Second consultation on assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues

Annexes 8 - 15

Consultation

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Contents

Annex 8

Analysis of refarming of 900 MHz and 1800 MHz spectrum

A8.1 This Annex discusses the challenges in using 900 MHz and 1800 MHz spectrum for LTE services, and also the challenges in using 900 MHz spectrum for UMTS services. It considers what timescales might be realistic for doing this.

A8.2 This is relevant to our competition assessment because that assessment depends in part on when Everything Everywhere, Vodafone and Telefónica will be able to use their existing 2G spectrum for UMTS or LTE. We are interested in when they would find it profitable to refarm existing 2G spectrum if new technologies offered significant commercial advantages. We consider there is uncertainty on when it will be profitable to refarm, especially in terms of refarming 900 MHz spectrum for LTE.

A8.3 We conclude that:

8.3.1 It likely that Vodafone and Telefónica would be able to refarm at least 2x10 MHz of 900 MHz spectrum from 2G to UMTS by around 2016.

8.3.2 The move to LTE900 is longer term and there is considerable uncertainty over when it might be profitable. Assuming LTE has a significant advantage over HSPA, we would expect Vodafone and Telefónica to be able to progressively refarm 900 MHz spectrum to LTE, as the availability of LTE900 user devices increases.

8.3.3 Everything Everywhere will be able to start refarming 1800 MHz spectrum to LTE quickly. It is likely to be able to refarm at least 2x10 MHz by the time of the first tranche of divestment in September 2013. It can then refarm progressively more of the 2x45 MHz of 1800 MHz that it will retain after divestment over time, as 2G-only devices fall in importance.

Options and general considerations for refarming spectrum

A8.4 We are interested in whether national wholesalers would find it profitable to refarm to new technologies if those new technologies offered significant commercial advantages over current technologies. So, for example, if 900 MHz spectrum was the only spectrum a national wholesaler had that was suitable for LTE and LTE gave an important competitive advantage, we want to know if Vodafone and Telefónica would find it profitable to use the 900 MHz spectrum for LTE.

A8.5 We consider that Vodafone, Telefónica and Everything Everywhere have a range of options for how they choose to use 900 MHz and 1800 MHz spectrum and whether and when to refarm it. What they choose to do will depend on their commercial strategies and which option they consider most profitable. Their options might include the following, though these are not mutually exclusive or exhaustive:

8.5.1 They could decide to continue using most of their spectrum for 2G services until the value of UMTS/LTE services grows and until the take-up of compatible user devices makes it becomes easier to move to UMTS/LTE.

8.5.2 They could take measures to refarm spectrum while continuing to serve existing customers as they refarm, including by:

- Using the same technology in other spectrum. For example, Vodafone and Telefónica could potentially move 2G traffic at 900 MHz to 1800 MHz.
- Using different technology in other spectrum. For example, Everything Everywhere could potentially move 2G traffic at 1800 MHz to UMTS2100, which would be easier the higher the take-up of UMTS2100 capable user devices.
- Using new technology in the same band. For example, for Vodafone and Telefónica moving to UMTS900, UMTS900 capable handsets would allow traffic to be moved to UMTS as the spectrum is refarmed from 2G (though there would be transitional issues, as discussed below).
- Upgrading their networks in the same band and same technology so as to squeeze more capacity out of the remaining spectrum, which is potentially relevant for refarming both 900 MHz and 1800 MHz.

8.5.3 They could reduce the 2G services they offer, for example by increasing relative prices for services from 2G only handsets, ceasing to sell or subsidise 2G handsets or reducing sales to MVNOs that focus on 2G sales.

A8.6 A number of factors may affect the speed of transition to from 2G to UMTS/LTE and also from UMTS to LTE, including:

8.6.1 How big any performance gap is between technologies and how much this matters to consumers. The larger any gap, the quicker we would expect refarming to be.

8.6.2 The availability and take-up of a good selection of user devices that assist with moving to the new technology.

8.6.3 The ability of different technologies to operate in different amounts of spectrum. In particular, UMTS operates only in 2x5 MHz blocks whereas LTE can operate in blocks of different sizes. For the 900 MHz and 1800 MHz bands, small blocks of 2x1.4 MHz and 2x3 MHz can be used for LTE. This may make it easier to refarm from 2G to LTE, rather than from 2G to UMTS.

8.6.4 For the transition from UMTS to LTE, the proportion of traffic on dongles, as dongle traffic will be much easier to move to LTE, because dongles that could use both UMTS and LTE will be relatively cheap.

A8.7 Below we consider 900 MHz spectrum first, and then 1800 MHz spectrum.

Refarming the 900 MHz band for UMTS and LTE

March 2011 consultation

A8.8 In the March 2011 consultation we said that if the provision of higher quality data services with LTE becomes important for consumers, we would expect the holders

of 900 MHz spectrum to have an incentive to de-fragment that spectrum and refarm it for LTE in the longer term.[1]

Responses on refarming the 900 MHz spectrum[2]

A8.9 In its response, Telefónica argued that this contradicts our estimates of the cost of refarming from 2G to UMTS in our October 2010 Advice to Government[3]. Telefónica points out that that Advice implies a present value over twenty years of £440m for releasing 2x10MHz of 900 MHz and over £900m for releasing 2x15MHz of 900 MHz, for our 'very high' estimates.

