Orange response to Ofcom consultation on 'Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz'

8 March 2007

Executive Summary

Orange welcomes the opportunity to comment on Ofcom's proposals for the award of 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz. Due to its potential importance to mobile operators, Orange's comments are limited, other than where stated, to the 2500-2690 MHz spectrum ('2.6 GHz').

The proposed award of 2.6 GHz spectrum represents the allocation of a significant amount of potentially very valuable spectrum, and as a result Ofcom is keen to press on with its award. Orange agrees that the 2.6 GHz 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.

Orange believes that Ofcom's current proposals risk critically undermining the 2.6 GHz spectrum, ultimately to the detriment of UK citizens and consumers, due to the significant number of outstanding issues which require resolution before any efficient award can be made. Orange believes therefore that Ofcom **must not proceed with the award under its current timetable** due to a number of significant issues with its proposed approach, including:

- ***Lack of clarity as to substitutable spectrum***
  Ofcom has not provided mobile operators with any clarity as to how and when UMTS equipment could be used in the current GSM bands, with EU discussions on this issue currently ongoing.

  This is extremely significant, as for mobile operators the GSM bands are a clear substitute to the 2.6 GHz spectrum. Mobile operators including Orange must know the extent to which, and on what terms they can use GSM bands for UMTS prior to being able to make an informed decision as to whether they want to seek award of 2.6 GHz spectrum, and how much they value that spectrum. Ofcom risks distorting any market award, leading to an inefficient outcome, should it not clarify this situation in advance of any allocation.

- ***Lack of certainty as to European dimension***
  Ofcom appears to be pressing on with the award of 2.6 GHz spectrum regardless of the possibility that the EU may adopt a harmonising measure that could apply to this band. Orange believes that Ofcom has not demonstrated that there is significant consumer benefit at risk from delaying the award until this situation is clarified. Furthermore, there is very clearly a risk that Ofcom's proposed approach could be undermined by any EU harmonising measure. Orange would contend that Ofcom should wait until this situation is clearer (prior to the expected CEPT study and consequential RSC discussions) prior to initiating any award.

- ***Significant uncertainty with Ofcom's proposed interference management approach***
  Ofcom is both proposing a move away from the CEPT band plan and the use of Spectrum Usage Rights (SURs) rather than spectrum masks in its quest to introduce technology neutrality in the 2.6GHz band. Orange has very real concerns that this approach could lead to significant inter-carrier interference, devaluing the spectrum and the commensurate benefits to consumers and citizens. Orange has commissioned an independent study annexed to this response which outlines a number of concerns with Ofcom's proposed approach, which must be addressed prior to any award of spectrum.

  Orange would contend that to ensure the timely and efficient award of the 2.6 GHz spectrum Ofcom should follow the CEPT band plan and retain the use of spectrum masks. The expected IMT-accreditation of WiMax means that operators would have a choice as to what type of technology they want to deploy, which should partially meet Ofcom's technology neutrality objective. In any case in reality, Ofcom's proposed approach is not technologically neutral (as retention of the CEPT's 5 MHz channel bandwidth and 120 MHz duplex spacing demonstrates) and Ofcom should not let dogma stand in the way of the efficient of the 2.6 GHz band.

In the absence of a true spectrum market, Ofcom is the monopoly supplier of spectrum to UK spectrum users and has a clear duty to act responsibly to users of spectrum in respect of any spectrum award. Orange however considers that there are far too many problems with Ofcom's current proposals resulting in its current timetable for the award of 2.6 GHz spectrum simply not being realistic.

We would therefore urge Ofcom to firstly resolve the issue of how and when flexible use of GSM bands (including allowing UMTS) will be enacted prior to any award of 2.6 GHz spectrum. Whilst this process is ongoing, Ofcom can seek to resolve the numerous issues that arise from its current novel proposals or determine to revert to a more traditional form of assignment, based on the CEPT band plan. Nonetheless it is clear that there are too many uncertainties for Ofcom to award the 2.6 GHz spectrum without risking a seriously inefficient outcome.

Responses to Questions

Question 1: *Do you agree with these proposals for the awards of the three bands or have any other comments on the contents of this document?*

Orange refers Ofcom to the points made in the Executive Summary above and answers to subsequent questions below.

Question 2: *Do you agree with the analysis in section 5 or have any comments on adjacent interference issues?*

Orange generally agrees with the overall analysis in section 5 on adjacent interference issues. Of concern from Orange's reading of this analysis and its subsequent presentation at the workshop of 8 February is the fact it would appear that the 2.6 GHz band does potentially suffer from a number of adjacent interference issues which will certainly require further investigation and possibly resolution **prior to any award**.

In terms of geographically adjacent interference, the results of the work commissioned by Ofcom demonstrate the significant risk of interference in the North-West of England from Irish MMDS operators. To address this issue, Ofcom indicates that it has requested MMDS deployment details from COMREG in Ireland so as to undertake an updated interference assessment based on actual as opposed to theoretical deployment parameters.

Orange suggests that it would have been appropriate to delay consultation on 2.6 GHz allocation until this assessment is available, given its potential impact on the viability of the spectrum. Nonetheless it would appear clear that Ofcom needs to undertake this modelling work based on actual MMDS deployment to gauge potential geographic interference issues that could arise **prior to** any award of the 2.6 GHz spectrum. It is clear also that a Memorandum of Understanding on border coordination with the Republic of Ireland is of significant importance prior to any award.

In addition, in terms of geographically adjacent interference Ofcom will require a Memorandum of Understanding with the French administration to ensure cross-border coordination with France. Orange would observe that, in moving away from the CEPT band plan, Ofcom is making this process more difficult, and risks a situation whereby the onus is on the UK (and UK operators) to go to greater lengths to mitigate interference due to the UK not following international harmonisation measures.

Orange would also observe that Ofcom's proposals for technology and service neutrality mean that potentially both these MoUs will become redundant and require re-negotiation with **every** change of use or technology.

In respect of RADAR systems operating in the band 2700 – 2900, Ofcom concludes that these will generate interference in the form of increased bit error rate across the 2.6 GHz band, but that this can be handled by the existing Forward Error Correction mechanisms embedded within modern communication system. There does not appear to be any evidence presented to back-up this conclusion and Orange suggests that the interaction between the intermittent 'bursty' bit errors arising from RADAR interference and the closed loop retransmission and adaptive modulation and coding mechanisms of packet based communication systems is studied in more

detail before reaching any final conclusions. Until this is completed the effect of such interference creates considerable uncertainty on the value of this spectrum.

In sum, Orange generally agrees with Ofcom's analysis but believes that Ofcom may have understated the resultant conclusions from this analysis and their impact. Prior to any award there are a number of issues, in particular in relation to geographic interference with Irish MMDS operators, which require much further investigation by Ofcom.

Question 3: *Do you agree that Ofcom should authorise use of the spectrum bands 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz?*

Orange does agree that Ofcom should **in time** authorise the use of the bands identified. Given the large amount of spectrum at stake, its potential use and subsequent value, clearly Ofcom would be remiss in its duties were it not to make this spectrum available **on resolution** of all potential barriers to allocation.

The issue from Orange's perspective is more a question of a) *when* the spectrum should be made available and b) *how* it should be made available. Whilst these issues are addressed in further detail in the answers to subsequent questions, from Orange's perspective it is clear that Ofcom's proposed timings are **far too early** and that there are serious issues with its intended allocation methodology.

From Orange's perspective in terms of timing, Ofcom simply has **not made the case** as to why the 2.6 GHz band has to be allocated in the envisaged time frame. Furthermore, Ofcom has not set out what the possible consumer welfare implications are of delaying the award. Clearly there are some potential users of the band who require access as soon as possible; however there are also other potential users who may want access to these bands but need further information before being able to make this decision. Orange considers that Ofcom has a duty of care to **all** potential users of the band in this regard, and should not unduly influenced by a sub-sect agitating for immediate spectrum award.

There are currently from Orange's perspective numerous reasons why Ofcom's timetable is **not realistic**, including:

- Lack of clarity for use of UMTS in GSM bands and attached conditions – including timescales and how this will be achieved
- Lack of clarity as to possibility of mobile applications in digital dividend spectrum
- UMTS 2600 MHz equipment is currently not on manufacturers' development roadmap, meaning that spectrum may go unused until this equipment becomes available at an as yet unknown future date

In terms of Ofcom's proposed allocation methodology, Orange believes that, quite simply, Ofcom is introducing **far too many unknowns** and experiments into the award process, including:

- Spectrum Usage Rights – including significant risk of interference between TDD and FDD applications under current proposals. It is far from clear from Orange's perspective why SURs have to be applied to the 2.6 GHz band given the likelihood that WiMax will become a member of the IMT-2000 family of standards and therefore able to apply UMTS masks.

- Technology neutrality – significant move away from received method of allocating spectrum in the UK and Europe, with commensurate risks.
- 'Clock auction' – complex auction award that is currently untried. Orange would suggest that Ofcom should at least await the results of the 10 GHz, 28 GHz, 32 GHz and 40 GHz award before proposing its use in the 2.6GHz band.

From Orange's perspective therefore, Ofcom is faced with a choice. It can either aim to meet its ambitious timetable by allocating the spectrum on a tried and tested basis (CEPT band plan, spectrum masks) or it can pursue its untested methods (technology neutrality, SURs) within a longer timeframe once the issues with these methods have been subject to much further investigation and resolution. It is in the opinion of Orange risky bordering on reckless for Ofcom to attempt to allocate such a valuable tranche of spectrum on the current proposed timetable whilst introducing novel concepts which have no proven track record.

Question 4: *Do you agree that awarding licences by auction would be the appropriate mechanism for authorising use of the spectrum bands 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz?*

Orange agrees with Ofcom's analysis that the 2.6 GHz spectrum should not be licence-exempt and therefore the question is how subsequent licences should be attributed. We recognise in this regard that auctions are **theoretically** the most efficient method of awarding spectrum. This is because there is of course an inherent risk with administrative allocation (or 'beauty contests') that regulators make incorrect decisions with resultant economic and social welfare loss. As such Orange does agree, **in theory**, that awarding licences by auction is potentially the appropriate mechanism for authorising use in the 2.6 GHz bands.

However, whilst theoretically auctions as a market mechanism offer the most economically efficient means of allocating scare resources, it should be recalled **in practice** that there are fine examples of regulators making efficient administrative choices, in particular in relation to GSM.

Furthermore, Orange would contend that the question is moot, in that it is unlikely that Ofcom is open to persuasion on the issue of auctions, or recognise the potential benefits of administrative allocation in certain situations (Ofcom's total analysis on this question amounting to one page in the consultation document). There is also a degree of circularity in that by deeming the allocation should be technology neutral, Ofcom is left with no choice but to auction the spectrum. It would appear pertinent therefore to first ask **whether the licences should be allocated on a technology neutral basis** rather than whether they should be auctioned, as the latter is the consequence of the former.

Regardless, it seems clear that Ofcom will allocate the 2.6 GHz spectrum via auction despite the fact that auctions are not necessarily the panacea to allocative efficiency that Ofcom contends. Orange would suggest that in practice the choice of auction may have (potentially negative) implications for UK plc that Ofcom in its one page analysis has not recognised.

In particular Orange would make the observation in relation to the inevitable auction of the 2.6 GHz spectrum that, as with any market mechanism, there is a disconnect between economic theory and practice which Ofcom dogmatically fails to recognise. In particular, **market efficiency depends on a number of assumptions** (perfect information, transparency, non-distortion) **which in practice are often not present**.

This situation is exacerbated by the fact that there is as yet no competitive market for spectrum in the UK; instead the 'market' is dominated by a monopoly supplier of spectrum (Ofcom). Given that Ofcom has such monopoly powers in relation to spectrum supply, there is a great onus for Ofcom to behave responsibly ("non-abusively" in the parlance of competition law) to those who depend on spectrum as a crucial input to their business. The previous large-scale auction of spectrum in 2000 demonstrated the potential for auctions in a situation of monopoly supply to distort market structures and cost bases, which arguably the mobile industry is still recovering from[1].

[1] Interestingly, the European Commission subsequently commissioned a report from McKinsey as to the lessons to be learnt from the 3G licensing process, very few of which appear to have been heeded in relation to the allocation of 2 GHz spectrum.

Orange would also contend that if as anticipated Ofcom decides on allocating the 2.6 GHz spectrum by auction on a technology neutral basis, that it risks putting UK operators at a competitive disadvantage to operators in other EU Member States that do no't use auctions and therefore do not potentially encumber operators with large sunk costs.

In conclusion Orange would accept that there are **theoretical** benefits from auctions which could indicate that it is the most appropriate allocation measure. As with any market mechanism however there is often a difference between theory and practice (a situation exacerbated in the potential spectrum market, where there is currently a monopoly supplier of spectrum with the potential to incur monopoly rents) that risks leading to a sub-efficient outcome. Orange would finally contend that in consulting on the issue of auctions before the question of technology neutrality, Ofcom is actually 'putting the cart before the horse'.

Question 5: *Do you agree that it is likely to be in the interests of citizens and consumers to proceed with the award of the 2.6 GHz and 2010 MHz bands as soon as practicable, rather than to delay the award pending reduction in uncertainty relating to other bands?*

In short, Orange does **not agree** that there is **any conclusive evidence** presented by Ofcom as to **why it would be against citizens and consumers' interest to delay the award of 2.6 GHz spectrum** prior to resolution of a number of key questions.

From Orange's perspective there are instead **numerous reasons** in addition to the uncertainty relating to other bands **why Ofcom should delay** in particular the allocation of the 2.6GHz bands. The premise for this is the fact that Ofcom's proposals will tie-up the 2.6 GHz spectrum for a number of years. If therefore Ofcom, in its haste to allocate the 2.6 GHz spectrum makes sub-optimal decisions, this will have ramifications for that spectrum in the long term. Ofcom would therefore in this regard be acting against the UK citizen and consumer.

In addition to uncertainty to other bands, as Orange outlines below in response to subsequent questions, the uncertainties associated with, *inter alia,* the effectiveness and practicality of the SUR/PFD approach, auction technique and technical feasibility of the close sharing as proposed casts **considerable doubt on the likely success of awarding such a large amount of valuable spectrum**. This uncertainty will, in the eyes of potential bidders, massively devalue the spectrum and undermine the auction process leading to a valuable resource being inappropriately and inefficiently awarded.

In terms of the uncertainty relating to other bands, it is clear that there is **significant uncertainty** as to the possible allocation of substitutable spectrum for mobile operators which **must** be addressed prior to the award of the 2.6 GHz spectrum. This uncertainty means that it is unclear as to what value mobile operators should place on the 2.6GHz spectrum, especially if it is not known whether further substitutes will be made available by regulatory decisions. Possible substitutes for the 2.6 GHz spectrum from the perspective of mobile operators include:

- Current 900 and 1800 MHz GSM bands, which could be refarmed for new technologies
- Possible allocation of spectrum to mobile services resulting from the digital dividend

From Orange's perspective the 900 and 1800 MHz are clear substitutes to the 2.6 GHz band and operators need to know firstly **how and when** flexibility will be introduced into the 900 and 1800 MHz bands to allow the use of technologies other than GSM. Secondly, operators need to know what conditions will be imposed if any on the use of the spectrum for alternative technologies and most crucially the extent to which current spectrum holdings will be subject to change, if at all. Only when this issue is resolved will operators know what value they can place on the 2.6 GHz band as a substitute.

Ofcom **must** therefore first clarify the situation in relation to the 900 and 1800 MHz bands prior to proceeding with the 2.6 GHz award. The timescales for resolution of the 900 and 1800 MHz issue at EU and national level are, as Orange understands it, sufficiently short term that they should not overly delay the award of 2.6 GHz spectrum. In short Orange can see **no good reason why Ofcom should not delay the 2.6 GHz award prior to resolution of this issue**.

Another possible substitute is the spectrum that could be released as a result of the 'digital dividend'. Orange believes that there are compelling reasons why part of the digital dividend should be made available for mobile services so as to extend cost-effective geographic coverage. Nonetheless Orange does recognise that the timescales for the release of digital dividend are sufficiently long-run that they should not **by themselves** delay the award of 2.6 GHz spectrum. This is however another example of substitutable spectrum that presents operators with significant uncertainty.

From Orange's perspective, Ofcom has not made a clear case as to why the 2.6 GHz spectrum should be made available as soon as possible, without resolution of the uncertainty surrounding other bands. In particular, it is not clear to what extent there will be significant consumer welfare loss from delaying the allocation of 2.6 GHz spectrum, as Ofcom has not undertaken any such analysis. Whilst there is clearly a community of potential users that wish to deploy in this band now, there are also a number of other potential users that do not know whether they want to deploy in this band **due to the fact Ofcom has not provided sufficient clarity on the availability of possible substitutes.** Ofcom should be as alive to the concerns of the latter as the former.

In short, Orange believes there are **numerous, compelling reasons to delay the award** of the spectrum, including the current uncertainty in relation to other bands. Ofcom does not appear to recognise the potential 'one off' opportunity that the 2.6 GHz spectrum could represent to mobile operators if other avenues are not made available**.** Ofcom has a duty to reduce the amount of regulatory uncertainty in this area – which is something it is quite capable of doing if the spectrum award is delayed until other issues relating to substitutable spectrum are resolved. From Orange's perspective Ofcom has not made a convincing case as to what the consumer detriment would be from awarding this spectrum e.g. 1 year later (especially in light of the fact that 2.6 GHz UMTS equipment is unlikely to be available to UMTS operators for a number of years).

Orange believes that Ofcom as the monopoly supplier of spectrum has a clear duty to resolve the uncertainty in relation to other bands, in particular 900 and 1800 MHz, prior to any award of 2.6 GHz spectrum. If Ofcom proceeds without having resolved this issue, the auction outcome is likely to be inefficient due to potential bidders not having the information needed to determine the value they place on the spectrum. Ofcom **must** therefore address this issue in advance of the award.

Question 6: *Do you agree Ofcom should aim to award the bands 2500-2690 MHz, 2010-2025 MHz and 2290-2302 MHz by the end of 2007, while keeping the position on the 2.6 GHz and 2010 MHz bands under review in the light of possible developments in European regulatory fora?*

As above in relation to Question 5, Orange strongly believes that Ofcom should delay the award of the 2.6 GHz spectrum until numerous sources of uncertainty are clarified. Many of these sources of uncertainty are caused by Ofcom itself and it is clear that if Ofcom would revert to a more accepted means of spectrum allocation (e.g. following CEPT band plan and adopting spectrum masks) that some of these uncertainties would be removed and an earlier allocation would be more feasible. However, Ofcom's current (untried and untested) proposals introduce inherent uncertainty due to their novelty and for this reason Orange believes that further clarity is required prior to any award.

One of the key risks in relation to this spectrum is the potential for an EU Decision in relation to this band and its consequent possible impact. Clearly, there is a risk that the 2.6 GHz band could be subject to an EU harmonising measure which could prohibit certain usages or technologies. Given the fact that Qualified Majority Voting is in operation in the Radio Spectrum Committee, and that, therefore, it is feasible that the UK could be outvoted on this issue (as it is outside the vanguard of the majority of EU opinion) Orange would contend that declaring, as was done at the workshop of 8 February that the spectrum is awarded "*caveat emptor"* is not sufficient. Ofcom has a duty of care to the potential licensees of 2.6 GHz spectrum to clarify the nature pf potential EU regulatory risk and that it would therefore be appropriate to delay award whilst discussion at the RSC and CEPT are still underway.

The uncertainties highlighted under Question 5 will massively undermine the award process if they are not addressed. Furthermore the uncertainty in the European position is of particular concern and it is inconceivable that bidders could offer the true value of the spectrum until this is resolved. Before awarding the 2.6 GHz spectrum Ofcom **must** therefore wait until:

- The European decision has been made later this year or alternatively there is greater clarity of the EU regulatory situation
- It has resolved the issues relating to 900 and 1800 MHz spectrum
- Technical issues relating to potential interference and the use of SURs have been resolved

Question 7: *Do you agree with Ofcom's proposals for licence conditions (technology neutrality, tradability, conditions of tenure and absence of roll-out obligations)?*

Orange would contend that the licence conditions as referenced in the question can be categorised in two distinct ways as follows:

1. Technology neutrality – including absence of roll-out obligations
2. Tradability – including conditions of tenure

In relation to technology neutrality, Orange would first observe that Ofcom seems to rely on the Framework Directive to justify its pursuit of technology neutrality. The Framework Directive does of course look to treat similar services in a similar manner. However, whilst technology neutrality is an objective, the Framework Directive "*does not preclude the taking of proportionate steps to promote certain specific services*

where this is justified"[2]. In addition, Article 6 (1) of the Authorisations Directive as elaborated in Annex B states that conditions may be attached to rights of use for radio frequencies including "*designation or service or type of network or technology*". In short, Ofcom is **not obliged** by the Framework Directive to undertake a technologically neutral approach.

Regardless, Orange would contend that Ofcom is not actually proposing technology neutrality insofar as Orange would understand it. Ofcom is certainly broadening the potential usage of the spectrum (although the extent to which the value of the spectrum may suffer from multiple technology usages thereby outweighing any benefits of this approach is clearly an issue). Ofcom is instead offering, at best, **quasi**-technology neutrality. This much is obvious from the fact that Ofcom is proposing allocating spectrum in 5 MHz blocks which is clearly more predisposed to some technologies rather than others, as well as the preservation of the 120 MHz duplex spacing for paired spectrum which could thwart the deployment of any other technology that requires a different duplex spacing.

The absence of rollout obligations are as Ofcom states an outcome of the 'technology neutral' approach that it has taken – clearly it would be meaningless for a PMSE operator and a mobile operator to have similar roll-out obligations. This is in itself a good example in terms of illustrating the issues with Ofcom's proposal for 'technology neutrality'. Whilst Ofcom undertakes its analysis with the supposition that PMSE may be a viable application in the 2 GHz spectrum, PMSE operators are not in practice going to be able to compete with telecoms operators for spectrum for PMSE usage, in particular in the 2.6 GHz band where they currently operate.

Whether it is by the market or Ofcom, ultimately in any award process technologies will be discriminated against – in choosing to pursue 'technology neutrality' Ofcom is merely leaving the process of discrimination to the market rather than making the judgment itself. Nonetheless it is clear that PMSE, despite in all probability not being able to pass the market's test (i.e. the technology which has the greatest economic value), still has significant cultural and social importance to the UK and by extension to its citizens and consumers. The market mechanism in this instance is not sophisticated enough to undertake account of this value to the UK. Whilst Ofcom is correct in saying therefore that PMSE operators cannot have roll-out obligations in the same way as e.g. mobile operators, it is in fact disingenuous to compare the two, given the extreme unlikelihood that PMSE will be awarded any of the 2.6 GHz spectrum under Ofcom's current proposals.

It would therefore be better for Ofcom to recognise that the 2.6 GHz spectrum is most valued by mobile and nomadic applications and should therefore be reserved for these services, with the possibility of rollout obligations, similar to 3G licence obligations, being introduced. Given that WiMax is likely to join the IMT family of standard anyway (and should therefore be able to use UMTS spectrum masks) there would appear to be few downsides for Ofcom to allocate the 2.6 GHz spectrum to IMT technology (without having to introduce its untried SUR concept) other than the fact that it will not be able to claim the award as 'technologically neutral'.

Further to this point Orange would contend that Ofcom's analysis as to whether there is potential for discrimination between the roll-out obligations incumbent on mobile operators and potential users of the 2.6 GHz spectrum is slightly disingenuous. Mobile operators have invested significant sums to grow the mobile market and meet coverage requirements. This success is subsequently attracting new entrants

[2] Recital 18, Directive 2002/21/EC on a common regulatory framework

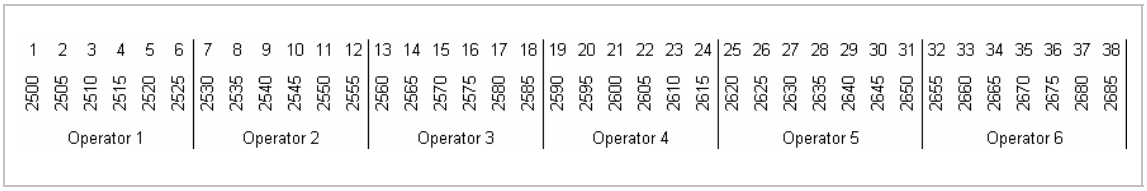
looking to deploy potentially disruptive technologies to compete in the communications market.

