could be significant demand:

i) Advanced mobile telephony services using 3G technologies and their evolutions (UMTS FDD, HSPA and Long Term Evolution) which are optimised for a mix of voice and data traffic. These would allow the further development of mobile telephony and data services currently available in the UK.

ii) Broadband wireless services using WiMAX standards (2005/revision e in particular) or a variant of the 3G family (UMTS TDD) which are optimised for carrying data with Voice over IP (VoIP) calls as one data application. These would allow the delivery of high data rate services to fixed, nomadic or mobile devices.

iii) Mobile multimedia services that could complement cellular or broadband wireless services or be stand-alone services. Using specific additional applications based on MBMS or TDtv for example, services like mobile television could be delivered to cellular or broadband wireless terminals. A service could also be delivered using technologies such as DVB-H or DMB. Any of these technologies could potentially allow the delivery of broadcast content to portable multimedia devices.

iv) Programme Making and Special Events (PMSE) services, primarily for digital video applications (e.g. wireless cameras, temporary links, mobile or portable links), enabling such activities as news coverage and the broadcasting of planned events, for example concerts or football games.

A12.9 The first three of these services can be grouped under the broad description of 'mobile data services'. Third party forecasts for end-user demand for mobile data services are available for the two main technologies which are expected to serve this demand: 3G/LTE and WiMAX. Therefore, Ofcom has evaluated demand for these two technologies but notes that this does not imply an expectation of which technologies (or which spectrum bands) will be used to serve this demand: the forecasts give an indication of the potential *total* end-user demand for such services.

A12.10 PMSE is an existing service which makes use of the 2.6GHz band and the demand forecasts considered here are for new services which can potentially be served in the 2.6GHz band. Therefore, Ofcom does not consider demand for PMSE in detail in its demand assessment.

A12.11 It is widely held that, to provide the best possible opportunity for latent demand for mobile data services to materialise and to be met, the following factors need to be in place at the same time[152]:

- Network: speed, quality and coverage;
- Device: penetration of data-optimised devices; and
- Service: data packaging (including price) and marketing.

A12.12 With respect to the Network element identified above, the 2.6GHz band appears to be of critical importance as it is the only new band available for mobile use which includes a significant amount of spectrum and is available for use in the short term. Therefore, the impact that the award of the 2.6GHz band is likely to have in

[152] These factors are identified, for example, by HSBC Global Research in *Data Accelerator: Mobile data ripples across the pond*, 7 May 2007.

facilitating adoption and usage of these services is likely to be significant and potentially instrumental.

A12.13 In addition, the proposed award of licences in the 2.6GHz band provides significant opportunities to address the Service factor: the potential for innovation and increased competition (both at the service and technology levels) provides the conditions for more attractive packages for the end-user and a higher level of visibility of services in the market. Additionally, operators may be able to achieve cost reductions through the use of new technologies (applicable to both new entrants and existing operators) and these could be passed on to the end-user.

A12.14 From the Device angle, a rapidly increasing number of devices are being shipped with integral HSPA capability, up from approximately 130 at the end of December 2006 to 261 as of June 2007[153]. This suggests that the availability of HSPA capable equipment (or future evolutions of 3G) will not prove to be an impediment to meeting demand for the take-up of services using 3G technologies and their evolutions. As discussed later in this Annex, there is already a high level of investment in WiMAX services across the globe from equipment vendors, with a number of WiMAX devices and embedded chipsets being developed and this suggests that it is likely that WiMAX CPEs will be available in a sufficiently timely manner to not impede the take-up of such services.

Overall picture of demand for mobile services from the ITU and associated spectrum requirements

A12.15 The ITU has conducted studies to translate demand into frequency requirements to support wireless data services. The corresponding report[154] published by the ITU in January 2007 identifies a lower bound for the overall mobile spectrum requirement of 760MHz by 2010 and 800MHz by 2015 for mobile services. Currently, only 350MHz are available in total in the UK for 2G/GSM and 3G/UMTS. The 2.6GHz band and the 2010MHz band would contribute an additional 205MHz. Therefore, if 2.6GHz and 2010MHz were awarded and available for mobile services, the total supply of mobile spectrum in the UK would still be 205MHz less than the lower requirement identified by the ITU for 2010.

A12.16 This strongly suggests that the 2.6GHz and 2010MHz bands are required to meet existing and growing demand for mobile data services.