A8.10 Vodafone argued that it would be unable to clear either 2x10 MHz or 2x15 MHz of its 900 MHz spectrum by 2013 or anytime soon thereafter.

A8.11 H3G estimated that the current customer bases of Telefónica and Vodafone could be supported on 2x7.5 MHz of 900 MHz spectrum, or even 2.5 MHz of 900 MHz spectrum if the 1800 MHz spectrum were used. It also noted that the 2G customer base was likely to rapidly decline as customers moved to smartphones.

Our current view on costs of refarming 900 MHz spectrum to UMTS

A8.12 Telefónica has already refarmed 2x5 MHz of 900 MHz spectrum from 2G to UMTS, whereas Vodafone has not yet done so. When Vodafone and Telefónica refarm more 900 MHz spectrum will depend on the cost of refarming relative to the benefits obtained.

A8.13 Telefónica points to the estimates of the cost of refarming from 2G to UMTS in our October 2010 Advice to Government. Those estimates were primarily concerned with the clearance and release of 900 MHz spectrum. In particular, those estimates were based on the assumption that the existing 2G traffic levels on 900 MHz spectrum had to be carried on any remaining 900 MHz spectrum used for 2G or transferred to an alternative frequency band.

A8.14 We consider that our previous estimates are not relevant for considering refarming the 900 MHz spectrum when it is for Vodafone and Telefónica's own use. This is because we now consider that the stock of UMTS capable handsets is relevant to the costs. Given that Vodafone and Telefónica's UMTS2100 network is less extensive than their 2G 900 MHz network, we consider that UMTS900 capable handsets are particularly important. The proportion of UMTS900 capable handsets is higher today compared to October 2010 and is now forecast to increase quickly with the rapid take-up of smartphones.

A8.15 The proportion of handsets that are UMTS900 capable is highly relevant to when it is profitable to refarm the 900 MHz spectrum for UMTS900 because the more traffic that is on UMTS900 capable handsets, the less challenging and less costly refarming will be. This is because traffic on the 2G 900 MHz layer that was previously generated from such handsets will switch across to UMTS as refarming proceeds. There is therefore no need to expand the 2G network to deal with such traffic, which was the source of the costs in our previous estimates of refarming. In

[1] See paragraph 5.71 in Annex 6: http://stakeholders.ofcom.org.uk/binaries/consultations/combined-award/annexes/Annex_6.pdf

[2] In responses there were also confidential sections on refarming, which we do not summarise here, but have taken account of in our assessment.

[3] http://stakeholders.ofcom.org.uk/consultations/spectrumlib/advice-to-government/

the limit, if all the traffic were on UMTS900 capable devices, there would be no costs associated with serving the formerly 2G traffic even when all the 900 MHz spectrum was refarmed. Costs would only relate to upgrading the network to HSPA. The stock of UMTS900 handsets may also affect the extra revenue from refarming, as the more data traffic that would be generated and the more consumers may value the service provided.

A8.16 We expect operators to migrate spectrum in 2x5 MHz blocks to UMTS. It is likely there would be some transitional issues (e.g. some quality degradation) with the network requiring re-optimisation after each block. These transitional issues could be mitigated by moving more traffic to existing refarmed blocks to the extent of their capacity, reducing the amount of displaced traffic during the transitional period. This is made easier because UMTS is more spectrally efficient allowing more calls and data can be handled per cell site compared to 2G technologies. Such issues might also be mitigated by adopting a regional approach to the transition. Additionally the duration of the transitional period is likely to reduce over time as experience is gained with the process of transition.

A8.17 In order to refarm all the 900 MHz band, Vodafone and Telefónica would need to defragment the interleaved spectrum. This will require significant coordination between the operators.

UMTS900 capable handsets

A8.18 Vodafone and Telefónica have some control over the speed at which UMTS900 handsets are encouraged onto their networks. If they wished to refarm rapidly, they could accelerate the move to UMTS900 capable handsets. For example, they could offer greater handset subsidies to existing consumers with handsets that were not UMTS900 capable, or could cease handset subsidies for handsets that were not UMTS900 capable, or they could use different tariff structures to encourage the take-up of UMTS900 capable handsets.

A8.19 It may be easier for Vodafone and Telefónica to move contract customers to UMTS900 capable handsets than pre-pay customers. The proportion of contract customers has grown over time, from 41% at the end of 2009 to 49% by the end of 2010, with the precise proportion varying between operators. This trend may continue in the future, partly as a result of falling mobile termination rates which may result in reduced subsidies for pre-pay handsets.[4]

A8.20 Currently the majority of handsets on Vodafone's and Telefónica's network are not UMTS900 capable. However, the proportion of UMTS900 capable handsets is expected to grow rapidly, much more rapidly than was the case with UMTS2100 capable handsets. This is mainly because of the current growth in smartphones.[5] Many commentators are predicting a large increase in the number of smartphones