Orange welcomes this given the benefits of competition to the customer and to the market in general. However, it is clear that in removing coverage obligations, Ofcom is enabling potential new market entrants in a way that it did not for 2G and 3G new entrants, by allowing them to compete off a lower cost base brought about by the absence of roll-out conditions. Orange welcomes competition but believes that the playing field must be equal for all and that it would be appropriate for roll-out conditions to be attached to licences for 2.6GHz that are assigned to IMT.

The issue of spectrum trading is from Orange's perspective less problematic. If spectrum trading as a policy is to be enacted, it makes sense for any new award of spectrum to be tradable. Implicitly Ofcom also appears to be relying on spectrum trading to undo any potential market failures from the initial allocation. However, Orange would note that in practice trading may not be able to address all possible failures in initial allocation and should not be viewed as a panacea for initial mistakes in this process. Ofcom must not rely on untried secondary trading to correct all issues arising from the initial reward.

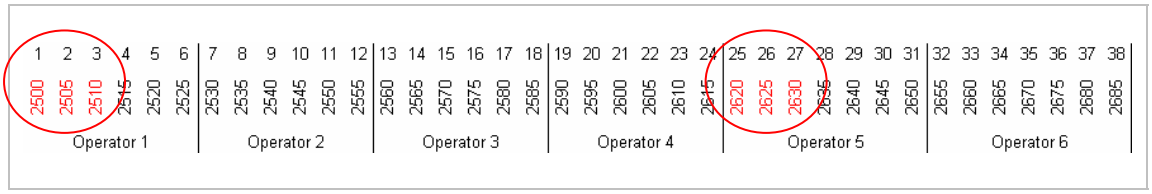
One such example as to the shortcomings of secondary trading to correct initial misallocation is in relation to change of use. If, for example, as in Figure 1 below all the 2.6 GHz spectrum was to be assigned to TDD applications, in practice trading is likely to be insufficient to enable any future move to FDD applications, given the possibility of there being different owners of spectrum at the relevant duplex spacing (e.g. 120Mhz).

Figure 1 – All 2.6 GHz spectrum assigned to unpaired



It could be imagined that after the initial award, a new entrant may wish to acquire spectrum to offer UMTS FDD – in Figure 2 below from operators 1 and 5 as the holders of spectrum which is 120 MHz apart. However, unless this new operator were able to simultaneously negotiate acquisition of, for instance, 3 blocks of spectrum from operators 1 and 5 to pair them for an FDD application, in practice it would end up being forced to pay above normal market rates as it would be clear to the selling parties that their spectrum was not substitutable with any other spectrum, distorting the market. Alternatively operator 1 may wish to exit the market and be a willing seller whereas operator 5 may not, meaning that pairing spectrum for FDD use would again not be possible.

Figure 2 – TDD to FDD



In short, Orange wishes to illustrate that trading is not a 'solve-all' solution to market inefficiencies or problems caused by the initial allocation of 2.6 GHz spectrum. Instead Ofcom should look to pre-empt any issues that can be envisaged now and not automatically assume that that an untried market mechanism (in an imperfect spectrum market) will correct all or any issues.

Question 8: *Do you have views on whether or not there should be a "safeguard" cap on the amount of spectrum that any one bidder could win in an award for the 2.6 GHz bands and, if so, do you have a view on whether 90 MHz would be an appropriate size for a safeguard cap?*

Orange recognises that, **theoretically**, a pure spectrum market should rely on *ex post* competition law to ensure that potentially dominant market player(s) do not act abusively by virtue of their spectrum holdings. However, as this is the first occasion where Ofcom is introducing its technology neutral approach and given that it would not be appropriate for Ofcom to introduce any further elements of experimentation or risk into the 2.6 GHz award, Orange believes that it is right that Ofcom should seek to cap *ex ante* the maximum amount of spectrum that one bidder could win in the award.

Given that it would appear to be justified for a cap to be introduced, the issue is then at what level this cap should be set. From Orange's perspective **the proposed cap of 90 MHz is extremely high**, and furthermore it has not been sufficiently justified by Ofcom. The only current justification provided by Ofcom is that 90 MHz has been selected as the appropriate cap as it is 50% higher than the "*largest individual requirement of which we are aware*".[3]

Orange would contend that this is an arbitrary means of selecting the level of the spectrum cap. If the largest requirement that has been identified is in the region of 60MHz, Orange would contend that this should be the basis of the spectrum cap. What is the benefit of enabling an operator to acquire 50% more spectrum than Ofcom itself recognises is likely to be needed – other than to enable potential acquisition of spectrum by spectrum brokers?

Furthermore Ofcom has not made it clear whether the cap would continue after the award of the spectrum – i.e. if the cap is an *ex ante* restraint on the amount of spectrum that can be held in the 2.6 GHz band after the award. If this is not Ofcom's intention and, subject to *ex post* competition law operators could acquire as much of the 2.6 GHz band they required, there would surely, by Ofcom's logic, be the ability for spectrum trading to address any additional requirements for a given operator. If an operator required more spectrum than the proposed spectrum cap then it could purchase this spectrum from other holders to make up this shortfall.

Orange would therefore propose that:

- The spectrum cap should be set at a maximum of 60 MHz
- Ofcom states explicitly that the 60MHz limit will be lifted on completion of the award, with the ability of spectrum trading (subject to competition law) to address any potential additional requirements.

[3] P. 86, section 6.155

Question 9: *Do you agree with Ofcom's proposal to package spectrum as lots of 2 x 5 MHz for paired use and 5 MHz lots for unpaired spectrum and to allow the aggregation of lots by bidders?*

Orange does agree with Ofcom's proposals to package spectrum lots of 2 x 5 MHz for paired use and 5 MHz lots for unpaired spectrum, as these spectrum blocks are the most appropriate for the most likely technologies envisaged in this band. Orange would make the point that by determining the spectrum packaging in this way Ofcom is *de facto* moving away from its stated aim of technology neutrality as there could be numerous applications with the potential for innovation and consumer benefit which require spectrum to be packaged in different ways. By following the CEPT band plan in this regard Ofcom appears to be implicitly recognising the benefits of harmonisation, which makes is insistence that the award is technologically neutral somewhat puzzling.

It is furthermore critical that bidders should be allowed to aggregate lots contiguously up to the safeguard cap to be decided by Ofcom as per Question 8. What does not appear to be clear is how, under Ofcom's proposals bidders will have visibility of which lot they are bidding for. The 38 spectrum lots are not of equal value, given their distinct characteristics (e.g. proximity to band edge and adjacent interference, proximity to TDD/FDD neighbours) and Ofcom as such needs to be much more explicit in how operators will be able to avoid lots they do not wish to acquire. In particular, Orange is concerned that any FDD application adjacent to a TDD carrier – even with a guard band – would be seriously devalued by the potential intra-carrier interference.

Orange has commissioned an independent technical study (Annex 1) examining, *inter alia,* the spectrum packaging proposals from Ofcom and their potential technical ramifications (and consequent impact on valuations) – attached as Annex 1 to this response. This study shows that FDD operations need to be safeguarded with the definition of appropriate guard bands, emission constraints, the banning of reverse duplex operation, EIRP restrictions and base station coordination. Orange would therefore urge Ofcom to reconsider its proposals in light of this study's conclusions.

Question 10: *Do you agree with Ofcom's proposed approach to allow the respective amounts of paired to unpaired spectrum for the band 2500-2690 MHz to be varied (maintaining the 120 MHz duplex spacing and allowing additional unpaired spectrum, if needed, at the top end of the band)?*

Following Ofcom's assertion that the auction will be technology neutral, it is clear that it would be necessary for the auction process to allow varying amounts of paired and unpaired spectrum, including the possibility of all 190 MHz being allocated to unpaired applications. As detailed above, Orange does not necessarily agree that Ofcom's proposed technology neutral approach is the right one, but if this policy decision is to be made it is consequential that the auction process should be able to determine the amount of paired and unpaired spectrum.

Orange agrees that Ofcom is correct to maintain the CEPT band plan's 120 MHz duplex spacing. Clearly, again, however this is not in itself a technologically neutral approach and illustrates the confusion at the heart of Ofcom's proposals. Ofcom is recognising the benefits of harmonisation and resultant scale economies (that enable e.g. mass handset production and resultant consumer benefits) by maintaining the 120 MHz spacing. Given that Ofcom implicitly recognises the benefits of such harmonisation (and the risk unless the 120 MHz spacing is maintained that the UK

could miss out on such benefits) it is curious that Ofcom maintains that it is following a purely technologically neutral agenda. In short, Ofcom's policy appears to be to 'have its cake and eat it'.

Furthermore, Ofcom is by enforcing the 120MHz duplex spacing discriminating against potential paired applications that may require a different duplex spacing. In addition, as Orange has detailed above, in practice once the 2GHz spectrum is assigned to a particular use (e.g. FDD) it will be extremely difficult, regardless of spectrum trading to change that usage.

As per the detailed comments made in Annex 1, FDD operations need to be safeguarded with the definition of appropriate guard bands, emission constraints, the banning of reverse duplex operation, EIRP restrictions and base station coordination.

Question 11: *Do you agree with Ofcom's proposals for a 5 MHz restricted block between FDD and TDD neighbours and between TDD and TDD neighbours and with a modified out-of-band base station mask for second adjacent 5 MHz blocks?*

Orange believes that Ofcom's proposals for restricted use, rather than guard bands, are seriously flawed. Furthermore the definition of the restricted block is inconsistent in Ofcom's consultation documents[4] meaning that it is difficult to ascertain the exact proposals or their meaning in this regard. To this end we have commissioned a technical study to examine these and other issues further, as per Annex 1.

In short however, Orange would recall that sharing studies have conclusively demonstrated that adjacent channel TDD / FDD sharing is not feasible, especially next to the FDD uplink.

The proposals appear, furthermore, to allow 'picocellular powers' in channels between FDD / TDD and TDD / TDD systems. As per Figure 16 of the consultation document, it is envisaged that EIRP levels of +28dBm/MHz will be permitted, equivalent to a total transmit power of around +34dB (assuming an isotropic antenna) in a 5MHz channel, rather higher than the +24 to +27dBm typical of UMTS picocellular base stations. In short Ofcom's proposals for picocellular powers between FDD / TDD and TDD / TDD systems are significantly higher than Orange's practical experience of picocellular EIRP levels, and that such 'restricted' use could therefore cause significant adjacent channel interference.

In contrast, the CEPT proposal for a guard band is sensible, and should be deviated from with great caution, as Ofcom would lose both the benefits of an interference-free regime and the benefits of harmonisation as detailed above. The proposal for restricted use as opposed to guard bands appears to be another example of Ofcom deviating from trusted spectrum management and policy methods, and instead proposing fairly radical experimentation in what, as it has recognised is potentially valuable spectrum.

Orange would maintain that the out-of-band (OOB) base station masks are clearly required, but there is some ambiguity as to what the values should be and whether they are feasible for all base station types. For further information please see section 2.5 of the report annexed to this response.

[4] The terms 'restricted', 'constrained' and 'guard bands ' appear to be used interchangeably.

Question 12: *Do you agree with Ofcom's proposals to award the 2010 MHz band as a single 15 MHz lot?*

Given the size of this block and its unsuitability to be subdivided Orange agrees that it would appear sensible to award the 2010 band as a single 15 MHz lot. Orange would contend that it is not immediately clear why the award of this block could not go ahead before the award of the main block of 2.6 GHz spectrum.

Question 13: *Do you agree with Ofcom's proposals to award the 2290 MHz band as a single 10 MHz lot?*

Again, given the size of the band and its unsuitability to be split this appears reasonable.

Question 14: *Do you agree with Ofcom's proposals to combine the award of the 2.6 GHz and 2010 MHz bands and to hold the award of the 2290 MHz band separately and in advance?*

Orange believes that the 2.6 GHz and 2010MHz bands should not be awarded in a single auction based on the current proposals because of the uncertainties in the usability of the spectrum under the proposed licence conditions and suitability of the auction process. The principle of SURs, technical restrictions to achieve sharing and the auction process all require further investigation, before trialling perhaps either with another band or a subset of this band.

Question 15: *Do you agree with Ofcom's proposals for a two-stage auction design for the 2.6 GHz and 2010 MHz bands?*

Orange makes the following comments on the assumptions that the issues detailed above are resolved prior to any auction of the 2.6 GHz spectrum. There are, in short, far too many issues requiring resolution or clarification for Ofcom to be considering at this point in time the intricacies of the auction design.

With this proviso in mind, Orange is generally concerned that the proposed auction methodology is yet another example of Ofcom treating the 2.6 GHz band spectrum as an experiment. Given the importance of this band, Orange would have thought that it would be appropriate for Ofcom to remove as many elements of uncertainty and experimentation as possible.

Nonetheless Orange contends that the auction is actually a three-stage process. The third stage is critical as it should allow undesirable channels to be avoided. Orange would propose that a form of second-price auction should be introduced into this third stage to allow undesirable assignments to be avoided. Without such a mechanism, operators have no comfort that they can avoid spectrum they do not value which commensurately undermines the whole auction process.

Furthermore, given that operators will not know what technologies are to be used until after the auction is finished, it is not clear how a precise valuation by bidders can be reached. In one possible outcome, if the 190 MHz were largely to be awarded to 4 WiMax operators and one UMTS FDD operator, assuming similar interference characteristics, the spectrum to the FDD operator in this example may be more valued than if all possible paired spectrum had been assigned to numerous UMTS

FDD operators. Operators will only be able to truly value the spectrum *ex post*, once the neighbouring spectrum proposed usage is known.

Orange has further concerns as to the auction design as follows. Firstly Ofcom has not detailed the proposed increments in the 'clock auction' nor detailed to what happens to these increments over the duration of the auction. It is not clear, for example, whether the increments will stay the same (therefore regressing in proportion to overall value) or will remain proportionately the same.

Whilst it is clear that further work on the auction design is required, Orange would suggest that Ofcom should first set about addressing the numerous uncertainties and points of clarification around the 2.6 GHz spectrum prior to further considering the auction's design. We look forward to further discussion and consultation on this issue.

Question 16: *Do you agree with Ofcom proposals to award the 2290 MHz band through a second price sealed bid auction?*

Orange has no specific comments in relation to the auction proposals for this band.

Question 17: *Do you have a preference for either of the two approaches to specifying technical licence conditions?*

At this point in time, given the current level of work undertaken and the uncertainties with Spectrum Usage Rights (SURs), Orange has a strong preference for the use of spectral power masks. Orange believes that there are significant problems with Ofcom's untried and untested proposals for SURs and that it would be reckless for Ofcom to proceed with allocation based on SURs prior to these issues being resolved. Many of Orange's concerns were raised in our response to Ofcom's Spectrum Framework Review[5] and seemingly have yet to be addressed.

To this end Orange would contend that Ofcom should not be proceeding with untried SUR approach in such potentially important spectrum and that instead it would be more appropriate for the SUR approach to be trialled in other bands first. Orange has commissioned an independent report annexed to this response which highlights the considerable problems with Ofcom's proposed approach for SURs. The use of spectral power masks is therefore strongly preferred until problems highlighted in this report with the SUR/PFD technique have been resolved.

As a starting point, Orange would contend that whichever technique is chosen, initial power limits need to be set that are consistent with the protection afforded by the **current regime as a minimum**, even if that requires the imposition of suitable guard bands. Ofcom should not be proposing a new approach to specifying technical licence conditions that is not as effective as the current system. In addition, Orange would propose that Ofcom needs to set out more clearly and explicitly a cost-benefit analysis for any move to an SUR-based regime.

In particular, Orange believes that masks will always be needed to control spurious emissions, and the control of (near-in) out-of-band (OOB) emissions appears to only be practically feasible through the definition of similar masks. Base station coordination, considered in earlier reports must also be retained in some capacity,

[5] http://www.ofcom.org.uk/consult/condocs/sfr/responses/orange.pdf

although the new procedures must be workable – coordinating with multiple parties at short notice would not be acceptable.

Question 18: *Do you have any comments on the transmitter spectrum masks defined below?*

Orange has a number of comments as follows. Firstly the OOB emission restrictions in channels offset by 10MHz (e.g. Figure 17 in the consultation document – 26dB) appear to be inconsistent with the additional isolation requirements identified by Masons in its technical report (40 to 60dB).

Another concern relates to User Equipment (UE) transmit power. The transmit mask for UE seems to assume UE transmit power up to +30 dBm. Orange would suggest however that +24 dBm, the current allowable UMTS maximum, is more realistic. Ofcom's proposals are problematic because by specifying the EIRP in dBm/MHz and by not (seemingly) excluding concatenation of the blocks to allow wider channel bandwidth to be used, it is permitting much higher average powers to be transmitted than are currently allowed today. For instance a system employing 20 MHz channel bandwidth would in theory be allowed to transmit at +37 dBm/5watts. However it can be easily envisaged that systems capable of supporting 100 MHz channel bandwidth will be developed which would permit +44 dBm/25watts. As such Orange would contend that **average** power levels above +24 dBm total power (regardless of bandwidth) are not generally reasonable for mobile devices.

Furthermore, Orange believes that operators must also know the maximum in-band power that can be transmitted in order to calculate receiver blocking characteristics of victim receivers at minimum coupling loss locations, based on total power received and not power spectral density.

An addition concern relates to Ofcom's analysis which seems to be based purely on UMTS channel bandwidth of 5 MHz, with the spectrum mask OOB limits specified out to 250% from the centre frequency of this 5 MHz channel (i.e. 12.5 MHz). This 250% value is typically the one used by 3GPP and is needed to cover the spectrum characteristics of a signal due to its own modulation, noise and spectral regrowth arising from non-linearities (in the Power Amplifier), and should be met with no additional RF filtering. The spectrum mask is defined, taking into account the allowable adjacent channel interference, so that a group of contiguous carriers (e.g. the whole of the current UMTS frequency allocation of 60 MHz) can be supported in the same base station without the use of any additional filtering on each carrier.

Spectrum mask OOB limits are therefore clearly proportional to channel bandwidth which the Ofcom proposal does not take account of (e.g. for a 20 MHz channel the OOB limit = 50 MHz from centre frequency not 12.5 MHz). The potential consequences of the current Ofcom proposal are that it seems to prevent the optimal deployment of Long Term Evolution (LTE) and probably WiMax in wider channel bandwidths than 5 MHz. On the other hand specifying the spectrum mask OOB limits in a manner proportional to bandwidth is very likely to lead to non-reciprocal interference limits between neighbours using different channel bandwidths with the wider channels causing more interference than narrower ones. Such non-reciprocal effects do not seem to be compatible with a technology neutral operating environment yet sticking with the current proposals would seem to hamper the deployment of future wider bandwidth systems. This dichotomy illustrates the difficulties with developing technical conditions that are truly technology neutral.

An additional comment is that the emissions allowed in the 'restricted' channels (see Figure 16) appear to be higher than would be considered 'typical picocellular' powers, and are likely to cause interference in adjacent channels being used by FDD technology.

Finally, the power masks also need to be extended to include restrictions on spurious emissions from other bands.

Question 19: *Do you have any comments on the SUR parameters defined below?*

Orange has annexed to this response an independent technical report which details a number of the problematic issues that are raised with the proposed move to SURs.

Orange would observe that the SUR parameters defined in the consultation document differ from those calculated by the independent study commissioned by Orange. The main factor driving this difference is the choice of propagation model (see Question 21). This difference highlights the pitfalls of attempting to define licence usage restrictions based directly on a combination of network/technology characteristics *and* the properties of the environment (calculated or measured) in which radio systems are to operate.

The PFDs to be applied to the guard channels between FDD and TDD systems (para 9.81 of the consultation document) are shown to be equal to those in the main channels. These should be reduced to reflect those PFD levels that would be expected when the channels are used as guard channels.

Question 20: *Do you have any comments on the SUR methodology and assumptions detailed in this annex?*

The report annexed to this report highlights a plethora of concerns relating to the proposed SUR/PFD methodology set out in this and previous consultations, and which to date Ofcom appears to have ignored. Specifically these concerns are:

- **PFD limits in principle**: PFD limits alone provide a blunt tool for controlling radio emissions, one which is not sufficiently sharp to take account of the complexity of issues raised by detailed technology and network configuration combinations that would be allowed with the current proposals.
- **Implementation**: many questions relating to the way in which the licences would be issued remain unanswered. The value of spectrum that is proposed to be auctioned is far too great for prototype techniques to be trialled.
- **Enforcement**: the proposals present very real technical and operational enforcement difficulties, which there is a danger Ofcom's field staff will not be in a position to overcome.

In particular section 3.5 of this report details a series of issues in relation to the SUR methodology and assumptions.

Orange's overriding concern is that responsible network operators will, according to the proposals laid out, be unable to maintain good quality networks at a reasonable and predictable cost because of unpredictable interference from networks operating in adjacent bands willing to accept a lower quality of service. This would severely

reduce the worth of the spectrum, and threatens to undermine the entire auction process.

Question 21: *Do you have any comments on the use of the Visualyse tool as described, on the assumptions or the propagation model proposed in this annex?*

In relation to the Visualyse tool Orange's first comment is that Visualyse was initially developed to simulate satellite communications and so would therefore be able to present results in the form of PFDs. But any tool that has the agreed formulae, assumptions and parameters built in should be sufficient to calculate appropriate SUR parameters, as long as the systematic uncertainties in the resulting values in a cluttered ground-based environment are acknowledged.

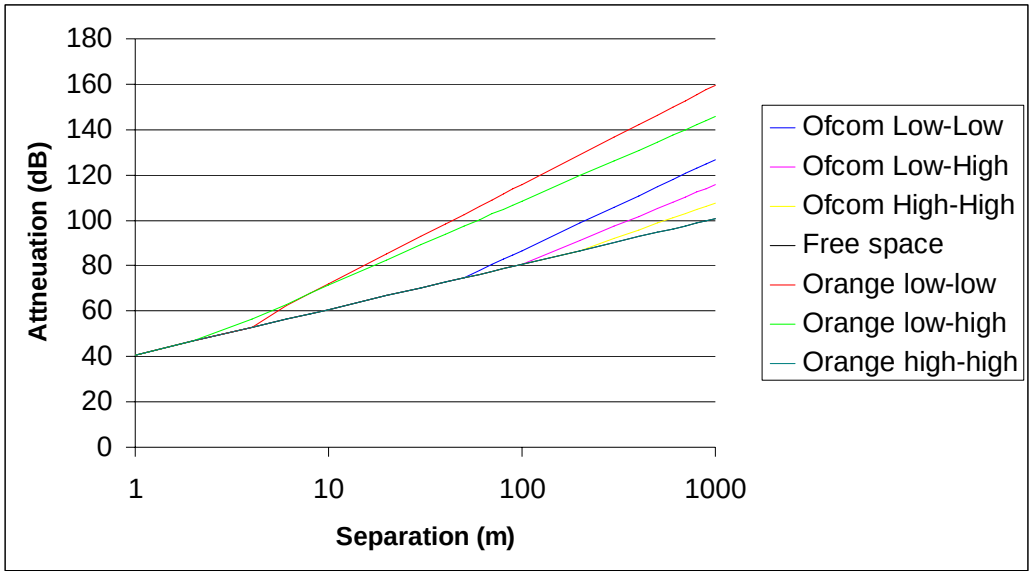
In relation to the propagation model Orange does not believe that the propagation model that has been used by Ofcom[6] is appropriate. This is significant because the proposed PFD limits are closely dependent on the model chosen. In particular:

- Predictions of path losses towards the edges of macro cells appear to be under estimated (by up to 30dB);

- The height dependency of path losses does not appear to have been modelled, particularly for a high-sited base station to base station.

Orange's proposes the use of Cost 231 Hata[7] model, because it better models the variation of propagation loss with height, the predictions of which Figure 1.