Demand for services using 3G technologies and their evolutions

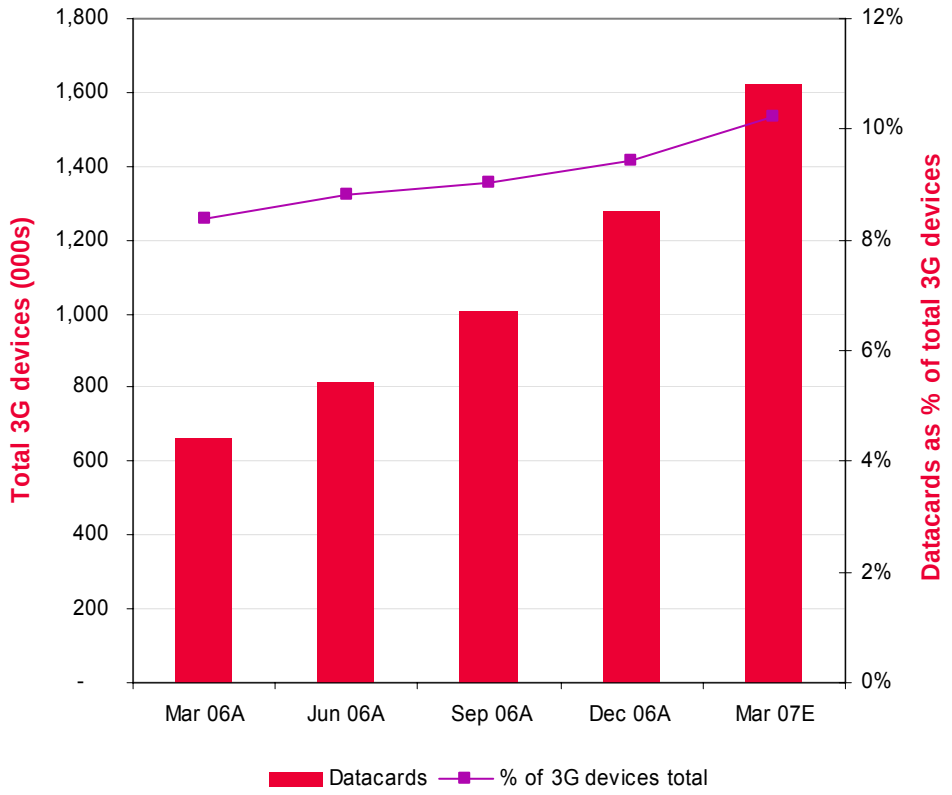
A12.17 Recent figures for the number of subscribers on existing 3G networks[155] show rapid increases in the UK the UK (+65% across all operators) and more generally in Western Europe (+87% across 12 EU countries) between March 2006 and March 2007.

A12.18 Whilst the above does not necessarily correlate with growth in the usage of 3G mobile data services (rather than voice), there is evidence of solid growth in this area: Vodafone's datacard numbers have risen from 0.7 million in March 2006 to

[153] According to the GSM Association, as of June 2007 there were 261 HSPA devices in production from 68 suppliers, comprising: 105 handsets, 43 laptops, 37 datacards, 23 wireless routers, 17 USB modems and 15 embedded modules (http://hspa.gsmworld.com/devices/default.asp)
[154] Report ITU-R M.2078 "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced", 2007. See section 8 in particular.
[155] Source: Informa

1.4 million by March 2007 (at a Group level, as shown in Figure 59 below). This growth has been more rapid than overall growth in 3G devices and is likely to accelerate as, in June 2007, Vodafone announced tariff changes for datacards, including price reductions and the introduction of a flat rate tariff[156].