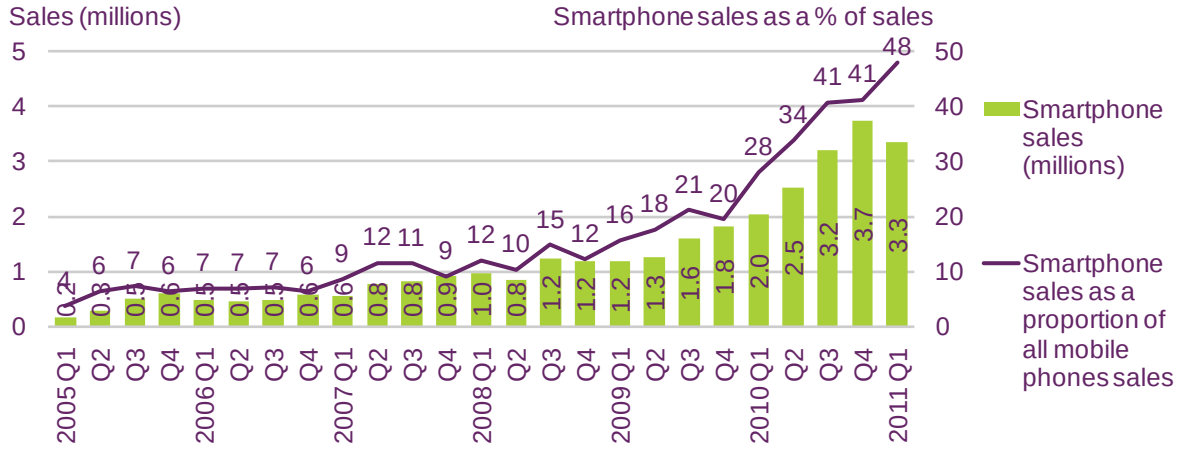
[4] See pages 259 and 260 of the Communications Market Report, 2011, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr11/UK_CMR_2011_FINAL.pdf And for the latest data by operators see: http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/tables/

[5] Smartphones are generally differentiated from 'feature' phones by their advanced operating systems that allow the installation of third-party mobile 'apps', which are commonly used to access internet content. Smartphones are also commonly equipped with advanced hardware such as touch screens, large colour displays, large memory capacities and fast internet connectivity with Wi-Fi or 3G. Smartphones users are therefore able to generate much higher data traffic compared to users of 'feature' phones.

over the next few years. While not all smartphones may be UMTS900 capable, we expect that the large majority will be.[6]

A8.21 Figure A8.1 shows sales data collected by GfK, which indicate that smartphone sales nearly tripled between Q1 2009 and Q1 2011. By the first quarter of 2011, around half of new handsets sold were smartphones. The Figure A8.1 also shows that there is a clear trend for smartphones to increase as a proportion of sales.

Figure A8.1: UK smartphone sales

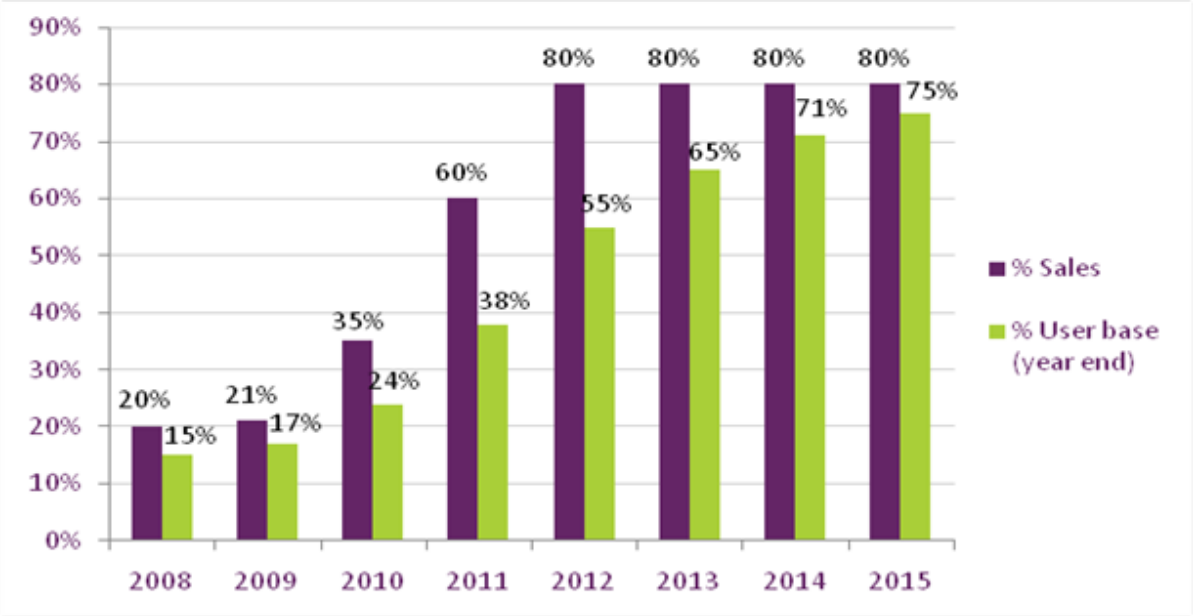


Source: GfK Retail and Technology Ltd, based on factual point-of-sale information
(1) Smartphones are defined as any handset running an open operating system, including Symbian (6.1 and above), Android, BlackBerry, iPhone, Palm, Windows Mobile or Linux operating systems;
(2) England, Scotland and Wales only (excludes Northern Ireland);
(3) Based on GfK 's coverage of 95% of the market – data have been extrapolated to represent whole market;
(4) Only represents sales through consumer channels, i.e. most business connections are excluded

A8.22 This trend of increasing smartphone adoption is expected to continue. This is illustrated in Figure A8.2, which shows projected figures from Enders Analysis for the proportion of smartphones in sales and the user base.