Figure 1 - Ofcom and Orange's proposed propagation model

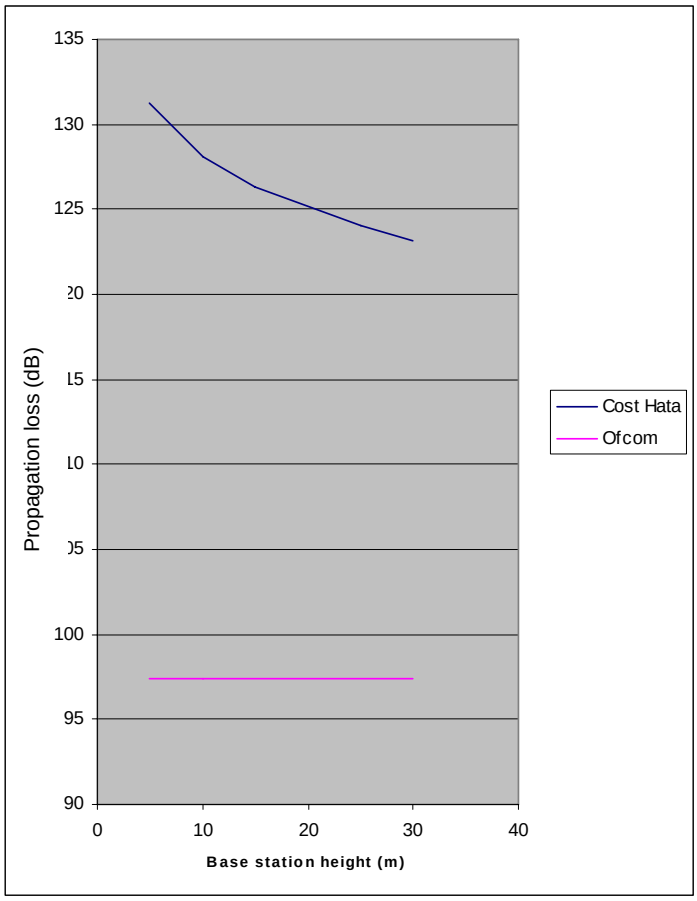


Predictions of variation of propagation loss with base station height are shown in Figure 2 below for both models.

[6] Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz, A12.21

[7] Line of site visibility has been assumed for the high-high (base station to base station case), and where the Cost/Hata model predicts less than free space loss, free space has been substituted

Figure 2: Ofcom and Orange's proposed propagation model, variation with base station height (300m separation)



Agreement of appropriate propagation models (with alternatives for varying terrain types) should therefore be an imperative for Ofcom.

Question 22: *Do you have any comments on the assumptions detailed in this annex?*

The figures are based on 'typical' deployments, whereas the SUR parameters should consider worst case scenarios (plural), if going such a broad brush approach is to be adopted.

The FDD DL base station height of 10m may be typical for microcells, but for macrocells 25m is more usual, making them more vulnerable to interference from other radios, especially similarly placed (above rooftop) base stations.

Annex 1
Independent study commissioned from ICC on ‘Spectrum Usage Rights in the 2.6 GHz band’

INTERCONNECT COMMUNICATIONS

SUR in the 2.6GHz band

Final Report

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Initial Report

SUR in the 2.6GHZ band

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Executive summary

Ofcom carried out a thorough review of its approach to radio spectrum management in 2005 known as the Spectrum Framework Review (SFR). The principles set out in that review have led to proposals to change the way in which it manages and licences radio spectrum use in the UK, including new forms of auction design, spectrum trading and technology-neutral spectrum usage rights (SURs).

The 2.6GHz band[1] (including spectrum identified for IMT-2000 expansion, and in which Orange therefore has an interest) has subsequently (and with no justification) been selected as a guinea pig for the implementation of SURs as part of a new auction, despite the industry's ongoing concerns. The ideas in the consultation document are further complicated by the proposal to use a new and complex auction process based on 'clock auctions', best and final offers (BAFOs) and a final assignment round.

The value of the 215MHz of spectrum planned to be released in these valuable bands is considerable, and Ofcom's proposals for licences to be awarded for 20 years means that it is vital that the way in which the spectrum is released and then managed is sensible. Any mistakes or inappropriate licence conditions in this showcase auction would remain in force for the 20-year duration of the licence.

This work has highlighted three areas for concern with the proposals, which individually introduce uncertainty into the viability of high quality operations in the spectrum under the proposed management rules, but which combined will inevitably lead to bidders being uncertain as to the value of the spectrum. This uncertainty in bidders' collective minds can only undermine the award process and lead to an auction outcome which is economically inefficient and yield reduced revenues.

Firstly, the SUR proposals are complex and untested. This analysis has highlighted problems, both in principle and that are likely to be encountered when they are implemented (generically and in the 2.6GHz band). Proceeding with them in such an important band and for such a large amount of spectrum would be risky and economically reckless, and any mistakes would be apparent for many years. This might take the form of interference in the band making it unreliable, market failure, loss of economic welfare or competitive disadvantage to other economies that followed CEPT band plan.

The determination and measurement of PFD levels (a technique derived from interference studies from satellites) appears to be unreliable in a cluttered urban environment and is more appropriate for controlling satellite emissions where the environment is less complex and propagation losses can be more reliably calculated as direct line of sight.

The SUR proposals place operators in a position such that they may, in response to the activities of adjacent channel operators, be forced to deploy a larger number of less vulnerable base stations, with considerable cost and network management implications, ultimately to the detriment of economic efficiency and consumer welfare. Furthermore, the cause of the interference will be outside the control of the operators and could occur

[1] This consultation also relates to the spectrum 2010-2025MHz and 2290-2302MHz

at any time, without notice. Any new spectrum management technique should ensure that it offers equivalent protection to current techniques.

Secondly, interference studies in the band have concluded that close sharing between TDD and FDD systems is not viable and that the latitude that the proposals give for licence holders to alter the way in which systems are deployed (e.g. the use of directional antennas) means that the usage of the band will ultimately be determined by the lowest common denominator: operators looking to roll out low quality, high capacity systems, to the potential detriment of dynamic efficiency. The externalities of these low quality systems will, in effect, be transferred to operators of neighbouring high quality systems: that is, relaxation of technical constraints on low quality systems will have an exaggerated effect on efforts made by high quality systems to maintain a reasonable end-to-end quality of service.

Finally, the auction rules will compound the uncertainty in bidders' minds in that, given the inability for specific channels to be *avoided*, the economic value of the wanted channels will also be diminished.

The consequence of bidders' inability to clarify the nature and thereby value of such a nebulously defined commodity will make it difficult for managers and network designers to justify to company board members a case for investment in the spectrum. This could undermine the auction process and inevitably mean that the spectrum is massively devalued and inefficiently allocated.

The *principles* behind the proposals are sensible and may, in time, turn out to be feasible. Many of the details, however, are flawed and so Ofcom should proceed with caution using a more realistic roll out schedule. This would allow the risks associated with the radical changes in the way the spectrum is released to be managed, as well as allowing a realistic roll back option to be planned.

Detailed recommendations for further investigation include:

Licensing policy, procedures and enforcement

Trial SUR/PFD principles in a representative band: as a 'shadow' process to the existing management techniques. Candidate bands might include the GSM bands (900 and 1800MHz) or Band III mobile, which would lead to:

- A better understanding of the practicalities and limitations of the PFD limit technique;

- Understanding of the engineering trade offs, between relaxation of traditional licence conditions towards pure SURs and their potential commensurate economic benefits, and the consequent threats to radio services;

- Fine tuning of the SUR/PFD methodology, based on the limitations discovered and lessons learnt.

Consider combinations of licence restrictions: including combining licence restriction techniques that Ofcom examined as part of the SUR consultation e.g. EIRP limits, aggregate PFD limits, coordination (including CDMA code coordination).

Investigate network implications for varying quality of service requirements

The SUR/PFD proposals should allow bidders (with the knowledge of existing IILs) to determine, in the absence of in-band interferers, the value of the spectrum based on an engineering assessment of the 'capacity' of the spectrum: the throughput and expected quality of service. Ofcom should, therefore, work with manufacturers and operators to investigate the likely impact of increasing PFD levels and varying network deployment characteristics on achievable link grade of service, and hence the engineering cost of 'hardening' the network.

Abandon reliance on field measurements: reliance on field measurements - in particular, aggregate PFD measurements - as a sole method for determining breaches of licence conditions has been shown by the work in this report to be impractical.

Investigate legal status of the regime: Ofcom needs to make sure that all legal aspects are investigated (eg Protection to neighbouring traditional licence holders, UE equipment licensing, Subsequent EU rulings). Including protection to more distant neighbours (see section 2.2.2);

Investigate initial SUR parameter determination: Ofcom should consider varying PFD limits dependent on various parameters, and not rely on single sets of values.

Influence the international community: these proposals need to be progressed using a sensible roll out approach whilst simultaneously seeking an international consensus so as to ensure that the UK is in step with any EU proposals regarding SURs.

Measurement area: the proposed measurement area of ten cells is too large and should be augmented by measurement/calculation over a single cell area.

Spurious emissions: power mask restrictions will need to be applied to all transmitters and measured directly at their output.

Technical considerations in the 2.6GHz band

Outlaw adjacent channel operation: sharing studies have conclusively demonstrated that adjacent channel sharing between FDD and TDD technology is not possible and so the CEPT plan, which reserves a guard channel between the TDD block and FDD uplink and downlink blocks must be preserved.

Outlaw duplex reversal: reversal of the FDD duplex should be explicitly outlawed, because attempting to operate even similar systems in adjacent channels will fail and render the spectrum worthless.

Restrict peak EIRP: upper EIRP limits should be introduced to ensure that, when combined with the SUR methodology, severe local interference is avoided.

Auction design and timing

Second-price option for final assignments: (and allowing all available channels to be bid for) should be considered for the final assignments stage of the auction. This will better allow undesirable channels to be avoided.

Trial the auction process: the complex auction process should be trialled before a commitment is made to its use for the award of such a large quantity of prime spectrum.

Ofcom may, after observing its use for auctions in the 10 GHz, 28 GHz, 32 GHz and 40 GHz bands, consider releasing a limited subset of the spectrum in this way, perhaps the 2010-2025, 2290-2303MHz and/or limited number (18, 19, 20 and 21) of channels within the unpaired (according to the CEPT band plan) 2500-2690MHz bands.

Award timing: the auction should not proceed until the issues raised in this report are first addressed and the consequent rules and background information are completed. Bidders will then need sufficient time to carry out any necessary due diligence preparations: a minimum of three calendar months.

1. Introduction

1.1 Background

This report was commissioned by Orange Personal Communications Services Limited and has been written by Interconnect Communications Ltd (hereinafter referred to as InterConnect) as a result of work undertaken in collaboration with the Communications and Spectrum Management Research Centre (ISYAM) at the University of Bilkent, Ankara, Turkey.

InterConnect was established in 1984 to provide comprehensive consulting and professional services to the telecommunications and wireless industry and is a leading independent management consultancy specialising in telecommunications, in particular numbering, interconnection and radio spectrum management and monitoring. InterConnect has supported the development of spectrum management regimes across Europe, the Middle East, Asia and Africa including spectrum planning, pricing, licensing, co-ordination and monitoring. In addition, InterConnect has conducted a number of detailed spectrum engineering studies including investigation into more spectrally efficient technology in the aeronautical and maritime sectors, and into the impact of digitalisation on broadcasting.

ISYAM was founded in 1994 as a Research Centre of Bilkent University and is mainly concerned with issues that intersect Telecommunications and Information Technology. Amongst other projects, ISYAM is developing the National Frequency Management System (NFMS) for the General Directorate of Radiocommunications in Turkey which includes spectrum engineering support as well as the database for licensing, monitoring, frequency management, accounting and other functions of the Directorate. The spectrum engineering support comprises technical analysis, interference analysis, frequency planning and assignment, international coordination, system engineering, and other technical modules.

1.2 Context

Ofcom carried out a thorough review of its approach to radio spectrum management in 2005. In that review, known as the Spectrum Framework Review (SFR), Ofcom set out its vision based on three principles:

- Spectrum should be free of technology and usage constraints as far as possible. Policy constraints should only be used where they can be justified;
- It should be simple and transparent for licence holders to change the holding and use of spectrum;
- Rights of spectrum users should be clearly defined and users should feel comfortable that they will not be changed without good cause.

These principles have led Ofcom to develop proposals to change the way in which it manages and licences radio spectrum use in the UK, including new forms of auction design, spectrum trading and technology-neutral spectrum usage rights (SURs).

Consultants[2] were engaged to examine the principle of SURs (and overriding spectrum management rights (SMRs)) more closely, looking specifically at implementation options and issues that may arise from these. This work examined technical options for the implementation of SURs, highlighting advantages and pitfalls of each, but avoided recommending a preferred option. The work also identified various issues with the technique which would require further investigation or limit its application.

Ofcom's subsequent consultation document[3] developed these ideas and opted to adopt the method of Power Flux Density (PFD) limits to control emissions across geographical boundaries and into adjacent spectrum, but with little evidence to support why this option had been chosen or why it was appropriate. In the ensuing consultation, the wider radio community supported the principle of SURs[4], but expressed concern and a belief that further work should be carried out to investigate the efficacy and practicability of PFDs to protect services from harmful interference.

The 2.6GHz band[5] (including spectrum identified for IMT-2000 expansion, and in which Orange therefore has an interest) has subsequently (and with no justification) been selected as a guinea pig for the implementation of SURs as part of a new auction, despite the industry's ongoing concerns. The ideas in the consultation document are further complicated by the proposal to use a new and complex auction process based on 'clock auctions', best and final offers (BAFOs) and a final assignment round.

Technical studies accompanying the consultation documentation furthermore reaffirm Orange's grave concern of potential sharing difficulties within the bands (especially the 2.6GHz band), both with potential technologies that may be implemented in the UK and with networks in neighbouring countries.

Orange, therefore, has three main concerns with respect to these proposals:

- **Feasibility and protection afforded by SURs and specifically PFDs**: the issued and concerns that Orange raised in response to Ofcom's generic SUR consultation proposals do not appear to have been taken into account. Orange believes that three aspects of the use of PFDs need further investigation and resolution before SURs can be introduced in practice:
    - **PFD limits in principle**: PFD limits alone provide a blunt tool for controlling radio emissions, one which is not sufficiently sharp to take account of the complexity of issues raised by detailed technology and network configuration combinations that would be allowed with the current proposals.
    - **Implementation**: many questions relating to the way in which the licences would be issued remain unanswered. The value of spectrum that is proposed to be auctioned is far too great for prototype techniques to be trialled.

[2] Technology-neutral spectrum usage rights, Aegis Spectrum Engineering, Feb 2006

[3] Spectrum usage rights: technology and usage neutral access to the radio spectrum, April 2006

[4] 'Next steps for SURs', 1 November 2006

[5] This consultation also relates to the spectrum 2010-2025MHz and 2290-2302MHz

- **Enforcement**: the proposals present very real technical and operational enforcement difficulties, which there is a danger Ofcom's field staff will not be in a position to overcome.

- **Engineering concerns over proposed packaging and adjacent channel use**: the engineering studies confirm the incompatibility of close FDD /TDD sharing, but Ofcom's final consultation appears to ignore this advice. Orange also believes that most of the consultants' suggested engineering mitigation proposals in the 2.6GHz band are impractical.

- **Complex auction process:** the auction process developed by Ofcom has not been trialled and, when combined with the uncertainties of SUR/PFD limits and engineering concerns, is likely to lead to an unsatisfactory outcome for the bidders and Ofcom, inevitably lead to economic inefficiency as well as technical difficulties. The auction design has not taken account of the difference in value of the channels that result from the process.

Orange is gravely concerned, therefore, that if these issues are not resolved prior to the award of spectrum, the value of the spectrum could be virtually negated due to the impracticality of using the proposed SUR interference management approach, which will undermine the auction.

1.3 Scope of work

The scope of the work documented in this report is an investigation into the concerns that Orange has around each of the three issues above, centring on the reliance on PFD limits to manage activities in the bands to determine whether such an approach is valid and appropriate in an auction for spectrum that is likely to be so valuable.

To enable a thorough and realistic view of the impact of the use of PFD based SUR's, and to validate Ofcom's assumptions on the viability of SUR's, sophisticated computer modelling algorithms have been employed. This modelling forms the underlying core of the results presented in this report and has been conducted using advanced software tools and techniques.

The results of the modelling have been used to derive recommendations for Ofcom and the industry in order to progress the principles of technology-neutral licensing and SURs, especially in the 2.6GHz bands.

1.4 Modelling approach

The systems that have been modelled represent generic FDD/TDD systems based on the UMTS standard. The configurations of the systems modelled are based on those suggested in the consultation document and supporting studies.

The modelling work proceeded in two stages:

- Pre-modelling calculations: estimated the power transmitted by each UE and base station (both total and code domain), and estimated the level of self interference

(intra- and extracellular) experienced by each radio based on a set of assumptions derived from real network experience.

- SUR modelling: a model of the geometry of each scenario, calculated the external interference to each radio and compared this with wanted levels to predict levels of interference to noise (I/N) and external to self interference (intra- and inter-cellular): Ie/Is.

The model also calculates PFD parameters at three heights (1.5m, 10m and 25m (above rooftop level)) using both a fine 300-point[6] mesh in the central cell (a good average) and a coarse 25-point mesh across seven central cells (reflecting a similar scenario to the proposed measurement regime[7]).

1.5 Contents of the document

The remainder of this document is structured as follows:

- Section 2 highlights concerns surrounding Ofcom's proposals in the 2.6GHz band;
- Section 3 draws conclusions and makes recommendations as to how Ofcom should proceed in the band and, more generally, with its SUR proposals;
- Annex A describes in detail the modelling that has been carried out to support this work;
- Annex B highlights errors, omission and comments in Ofcom's consultation document and supporting technical documents;
- Annex C contains a list of acronyms used in the document.

[6] Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', para A12.18

[7] Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', paras A11.4 and A11.6

2. Concerns

2.1 Introduction

This section sets out in more detail the concerns that have been identified with the proposals for auctioning and managing the spectrum in the 2.6GHz band. This section deals largely with those spectrum engineering concerns which Orange believes make the imposition of PFD based SUR's untenable. It does **not** therefore represent the full set of issues which Orange has with Ofcom's auction proposals.

Three areas of concern have been identified by Orange:

- Feasibility and protection afforded by SURs and specifically PFDs.
- Engineering concerns over proposed packaging and adjacent channel use.
- Complex auction process.

This section addresses each of these areas as follows:

- Section 2.2 examines concerns about the **principle of SUR**.
- Section 2.3 examines concerns about how the **SUR technique would be implemented** in practice
- Section 2.4 examines concerns about the **SUR technique would be enforced**.
- Section 2.5 examines **interference** concerns with the proposed packaging and adjacent channel use
- Section 2.6 examines concerns about the proposed **auction rules**.

2.2 Spectrum Usage Rights (SUR): in principle

Ofcom and its consultants considered several possible implementations of SURs and acknowledged that there are advantages and disadvantages of each technique. Nevertheless Ofcom, in its current consultation documentation, appears to have decided to opt for the use of PFD limits to control all emissions with no justification and despite the reservations of industry and their own consultants.

This section examines some potential pitfalls of the SUR/PFD technique, even if it were implemented and enforced efficiently.

2.2.1 High power transmitters

The SUR/PFD principal is alleged to allow network operators flexibility in the way in which they implement their networks, permitting configurations that deviate away from the way in which current networks are typically implemented. Based on the PFD

principle proposed, two extremes (away from the normal configuration) of network deployment would become possible: low density deployment of high-power transmitters (base stations or user equipment); or high density deployment of low-power transmitters. Figure 2-1 shows schematically the different configurations populated to the maximum allowed, and an average or 'normal' configuration. The areas in light blue represent regions where the PFD limit is allowed to be exceeded (ie 50% of the total, under Ofcom's proposals).

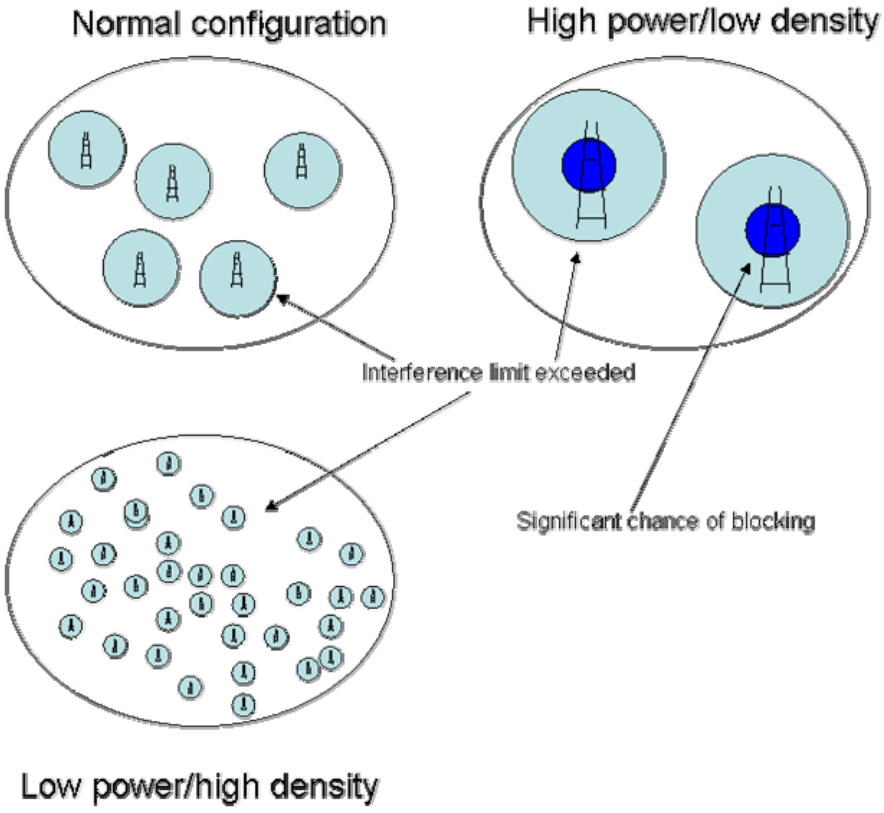

Figure 2-1:Low-, normal- and high-density configurations

Ofcom's proposals do not, however, comment on the maximum power that can be generated from any one point. Figure 2-2 illustrates, schematically, the pattern that would be observed for each of the three scenarios. High power/low density systems have widely spaced transmitters transmitting high powers, but falling to low levels at interstitial points in order for, on average, 50% of the area to exceed the PFD limit. Conversely, low power/high density systems have closely spaced transmitters transmitting powers a little above the PFD limit, and falling little to closely spaced interstitial points, in order for the 50% average to be achieved.

Figure 2-2 also shows the power levels that are likely to cause interference (Adjacent channel interference power) and/or blocking (Receiver blocking power) to a radio system operating in an adjacent channel in the same geographical area.