Figure 59: Vodafone Group datacard subscriptions



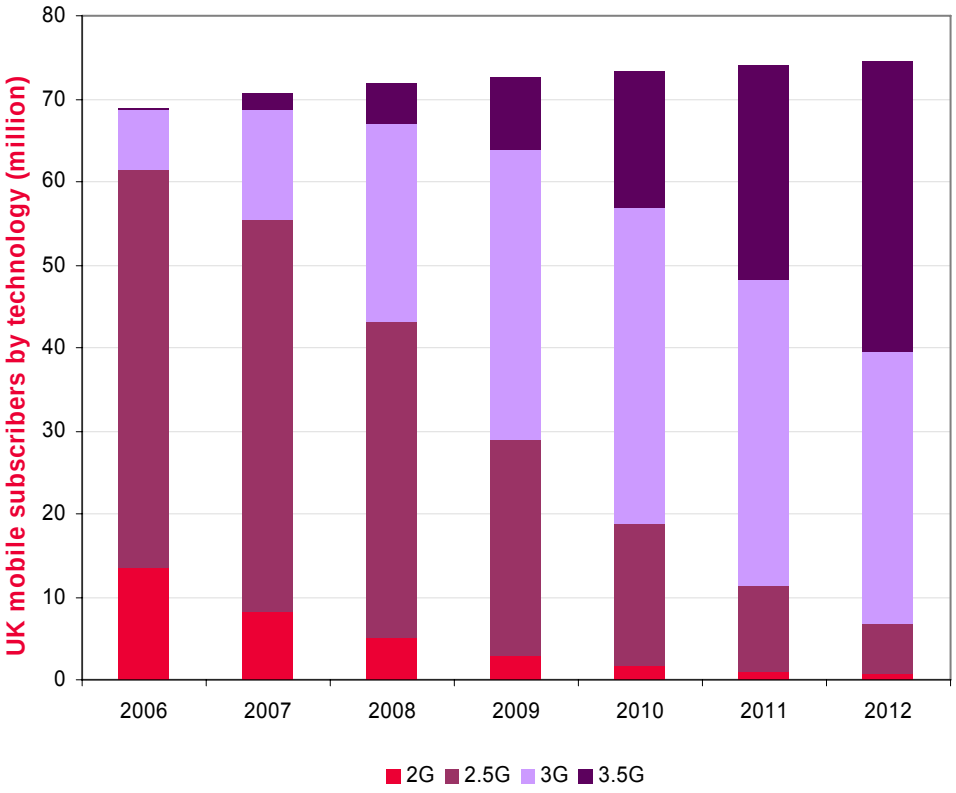
Source: Dresdner Kleinwort, *Vodafone Group: Growing the market for mobile broadband*, 18 June 2007

A12.19 Going forward, subscriber forecasts for advanced mobile telephony services show rapid growth through to 2012 as services become more affordable and customers migrate from other technologies such as 2G and 2.5G.

A12.20 For example, as shown below in Figure 60, Analysys Research forecasts that, by 2012, 47% of mobile subscribers in the UK (35.0 million) will be using HSPA[157], with a further 44% (32.7 million) on UMTS/WCDMA[158] – a base which could potentially migrate to HSPA in the immediate future beyond 2012.

[156] Source: http://www.vodafone.com/start/media_relations/news/local_press_releases/uk_press_releases/2007/mobile_broadband.html
[157] Shown as 3.5G in the chart legend
[158] Shown as 3G in the chart legend