[6] This is consistent with the GSA's statement in its UMTS900 Global Status of 28 October 2011 which said that 663 UMTS900-HSPA devices have been launched (including over 300 phones) and that "UMTS900 is standard today in most new devices destined for Europe, the Middle East, Africa, and Asia Pacific markets. The 900/2100 MHz combination for 3G/WCDMA-HSPA is commonplace." http://www.gsacom.com/index.php4
Qualcomm has presented data (sourced to GfK) to other regulators showing close to 90% of 3G handsets sold in the EU5 countries in early 2011 supported UMTS/HSPA900. See page 5 in http://www.regjeringen.no/pages/16233436/294568_1_P_QualcommEuropeInc.pdf
As set out in the report by Real Wireless, The timing of the consumer and operator features available from HSPA and LTE technology paths, popular user devices that are UMTS900 capable include: Apple iPhone 4S, iPad2, Samsung Galaxy S, Blackberry Playbook, Nokia N8, and HTC HD7.

Figure A8.2: UK smartphone share of sales and users



Source: Enders Analysis, Smartphones and mobile advertising, January 2011

A8.23 Other analysts and commentators also predict rapid growth in smartphones.[7] This is also consistent with a recent survey of mobile operators in Europe[8] and our latest consumer research.[9] With the increase in the proportion of smartphones, the proportion of 2G only handsets will decrease.

A8.24 This rapid increase in the proportion of handsets that are smartphones suggests that Vodafone and Telefónica have significant opportunity to increase the proportion of handsets on their networks that are UMTS900 capable over the next few years. We consider it reasonable to assume that over half of handsets will be UMTS900 capable by 2016.[10]

[7] For example, Analysys Mason predicts the proportion of active handsets that are smartphones in Western Europe predicted to rise from 23% in 2010 to 72% in 2016, with the total number of handsets being broadly flat over this period,
http://www.analysysmason.com/About-Us/News/Insight/Smartphone_penetration_Aug2011/
Business Monitor International estimates smartphones will account for up to two thirds of UK market by 2015,
http://www.mobiletoday.co.uk/News/12482/Smartphones_will_account_for_two_thirds_of_UK_market_by_2015.aspx
MobileSQUARED forecasts that smartphone penetration in the UK by the end of 2011 will be 39% and will be 80% of total devices by 2016,
http://www.mobilesquared.co.uk/pdfs/adsmobi_whitepaper_october2011.pdf

[8] Credit Suisse, European wireless survey, 30 November 2011, surveyed 18 European mobile operators. When asked whether adoption of smartphones (measured in millions of new users per annum) was slowing, the large majority (89%) said 'no' for the market in general, and all (100%) said 'no' for business.

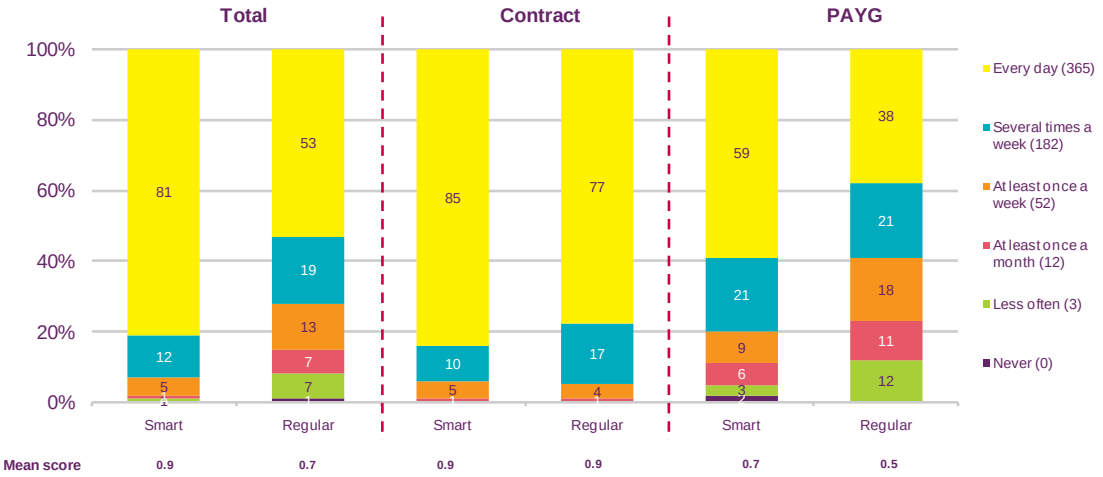
[9] See Section 3.2.9. of The Consumer Experience 2011, published by Ofcom on 6 December 2011. This found that 38% of UK mobile phone owners claimed to own a smartphone in Q2 2011, an increase of 8% since Q1 2011. Of non-smartphone users, 3% say they are certain to get a smartphone in the next 12 months and a further 11% say they are likely to get one. A third of non-smartphone owners say they are unlikely to get one, and 40% say they are certain that they will not.
http://stakeholders.ofcom.org.uk/binaries/research/consumer-experience/tce-11/ce-research-2011.pdf