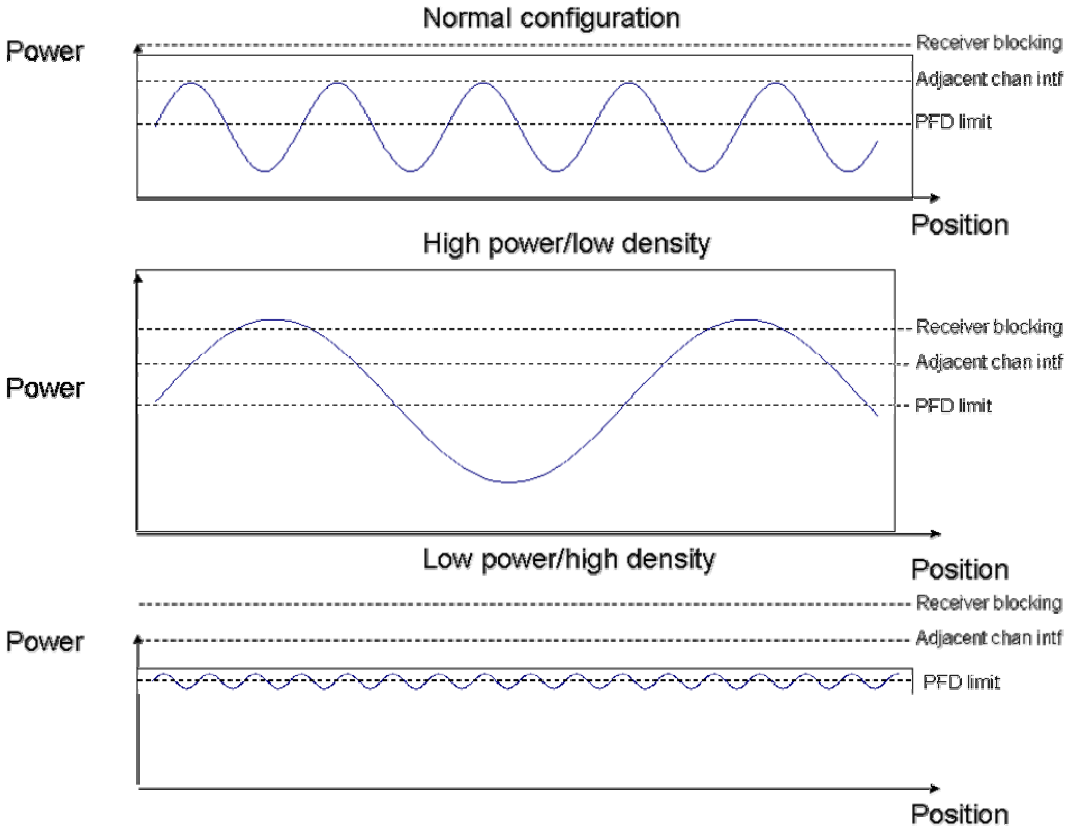

Figure 2-2:Variation of PFD with position for each configuration

The normal (victim) configuration assumes that neighbouring (in spectrum) radios, when deployed in the same geographic area generate maximum PFDs that are *just* insufficient to cause interference[8].

The high-power/low-density configuration[9] would cause significant interference to the normal systems located close to transmitters, and indeed close to the base stations there is an increased chance of front-end receiver blocking[10], causing general degradation in the service of affected radios. This would be exacerbated by directional antennas (see section 2.2.5).

[8] Section 2.5, however, highlights that for the proposals in the 2.6GHz band, this cannot be achieved for FDD adjacent to TDD systems, especially between base stations transmitting power equivalent to macro/microcellular base stations.

[9] Assuming equal transmitter heights. Work later in this document (section 2.4.3) demonstrates that the dependence of PFD measured at various heights and antenna height can be significant, which complicates the picture, and exposes the poor correlation between measured PFD and interference probability.

10 The blocking performance of a UMTS base station and UE is -44dBm and -56dBm at 10 MHz offset, respectively. A UMTS base station transmitting at full power (+43dBm) generates an EIRP of +60dBm. Assuming an ACIR of -49dB at 10MHz and 60dB loss (equivalent to a victim UE 10m from the base station), the power received will be -49dBm, a margin of 5dB. Therefore decreasing transmitter density by a factor of three would start to introduce UE blocking.

The logical extreme would be for an operator to deploy a single regional base station, transmitting power normally associated with broadcast transmissions (indeed TDD technology would be ideal for broadcast TV services in this band) to achieve wide area coverage at low cost. Operations in nearby bands would be decimated by such a deployment.

A high-power/low-density configuration (with equivalent PFD, when averaged across the area) would logically be actively chosen by an operator as part of its network planning process. In a high-density urban environment such a configuration is unlikely. In a rural environment, however, this high power configuration may be the norm, presenting the most severe challenge to victim radios operating close to the high-power transmitters. Ofcom's proposals, however, suggest that an urban environment is the limiting case and ignores interference potential in rural areas. One consequence of this is that a potential digital divide is risked whereby there will be a de facto higher QoS paramenter for urban users than for rural, contra to Ofcom's objectives and remit.

In addition measurements of an operator's network over a very wide area (ten cells is suggested), allows the effect of a small number of high power transmitters in one area to be diluted by relatively underused rural sites.

A high-power/low-density configuration will be generated in any location when operators allow small numbers of UEs access to high data rate (and correspondingly high-power) services.

The low-power/high-density configuration (with equivalent PFD, when averaged across the area) should cause minimal interference to the normal system, but as the equivalent of the normal vs high power scenario, is likely to *itself* be limited by interference from the normal system.

Modelling of FDD systems suffering interference from TDD systems, that has been carried out as part of this study, confirms this observation. Figure 2-3 illustrates the likely interference environment in which FDD systems would have to operate in the presence of equivalent TDD systems offset by 10MHz, as recommended by Ofcom. UEs experiencing external interference greater than their levels of self interference (Ie/Is>0dB) are likely to be strongly affected; lower levels of interference (Ie/Is in the ranges 0 to -10dB, and -10 to -20dB) would have a lesser, but noticeable affect on network operation.

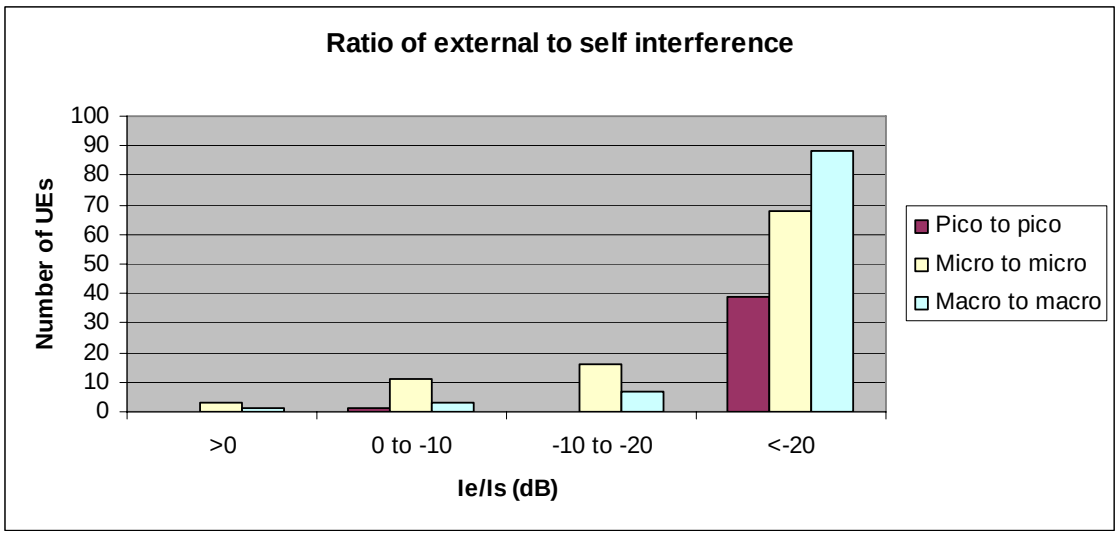

Figure 2-3: Ratio of external to self interference for victim UEs

Comparing these results with the corresponding PFD thresholds calculated for the interfering TDD systems reveals that the most benign interference scenario involves the picocellular systems, but has the highest PFD. The worst-case interference scenario (microcellular systems) has a PFD 15dB lower.

System	PFD (dBW/m^2/MHz)
TDD Macrocellular	-65.2
TDD Microcellular	-64.8
TDD Picocellular	-50.8

Table 2-1: Corresponding in-band (X2) PFD measures

This work demonstrates, therefore, that although a single PFD threshold can be calculated based on the power flux levels generated by typical network configurations, there appears to be little correlation between these levels and the likelihood of interference events experienced by victim UEs.

2.2.2 Interference to distant neighbours

Ofcom's proposals allow near neighbours (geographically and spectrally) to bilaterally raise their transmit powers, with no absolute limit being set. This could, however, have a knock-on effect for more distant neighbours, e.g. those three slots away, with no redress. Figure 2-4 illustrates a potential scenario. The 'default' PFD limits set by Ofcom[11] for operations in channel 3 by operator 1 are shown.

[11] For example, those SUR parameters derived in 'Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', section 9.

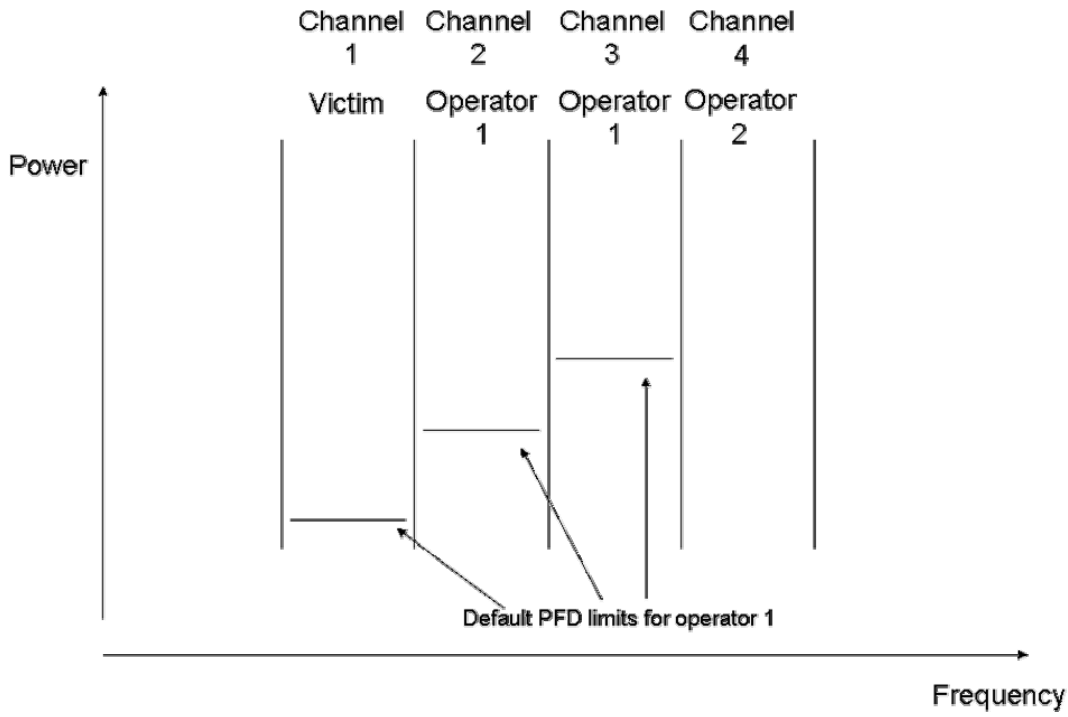

Figure 2-4:Default PFD limits to protect victim from operator 1 in channel 3

Negotiations between operator 1 and 2 may result in the PFD limit for operator 2's system in channel 4 to be increased as shown in figure 2-5.

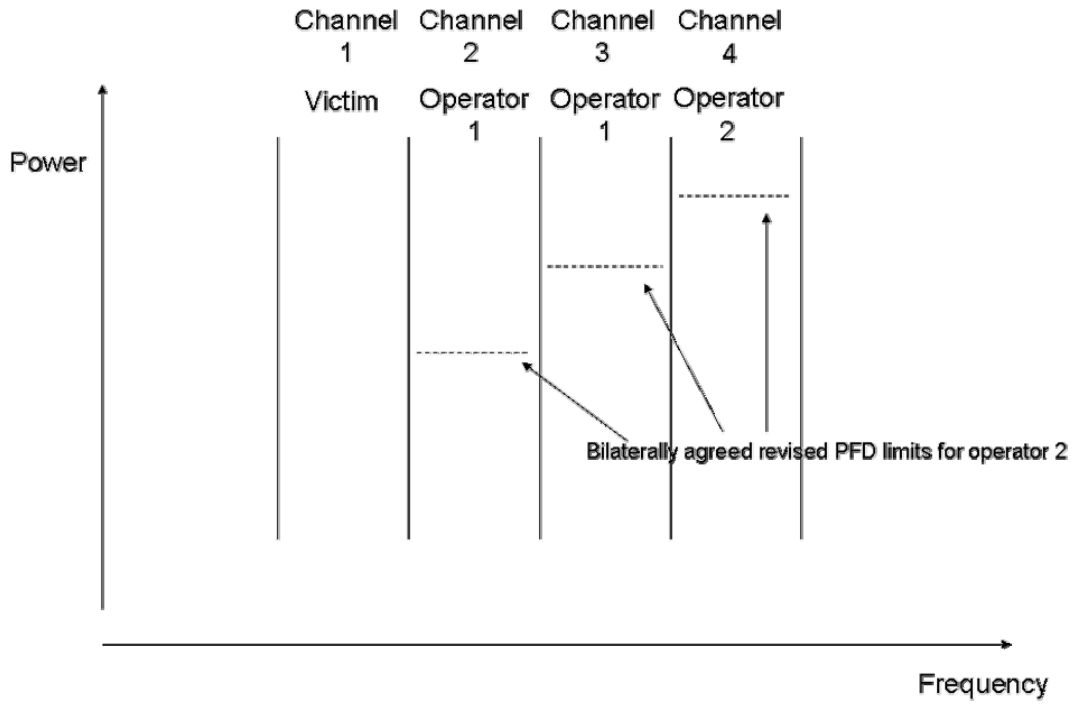

Figure 2-5:Increased PFD limits for operator 2 in channel 4

The consequence of this agreement for the victim (in channel 1) is, however, illustrated in figure 2-6. The PFD limits set to protect the victim have been breached by operator 2 (in channel 4), despite its modified PFD in channel 2 being below the default two-channel offset limit.

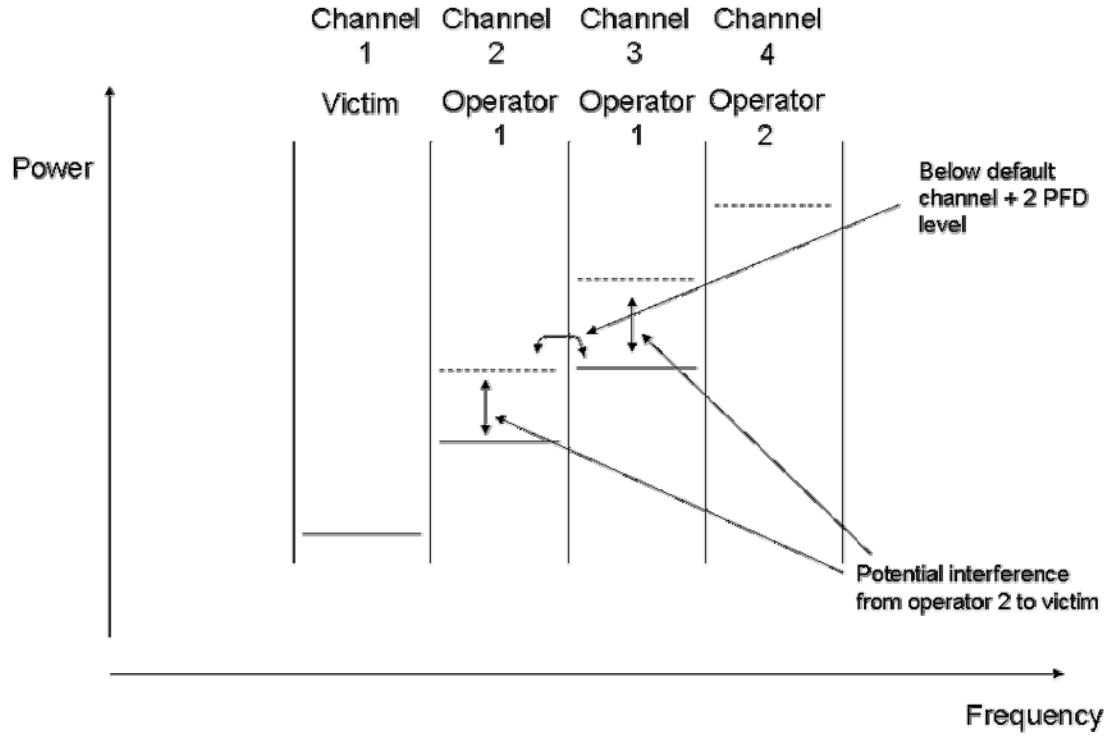

Figure 2-6:Impact on victim of increased PFD in channels 2 and 3

Management of such a scenario in a multi-operator case would be complex to resolve and would require modifications to Ofcom's proposals. Similar PFD overspill may also occur for geographical neighbours, and the probability of intermodulation products affecting this and more distant bands will be increased.

Finally, the consultation documentation restricts adjacent channels with an offset of one and two channels. The sharing studies, however, highlight interference for this system could be apparent at an offset of three channels 15MHz). More generally, greater offsets still may need to be controlled (particularly for narrowband or high power systems).

2.2.3 User equipment specification

Manufacturers of UE normally adhere to agreed specifications, either nationally or internationally determined by standards bodies. As a consequence, consumers are able to buy standard equipment nationally or globally. These PFD proposals, however, sever the link between operators' licence conditions and equipment standards leaving either manufacturers uncertain of requirements, operators little ability to deviate from *de facto* standards or allowing PFD limits to be breached by non-standard equipment.

2.2.4 Directional antennas

Directional antennas contain power fluxes, particularly at higher frequencies which, under a coordinated regime (to avoid link interference), allows very high densities of radios to be used. The application of the PFD principle[12] to such systems, however, would allow very high EIRPs to be transmitted and represents an extreme case of the high power transmitters discussed in section 2.2.1. The containment of the radio signals to narrow beams would allow high densities of radios to be deployed causing – in the absence of coordination - a higher rate of extreme interference events (and even blocking), which could disable some fixed UEs completely, particularly at locations far from the interferer's base station, as shown in figure 2-7.

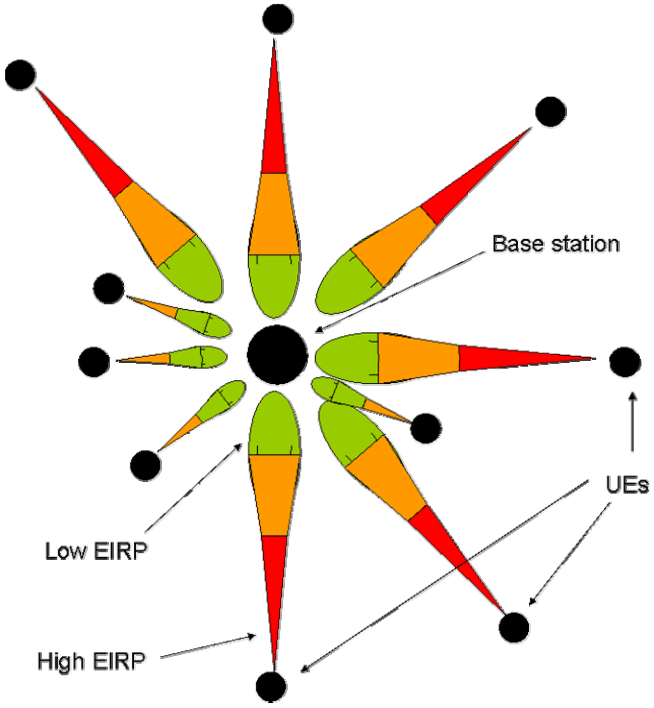

Figure 2-7:PFD distributions associated with directional antennas

Ofcom's original consultation[13] of SURs highlighted the inappropriateness of the model for directional antennas, but no alternative model has been proposed for this consultation and further, the proposed use of spectrum after the auction does not restrict operators from this kind of deployment and would result in operational anarchy.

A scenario identical to the microcellular system but with UEs fitted with 8dBi antennas was modelled and, despite the measured PFD levels only being moderately raised (due to focussing of the power along narrow beams), interference events to victim receivers are higher (figure 2-8).

[12] Practical issues associated with the measurement of PFD levels with directional antennas are highlighted in section 2.4.5.

[13] Technology-neutral spectrum usage rights, Aegis Spectrum Engineering, 10 February 2006

System	X2 (dBW/m^2/MHz)	X3 (dBW/m^2/MHz)	X4 (dBW/m^2/MHz)
Omni directional antennas	-64.8	-97.8	-107.8
Directional antennas (+8dBi)	-62.3	-95.3	-105.3

Table 2-3: PFD levels measured for microcellular systems vs UE antenna (1.5m height)

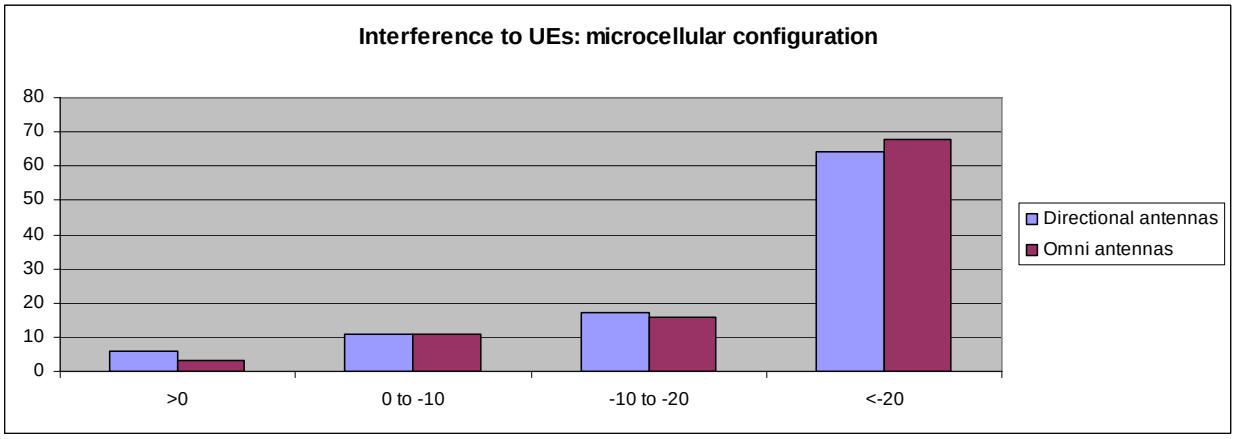

Figure 2-8: Impact of adding 8dBi directional antennas to microcellular system

The discussion above relates to interference to victim user equipment from fixed (directional) antennas fitted to the interferer system's UEs. This is in addition to the major interference expected between base stations, as highlighted by the Mason report.

2.2.5 Service neutrality

ITU service definitions have been developed for good reasons: they acknowledge that similar deployments can better coexist than dissimilar. Satellite services, for example, are particularly vulnerable to emissions from fixed links, whilst aeronautical services are vulnerable to high-power ground-based services. The ITU has thereby been able to protect radio services by acknowledging group characteristics of such services (e.g. downlinks for mobile services are small in number and can be coordinated) and thereby been able to allow relaxed sharing criteria within the groups.

Mason's work has demonstrated how TDD equipment when neighbouring FDD equipment (allowed by the PFD proposals) introduces aspects of service mixing i.e. UEs transmitting in the same band as base stations, which in turn leads to harmful interference in typical deployment scenarios.

Deviating further from a configuration that typifies a traditional mobile service to a fixed services configuration (i.e. using directional antennas) exacerbates the situation further.

The logical extension of this scenario (and of service neutrality) would be to allow reversal of the FDD duplex. Mason's work clearly demonstrates that this would maximise disruption for typical deployment scenarios (because of interference between

base stations), in practice rendering them unusable, despite the PFD limits remaining intact.

2.2.6 Departure from international activities

The UK has often been at the forefront of innovations in regulation of radio and telecommunications. Furthermore, EU policy is to encourage service and technology neutrality. Nevertheless, the UK takes considerable risks in departing from international spectrum management procedures and norms in pursuing SURs implemented in the form of PFD limits. Aside from risking being sidelined in international co-ordination activities, the collective effort that is invested into solving tactical management problems by the international community is considerable, and the UK risks losing access to these activities if its proposals are not widely adopted.

In addition, the EU's forthcoming regulatory framework review will reveal the extent to which service and technology neutrality are likely to be formalised within the EU regulatory framework, and the extent to which enablers such as SURs will be coordinated at European level. It would appear to be appropriate therefore for Ofcom to await the outcome of these discussions prior to the introduction of SURs in the UK.

International harmonisation efforts, furthermore, have a valuable role to play in the management of radio spectrum around the world - GSM being an exemplar of what international benefits can be achieved – and Ofcom needs to be sure that these proposals balance needs of liberalisation with harmonisation

2.2.7 Coordination principle

The PFD principles appear to rely solely on management of the bands by modelling and measuring PFD levels, and abandoning base station coordination. The Mason work (and similar studies[14]) has highlighted, however, that such an approach is short sighted and cannot work in this band with these applications.