Figure 60: UK mobile subscriber forecast by technology: 2006–2012

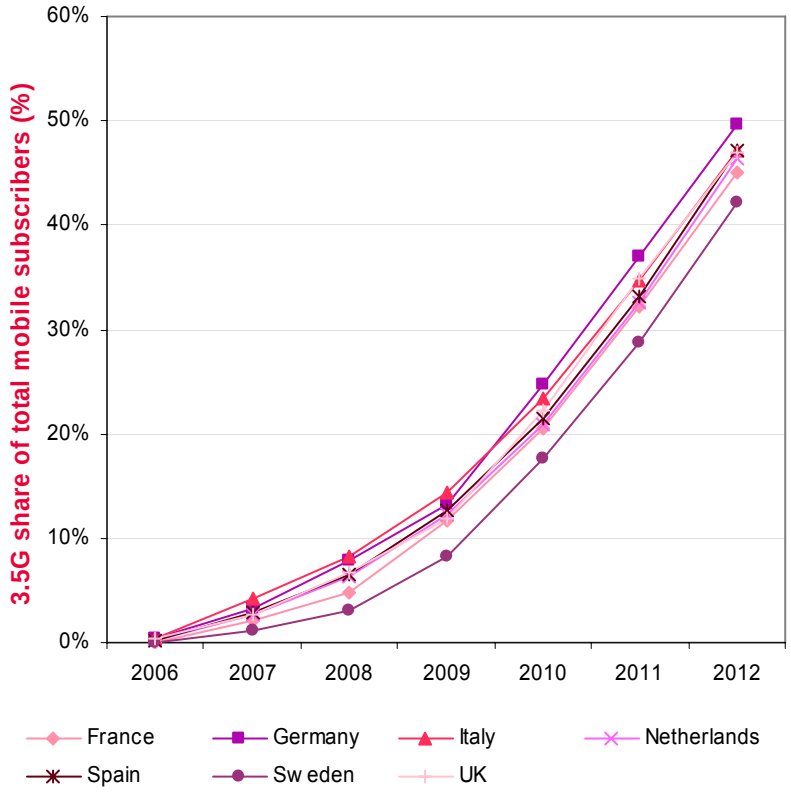


Source: Analysys Research, pre-publication data from *Western European Mobile Market: trends and forecasts 2007-2012*, due for publication in August 2007[159]

A12.21 A similar picture is apparent for other major Western European countries, as shown in Figure 61 below, with HSPA growing to between 42% and 50% of mobile subscribers by 2012.

[159] Prior to publication, the forecasts from Analysys Research may change but it is expected that any changes will be minor

Figure 61: Forecasts of 3.5G subscribers as a percentage of total mobile subscribers in selected Western European



Source: Analysys Research, pre-publication data from *Western European Mobile Market: trends and forecasts 2007-2012*, due for publication in August 2007[160]

A12.22 The evidence set out above shows that there is the potential for significant near-term (and longer-term) demand for advanced mobile telephony and mobile broadband services using 3G technologies and their evolutions.

Demand for services using services using WiMAX or a variant of the 3G family

A12.23 As is the case for 3G technologies and their evolutions, third-party forecasts for demand for services using WiMAX (2005/revision e in particular) or a variant of the 3G family (UMTS TDD)[161] show rapid growth.

A12.24 Recent forecasts for WiMAX published following Sprint-Nextel's announcement that it would use WiMAX 2005/revision e for its 2.5GHz network in the United States (which was seen to be a key element of WiMAX's future success) show significant demand for WiMAX:

- Informa forecast global WiMAX subscribers of 65.6 million by 2012, with Western European subscribers growing to 6.4 million in the same period (of which 58.6

[160] Prior to publication, the forecasts from Analysys Research may change but it is expected that any changes will be minor

[161] Standards which are optimised for carrying data with Voice over IP (VoIP) calls as one data application

million and 6.1 million respectively are forecast to be using 802.16 2005/revision e)[162];

- Visiongain forecast global WiMAX (fixed plus mobile) subscribers of 29.6 million by 2012, with European subscribers of 4.2 million by the same date (the report recognises that, after 2010, growth is likely to accelerate as a higher number of devices will be available, technology will have matured and coverage will have increased)[163];

- Senza Fili Consulting forecast global WiMAX subscribers of 54 million by 2012, with 61% using it for mobile access[164];

- Park Associates forecast global mobile WiMAX subscribers of 88 million by 2012[165].

A12.25 These quantified forecasts are also affected by the expectations of barriers to the development of WiMAX services. For example, the on-going process of assessment of the WiMAX technology within the ITU to determine whether it should be part of the IMT-2000 family of technologies is one such barrier. The 2.6GHz band is designated internationally for IMT-2000[166], which does not restrict it to IMT-2000 technologies but could give rise to such restrictions in certain jurisdictions. The inclusion of WiMAX in the family of technology would also remove the scope for some possible regulatory barriers to materialise. Final approval for the inclusion of WiMAX in IMT-2000 will be considered during October 2007.[167]

A12.26 For the forecasts highlighted above, Informa have stated that their forecast includes an assumption that WiMAX will be included in IMT-2000 from early 2008. Visiongain have not included this in their forecast and believe that this could increase their forecasts by "up to 20%" for Europe. The Visiongain forecast for 2012 would therefore increase to up to 5 million, more in line with the Informa forecast.

A12.27 The forecasts above naturally show some uncertainty around the potential size of the emerging WiMAX market (which is less certain than the HSPA market as it involves the roll-out of a new service rather than the evolution of an existing service and customer base). Nonetheless, the consensus view amongst the third-party forecasts summarised above is that the potential prospects could be significant and could well be even more substantial when the scope for regulatory barriers to be removed in some member states is taken into account.

Consumer expectations for mobile data services

A12.28 UK consumer research from Point Topic published in January 2007 showed a high level of interest in mobile broadband applications, with 60% of home Internet users wanting to be able to email on the move, more than 45% wanting to be able to browse and search the internet and over 30% wishing to do their banking while mobile.