[10] For example, Enders Analysis's forecasts above (which are broadly consistent with other forecasts) imply the stock of smartphones would increase by 50% between the end of 2010 and the end of 2015

A8.25 From the point of view of the costs to refarming, it is not the proportion of UMTS900 capable handsets in itself that is important. Rather it is the proportion of 2G traffic on the 900 MHz spectrum that UMTS900 capable handsets account for before refarming. The difference between these two things is likely to be substantial. UMTS900 capable phones are likely to have higher traffic levels per handset than 2G only phones. This can be seen indirectly by comparing the use of smartphones with regular mobile phones, given that smartphones are more likely to be UMTS900 capable than regular mobile phones.

A8.26 Ofcom's consumer research found that 81% of smartphone owners make and receive calls on their mobile every day, compared to 53% of regular phone users. As explained in the Communications Market Report, this difference in use can be partly explained by contract type, with contract phone users making calls significantly more often than pay-as-you-go users overall. This has been confirmed by analysing the research results, isolating the regular mobile phone users on contracts and comparing them with smartphone users on contracts – call frequency profiles are similar for both. But there are differences between regular and smartphone pay-as-you-go users; smartphone users make calls more frequently.

Figure A8.3: Frequency of making calls: adults



Source: Ofcom omnibus research, March 2011
Q.7a How often, if at all, do you use your mobile phone to make or receive calls?
Base: GB adults who use a mobile phone (n = 1810).

A8.27 Our customer research has also found that smartphone users send texts more often.[11] Data use will also be higher on smartphones than regular phones, given the higher functionality of smartphones.

(from 24% to 75%). If we assume that the large majority (say 90%) of smartphones over this period are UMTS900 capable, this would imply that the stock of handsets that are UMTS900 capable would increase by 45% by the end of 2015. Given that a sizeable minority of handsets were already UMTS900 capable at the end of 2010, this would imply that well over 50% of handsets would be UMTS900 capable by 2016.

[11] See section 1.5.5 of our 2011 Communications Market Report, http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr11/

Conclusion on refarming 900 MHz spectrum from 2G to UMTS

A8.28 We consider it reasonable to assume that over half of handsets will be UMTS900 capable by 2016. This is based on the current rapid growth in smartphones, the large majority of which are UMTS900 capable. We expect the growth in smartphones to continue. We also consider that Vodafone and Telefónica would be able to accelerate the take-up of UMTS900 handsets if it were important for them to do so.

A8.29 Of the remaining handsets, many would be 2G-only handsets, which on average will tend to be associated with less intensive use (lower calls, lower texts and lower data use) than UMTS900 capable handsets.

A8.30 We consider that by around 2016 it is likely that the large majority of traffic will be on UMTS900 capable devices. This means that there would be little or no material costs in refarming in terms of dealing with displaced 2G traffic (because the traffic will move to UMTS900). We therefore consider it likely that Vodafone and Telefónica would find it profitable to refarm at least 2x10MHz of 900 MHz spectrum from 2G to UMTS by around 2016, if UMTS offers significant advantages to consumers over 2G. If the advantages of UMTS (or LTE) were sufficiently large, it might be profitable for them to refarm earlier and incur costs of dealing with displaced 2G traffic (or ceasing to serve it).

Refarming 900 MHz spectrum to LTE

A8.31 Vodafone and Telefónica could refarm spectrum to LTE either from UMTS or directly from 2G, or potentially utilise all three technologies in parallel. We would expect them to progressively move to LTE as LTE900 capable user devices are taken up. If they move first to UMTS, it may be possible to handle the traffic that is displaced from the first 2x5 MHz UMTS900 carrier that is moved to LTE with the other UMTS carriers. Or the UMTS traffic could be served directly by the new LTE900 carrier to the extent that some user devices (e.g. dongles) are both UMTS900 and LTE900 capable.

A8.32 There is currently a paucity of LTE900 user devices, with few public announcements on LTE900 handsets. However, research on unannounced product roadmaps suggests that there could eventually be a similar number of devices available for LTE900 as for LTE1800. However, while it is possible that LTE900 could catch up with LTE1800 over time, today the availability of LTE900 user devices is some way behind LTE1800.[12]

A8.33 Refarming in this way would be consistent with the way that NTT DoCoMo is currently moving its 2.1 GHz spectrum from UMTS to LTE in Japan. NTT DoCoMo started to refarm 2x5 MHz from UMTS to LTE in December 2010 and plans to refarm more as the proportion of traffic on LTE capable devices increases.[13]

[12] See the report by Real Wireless, The timing of the consumer and operator features available from HSPA and LTE technology paths.