Coordination with a single (or small number of) operator(s) on a national (and international) basis is feasible and is a standard operating practise for most networks. Coordination with large numbers of small base stations, however, operated by multiple parties in adjacent channels is unrealistic and would lead to administrative overload, hamstrung network roll out or catastrophic interference with commensurate economic inefficiency and reduced consumer welfare.

Note: the modelling in this work has used relatively benign base stations configurations that are separated to the maximum extent possible for each scenario, with antennas not aligned, and with 10MHz spacing. The predictions of interference, therefore, are low compared to Mason's work. In reality, allowing operators to place base stations where they please without consultation with neighbouring operators risks significant harmful interference.

[14] ITU, ITU-R Report M.2030, Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2600 GHZ operating in adjacent bands and in the same geographical area.

2.2.8 Code co-ordination

International coordination of CDMA systems can be helped with code coordination, but this form of mitigation is ignored by the PFD principles set out by Offcom.

2.3 Spectrum Usage Rights (SUR): implementation

Ignoring implementation issues is short-sighted because it limits the practicality of the proposals and thus devalues the spectrum, as highlighted below.

2.3.1 Initial SUR parameters

The selection of the initial SUR parameters for the 2.6GHz band, and more generally, will be key to the success of Ofcom's proposals. Limits that are too lax risk interference to (or disturbance of) victim systems; whilst limits that are too stringent risk poor spectral efficiency.

Ofcom needs to make assumptions about, *inter alia*, technology, network configurations and modelling of the environment to derive the initial SUR parameters for the 2.6GHz bands demonstrates, however, there is difficulty in selecting the appropriate initial parameters, both in these bands and more generally.

The starting point for such a set of parameters (and hence licence conditions) needs to be that which, where appropriate, offers **equivalent protection to current management techniques**. The technique should consider worst-case scenarios and ensure that all reasonable operations[15] are protected from adjacent bands, with guard bands implemented where necessary. The relaxation of traditional constraints, such as service types, would lead to be a corresponding reduction in PFD levels to reflect the increased threat.

If suitable SUR parameters cannot be derived for all technology combinations (e.g. FDD adjacent to TDD systems) the methodology should instead allow the implementation of effective guard bands.

2.3.2 Propagation model

Orange does not believe that the propagation model that has been used by Ofcom[16] is appropriate. This is significant because the proposed PFD limits are closely dependent on the model chosen. In particular:

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15 Legacy systems will have a well defined level above which harmful interference (especially when noise limited) will occur.

State-of-the-art systems are more resilient to interference, but can suffer a reduction in system data throughput before bearer failure occurs. Any increase in throughput uncertainty or interference probability can generally be mitigated by network designers with the implementation of further cell sites, but obtaining local authority permission is becoming ever more problematic, has costs implications and will lead to the requirement for yet more base station coordination activity.

16 Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz, A12.21

- Predictions of path losses towards the edges of macro cells appear to be under estimated (by up to 30dB);

- The height dependency of path losses does not appear to have been modelled, particularly for a high-sited base station to base station.

Orange's proposes the use of Cost 231 Hata[17] model, because it better models the variation of propagation loss with height. The predictions of which are shown in figure 2-9.

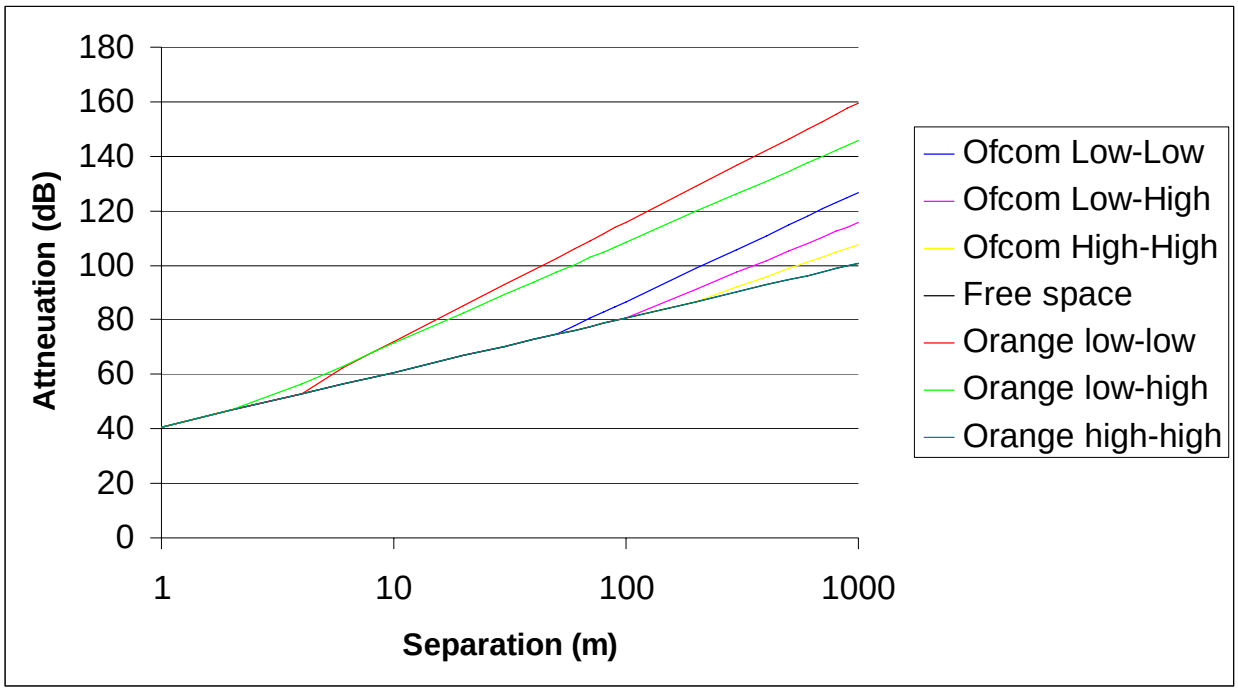

Figure 2-9:Ofcom and Orange's proposed propagation model

Predictions of variation of propagation loss with base station height are shown in figure 2-10 for both models.

[17] Line of site visibility has been assumed for the high-high (base station to base station case), and where the Cost/Hata model predicts less than free space loss, free space has been substituted

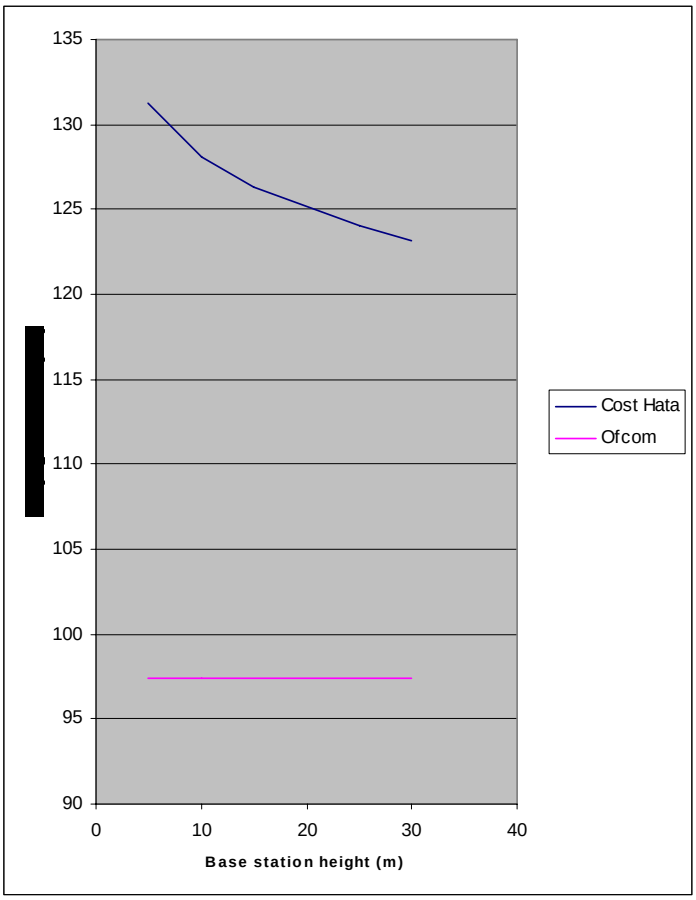

Figure 2-10:Ofcom and Orange's proposed propagation model, variation with base station height (300m separation)

Agreement of appropriate propagation models (with alternatives for varying terrain types) is an imperative.

2.3.3 Statistical fluctuations

The PFD limits that have been derived by Ofcom are based on idealised geometries and conditions. In reality, however, environmental and measurement characteristics will impact on the precision and accuracy of both measurements taken in the field and model predictions. Specifically:

- Variability of local clutter: Ofcom acknowledges that local clutter (modelled by the log-normal term) is ±8dB meaning that propagation loss can vary very significantly. This uncertainty can increase to ±15dB when considering differences between dense urban and rural locations, unless suitable models are applied.

- Measurement time: interferer network activity varies significantly throughout the day and the year. Limitations in air interface capacity means that heavily loaded networks tend to achieve radio resource full capacity regularly. Nevertheless, the time in which measurements are taken must represent the 'window' of maximum (worst case) activity in order for the results to be valid

- Propagation anomalies, such as tropospheric ducting, which may also occur on certain days, enhancing propagation for as much as 10% of the time.

- Measurement period: the period over which the measurement is to be taken must ensure that short-term fluctuations (such as fades) are averaged, but not so long that fluctuations such as traffic levels do not suggest a benign environment when averaged. The original Ofcom proposals suggested that measurements would be allowed to exceed the PFD limit on 10% of occasions before the location is considered to have breached the limit. This omission in the current consultation suggests that the number of occasions has been reduced to zero. Figure 2-11 illustrates how, in the presence of noise and fluctuations, this effectively reduces the PFD level allowed by a amplitude of the worst case noise, or at least two standard deviation of the noise/fluctuations.

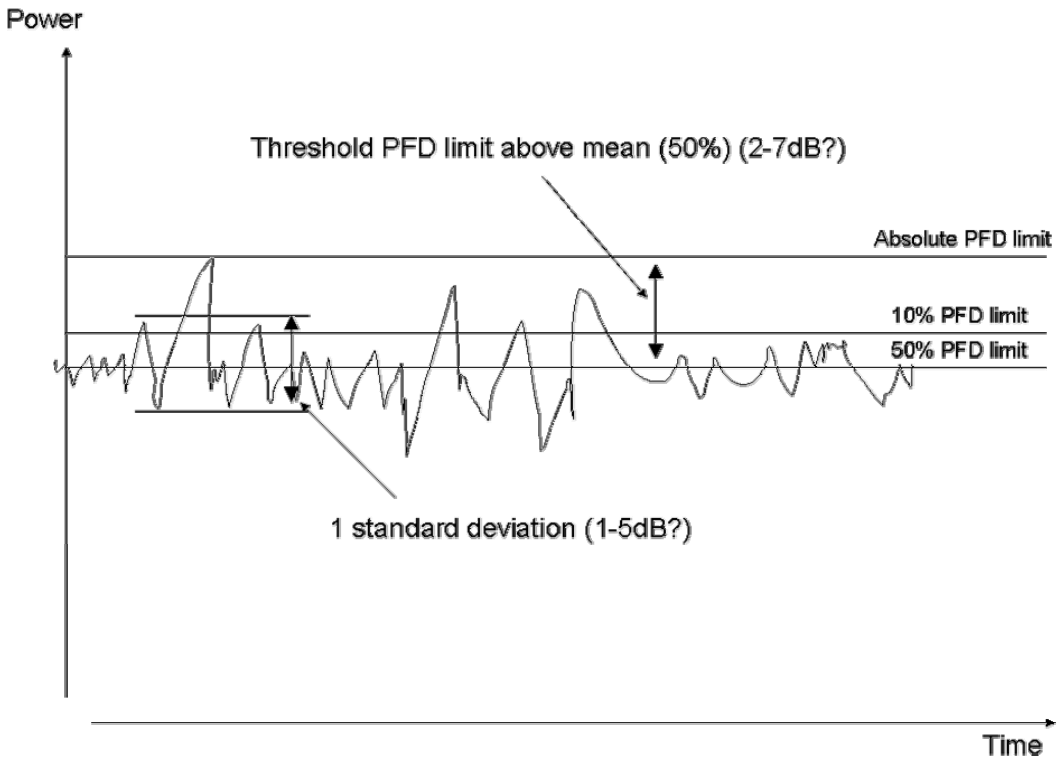

Figure 2-11:Typical fluctuations in the time domain and implications for measurement thresholds

- Measurement location (grid characteristics): Ofcom's modelling methodology calculates the average PFD levels in a typical cell through the calculation of 300 points, which is sufficient to average fluctuations across the cell. The practical equivalent of such calculations suggests using 25 measurement points over 10 cells modelling carried out as part of this work, however, suggests that this number of measurements limits precision to between 1.3 and 3.9dB (see section A-2.1, *Dependence of PFD parameters on measurement grid*).

- Height dependency of measurements: the measured PFD is sensitively dependent on the propagation environment and varies markedly with height (see section A-2.1, *Dependence of PFD parameters on network configuration and measurement*

height). At rooftop level, however, losses between base station antennas is best modelled as line of sight.

- Topographical features: the modelling that has been carried out by Ofcom[18] is based on relatively flat terrain. The interference that is experienced (and hence PFDs measured) will depend strongly on the exact topology, with propagation losses (and hence interference signal strengths) varying, in the extreme, between the model predictions and those of free space, which at 300m can be 36dB for base station to mobile interference.

As a consequence, the likelihood of being able to define PFD levels with any semblance of reliability in real environments is low, which (when combined with practical measurement difficulties (section 2.4.1)) will undermine the protection that can be afforded victim systems, thereby reducing their usefulness and, as a consequence, their value.

2.3.4 SUR parameters: urban versus rural

The radio environment of a UE is complex in an urban environment, with interference being received from codes destined for other UEs (intracellular) and from other base stations (extracellular). In a typical rural environment, however, the level of self interference is low, with little raising of the noise floor. This means that, for infrastructure tailored to work in such an environment, the component radios would be more susceptible to disruption and interference from interfering networks operating at maximum PFD in adjacent channels. Furthermore, the PFD levels produced from such a system operating in a rural will be lower than in an urban environment.

The reliance on a single set of PFD parameters in urban and rural environments is, therefore, flawed and likely to lead to increased disruption of rural systems. Although this may introduce further complications in categorising such environments.

2.3.5 Modelling versus real measurements

There is considerable uncertainty in the predictions of modelling tools, particularly if account is not taken of detailed topology. This uncertainty of prediction is likely to be echoed by an uncertainty in measurements in the field (see section 2.4) such that modelled and measured results will vary by as much as 20dB and potentially more. Ofcom's current proposals do not appear to offer any way of reconciling these two positions, and so the legal significance of each is unclear, which is likely to lead to a position in which victims are afforded little protection.

2.3.6 Quality of service requirements

Ofcom's proposals assume a starting point of networks having equal tolerance to disturbance and so implicitly equal quality of service requirements. It is not clear, however, what the achieved quality of service would be, and how networks with different quality of service requirements[19] should be approached. Uncertainty in the proposed

[18] Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz, section 12

[19] The quality of service requirements for a UMTS and WiMax network – a candidate technology for the band - are likely to be at variance.

SUR regime and the difficulties this bring to network operators who currently operate in a regime that enables guaranteed QoS levels to be achieved through network planning largely because the interference is self induced with practically zero external sources. Equal PFD limits would not, therefore, necessarily achieve an equitable result.

2.3.7 Guard bands

The proposals leave no latitude for guard bands to be put in place, even where engineering studies (such as the Mason study for the 2.6GHz band) show that such bands are required.

2.3.8 Cellular reuse issues

CDMA technology is able, as a consequence of careful transmitter power control, to be operated with a 1:1 reuse factor: that is the same channel can be reused in all cells. For some technologies (eg WiMax) it is deployed with a 1:3 reuse factor (see figure 2-12), but with a corresponding reduction in spectrum efficiency.

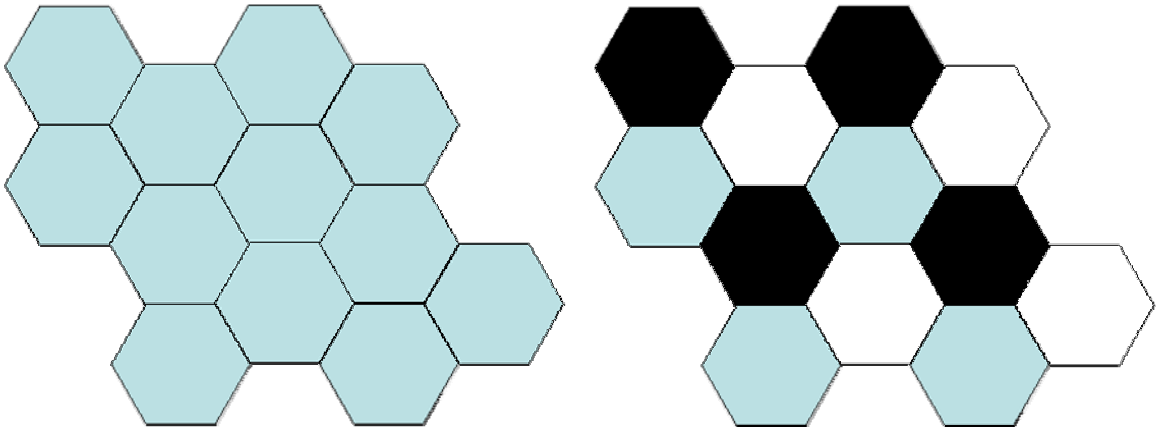

Figure 2-12:1:1 and 1:3 reuse patterns

The PFD levels generated and resilience to external interference by each configuration is likely to vary, although no modelling has been carried out on this system as part of this work

2.3.9 Spurious emissions

Spurious emissions (quite apart from intermodulation products that may occur as a result of interactions of high power radios with other radios or elements in the environment close to the transmitter) can be a nuisance to many other radios and indeed are outlawed by European law. The SUR principle is inappropriate for controlling these emissions for which there can be no negotiation.

2.4 Spectrum Usage Rights (SUR): enforcement

Ofcom's proposals for SURs in the 2.6GHz bands ignore the practicalities of enforcing the new regulations, inevitably by Ofcom's field monitoring team, and thereby overlook some serious challenges.

2.4.1 Measurement practicality

Measurements carried out would need to be accurate and precise, with all attempts made to remove systematic and random errors. Ofcom is well equipped to carry out such measurements on a small scale, but were disputes to arise in widely spread geographical regions, the teams may become overloaded.

Accurately calibrated measuring equipment, probably power meters with suitably tuned band pass filters, supported by investigations using spectrum analysers, would need to be incorporated into appropriate measurement procedures. Each filter needs to be tuned for the channel(s) of interest; if tuneable filters with appropriate characteristics are not achievable, fixed filters for each channel will need to be procured and maintained, which would be expensive. The stringent roll off characteristics of the technical proposals in the 2.6GHz band would need to be matched by equally (if not, more) stringent roll off characteristics of the measurement filters.

The grid of measurement points would need to be evenly placed around the measurement area to ensure that representative measurements are taken. The procedure for setting out this grid is not clear, and modelling work has demonstrated the sensitive dependence of the SUR parameter measurements on the exact position of the grid (even before the impact local clutter, topology and other effects have on the measurements). Siting of measurement equipment relative to base stations will have a particularly strong influence on the results.

Practical considerations that will need to be faced (and seen to be so) include placement of monitoring equipment relative to obstructions (especially in urban areas) and access to private land. In undulating areas, these choices will have a particularly strong influence on results.

In urban environments, networks are typically engineered to work inside buildings, but Ofcom's proposals are for only external measurements to be taken. This will present a confused picture of the interference environment within buildings.

2.4.2 Measuring out of band emissions

Measuring and characterising out-of-band emissions are simply not feasible in the field in the presence of strong victim network transmitters. The only way to determine these characteristics are by analysing emissions directly from radio equipment and comparing to power masks. The case studies documented by Aegis[20] all control OOB emissions relative to the in-band transmit power.

[20] Technology-neutral spectrum usage rights, Aegis Spectrum Engineering, 10 February 2006, Annex A

2.4.3 Height dependency of PFD

The dependency of recorded PFD levels on measurement height is likely to be more marked than suggested by Ofcom's calculations. The difference in path loss from a base station placed at roof-top level to a similarly placed base station compared to UEs experiencing scatter from clutter at ground level is likely to vary by up to 40dB at a range of 1km (see figure 2.7), and will vary dependent on local buildings.

2.4.4 Differentiating emissions from various parties

CDMA appears as white noise to an uncorrelated receiver. Determining, therefore, which parties are contributing what would be a complex theoretical exercise and impossible practically. Traditional modulation techniques allow individual signals to be identified and analysed by monitoring staff, and so even were measurement levels to be convincingly found to exceed limits, disassociating the contributions of legal operators' equipment from one another, noise and interference from equipment in more distant bands would be a further, almost certainly intractable problem.

2.4.5 Directional antennas

The location of monitoring measurement points relative to directional antennas will significantly influence the signal strength measured. Figure 2.6 illustrated the sharp variations in PFD levels emanating from UE (the effect for base stations would be more gradual) but setting up in front of a highly directional UE antenna (say 8dBi) could see signal strengths alter from average levels by up to +20dB.

2.5 Interference in the 2.6GHz band

Mason's and various other studies[21] have highlighted the potential for interference and even blocking between base stations, especially in close proximity. ITU Report M.2030 concurs with the Mason conclusions that co-location of macrocell base stations serving adjacent channels is not possible, but that with suitable mitigation techniques, more distant channel site sharing is possible. Even for coordinated systems (where macrocell base stations need to be separated by up to nineteen kilometres), the potential for interference is high, and so abandoning base station coordination would be impossible.

Problems of mobile to mobile interference are also highlighted in both Mason's and the ITU reports, which conclude that the normal operation of mobile networks will be impacted and regulatory obligations for end-to-end reliability more difficult to achieve.

2.5.1 Interference to user equipment

A 2% additional chance of loss of service by UEs as a result of UE to UE interference (with 10MHz offset) derived by Ofcom[22] is unacceptable in a public network, when seen in the context of an already challenging operational and regulatory environment.

[21] ITU, ITU-R Report M.2030

[22] Technical Study: Adjacent and In-Band Compatibility Assessment for 2500-2690MHz, p29

The simulation work carried out as part of this study (see section A-2.2) has confirmed several of the findings of the Mason report, although less markedly, because a Monte Carlo method has been used as opposed to worst case scenarios.

2.5.2 Proposed base station interference mitigation

Interference studies between FDD and TDD systems have conclusively shown that interference between base stations is critical unless suitable mitigation techniques are applied, most notably coordination.

Ofcom's proposals appear to rule out the necessity for coordination thereby ruling out most of Mason's mitigation techniques. But Ofcom's assumption is well founded: the proposals for allowing more freedom in the way in which equipment is deployed in the band would make necessary arrangements for coordination between many base stations (and even fixed UE) associated with multiple operators around the country impractical.

Mason's ten mitigation suggestions[23] for co-located base stations have varying levels of practicability as detailed below. A key observation is that most of Mason's mitigation proposals only apply to macrocellular sites, whereas in an urban environment, greater use would be made of micro- and picocells and, although lower power, most of the techniques would therefore not be suitable in these areas.

1. Site Placement (micro- and macrocell coexistence)
Coordinating the use of mixed micro- and macrocell base stations would be impractical in an environment where PFD limits is the main tool for spectrum management. Once one operator has rolled out a macrocell network, a second (and potentially further) operator(s) would be forced to used microcellular base stations, which is contrary to the principles of SURs and would be uneconomical for large area coverage.

2. Antenna Separation
Shared antenna towers are already crowded with operators having fixed separations for their existing installations. New antennas would generally be expected to be installed at the same height as existing installations, which may be physically impossible if there is insufficient pole space or could lead to wind-loading issues on site. Aside from these concerns, this technique would only be appropriate for macrocellular base stations. In addition the 'widely accepted'[24] figure of 30dB isolation is not that currently used by UK operators. The current minimum is 45dB consistent with theoretical 0.1dB degradation of noise floor.