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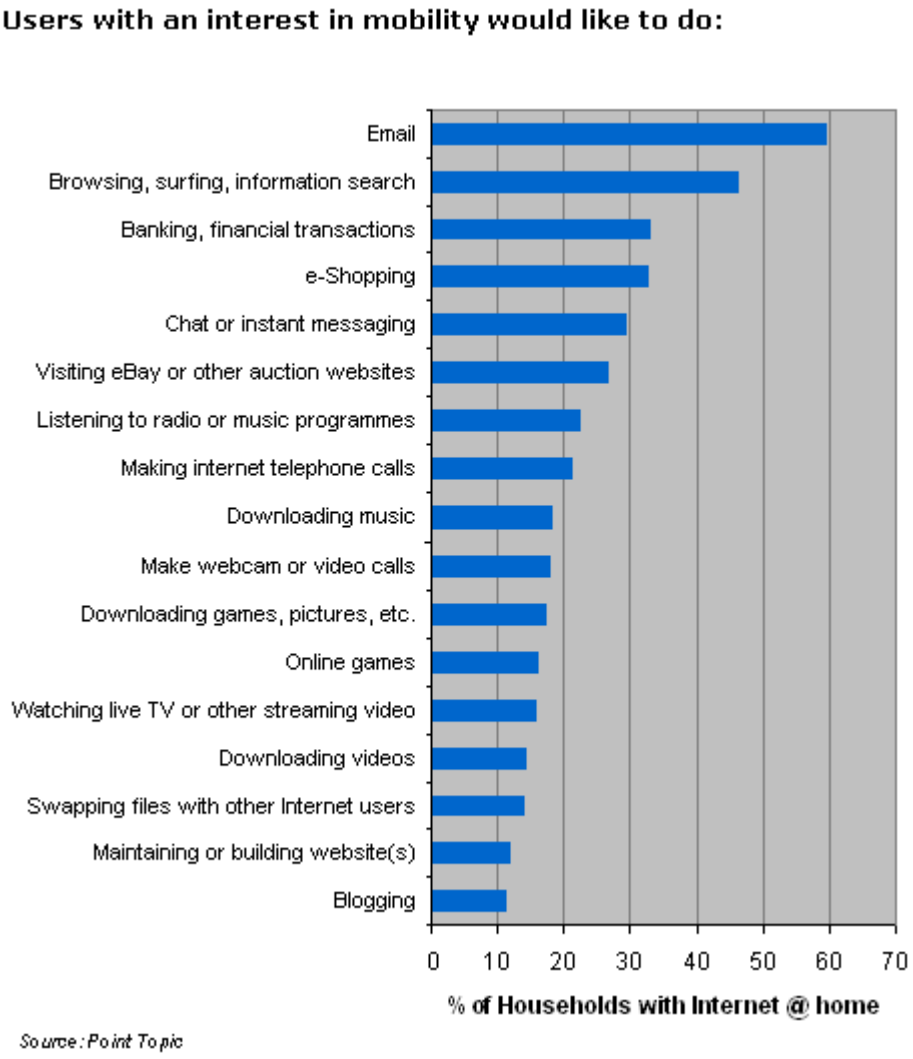
[162] Source: Informa, *WiMAX Broadband Convergence: Emerging Fixed, Portable & Mobile Revenue Opportunities*, May 2007
[163] Source: Visiongain, *Mobile WiMAX Market Forecasts to 2012*, February 2007
[164] See http://www.senza-fili.com/reports/wimax-ambitions-and-reality/press-release.php
[165] See http://www.tekrati.com/research/News.asp?id=8847
[166] In the ITU radio regulations and in two ECC decisions that CEPT member states can adopt.
[167] See http://www.wcai.com/pdf/2007/gdc_june29.pdf

A12.29 To put this survey data into context, as of the end of 2006 63% of adults in the UK lived in a home with some form of Internet access and 50% of adults lived in a home with a broadband connection (the remainder are served by narrowband/dial-up).[168] This, combined with the interest in mobile broadband applications indicated by the Point Topic research, suggests that the potential level of consumer interest in such services could be significant.