[13] http://www.telecomsmarketresearch.com/resources/Spectrum_3.shtml http://www.google.co.uk/url?q=http://edu.tta.or.kr/sub3/down.php%3FNo%3D88%26file%3D2-1_110906%2520TTA%2520Workshop%2520(DOCOMO)%2520submission.pdf&sa=U&ei=QR7QTv_sJIGK8gOyzpnqDw&ved=0CCcQFjAD&usg=AFQjCNHPo61jx_gf_pp7O6gkP33A7jAEVg

A8.34 In order to refarm a contiguous 2x10 MHz block for LTE in the 900 MHz band, Vodafone and Telefónica would need to defragment the interleaved spectrum, which will require significant coordination between the operators.

A8.35 Whether LTE provides the capability to provide voice services could also affect the speed of refarming to LTE. The GSMA expects devices and services that support Voice over LTE will appear in late 2011 to early 2012.[14] We therefore think this is unlikely to be a constraint in practice.

A8.36 We therefore consider that the move to LTE900 is longer term and there is considerable uncertainty over when it might be profitable. This partly depends on how much of a commercial advantage LTE gives over HSPA – the larger the advantage, the more incentive Vodafone and Telefónica have to refarm. If LTE has a significant advantage over HSPA, we would expect Vodafone and Telefónica to progressively refarm 900 MHz spectrum to LTE, as the availability of LTE900 user devices increases.

Refarming the 1800 MHz band for LTE

March 2011 consultation

A8.37 In the March 2011 consultation we noted that it was partly because of the concern that Everything Everywhere could launch LTE at 1800 MHz with a large contiguous bandwidth before other operators that the European Commission was concerned about the Orange/T-Mobile merger. It allowed the merger after accepting commitments from Everything Everywhere's parent companies to divest some of Everything Everywhere's 1800 MHz spectrum.[15]

Responses on refarming the 1800 MHz spectrum

A8.38 Everything Everywhere argued in its response that whoever acquires the divested 1800 MHz spectrum would be better placed than it to introduce an LTE1800 service, with the acquirer being able to launch a 2x10 MHz LTE service from the end of 2013.

A8.39 Other responses argued that Everything Everywhere would easily be able to rapidly refarm a 2x20 MHz LTE1800 carrier, even allowing for the divestment.

Our view of Everything Everywhere's incentive to refarm the 1800 MHz spectrum

A8.40 How quickly Everything Everywhere refarms the 1800 MHz spectrum to LTE will depend on the cost of refarming relative to the benefits obtained.

A8.41 Unlike the situation with Vodafone and Telefónica refarming to UMTS900, there are currently few LTE1800 user devices. On its own, this may suggest that refarming 1800 MHz spectrum is more difficult for Everything Everywhere compared to Vodafone and Telefónica refarming 900 MHz. However, there are other factors which work in the other direction. Firstly, there are no interleaving constraints for Everything Everywhere to deal with, unlike for the 900 MHz spectrum.

[14] See section 2.9 of the report by Real Wireless, The timing of the consumer and operator features available from HSPA and LTE technology paths.
[15] See paragraph 6.137 in Annex 6 of the March 2011 consultation

A8.42 Secondly, Everything Everywhere has an advantage in that it has a large amount of spectrum. While it has to release 2x10 MHz of 1800 MHz spectrum in 2013 and a further 2x5 MHz in 2015, until it releases this spectrum it has 2x60 MHz of 1800 MHz spectrum. It also has a larger network at around 18,000 sites which also gives it more capacity. Importantly. It also has 2x20 MHz of 2.1 GHz spectrum.

A8.43 UMTS2100 is probably more relevant to the refarming of 1800 MHz than 900 MHz spectrum, because Everything Everywhere's UMTS2100 network is more extensive than Vodafone and Telefónica's UMTS2100 networks. This is likely to make refarming the 1800 MHz spectrum easier because a large and growing proportion of user devices are UMTS2100 capable. At the end of 2010, 41% of mobile connections were 3G, compared to 34% at the end of 2009.[16] We assume that all of these would be 2100UMTS capable, because of the prevalence of use of 2100MHz for UMTS. These UMTS2100 capable handsets are likely to account for a disproportionately high amount of traffic for the same reasons as UMTS900 handsets (as discussed above). This percentage is likely to rise rapidly over the next few years given the growth of smartphones (as discussed above). This means that if the amount of 1800 MHz spectrum used for 2G services were reduced much of the traffic could be dealt with by UMTS2100, because the handsets are capable of using UMTS2100.

A8.44 Once some of the 1800 MHz spectrum has been refarmed to LTE, it is likely to be possible to move some traffic from UMTS2100 to LTE1800 reasonably rapidly, helping to free up the UMTS2100 layer. This is because it is probably possible to move dongle traffic relatively easily from UMTS2100 to LTE1800. Dongles that could use both UMTS2100 and LTE1800 will be relatively cheap, and as dongles have much higher data usage, this may allow an operator to relatively easily move significant volumes of traffic from UMTS2100 to LTE1800.