3. Antenna Polarisation
Most operators already use cross polarised antennas on the vast majority of their sites to implement receive diversity. Evolution of UMTS (R7) supports Multiple-Input Multiple-Output (MIMO) which means both polarisations will then be used for transmitting. Future systems such as LTE & Wimax will rely on multiple antenna techniques (MIMO, beamsteering etc) where all polarisations are likely to be needed. It would seem unrealistic, anyway, to co-ordinate polarisations between operators and given that there

[23] 2500-2690MHz, 2010-2025MHz and 2290-2302MHz Spectrum Awards – Engineering Study (Phase 2), Annex A, p10
[24] IBID

are only two schemes supporting diversity (vertical/horizontal & cross polarised), limiting any such techniques to just two operators.

4. Adaptive Antennas
Adaptive antennas would help to mitigate interference mainly because they tend to focus the wanted signal where it is needed and some can adapt nulls towards individual interference sources (though it is not clear if this will work on "out of band" interferers). The use of such technology is effectively equivalent to “active” directional antennas, and so the PFD proposals would allow operators to increase powers and deployment densities to more than offset the gains of the technique. Adaptive antennas would also be problematic for deployment due to size, loading, visual intrusion which would act as limiting factors on physical deployment.

5. Transmitter/receiver improvements
Today’s systems are designed to co-exist with realistic, cost effective and implementable transmitter and receiver characteristics. The cost of designing, testing and implementing high-roll off, low insertion loss filters is very significant. It is questionable whether such costs are justified by the advantages of the proposed co-existence criteria.

6. TDD power control
Power control is an intimate feature of many CDMA technologies and allows, amongst others, UMTS systems to use a 1:1 cell reuse pattern. In new technologies and services, such as WiMax and future versions of UMTS (such as HSDPA) power control will be less constrained. Power control cannot, therefore, be quoted as a standalone technique to improve interference mitigation, especially when the overriding control on power is the PFD limits. Mason’s and Ofcom’s reports appear to be confused as to exactly the out-of-band filter characteristics required (see section C).

7. Handover
Handover is a technique that systems and network designers use to mitigate interference. Designing in additional network capacity to provide overhead to allow greater use of handover precipitated by external interference will, however, be a further cost to borne by the operators thereby devaluing the spectrum (and potentially de-railing of the auction).

8. Antenna Azimuths
This technique is not practical on a nationwide basis especially since this parameter is used for network optimisation. It may be possible on a site-by-site basis but this then places a restriction on an operators’ ability to optimise frequency re-use. Furthermore Antenna Azimuths would be even more difficult to apply using MIMO technology.

9. TDD synchronisation
This technique does not help to mitigate TDD/FDD interference, and Orange has carried out analysis to demonstrate that in some scenarios unsynchronised networks actually work better on average if different UL/DL switching points (or different frame lengths) are used.

10. Low Power
The use of large numbers of low power base stations runs contrary to Ofcom’s aggregate PFD approach. The costs and practicality (especially given the public’s

wariness of base station deployment and the limited availability of sites) of rolling out a much denser network would be prohibitive.

In short, there are numerous and considerable difficulties with Mason's proposed interference mitigation techniques which must be addressed prior to the introduction of SURs.

2.5.3 Use of adjacent channels

Mason's and other research clearly states that immediate adjacent channel operation of TDD and FDD systems is not possible, and furthermore, UMTS blocking specifications implicitly assume systems will not be operated closer than a 10MHz offset, the minimum for which a value is quoted. Closer examination of Mason's calculations[25] suggest that at 5MHz offset (and where the primary mitigation technique of out-of-band filtering is ineffective), at a range of 50m, additional isolation of 40dB, 16dB and 19dB is required for interference avoidance to macro-, microcell base stations and FDD UEs, respectively.

Ofcom's current proposals, however, suggest that it is possible 'at pico-cellular powers' (although the exact meaning of 'guard channel', 'restricted channel' and 'constrained channel' is inconsistent in the consultation document (see section C)).

The spectrum power masks[26] quoted in the consultation document, however, suggest that powers should be restricted to +34dBm (or 2.5W). Typical picocellular maximum powers are however, at most, +24 to +27dBm (250mW-500mW).

The result of allowing such a macrocellular system to operate at 5MHz offset from a low-power TDD system is summarised in figure 2-13. This shows that, although average interference powers are low, instances of interference and perturbation of the FDD system still increase markedly.

[25] Award of available spectrum 2500-2690, 2010-2025 and 2290-2300MHz, table A-5

[26] Award of available spectrum 2500-2690, 2010-2025 and 2290-2300MHz, figure 16, p128

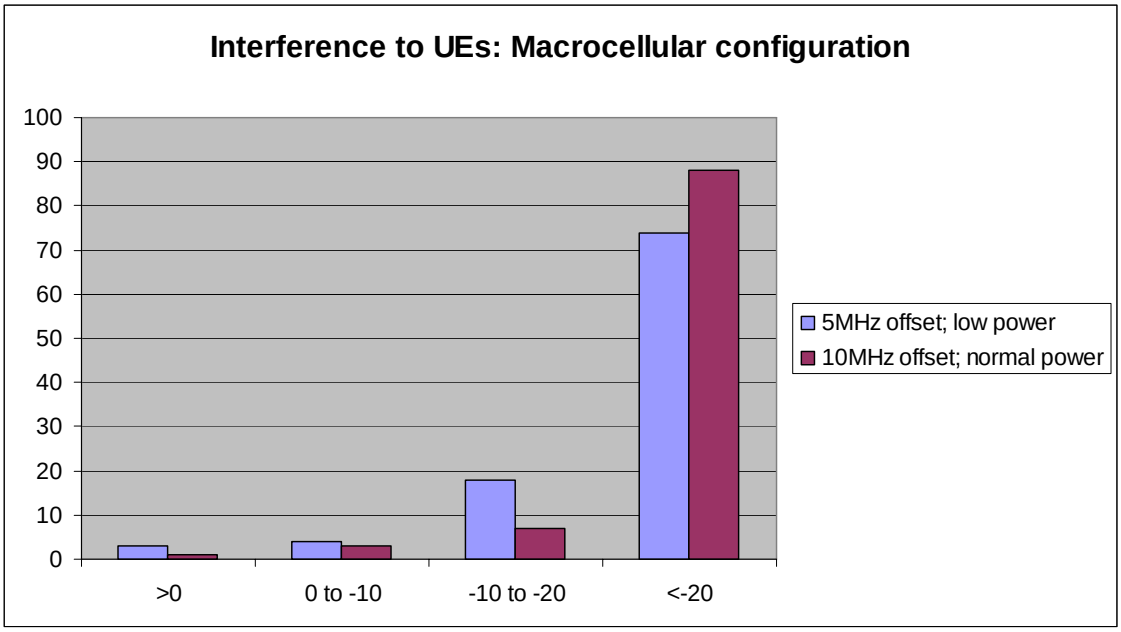

Figure 2-13: Relative interference suffered by FDD UEs (macrocell) from a TDD system (macrocell) operating at reduced power (compared with a similar system operating at full power with a 10MHz offset)

2.5.4 Unilateral licence changes

Equipment that has been improved to enjoy a reduced transmit ACLR would help to mitigate interference between adjacent (or near adjacent) systems. The Adjacent Channel Interference Ratio (ACIR) is also dependent on victim receivers' ACS. In particular, UE adjacent channel performance is always likely to be dominated by receiver design limitations.

Unilateral changes to licence conditions must not, therefore, be allowed (as suggested in the 9th February workshop), without consultation with the victim network.

2.6 Auction implications

2.6.1 Avoiding specific channels

The auction design (particularly the clock auction) is based on the assumption that each of the channels has equal worth.

The supporting documentation[27], however, highlights problems that are likely to be encountered in the absence of satisfactory international agreements with France and Ireland and the presence of aeronautical interference in the band. Furthermore, Ofcom's intention to allow adjacent channel operation of TDD and FDD systems will make boundary channels (notably channel 13, on the assumption that the final plan is identical to the CEPT plan) undesirable because of the danger of interference.

[27] Technical study: Adjacent and in-band compatibility assessment for 2500-2690MHz

The final section of the auction allows bidders to bid a premium for desirable channels but does not so easily allow undesirable channels to be avoided.

2.6.2 Award timing

The timing of the award is not clear, and many unknowns exist including the final PFD levels; European policy and availability of the generic radio modelling tool. This uncertainty in the background to the auction and lack of clarity, even shortly before the auction starts, leaves bidders unsure of the rules and nature of the commodity under auction, which will inevitably undermine the process.

2.7 Summary

The value of the 215MHz of spectrum planned to be released in the valuable 2.6GHz bands is considerable, and Ofcom's proposals for licences to be awarded for 20 years means that it is vital that the way in which the spectrum is released and then managed is feasible. Any mistakes or inappropriate licence conditions in this showcase project would remain in force for the 20-year duration of the licence.

This work has highlighted three areas for concern with the proposals, which individually introduce uncertainty into the viability of high quality operations in the spectrum under the proposed management rules, but which combined will inevitably lead to bidders being uncertain as to the value of the spectrum. This uncertainty in bidders' collective minds can only undermine the award process and lead to an auction outcome which is economically inefficient and yield reduced revenues for the treasury[28].

Firstly, the SUR proposals are complex and untested. This analysis has highlighted problems, both in principle and that are likely to be encountered when they are implemented (generically and in the 2.6GHz band). Proceeding with them in such an important band and for such a large amount of spectrum would be risky and economically reckless, and any mistakes would be apparent for many years. This might take the form of interference in the band making it unreliable, market failure, loss of economic welfare or competitive disadvantage to other economies that followed CEPT band plan.

The determination and measurement of PFD levels (a technique derived from interference studies from satellites) appears to be unreliable in a cluttered urban environment and is more appropriate for controlling satellite emissions where the environment is less complex and propagation losses can be more reliably calculated as direct line of sight.

The SUR proposals place operators in a position such that they may, in response to the activities of adjacent channel operators, be forced to deploy a larger number of less vulnerable base stations, with considerable cost and network management implications, ultimately to the detriment of economic efficiency and consumer welfare. Furthermore, the cause of the interference will be outside the control of the operators and could occur

[28] There is also the possibility of speculative organisations gaining control of the spectrum until the uncertainties are resolved, and they may even allow licence modifications to be made that cannot be subsequently rescinded.

at any time, without notice. Any new spectrum management technique should ensure that it offers equivalent protection to current techniques.

Secondly, interference studies in the band have concluded that close sharing between TDD and FDD systems is not viable and that the latitude that the proposals give for licence holders to alter the way in which systems are deployed (e.g. the use of directional antennas) means that the usage of the band will ultimately be determined by the lowest common denominator: operators looking to roll out low quality, high capacity systems, to the potential detriment of dynamic efficiency. The externalities of these low quality systems will, in effect, be transferred to operators of neighbouring high quality systems: that is, relaxation of technical constraints on low quality systems will have an exaggerated effect on efforts made by high quality systems to maintain a reasonable end-to-end quality of service.

Thirdly, the auction rules will compound the uncertainty in bidders' minds in that, given the inability for specific channels to be *avoided*, the economic value of the wanted channels will also be diminished.

The consequence of bidders' inability to clarify the nature and thereby value of such a nebulously defined commodity will make it difficult for managers and network designers to justify to company board members a case for investment in the spectrum. This could undermine the auction process and inevitably mean that the spectrum is massively devalued and inefficiently allocated.

3. Conclusions and suggestions

3.1 Overview

This study has demonstrated significant concerns with the underpinning assumptions and methodologies used by Ofcom in proposing SURs in the 2.6GHz spectrum. As a result the economic value of the spectrum on offer in the 2.6GHz band would be significantly undermined if Ofcom were to proceed with its plans to auction the 215MHz of available spectrum using the proposals contained in the consultation.

The principles behind the proposals are sensible and may, in time, turn out to be feasible. Many of the details, however, are flawed and so Ofcom should proceed with caution using a more realistic roll out schedule. This would allow the risks associated with the radical changes in the way the spectrum is released to be managed, as well as allowing a realistic roll back option to be planned.

3.2 Licensing policy, procedures and enforcement

The proposals need to strike the right balance between liberalisation of the use of radio spectrum and the pursuit of ever greater spectral efficiency. Encouraging the concentration of higher densities of systems into the same spectrum needs to be balanced by mutual protection, informed by sensible engineering considerations. Ofcom needs to be sure, also, that the proposals are workable and achieve the results for which they were designed. To this end, the following recommendations are made.

3.2.1 Trial SUR/PFD principles

Following resolution of the issues raised in this report, the principles, methodology (and methodology options) and implementation of the SUR/PFD approach should be trialled, as far as possible, in a representative band as a ‘shadow’ process to the existing management techniques. Candidate bands might include the GSM bands (900 and 1800MHz) or Band III mobile.

Other aspects that would benefit from further investigations are:

- Correlation of model predictions to measurements on the ground;
- Trial interference investigation exercises;
- Computer modelling of more extreme scenarios (e.g. single transmitters, fixed links);
- Gathering of test data from measurement grids, investigating the impact of the factors highlighted in section 2.3.3;
- Investigations as to whether generically derived[29] SUR parameters are feasible;

[29] The derivation of generic SUR parameters seems unlikely, however, as the definition of successive generations of technology standards is based on a complex mix of requirements demands and improving technical capabilities.

- Calculation of modifications to the interference environment that would be brought about by adjacent channel operation;

- The limitations of the technique with directional antennas;

- The impact of not restraining emissions in channels at offsets greater than two channels (especially for high power transmitters).

Technologies that might be used in this 2.6GHz band (and for which ECC reports happen to be available) have been taken as the starting point for PFD calculations, but this will not generally be the case. Further work needs to be carried out to investigate the availability of typical technologies or specifications in any particular band and whether deployment parameters are readily available to allow the calculations to be carried out, else the important initial SUR parameters will not be able to be calculated.

These investigations would lead to:

- A better understanding of the practicalities and limitations of the PFD limit technique;

- Understanding of the engineering trade offs, between relaxation of traditional licence conditions towards pure SURs and their potential commensurate economic benefits, and the consequent threats to radio services;

- Fine tuning of the SUR/PFD methodology, based on the limitations discovered and lessons learnt.

3.2.2 Consider combinations of licence restrictions

Ofcom should consider combining licence restriction techniques that it examined as part of the SUR consultation e.g. EIRP limits, aggregate PFD limits, coordination (including CDMA code coordination). The investigations carried out above will help to inform the best combination of techniques based on the band and proposed services and technologies. It may be necessary to introduce further characterisations of systems (e.g. FDD vs TDD, fixed vs mobile), acknowledging the contribution of system characteristics to their ability to share, or reduce spectral packaging density, perhaps through the introduction of guard bands.

3.2.3 Investigate network implications for varying quality of service requirements

The SUR/PFD proposals should allow bidders (with the knowledge of existing IILs) to determine, in the absence of in-band interferers, the value of the spectrum based on an engineering assessment of the ‘capacity’ of the spectrum: the throughput and expected quality of service. Even with foreknowledge of the final SUR parameters and more detail of neighbouring network configurations, the impact on achievable grade of service at a link level up to system level is not clear.

Ofcom should, therefore, work with manufacturers and operators to investigate the likely impact of increasing PFD levels and varying network deployment characteristics on achievable link grade of service, and hence the engineering cost of ‘hardening’ the network.

3.2.4 Abandon reliance on field measurements

Field measurements may help investigations into the feasibility of PFD aggregate limits, in principle, but reliance on them as a sole method for determining breaches of licence conditions has been shown by this work to be impractical (sections 2.2.1, 2.2.4, 2.2.6 and 2.4.3). The PFD limit should therefore be implemented using reliable models and direct equipment transmission measurements. Measuring the output from real systems is practically easier and more reliable than measurements in the field.

3.2.5 Investigate legal status of regime

The introduction of the auction and SUR/PFD techniques is a radical departure from traditional spectrum management techniques and will require an accompanying change to the legal status of licences. Ofcom needs to make sure that all legal aspects are investigated, including:

- Including protection to more distant neighbours (see section 2.2.2);
- Protection to neighbouring traditional licence holders;
- UE equipment licensing;
- Subsequent EU rulings.

3.2.6 Investigate initial SUR parameter determination

This work has highlighted the inappropriateness of a unified approach to the definition of SUR parameters. If, on the one extreme, adjacent channel interference, or on the other extreme, inefficient spectrum packaging (with the introduction of overzealous guard bands) is to be avoided, the methodology for determining the initial SUR parameters needs to be reviewed, because they will determine the value that bidders associate with the spectrum.

Ofcom should consider varying PFD limits dependent on various factors including:

- Rural vs urban areas (see 2.3.4);
- Guard bands introduced (e.g. to traditionally-managed blocks);
- Limitations on technology ***types***[30] (e.g. FDD vs TDD (see 2.5), broadcast);
- Limitations on implementation configurations (e.g. directional antennas (see section 2.2.6));

The proposals should not, as a matter of principle, avoid the deployment of guard bands, where appropriate. Licence holders will, in any case, be free to negotiate the limited use of these bands once the licences have been awarded.

[30] Technology neutrality is a widely supported principal, but attempting to implement technology ***types*** that are incompatible, according to engineering assessments, would be nonsensical. Indeed the proposals, by identifying ‘paired’ and ‘non-paired’ spectrum, effectively acknowledge this difference.

3.2.7 Influence the international community

The international community, led in Europe by the European Commission, is searching for a way forward for the practical implementation of a technology-neutral licensing regime. Ofcom would be well advised, therefore, to progress these proposals using a sensible roll out approach so as to ensure that the UK is in step with any EU proposals regarding SURs whilst simultaneously seeking an international consensus leading to similar conclusions: the key to their long-term success.

3.2.8 Measurement area

The proposed measurement area of ten cells is too large and should be augmented by measurement/calculation over a single cell area.

3.2.9 Spurious emissions

Spurious emissions mask restrictions will need to be applied to all transmitters and measured directly at the output of transmitters.

3.3 Technical considerations in the 2.6GHz band

3.3.1 Outlaw adjacent channel operation

Sharing studies have conclusively demonstrated that adjacent channel sharing between FDD and TDD technology is not possible and so the CEPT plan, which reserves a guard channel between the TDD block and FDD uplink and downlink blocks must be implemented. The impracticality of designing filters capable of rolling off sufficiently within 1MHz (especially for picocellular equipment) precludes Ofcom's proposals to allow 'picocellular powers' in channels adjacent to FDD systems.

More generally, Ofcom needs to maintain groups of characteristics (such as service type) and group characteristics of technology, (FDD vs TDD), when determining auction design/management procedures, all of which impact on system coexistence.

3.3.2 Outlaw duplex reversal

Reversal of the FDD duplex should be explicitly outlawed, because attempting to operate even similar systems in adjacent channels will fail and render the spectrum worthless.

3.3.3 Restrict peak EIRP

Ofcom chose to abandon EIRP limits in its original consultation concluding that they would not solve the trade off between adjacent channel interference and reduced spectral efficiency. Ironically, the PFD proposal allows extremely high individual equipment transmit powers, which will lead to severe interference and even receiver blocking (see 2.2.1). Upper EIRP limits should be introduced to ensure that, when combined with the SUR methodology, severe local interference is avoided.

The implementation of EIRP limits (particularly for base stations) will also help to mitigate the problem of high local flux densities generated by directional antennas.

3.4 Auction design and timing

3.4.1 Second-price option for final assignments

Second-price auction (and allowing all available channels to be bid for) should be considered for the final assignments stage of the auction. This will better allow undesirable channels to be avoided.

3.4.2 Trial the auction process

The complex auction process should be trialled before a commitment is made to its use for the award of such a large quantity of prime spectrum. Ofcom may, after observing its use for auctions in the 10 GHz, 28 GHz, 32 GHz and 40 GHz bands, consider releasing a limited subset of the spectrum in this way, perhaps the 2010-2025, 2290-2303MHz and/or limited number (18, 19, 20 and 21?) of channels within the unpaired (according to the CEPT band plan) 2500-2690MHz bands

3.4.3 Award timing

The auction should not proceed until the issues raised in this report are first addressed and the consequent rules and background information are completed. Bidders will then need sufficient time to carry out any necessary due diligence preparations: a minimum of three calendar months.

3.5 Summary

A summary of the concerns raised in this report and mitigation suggestions is shown in table 3-1.

Issue	Technical impact	Commercial impact	Mitigation
High power transmitters cause severe interference and even receiver blocking to victim systems	[1] Base stations capacity are severely reduced and/or a proportion of UEs are disabled	[1] Operators are forced to deploy a larger number of less vulnerable, lower sited base stations, with considerable cost and network management implications. The cause of the interference will be outside the control of the operators and could occur at any time, without notice	[1] Impose EIRP caps and require coordination for higher EIRPs
High data rate equipment transmits higher power which will increase local interference	As [1]	As [1]	As [1]
There appear to be no provisions set out by Ofcom for preventing neighbouring users agreeing to ever higher transmit powers at the expense of more distant neighbours (both geographically and spectrally) not protected by these proposals	Neighbouring systems are disrupted	As [1]	Impose EIRP caps and require coordination for higher EIRPs Impose restrictions at three channels offset
The PFD proposals sever the link between operators' licence conditions and equipment standards leaving either manufacturers uncertain of requirements, operators little ability to deviate from *de facto* standards or allowing PFD limits to be breached by non-standard equipment	Non-standard equipment is required for UK	The cost of UK equipment rises because of its specialised nature	
ITU service definitions have been developed for good reasons: they acknowledge that similar deployments can better coexist than dissimilar	Increased danger of interference from different service types Technology neutrality is fine in theory, but mixing different types of technology in neighbouring bands has practical difficulties	As [1]	Maintain restrictions on service types, whilst allowing specific technology neutrality

Departure from international standards/standards mechanisms and the international effort that is invested therein could isolate the UK.	Difficulty in international coordination and uncertainty in future regulations	Undermines confidence in the band, thereby undermining its value	Use a sensible roll out approach whilst simultaneously seeking an international consensus leading to similar conclusions
International harmonisation efforts have a valuable role to play in the management of radio spectrum around the world - GSM being an exemplar of what international benefits can be achieved – and Ofcom needs to be sure that these proposals balance needs of liberalisation with harmonisation	Ditto	Ditto	Ditto
Directional antennas are not appropriate for managing using PFD limits	The application of the PFD principle to directional antennas would allow very high EIRPs to be transmitted and represents an extreme case of the high power transmitters. The containment of the radio signals to narrow beams would allow high densities of radios to be deployed causing – in the absence of coordination - a higher rate of extreme interference events (and even blocking)	As [1]	Carry out further investigations
Coordination principle	Mason's work (and similar studies) has highlighted, however, that total reliance on PFSD limits is short sighted and cannot work in this band with these applications		Consider combinations of licence conditions
Code co-ordination, is a useful technique and may help to coordinate small numbers of networks	Lost opportunity for improving base station sharing	Reduced band capacity reduces the value of radio spectrum	
The starting point for negotiations needs to be equivalence to the current regime. Errors in the determination of PFDs could, however, lead to overly onerous licence conditions or insufficient protection, which will have a material effect on the value that the market perceives the spectrum to have	On the one extreme, adjacent channel interference, or on the other extreme, inefficient spectrum packaging (with the introduction of overzealous guard bands) is to be avoided, the methodology for determining the initial SUR parameters needs to be reviewed, because they will determine the value that bidders associate the spectrum	As [1], or reduced band capacity reduces the value of radio spectrum Furthermore, if the default set of parameters is not clear prior to award, the value of the spectrum will be severely compromised	Carry out further investigations into more appropriate ways of determining initial, default SUR parameters