Figure 62: UK consumer research on interest in mobile applications



Source: Point Topic, January 2007

A12.30 A recent survey commissioned by Motorola[169] in the US showed that the top four expected uses of WiMAX[170] mobile broadband were:

[168] Source: The Communications Market: Broadband – digital progress report, Ofcom, 2 April 2007 (http://www.ofcom.org.uk/research/cm/broadband_rpt/broadband_rpt.pdf)

[169] See http://www.motorola.com/mediacenter/news/detail.jsp?globalObjectId=8320_8250_23#

[170] The survey defined WiMAX as "being able to be used while walking or travelling in a car, cab, bus or train, and the Internet connectivity it provides will have the connection speeds of cable or DSL, but with the mobility and roaming of today's cellular networks". Therefore, the results appear equally valid for HSPA and LTE.

- responding to email;
- reading and watching “live” online media (e.g. news);
- mobile entertainment, such as interactive, on-demand, mobile TV; and
- download and listen to music.

A12.31 The Point Topic survey covered mobile versions of well understood applications, while the Motorola survey would appear to have considered more ‘aspirational’ services which are reliant on the interviewee interpreting, to some degree, the service being described and would appear to be more bandwidth intensive than the applications considered by Point Topic. As such, these results should be treated with some caution. Nonetheless, these surveys of consumer demand would appear to indicate a high level of interest in the use of mobile versions of existing data applications and in the use of new and innovative applications.

Current and emerging global use of the 2.6GHz band for mobile data services

A12.32 This section examines the evidence of current and emerging use of the 2.6GHz band for wireless data services in a number of areas across the globe:

- Development of technologies capable of operating in the 2.6GHz band
- Significant investments in use of the band when operators already hold licences for 2.6GHz
- Upcoming 2.6GHz licence awards outside of the UK

Development of technologies capable of operating in the 2.6GHz band

A12.33 Operators and equipment manufacturers across the globe are investing heavily in technologies in the 2.6GHz band (including both 3G and WiMAX), and in providing services in this band. The main technologies that are expected to be of interest in the 2.6GHz band are summarised in the table below.

Table 79: mobile technologies most likely to be used at 2.6GHz

Wireless technology	*Description*
3G WCDMA enhancements	
HSDPA	An upgrade to UMTS which increases downlink speeds to up to 14.4Mbit/s and decreases latency[171].
HSUPA	An upgrade to UMTS which increases uplink speeds to up to 5.8Mbit/s and decreases latency.
HSPA	A combination of HSDPA and HSUPA.
HSPA+	Expected to become available in 2008 as part of 3GPP Release 7 and can achieve data rates of up to 28Mbit/s
3G LTE	Due for release as part of 3GPP Release 8. Target downlink speeds are 100Mbit/s, with an uplink of 50Mbit/s and latency of 20ms.
Broadband wireless access	
WiMAX 2005/revision e	Mobile broadband wireless standard. Uses OFDM technology to achieve data rates of up to 31Mbit/s.
Broadcasting technologies	
MBMS	Multimedia Broadcast Multicast Service is a broadcasting service which can run over existing GSM and UMTS networks.
TDtv	A low cost upgrade to 3G networks enabling them to operate in a broadcasting mode, thereby potentially avoiding the need for operators to invest in a standalone broadcast network, such as DVB-H
DMB and DAB-IP	Developments of the DAB digital radio standard to support multimedia broadcasting. Virgin uses DAB-IP services from BT to offer mobile TV in the UK.
DVB-H	ETSI standard for mobile TV broadcasting, with widespread support in Europe.

Source: adapted from Table 2.2 in Analysys Research's report *The future of the Global Wireless Industry: scenarios for 2007-2012*, May 2007

A12.34 All of the UK mobile network operators are currently offering HSDPA services and it is likely that devices (such as HSDPA/HSUPA/HSPA enabled laptops and handsets) will continue to be developed and to be available to enable demand to be met, potentially including at 2.6GHz should the European and/or global market be sufficiently large to encourage equipment vendors to develop devices which can operate in this band.

[171] Most UK networks currently offer downlink speeds of 1.8Mbit/s although this is expected to increase with time.