A8.45 Also, over the next few years the number of LTE1800 capable handsets and other user devices is expected to grow. Along with 800 MHz and 2600 MHz, 1800 MHz is one of the top three bands supported in Europe. There is growing momentum for LTE1800 devices which are starting to become available.[17]

A8.46 Operators are likely to be able to take steps to encourage consumers to move from one technology to another. This is illustrated by Verizon Wireless in the USA, which launched a promotion doubling the amount of data its LTE smartphone customers can use per month, thereby encouraging consumers on to its lightly loaded LTE network and freeing up capacity on its CDMA network.[18]

Conclusion on refarming 1800 MHz spectrum from 2G to LTE

A8.47 Everything Everywhere's large amount of 1800 MHz and 2100 MHz helps refarming. We consider that it will be possible for Everything Everywhere to start refarming 1800 MHz spectrum to LTE quickly, and that it is likely to be able to refarm at least 2x10 MHz by the time of the first tranche of divestment in September 2013. It can then progressively refarm more of the 2x45 MHz it will retain after divestment over time, as 2G only devices fall in importance.

[16] See Figure 5.55 of Ofcom's 2011 Communications Market Report, http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr11/uk/

[17] See the report by Real Wireless, The timing of the consumer and operator features available from HSPA and LTE technology paths on 1800 MHz LTE user devices.

[18] http://www.rethink-wireless.com/2011/11/10/verizons-lte-data-deal-eases-iphone-strain-3g.htm

A8.48 The acquirer of the divested 1800 MHz spectrum will have 2x10 MHz of cleared spectrum ready to use for LTE in September 2013 and a further 2x5 MHz in 2015. The acquirer of this spectrum therefore does not have any refarming issues.

Question A8.1: Do you agree with our assessment of when Everything Everywhere, Vodafone and Telefónica are likely to be able to refarm their existing 2G spectrum? In particular, do you agree with our views on the importance of user devices and the likely availability and take-up of devices that use different technologies and bands? Please state the reasons for your views, including if appropriate your views on handset roadmaps and the practical constraints which apply to those road maps.

Annex 9

Research on spectrum auctions and holdings in Europe and elsewhere

A9.1 This annex sets out some general facts in relation to the spectrum holdings and awards for mobile use in other countries. It primarily focuses on the experience of other Western European countries because they are more similar to the UK situation. However, where relevant we also address experience from other parts of the world.

A9.2 The annex is structured as follows. The first part overviews the regulatory actions taken by national regulators to promote competition and redress imbalances in spectrum holdings. The second part summarises the auction outcomes in those countries where the award of 800 MHz and/or 2.6 GHz has already taken place. Finally, we provide some further details on the spectrum allocation and auction outcomes for a number of European countries

Regulatory interventions to promote competition

A9.3 Historically, the 900 MHz was the first spectrum band made available for mobile services, and therefore was allocated to early entrants. As demand grew, further allocations, typically at higher frequency bands, were granted to meet the increased traffic. Later entrants were assigned spectrum available at the time of entry, which typically was more limited and in higher frequencies, sometimes by administrative allocation, e.g. beauty contests, and sometimes through auctions.

A9.4 This has resulted in spectrum assignments to mobile operators across 900 MHz, 1800 MHz and 2.1 GHz band differing significantly. As acknowledged by BEREC,[19] asymmetries have emerged in terms of the amount, type (frequency), and expiry date of the spectrum licences held by mobile operators.

A9.5 Many regulators have intervened to redress imbalances in spectrum ownership and have done so in two main ways:

9.5.1 reallocation of part or all of the existing 900 MHz and 1800 MHz spectrum; and

9.5.2 auction measures aimed at promoting spectrum acquisitions by new entrants or smaller incumbents in the award of 800 MHz and 2.6 GHz.

Reallocation of 900 MHz and 1800 MHz

A9.6 National regulators that intervened to reallocate the existing 900 MHz and 1800 MHz spectrum have followed two approaches. Some required the existing holders to release some spectrum as a condition for refarming. They subsequently redistributed the released spectrum directly to those wholesalers that did not have holdings in the relevant bands or sold the released spectrum in auctions in which the releasing wholesalers were not allowed to participate. Others regulators did not

[19] RSPG BEREC Report on Competition: Transitional Issues in the Mobile Sector in Europe, February 2011.

renew the existing licences and awarded (or are planning to award) all spectrum rights in the 900 MHz and 1800 MHz bands through auctions.