Impact of flexibility in service type (Fixed, mobile, others?)	Breaks away from assumptions of BS/mobile model used in all work so far and could cause increased incidence of interference	Operators will have to accept increased incidence of network degradation, or invest in more redundant capacity, with a consequent devaluing of the value of the spectrum (need to quantify)	Carry out modelling to investigate the magnitude of potential problems - Continue to enforce service types
Modelling, particularly propagation models, are not reliable and basing legality of use on such models for this type of licence would be unwise	The principle of PFD limits is undermined	Activity in the bands cannot be controlled, leading to the value of the spectrum being undermined	Develop better models that are more appropriate for varying conditions, or use an alternative approach
Statistical fluctuations in real parameters and brought about by imperfect measuring techniques	Ditto	Ditto	Develop a more detailed set of criteria tailored to different scenarios to reduce fluctuations Move away from the principle of PFDs
The optimum measurement duration and time (of day, month or year) is not clear	Monitoring resources will need to be in place for long time periods to ensure that both worst-case and typical statistics are available. Ofcom's own propagation model acknowledges 8dB of log-normal fluctuations 'from day to day'	Operators have to wait a long time before network problems can be investigated (even if their bands (or part of) were not used for the duration)	- Trial the monitoring process with real networks - Carry out quantitative investigations
Time that PFD limits are allowed to be breached should be 0% Ofcom appears to have abandoned the Aegis proposals in this area without comment	Extremely long measurement periods are required to prove that fluctuations in PFD levels never breech limits, or, PFD limits are set too high	Ofcom's enforcement function is not able to carry out sufficient measurements, or as [1]	Move away from the principle of PFDs, or as [1]
PFD limits are set assuming an urban environment, but this would encourage high peak powers from smaller numbers of transmitters in rural areas, potentially leading to harmful	As [1]	As [1]	As [1]

interference			
Spurious emissions cause harmful interference	As [1]	As [1]	Spurious emission masks should be applied
The legal and operational significance of modelling predictions vs real measurements are not clear NZ experience shows that taking such complex issues to court is expensive and difficult to prove interference	The result of the two could vary as a consequence of statistical fluctuations	Legal challenges to monitoring data	- Carry out extensive trials of the predictive software and compare with real networks to understand the nature and magnitude of the differences - Abandon field measurements in favour of technique based on combination of spectral masks and modelling, but not necessarily abandon the concept of SURs
Ofcom's proposals assume a starting point of networks having equal tolerance to disturbance and so implicitly equal quality of service requirements.	It is not clear what the achieved quality of service would be, and how networks with different quality of service requirements should be approached. Equal PFD limits would not necessarily achieve an equitable result	As [1]	In such a laissez-faire model, Ofcom might need to consider relaxing the end-to-end quality of service requirements on mobile network operators
Guard bands	Sharing studies in the 2.6GHz band have clearly demonstrated the need for guard bands. Their omission from the management methodology will cause interfernce	As [1]	Guard bands should be included as an adjunct to SURs
The PFD levels generated and resilience to external interference by differing reuse configurations varies, despite the same technology being deployed. The 1:3 configuration will generate higher PFDs and is likely to be more resilient to external interference.	Restricting the way in which the 1:3 network may be rolled out based on a set of SUR parameters assuming 1:1 configuration would be an unreasonable constraint; however, assuming PFD limits for a 1:3 network when, conversely, a 1:1 configuration is rolled out is likely to lead to interference from a network operating to those limits	As [1]	Initial SUR parameters need to be set to allow network operators latitude make engineering decisions not determined by external factors
Potential monitoring and enforcement overload	Ofcom does not have the resources to carry out more than one investigation at one time, but it is not clear in practice how many will be required,	Operators could find themselves with no recourse and may be	- Abandon field measurements in favour of technique based on combination of spectral masks

	especially when the techniques is adopted for more bands	forced to carry out their own investigations whilst network operations are disrupted	and modelling, but not necessarily abandon the concept of SURs
Measurement practicality	Practical considerations that will need to be faced (and seen to be so) are placement of monitoring equipment relative to obstructions (especially in urban areas) and access to private land. In undulating areas, these choices will have a particularly strong influence on results.	Ofcom's enforcement function is not able to carry out sufficient measurements, or as [1]	- Abandon field measurements in favour of technique based on combination of spectral masks and modelling, but not necessarily abandon the concept of SURs
Measuring OOB signals produced by interfering systems would be impractical in the presence of strong signals intended for victim receivers – this is only reliably measurable at transmitter outputs	OOB signal measurements are impractical in the field	Operators are, in effect, offered no protection through field measurements once networks are deployed	- Abandon field measurements in favour of technique based on combination of spectral masks and modelling, but not necessarily abandon the concept of SURs - Make measurements at Tx output to ensure that the OOB power is consistent with that modelled (relative to the IB)
The distribution and number of the grid of measurements. The exact placement of the grid will an affect as to the PFD measured (to say nothing of indoor locations)	Affects the power that can be transmitted from a network and provides uncertainty to the measurement process	Uncertainty as to how the network can be deployed, leaving choice as to whether to be conservative or aggressive, leading to potential later regulatory problems	- Investigate the impact of least and worst-case variations - Make the measurement process more rigorous
PFD heights of 1.5 and 10m do not reflect situation at macrocell BS heights	PFD measurements cannot be reliably made and therefore the principle of PFD limits is undermined	As [1]	Consider combinations of licence conditions
Identifying sources of signal/noise would be problematic (and difficult to legally enforce), and will become increasingly so with the advent of CDMA and similar	Should network performance degradation be encountered during to aggregate noise/interference, it will be technically impossible	Operators will have to accept increased incidence of network	- Base future management practice on combination of SURs, coordination and spectral

systems	for sources to be identified	degradation, or invest in more redundant capacity, with a consequent devaluing of the value of the spectrum (need to quantify)	masks?
Measurement problems will be exacerbated by directional antennas Aegis concludes that directional antennas will be needed	Omni directional monitoring equipment will not be able to get a full picture of the usage environment. There is an increased probability of severe interference events, although not an overall increase in aggregate interference	As [1]	As [1]
Proposed base station interference mitigation are impractical	As [1]	As [1]	As [1]
Impact of TDD systems adjacent to FDD systems	Mobile-mobile and BS-BS interference is experienced which is not sufficiently mitigated by Ofcom's proposed restricted bands. Mobile-mobile blocking is encountered which is NOT acceptable (see Ofcom and Mason's analysis)	Operators will have to accept increased incidence of network degradation, or invest in more redundant capacity, with a consequent devaluing of the value of the spectrum (need to quantify)	- Carry out modelling to investigate the impact of FDD/TDD neighbours - Carry out trials to investigate the impact of FDD/TDD neighbours
Impact of ability to reverse duplex	Worse than TDD neighbours (because for TDD, restricted blocks will be in place) and would cause massive disruption	Severe degradation of network performance, especially mobiles	- Ensure that rules explicitly restrict reversing duplex
Proposal (in workshop) to allow higher power in-band emissions if ACLR is improved are flawed, because of ACS component	As [1]	As [1]	As [1]
Not possible to avoid specific channels	As [1]	As [1]	As [1]
The timing of the award is not clear, and many unknowns exist: the final PFD levels; European policy; availability of the generic radio modelling tool.		Uncertainty in the background to the auction and lack of clarity, even	The auction should not proceed until the rules and background information are complete, and

		shortly before the auction starts leaves bidders unsure of the rules and nature of the commodity under auction, which will inevitably undermine the process	sufficient time has elapsed to allow bidders to carry out any necessary due diligence preparations: a minimum of three calendar months

A Modelling

A-1 Methodology

A-1.1 Overview

The systems that have been modelled represent generic FDD/TDD systems based on the UMTS standard. The configurations of the systems modelled are based on those suggested in the consultation document and supporting studies.

The modelling work proceeded in two stages:

- Pre-modelling calculations: estimated the power transmitted by each UE and base station (both total and code domain), and estimated the level of self interference (intra- and extracellular) experienced by each radio based on a set of assumptions derived from real network experience.

- SUR modelling: a model of the geometry of each scenario, calculated the external interference to each radio and compared this with wanted levels to predict levels of interference to noise (I/N) and external to self interference (intra- and inter-cellular): Ie/Is.

The model also calculates PFD parameters at three heights (1.5m, 10m and 25m (above rooftop level)) using both a fine 300-point[31] mesh in the central cell (a good average) and a coarse 25-point mesh across seven central cells (reflecting a similar scenario to the proposed measurement regime[32]).

A-1.2 Premodelling

Premodelling work was carried out to estimate the operational characteristics of the systems being by the main SUR calculation model.

The interference environment for UEs within a WCDMA systems is complex, especially at cell edge, where extra-cellular interference dominates. In fact, in real WCDMA systems, the cells 'breathe', meaning there is no clearly defined edge, but the model has assumed a mesh of evenly spaced base stations.

The base station code domain transmit power to UEs is generally observed to be constant for UEs close to the cell centre (where intracellular interference dominates), bit increases for UEs further out in order to overcome increasingly dominant extra-cellular interference. This has been modelled by assuming that the maximum code power (eg 2W for voice service) is directed to UEs on cell edge, with a linear reduction with base station to UE separation of upto18dB[33] to the centre of the range, whereupon it remains, constant. See figure A-1.

[31] Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', para A12.18

[32] Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', paras A11.4 and A11.6

[33] Typical for UMTS FDD networks

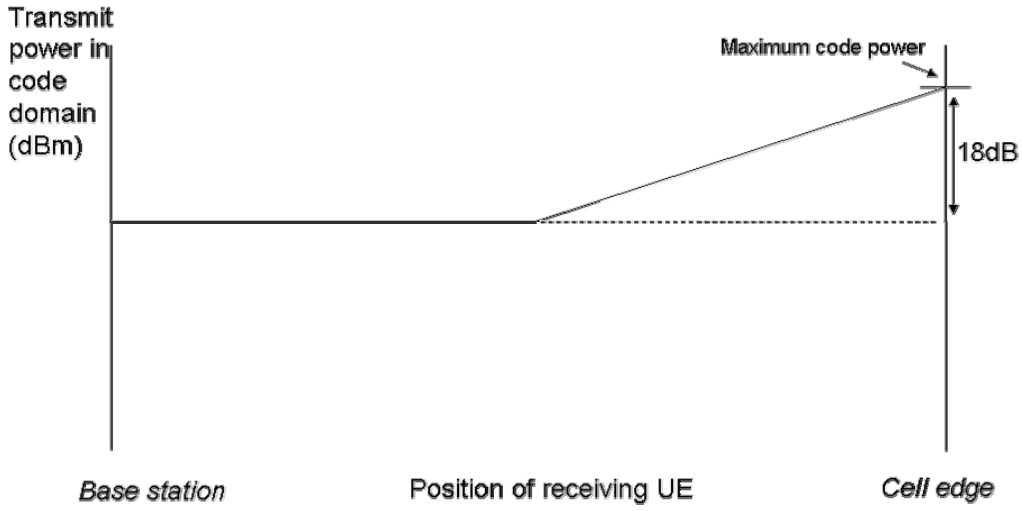

Figure A-1:Base station code domain transmit power estimation

The corresponding self interference to each UE relative to its received wanted power is then assumed to be that typical for the service in question (eg C/I is typically -18 dB for voice).

UE transmit power is calculated as that required to achieve the requisite Eb/No (after dispreading process) at the corresponding base station. The noise floor at the base station is assumed to be raised by self interference contributions from UEs within the cell and values published in EC Report 45 have been used. See figure A-2.

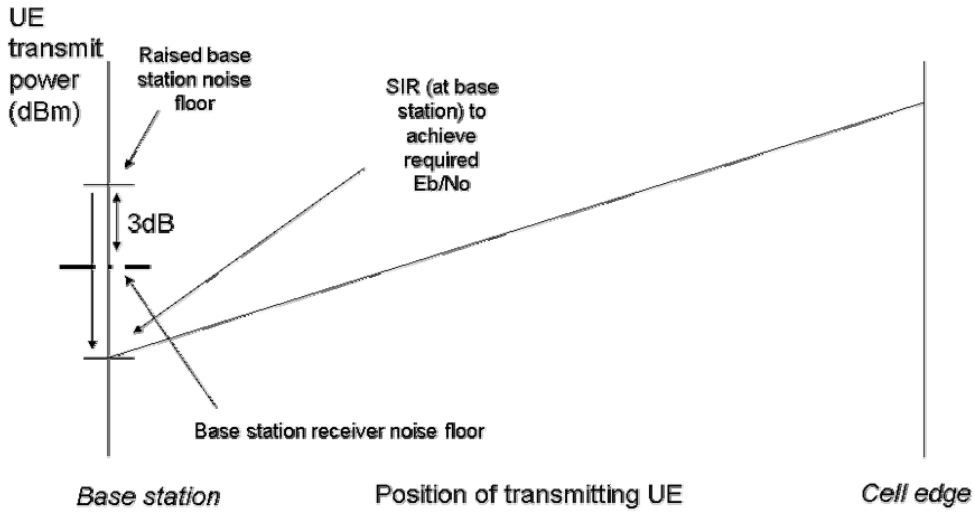

Figure A-2:Required UE transmit power estimation

A-1.2 SUR modelling

SUR modelling has been carried out according to the methodology set out in figure A-3.

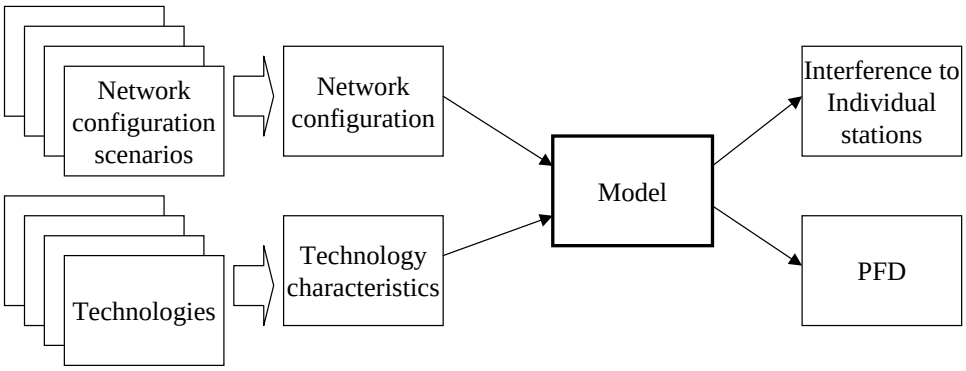

Figure A-3:Modelling methodology

19 cells have been modelled for both victim and interferer scenarios. All scenarios have relatively high densities of users and so seven central cells (and certainly central cell would be dominated by interactions with these radios).

The configuration of victim and interferer bases stations and their directional antennas is illustrated in figure A-4. The model allows interferer and victim base stations to be offset to represent them being located on an interstitial grid, a benign configuration that maximises the separation between base stations. The base stations are offset in such a way that, for tri-sector scenarios, the directional antennas are aligned, but not on bore sight, as shown in figure A-3. The predictions of interference, therefore, are low compared to Mason's work. In reality, allowing operators to place base stations where they please without consultation with neighbouring operators risks significant harmful interference.

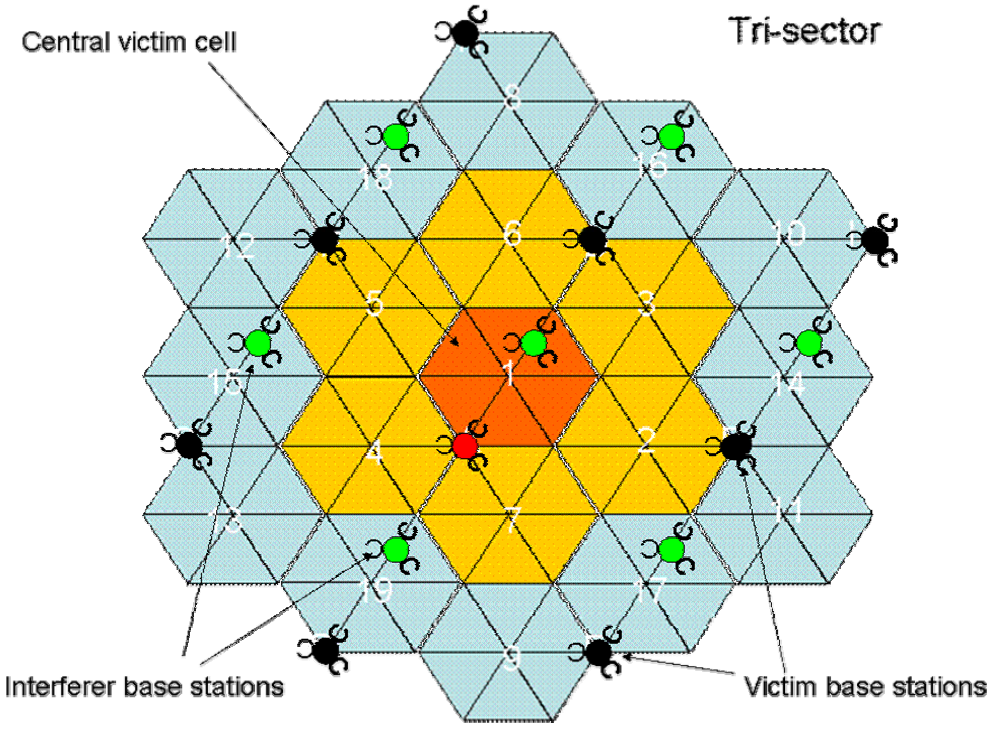

Figure A-4:Modelling area and configuration for tri-sector antennas – interstitial arrangement

The locations of UEs relative to the base stations is randomised - figure A-5 shows a typical distribution used.

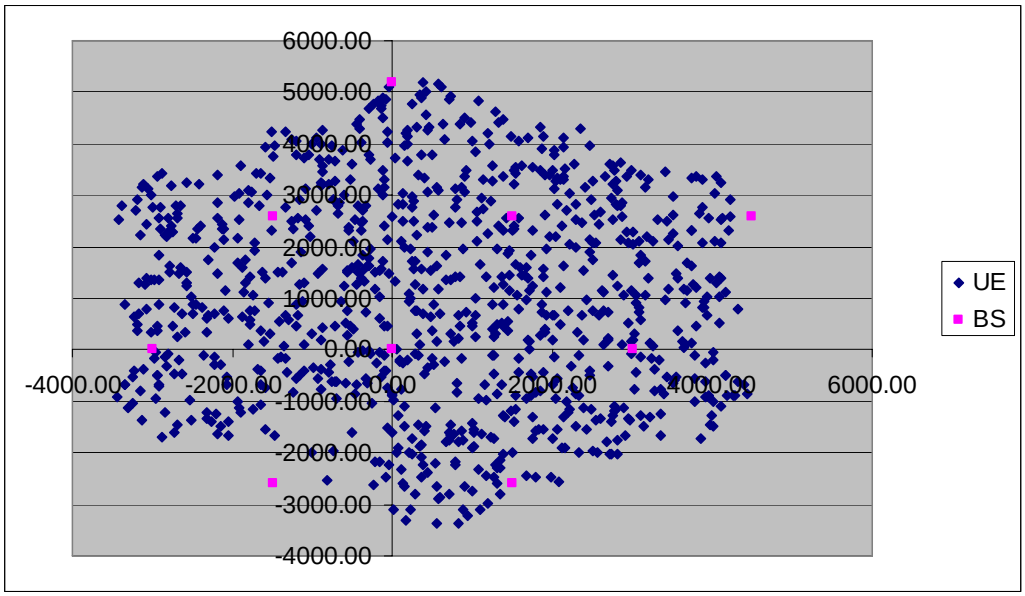

Figure A-5:Example UE distribution (Macrocell)

Interference power received by the victim radios in cell 1 are then calculated as the aggregate of contributions from all of the interferer radios in the simulation by using appropriate values of ACIR[34], mostly offset by 10MHz, in line with Ofcom's proposals. The propagation model that was used is based on a Cost Hata model in an urban environment. Propagation loss between high sited antennas, however, is assumed to be line of sight. The model then predicts data for the modes of interference shown in table A-1.

Interference scenario	**External interference received (dBm)**	**I/N ratio (dB)**	**C/I ratio (dB)**
TDD UEs to FDD base station (uplink) (channel 15)	Single value	Single value	Single value
TDD base stations to FDD base station (uplink) (channel 15)	Single value	Single value	Single value
TDD UEs to FDD UEs (downlink) (channel 24)	Multiple values	Multiple values	Multiple values
TDD base stations to FDD UEs (downlink) (channel 24)	Multiple values	Multiple values	Multiple values

Table A-1:Interference modes

[34] No mitigation techniques at base stations were included reflecting Ofcom's policy of avoidance of coordination.

A-2 Results and discussions

A-2.1 PFD calculations

The results of the pre-modelling were used to populate the main model with individual radio transmit powers and estimates of associated self interference levels. The powers used in the model are summarised in table A-3, and compared with those quoted in the EC Report 45 (from which Ofcom used the microcellular case). These differences represent departures from the details of the scenarios used: report 45 purports to represent 'average' usage; whereas this work is intended to represent heavy (but, by no means, worst case) usage.

System	Average UE Tx power (dBm)	
	Pre-modelling results	Report EC45 assumption
FDD picocellular	-26.9 (cell radius 40m;20 users)	-2.5 (cell radius 40m;2 users)
FDD microcellular	+15.94 (cell radius 315m;50 users)	+6.6 (cell radius 315m;65 users)
FDD macrocellular	+16.53 (cell radius 1000m;50 users)	+7.5 to +8.3 (cell radius 1000m;2 users)

Table A-2:Average UE transmit power used in model

Dependence of PFD parameters on measurement grid

The model was used to calculate the aggregate PFD at 25 random points within the central seven hexes, thereby simulating a measurement team in the field. Figure A-6 shows the results from the simulation, and highlights the median measurement, which denotes the level equivalent to the 50% threshold.

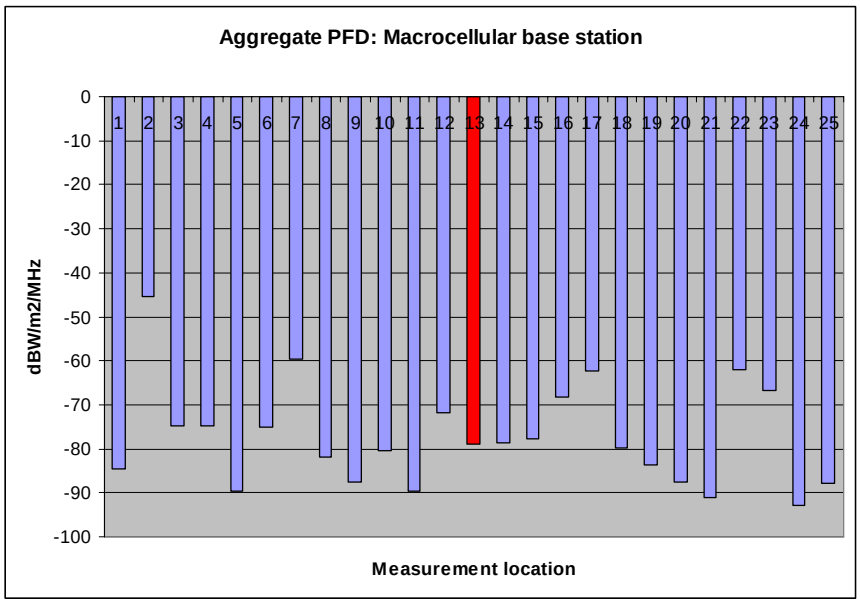

Figure A-6:25-point PFD calculations highlighting median point (X2 @ 1.5m)

The calculation was repeated 50 times to investigate the variation on the median values calculated. The results are shown in table A-3.

System	Median X2 (dBW/m^2/MHz)	Standard deviation
FDD Macrocell: DL	-74.9	3.9
FDD Macrocell: UL	-65.3	2.2
FDD Microcell: DL	-77.2	2.7
FDD Microcell: DL (Ofcom calc.)	*-56.6*	*N/A*
FDD Microcell: UL	-64.7	1.8
FDD Microcell: UL (Ofcom calc.)	*-68.5*	*N/A*
FDD Picocell: DL	-50.8	1.7
FDD Picocell: UL	-74.1	1.3
TDD Macrocell	-65.2	2.1
TDD Microcell	-64.8	1.6
TDD Microcell (Ofcom calc.)	*-64.8*	*N/A*
TDD Picocell	-50.9	1.8

Table A-3:PFD parameters spreads over 50 measurements

The spread in results for each type of system (standard deviation) illustrates the level of uncertainty of the PFD parameter calculated using 25 points and lies between 1.3 and 3.9dBW/m^2/MHz.