A12.35 For WiMAX, Ofcom is aware of significant industry effort being expended in the development of the technology given the presence of major equipment vendors and operators on the board of the WiMAX Forum[172], along with existing investment in WiMAX in the 2.6GHz band (see the next sub-section for further details). It is interesting to note that Vodafone has recently launched commercial fixed WiMAX services in Malta[173] and is involved in WiMAX in a number of other markets (either directly or through affiliates)[174] and its CEO has made public statements questioning the rate of development of LTE[175]

A12.36 Nokia Siemens Networks and Motorola are among the major equipment vendors who have already launched products for WiMAX 2005/revision e[176, 177] (with Nokia announcing that they are expecting to ship handsets "*with WiMAX in the first half of 2008*" [178]). Furthermore, a number of equipment manufacturers have announced plans to launch WiMAX 2005/revision e capable network and customer devices in the near future, with Sprint-Nextel's announcement of a USD3 billion WiMAX network encouraging investment from major equipment manufacturers. For example, in January 2007 Sprint-Nextel, along with its strategic partners, announced[179]:

- that Nokia would be a key infrastructure and consumer electronic device supplier
- that Motorola was undertaking a strategic initiative to develop mobile WiMAX chipsets for use in Motorola's next-generation WiMAX devices
- that Samsung would deliver six WiMAX-capable devices (including Ultra Mobile PCs and personal media players), as well as entering the WiMAX chipset business
- that Intel had completed the design of a single-chip, multi-band WiMAX/WiFi chipset that would be made available in card and module forms in late 2007
- that LG Electronics Inc. intends to develop an infotainment device that would work on the Sprint-Nextel WiMAX network

[172] The following organisations are represented on the WiMAX Forum board: Airspan, Alcatel-Lucent, Alvarion, Aperto Networks, AT&T, British Telecom, Fujitsu, Intel, KDDI, Korea Telecom, Motorola, Nokia, Samsung, Sprint and ZTE (http://www.wimaxforum.org/about/board/)
[173] See http://www.vodafone.com.mt/jsp/vfm_news/process_news.jsp?article_id=883
[174] See http://www.unstrung.com/document.asp?doc_id=127623
[175] See http://www.lightreading.com/document.asp?doc_id=117304
[176] Nortel is conducting trials and completing network deployments in a number of countries, including: Australia, Brazil, the Dominican Republic, Greece, Japan, Mexico, Russia, Taiwan and the USA (http://www2.nortel.com/go/news_detail.jsp?cat_id=-8055&oid=100222174&locale=en-US)
[177] Nokia Siemens Networks already includes mobile WiMAX in its product portfolio (http://www.nokiasiemensnetworks.com/NR/rdonlyres/FD9E3BD7-012B-477D-8873-804B2F53A0D2/0/WiMAX_Enabling_Mobile_WiMAX_brochure.pdf)
[178] Nokia has indicated that they are expecting to ship handsets "*with WiMAX in the first half of 2008*" (http://www.zdnetasia.com/news/communications/0,39044192,62025152,00.htm). This and other examples provide an indication of the current activity and interest surrounding mobile WiMAX.
[179] See http://www2.sprint.com/mr/news_dtl.do?id=15000

A12.37 Since this announcement, Sprint-Nextel have further stated that it will be partnering with Clearwire in the US to construct a nationwide WiMAX network with commercial services due to be launched during 2008 under a common brand.[180]

Significant investments in use of the band when operators already hold licences for 2.6GHz

A12.38 In addition to the evidence cited above regarding the development of equipment suitable for the 2.6GHz band, a number of licence holders in the 2.6GHz band are already investing heavily in rolling out networks to offer broadband solutions. The information presented here only includes some examples of the interest and investments that the 2.6GHz band attracts across the world. However, these clearly illustrate the materiality of demand for use now in a number of markets where the spectrum has been assigned for use.

a) Sprint-Nextel in the US announced in August 2006 that it would invest USD 2.5–3 billion before the end of 2008 rolling out a mobile WiMAX based network to cover 80–85% of households[181]. The company is planning to soft launch two WiMAX services in December 2007.

b) Clearwire in the US already held rights to use significant parts of the 2.6GHz band and has continued to acquire 2.5 GHz spectrum in the US, including a June 2007 USD300 million purchase of spectrum from AT&T following its merger with BellSouth[182].

c) Nextwave in the US holds spectrum in the 1.7, 2.1, 2.3 and 2.5 GHz bands which cover 249 million people. A trial network is due to become operational in 2007 in Henderson, Nevada[183].

d) Inukshuk Wireless in Canada (a joint venture between Rogers Communications and Bell Canada) launched a pre–WiMAX network in March 2006 in the 2.3, 2.5 and 3.5 GHz bands and is expecting to cover 60% of Canadian households by the end of 2007, with total investment to the end of 2008 forecast at USD200 million[184].

e) Wind Telecom in the Dominican Republic is planning a commercial launch of WiMAX services in the 2.5GHz band in September 2007 using Nortel equipment[185].

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[180] See: http://www2.sprint.com/mr/news_dtl.do?id=17520

[181] In September 2006, Sprint-Nextel launched their FanView service which allows NASCAR fans to rent a PDA style device at the race track which receives race data, including video and audio feeds, over the 2.5 GHz band using DVB-H (http://www2.sprint.com/mr/news_dtl.do?id=10220). The device was named as one of TIME magazine's best 100 inventions of 2006.

[182] See http://www.wimaxday.net/site/2007/06/04/clearwire-completes-300m-purchase/

[183] See pages 8 and 9 in Nextwave's 2006 10-K (http://www.nextwave.com/sites/Corporate/images/media/512_NextWaveWireles_Inc_2007_10K.pdf)

[184] See http://www.inukshuk.ca/pdf/PressReleases/Inukshuk%20%20March%2031%20Release%20-%20Final%20_3_.pdf and http://www.inukshuk.ca/anglais/20050916press.html

[185] See http://www.govtech.com/dc/articles/104640

f) In South Africa, mobile operator Vodacom is planning to launch a 2.6GHz WiMAX network in partnership with iBurst to compete with the 3.5 GHz network announced by Telkom, the fixed line incumbent[186].

A12.39 From the above, it can be seen that existing licence holders in the 2.6GHz band are already making significant capital investments in rolling out networks, with innovative products (such as Sprint-Nextel's FanView service, which uses DVB-H technology) already emerging.

Upcoming 2.6GHz licence awards outside of the UK

A12.40 Several administrations in Europe and other regions are preparing to award the 2.6GHz band and are planning to hold their award in timeframes similar to those considered by Ofcom, as shown in the table below.

[186] See http://www.telegeography.com/cu/article.php?article_id=18404&email=html

Table 80: Planned timing of 2.6GHz awards internationally

Country	*Indicative timetable for award and comments*
Germany	Planned for early 2008[187]
The Netherlands	Due to take place in early 2008[188]
Norway	Due in October 2007[189]
Sweden	Due in first half of 2008[190]
Japan	Plans to award two licences to new entrants (i.e. excluding existing telecommunications companies such as KDDI, NTT DoCoMo and Softbank)[191]
Taiwan	Six regional licences awarded in July 2007 (three in the north and three in the south). 13 applications to bid were received, with eight applicants being pre-qualified to bid. Only one of the three major telecom companies who bid was awarded a licence. A further national licence is to be awarded in two years[192]
Thailand	The National Telecommunications Commission (NTC) is considering awarding 2.5GHz and 3.5GHz technology neutral licences through an auction process by the end of 2007[193]
Ukraine	The National Commission of Communications (NCRC) has indicated that it will licence the 2.5GHz band for use by WiMAX in the near future.[194]

A12.41 In addition, as discussed in the December Consultation (see paragraph 6.34), ECC Decision (05)05 identifies 1 January 2008 as the date by which the 2.6GHz band should generally be available for use and ECC Decision (06)01 identifies 1 October 2006 as the date by which the 2010MHz band should generally be available for use.

A12.42 These dates reflect the timing considered suitable within CEPT for the award of the two bands, based on an assessment of requirements and demand.

[187] See http://www.rfdesignline.com/news/197003696
[188] See http://ec.europa.eu/information_society/policy/radio_spectrum/docs/ref_docs/rsc19_public_docs/rscom07_05_rev3.pdf
[189] See http://www.npt.no/portal/page/portal/PG_NPT_NO_EN/PAG_NPT_EN_HOME/PAG_RESOURCE_TEXT?p_d_i=-121&p_d_c=&p_d_v=50655
[190] See http://www.pts.se/Sidor/sida.asp?Sectionid=3294&Itemid=&Languageid=EN
[191] See http://www.soumu.go.jp/joho_tsusin/eng/Releases/Telecommunications/news070515_1.html and http://www.wimaxday.net/site/2007/05/16/411/
[192] See http://www.wcai.com/pdf/2007/gdc_july17.pdf and http://www.wcai.com/pdf/2007/gdc_july26.pdf
[193] See http://www.wimaxday.net/site/2007/03/13/wimax-licenses-in-thailand-at-year-end/
[194] See http://www.wimaxday.net/site/2007/06/21/ukraine-may-soon-auction-25-ghz/