Dependence of PFD parameters on network configuration and measurement height

The PFD parameters were then calculated[35] for the different network configurations and technologies at 1.5m using a 300-point calculation (for greater precision) and are summarised in table A-4.

System	X2 (dBW/m^2/MHz)	X3 (dBW/m^2/MHz)	X4 (dBW/m^2/MHz)
FDD Macrocell: DL	-75.1	-120.1	-125.1
FDD Macrocell: UL	-65.2	-98.2	-108.2
FDD Microcell: DL	-77	-122	-127
FDD Microcell: DL (Ofcom calc.)	*-56.6*	*-101.6*	*-106.6*
FDD Microcell: UL	-65	-98	-108
FDD Microcell: UL (Ofcom calc.)	*-68.5*	*-101.5*	*-111.5*
FDD Picocell: DL	-51	-96	-101
FDD Picocell: UL	-74	-107	-117
TDD Macrocell	-65.2	98.2	-108.2
TDD Microcell	-64.8	-97.8	-107.8
TDD Microcell	*-64.8*	*-102.2*	*-112.2*

[35] Using a fine 300-point mesh in the central cell, as carried out by Ofcom, Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', para A12.18

(Ofcom calc.)			
TDD Picocell	-50.8	-95.8	-105.8

Table A-4:PFD parameters at 1.5m (calculated using 300-point grid) and compared to equivalent Ofcom calculations

Comparing the values for the 'microcellular' cases with those derived by Ofcom[36] shows the aggregate powers measured from UEs to be similar – suggesting that the more aggressive propagation model used in this work cancels the higher average transmit powers. The values calculated for the downlink (base station transmissions), however, vary by 30dB, showing that the propagation model has even more effect, because the average separation[37] of measurement points from the coarse grid of base stations is higher.

The variation of PFD parameters with height was then examined. Ofcom proposes that measurements be taken at 1.5m and 10m heights, those typical of UEs and microcell base stations, respectively. As part of this work, calculations are made at 25m, representing the situation above rooftop height. The results for in-band emissions (X2) are shown in table A-5 and figure A-7.

System	**@1.5m (dBW/m^2/MHz)**	**@10m (dBW/m^2/MHz)**	**@25m (dBW/m^2/MHz)**
FDD Macrocell: DL	-75.1	-50.1	-45.1
FDD Macrocell: UL	-65.2	-65.4	-65.7
FDD Microcell: DL	-77	-65	-64.5
FDD Microcell: DL (Ofcom calc.)	*-56.6*	*-53.8*	*N/A*
FDD Microcell: UL	-65	-65.2	-65.5
FDD Microcell: UL (Ofcom calc.)	*-68.5*	*-67.3*	*N/A*
FDD Picocell: DL	-51	-51.2	-51.5
FDD Picocell: UL	-74	-74.2	-74.5
TDD Macrocell	-65.2	-50	-45
TDD Microcell	-64.8	-64.8	-64.3
TDD Microcell (Ofcom calc.)	*-64.8*	*-63.7*	
TDD Picocell	-50.8	-51	-51.3

Table A-5:In-band emissions parameter (X2) at various heights (calculated using 300-point grid) and compared to equivalent Ofcom calculations

[36] 'Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz', section 9

[37] Average measurement point to base station separation would be around 315/2 = 157m; average measurement point to UE separation would be around 45m

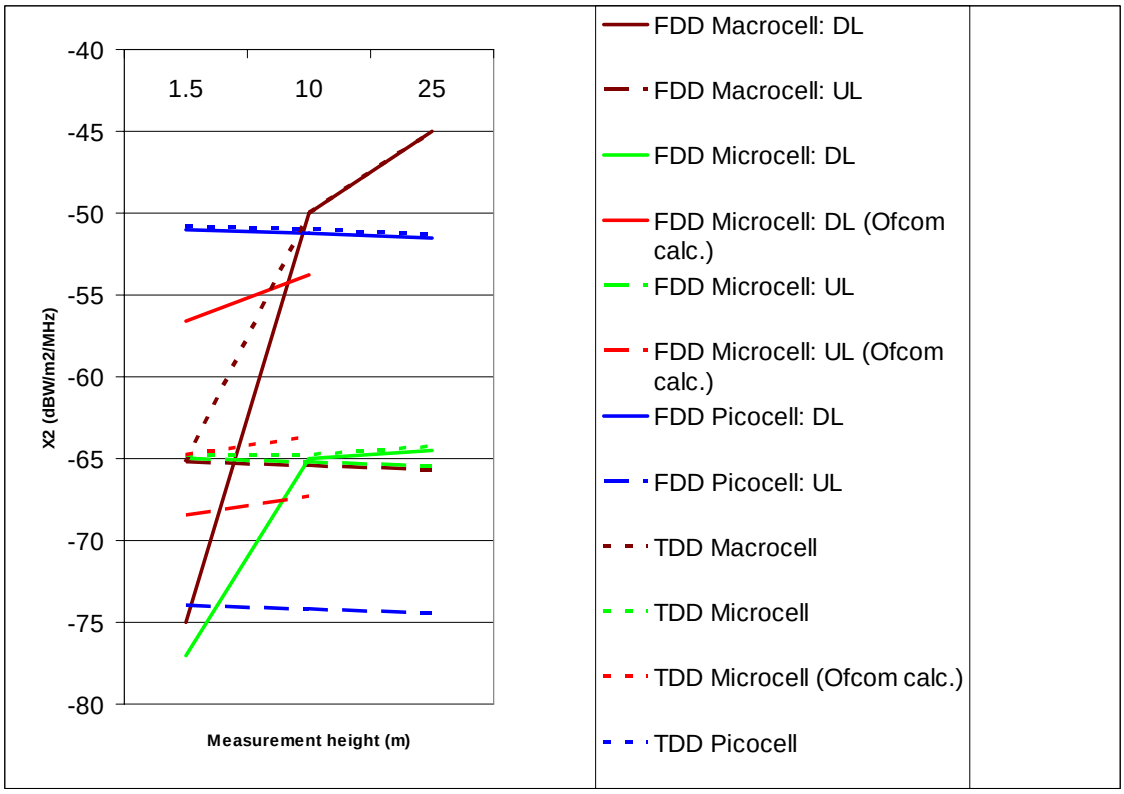

Figure A-7: In-band emissions parameter (X2) at various heights (calculated using 300-point grid) and compared to equivalent Ofcom calculations

Emissions from UEs (UL) dominate the aggregate PFD levels calculated for macrocellular and microcellular systems at 1.5m, the reverse of that shown by Ofcom (for its microcellular system), and explained by the difference in propagation model (as above).

Emissions from higher sited base stations show a greater dependence on measurement height than Ofcom's work (again, differences in the propagation model), especially for the macrocell, where a range of almost 30dB is observed. This is consistent with the high-placed monitor achieving line of sight to the macrocell base station at 25m. Indeed, for macrocells, emissions from the base stations dominate.

This variation of measured PFD with height would appear to make it unsuitable as a mechanism for controlling emissions from base stations, although it appears to work better for measuring emissions from UEs, at least in an urban environment.

The aggregate PFD generated by these scenarios appears, therefore, to be dominated by the increasing density of radios (UEs and base stations) as the cell size decreases, not the increasing average radio power; the power generated by a grid of picocellular systems generates the highest flux, which would appear therefore be the best system to use for setting PFD limits.

In conclusion, the PFD limits calculated vary considerably (35dB) for typical networks based on factors such as base station height and type; major differences appear between the model used for this work and that used by Ofcom, mainly driven by differing choice of propagation model and network configurations.

PFD measures appear, therefore, to be an unreliable way of controlling networks' emissions, especially from base stations. These predictions are from a flat earth model, and it can only be assumed that once penetration of buildings and terrain undulations are taken in to account, this reliability will be further impaired. Alternative management methods should, therefore, be considered, such as individual base station coordination.

A-2.2 Interference calculations

Correlation between PFD measures and interference statistics

The model calculates the interference suffered by the victim FDD system from the interfering TDD system, both for base stations and UEs. Figure A-7 and table A-7 illustrate typical results, in this case showing the impact of a TDD microcellular system on an FDD microcellular system[38]. The absolute levels of interference are shown (noise from UEs/BSs), along with the level of that interference when compared with self (comprising intra- and intercellular components) interference (Is/Ie)

Closer examination allows us to examine the impact of the TDD system on the FDD system by comparing external interference with the self interference inherently experienced by the victim radios. In this case, interference to the base station interference is not a problem (-19.9 and -15.0dB, from UEs and BSs, respectively), because the base stations are well separated and not aligned.

	Noise (dBm)	Ie/Is (dB)
Interference from UEs	-110.2	-19.9
Interference from BSs	-115.1	-15.0

Table A-7: Interference suffered by a microcellular FDD BS from a microcellular TDD system

The impact of the TDD system on the UEs is summarised in figures A-8 and A-9. In the sample of 50, one UE will suffer severe interference (Ie/Is>0dB) and a further 14 will be affected (0dB to -10dB).

[38] The base stations are arranged to be at interstitial locations, separated by 472.5m. The channel offset is 10MHz.

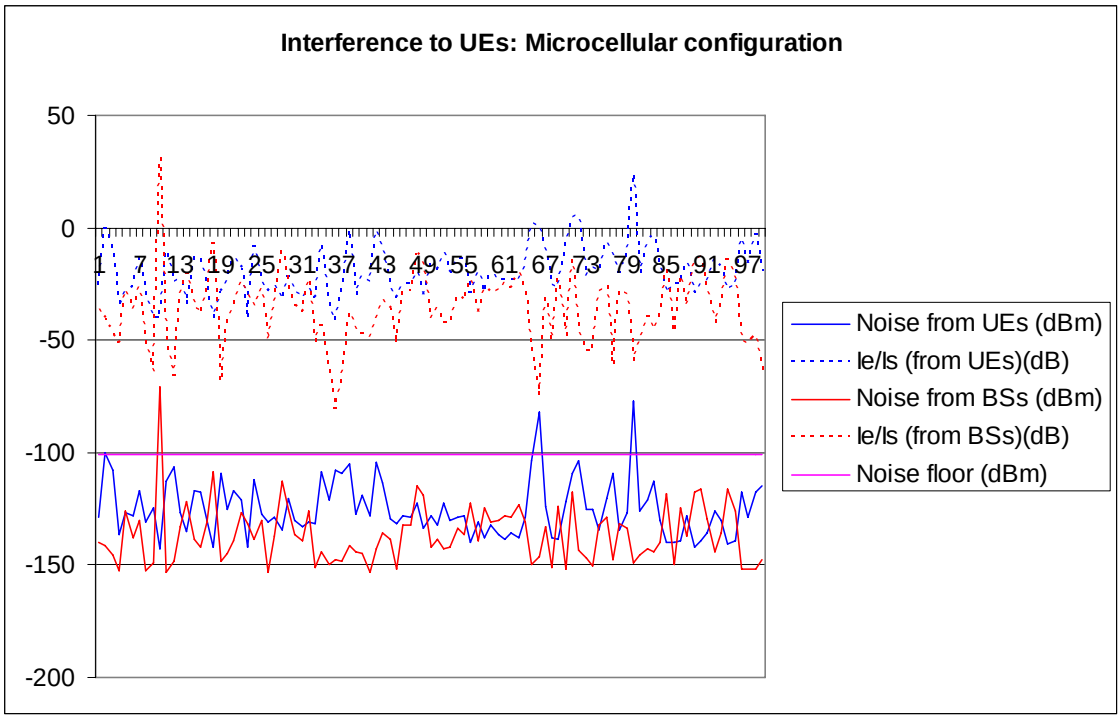

Figure A-8: Interference suffered by microcellular FDD UEs from a microcellular TDD system

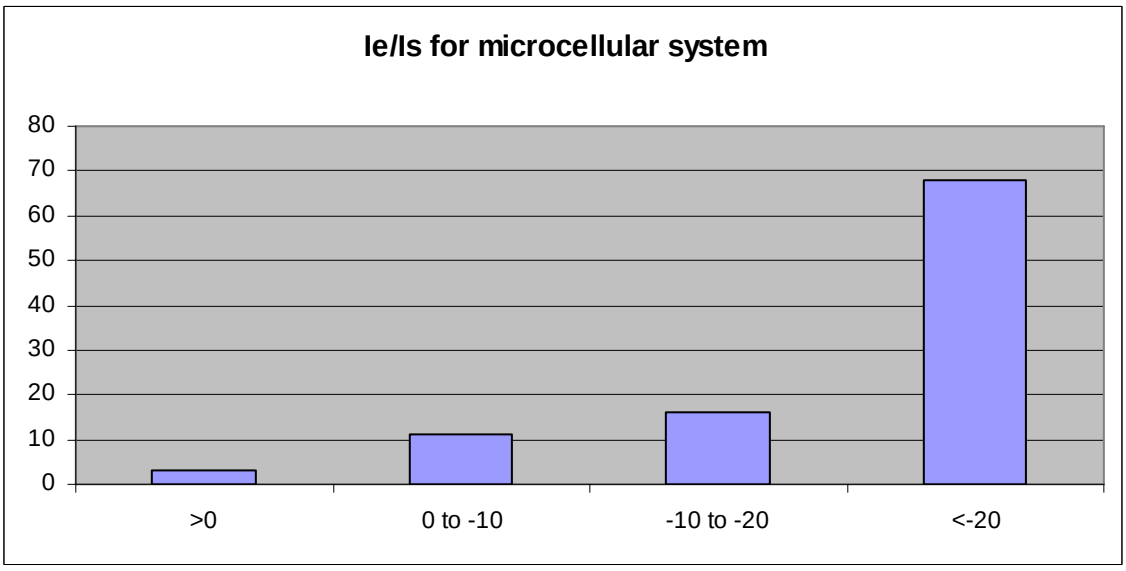

Figure A-9: Relative interference suffered by UEs for microcellular

Figure A-10 compares similar results for three scenarios representing small and large scale networks components: TDD picocellular to FDD picocellular; TDD microcellular to FDD microcellular; TDD macrocellular to FDD macrocellular

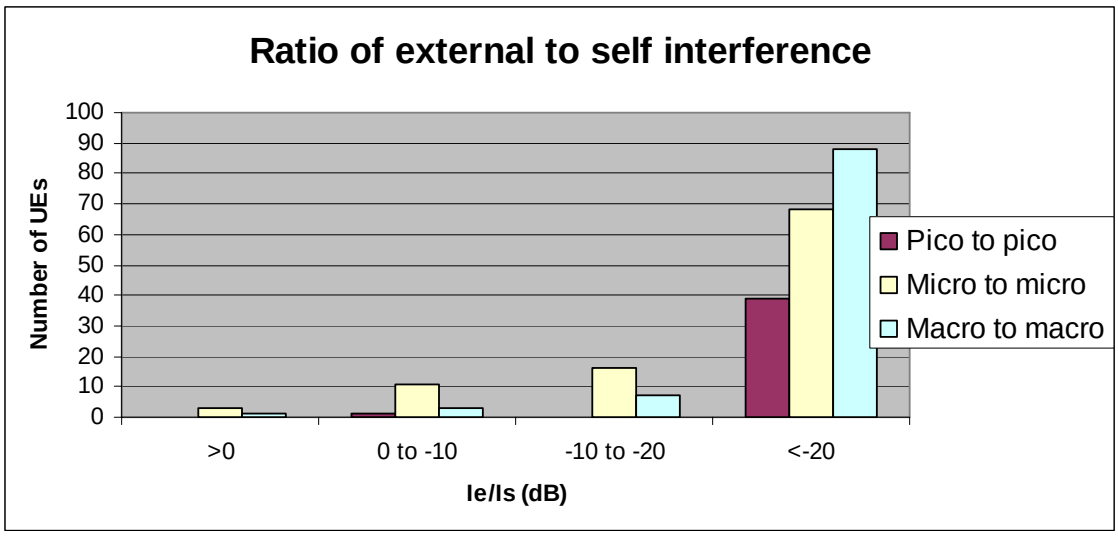

Figure A-10: Ratio of external to self interference for victim UEs

Comparing these results with the corresponding PFD thresholds calculated for the interfering TDD systems reveals that the most benign interference scenario involves the picocellular systems, but has the highest PFD. The worst-case interference scenario (microcellular systems) has a lower PFD.

System	PFD (dBW/m^2/MHz)
TDD Macrocellular	-65.2
TDD Microcellular	-64.8
TDD Picocellular	-50.8

Table A-8: Corresponding in-band (X2) PFD measures

This work demonstrates, therefore, that although a single PFD threshold can be calculated based on the power flux levels generated by typical network configurations, there appears to be little correlation between these levels and the likelihood of interference events experienced by victim UEs.

Adjacent channel operation

The Ofcom technical study demonstrated how, in worst-case, mobile to mobile interference is 2% likely for two mobiles systems operating FDD and TDD in adjacent channel. The Ofcom proposal is to allow only low power transmissions in adjacent bands, equivalent to a power mask limit of 28dBm/MHz[39]. The result of allowing such a microcellular system operate at 5MHz offset from such a low-power TDD system is summarised in figure A-11. This shows that, although average interference powers are low, instances of interference and perturbation of the FDD system increase.

[39] Main consultation document, para 9.7.

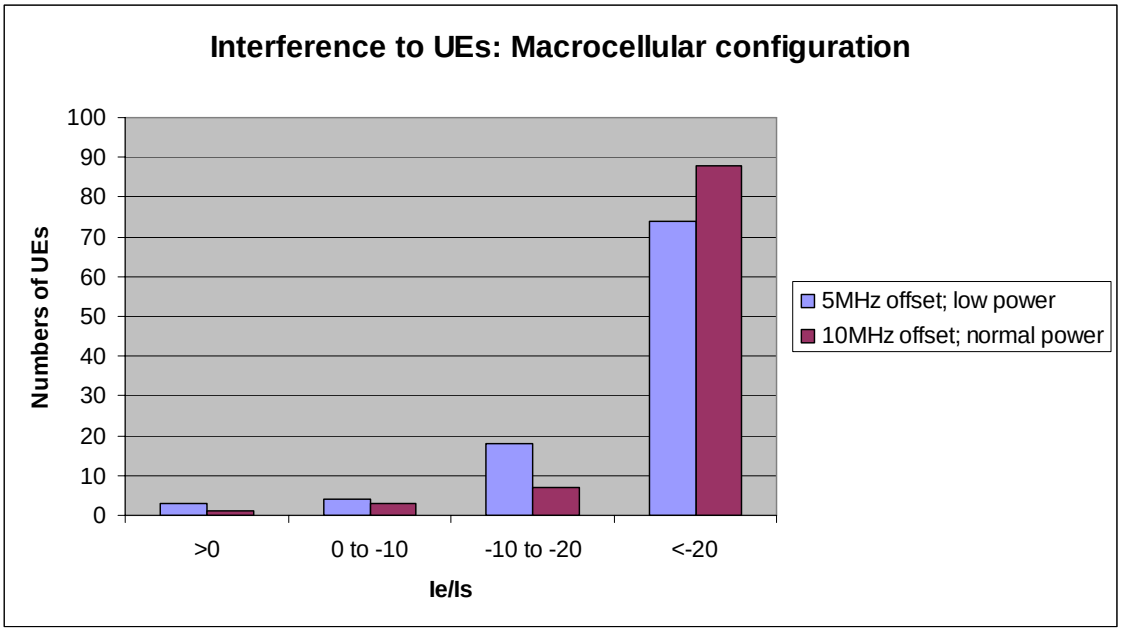

Figure A-11: Relative interference suffered by FDD UEs (macrocell) from a TDD system (macrocell) operating at reduced power

Proposals, therefore, to allow low-power operation adjacent to FDD systems should be carefully considered.

Directional antennas

A scenario identical to the microcellular system but with UEs fitted wiuth 8dBi antennas was modelled and, despite the measured PFD levels only being moderately raised (due to focussing of the power along narrow beams), interference events to victim receivers are higher.

System	X2 (dBW/m^2/MHz)	X3 (dBW/m^2/MHz)	X4 (dBW/m^2/MHz)
Omni directional antennas	-64.8	-97.8	-107.8
Directional antennas (+8dBi)	-62.3	-95.3	-105.3

Table A-9: PFD levels measured for microcellular TDD systems: Omni vs directional antenna

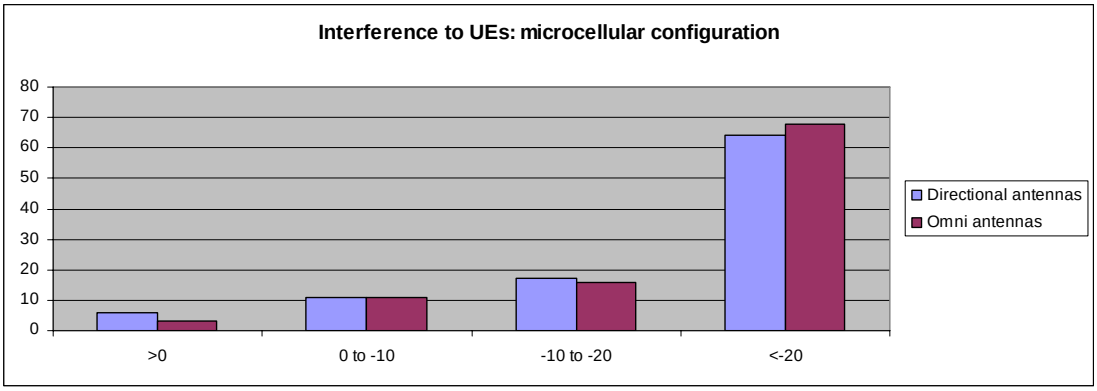

Figure A-13: Impact of adding 8dBi directional antennas to microcellular system

B Errors and highlights in consultation documentation

This section highlights some aspects of the supporting documentation that may be incorrect or unclear.

B-1 Award of available spectrum: 2500-2690, 2010-2025 and 2290-2302 MHz spectrum awards – Ofcom

Table 2: the maximum EIRP value +5 to +10 MHz of -22dBm/MHz appears to suggest an additional OOB filtering of 26dB, whereas the Mason report suggests a requirement of 40, 55 and 60dB (picocell, microcell and macrocell).

The use of the terms ‘restricted’ and ‘constrained’ channel, and ‘guard channels’ is inconsistent in the document, but appear to be largely used interchangeably.

Table 21 is incomplete, but appears to place no adjacent channel PFD restriction on channel Cx.

Para 9.81: States that ‘Channel 24 [the guard channel] is being treated as a normal TDD channel for the purposes of defining SURs though in the award process C24 may in fact be reserved as a guard channel’. This **must** be the case.

B-2 2500-2690, 2010-2025 and 2290-2302 MHz spectrum awards – engineering study (phase 2) – Mason Communications Ltd

Table A-8: The Rx/Tx filter details are not clear from this table, but appear to require 60, 55 and 40dB additional isolation for the TX and Rx channels of macro, micro and picocellular base stations, respectively. The values in the table appear, however, to be inconsistent.

Mason’s Rx/TX filter numbers not clear, but apparently expect -60dB for macro (55dB mico; 45dB pico). Ofcom’s power masks appear to only demand additional -26dB.

B-3 Adjacent and in-band compatibility assessment for 2500-2690MHz – Ofcom

Table on page 16, Potential chip loss, appears to dismiss a 7% loss of chips for brought about by solid state radar as ‘not considered significant’, with which operators would disagree.

ACIR table on p29 showing -45dB is at odds with the value of -42.4dB used in the Mason report. Furthermore, the ‘WiMax’ ACIR parameter suggests that adjacent channel interference can be controlled by the interfering equipment only. It is, in fact, a function of both the receiver (ACS) and transmitter (ACLR) characteristics (see section 4.1 of the Mason study).

C List of acronyms

ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
CDMA	Code Division Multiple Access
EIRP	Equivalent Isotropic Radiated Power
FDD	Frequency Division Duplex
IIL	Indicative Interference levels
PFD	Power Flux Density
SMR	Spectrum Management Rights
SUR	Spectrum Usage Rights
TDD	Time Division Duplex
UE	User Equipment