A9.7 Below we summarise the main regulatory interventions undertaken in Western European countries:

9.7.1 In Austria, the regulator decided to re-auction the 900 MHz and 1800 MHz bands (together with 800 MHz spectrum) by mid 2012;[20]

9.7.2 in Belgium, Telenet Tecteo, which was recently awarded the fourth 3G licence in the 2.1 GHz band,[21] has the option of buying 2x4.8 MHz of 900 MHz spectrum and 2x10 MHz of 1800 MHz spectrum available from 2015;

9.7.3 in Denmark, 2x5 MHz at 900 MHz and 2x10 MHz at 1800 MHz were sold in auctions in which the releasing operators (TDC, Telia and Telenor) were not allowed to participate. The spectrum went then to the later entrant, Hi3G, which paid the minimum reserve price in both auctions;[22]

9.7.4 in France, Iliad has been granted 2x5 MHz of 900 MHz spectrum released by the three existing wholesalers in the 900 MHz band;[23]

9.7.5 in Ireland, ComReg is considering re-auction of the entire 900 MHz and 1800 MHz bands jointly with the 800 MHz;[24]

9.7.6 in Italy, the Government required Telecom Italia, Vodafone and Wind to release 2x5 MHz of 900 MHz as part of the refarming process. This freed block will be reallocated (by the end of 2013) for 3G use to a '3G only' wholesaler (i.e. H3G) or a new entrant. In addition, any operator with no holdings of 1800 MHz before the September 2011 auction (i.e. H3G) or any new entrant could exercise an option to be assigned (up to) 2x10 MHz of 1800 MHz[25].

9.7.7 In the Netherlands, as in Austria, the existing licences in the 900 MHz and 1800 MHz bands will not be renewed and will be awarded through an auction;

9.7.8 in Spain, a block of 2x5 MHz of 900 MHz was freed and assigned by beauty contest. The two old incumbents (Movistar and Vodafone) were not allowed to take part and the block went to Orange.[26] Two further blocks of 2x5 MHz of 900 MHz were released by the incumbents and made available in the recent auction. Finally, three blocks of 2x5 MHz of 1800 MHz spectrum were freed and assigned by beauty contest. Movistar, Vodafone and Orange were not allowed to take part and Yoigo won the three blocks;[27] and

[20] http://www.rtr.at/en/tk/FRQ_Auction2012_Info
[21] Telenet Tecteo was granted a license in July 2011 (source: http://bipt.be/ShowDoc.aspx?objectID=3545&lang=EN).
[22] http://en.itst.dk/spectrum-equipment/Auctions-and-calls-for-tenders/900-1800-mhz-auction
[23] http://www.arcep.fr/uploads/tx_gsavis/10-0043.pdf
[24] http://www.comreg.ie/_fileupload/publications/ComReg1175.pdf
[25] http://www.agcom.it/default.aspx?DocID=2525
[26] http://www.boe.es/boe/dias/2011/06/10/pdfs/BOE-A-2011-10107.pdf
[27] http://www.boe.es/boe/dias/2011/06/14/pdfs/BOE-A-2011-10328.pdf

9.7.9 in Sweden, 2x5 MHz at 900 MHz spectrum was freed by Teliasonera, Tele2 and Telenor and granted to the later entrant, Hi3G.[28]

A9.8 Reallocation permitted later entrants that initially had no access to the 900 MHz band to obtain some spectrum below 1 GHz, typically a block of 2x5 MHz. This has been the case for Hutchison in Denmark and Sweden (and it is also likely in Italy), for Iliad in France and very recently for Telenet Tecteo in Belgium. In Spain, although spectrum was not directly assigned to it, Yoigo was given the opportunity to obtain 900 MHz spectrum, first in a beauty contest in which Movistar and Vodafone could not take part, and later in the 2011 auction where there was arguably less competition from the three biggest incumbents as they were restricted by spectrum caps (and in fact one block of 2x5 MHz of 900 MHz went unsold).

Auction measures

A9.9 Along with reallocation of 900 MHz and 1800 MHz, and in some cases as alternative means, regulators have implemented (or are planning to implement) remedies within auctions to encourage entry and promote competition. These remedies span a large set of different measures, including spectrum caps, wholesale access obligations attached to awarded licences, and spectrum reservation.

A9.10 Spectrum caps are the most common measure adopted in the European auctions but they vary between countries ranging from loose 'safeguard' caps (such as in Sweden and in Norway) to more stringent ceilings (such as in the Netherlands and Germany).

A9.11 Spectrum caps tend to be band-specific, although some countries have also implemented caps that apply to several frequencies in combination (e.g. caps on sub-1GHz spectrum in Italy and Spain) or to the total holdings of wholesalers (for example, in Spain and Switzerland). Some countries opted to impose asymmetric caps on operators (in the Netherlands and Germany), with incumbent operators subject to more or less stringent caps depending on their existing spectrum holdings

A9.12 Figure 9.1 summarises the spectrum caps applied in a sample of European countries.

[28] http://www.pts.se/en-gb/News/Press-releases/2009/PTS-issues-decision-concerning-space-in-the-900-MHz-band-which-will-ensure-continued-high-coverage-for-mobile-telephony-in-Sweden/

Figure 9.1: Auction measures adopted in European countries

Country	Bands available	Auction remedies
Austria	2.6 GHz	Cap of 2x30 MHz (applied to wholesalers that already had spectrum at 900 MHz or 1800 MHz)[29]
Belgium	2.6 GHz	Cap of 2x20 MHz
Denmark	2.6 GHz	Cap of 2x20 MHz
Finland	2.6 GHz	2x20 MHz cap on paired spectrum or the whole unpaired spectrum
France	800 MHz and 2.6 GHz	Caps: - 2x15 MHz of 800 MHz; - 2x30 MHz of 2.6 GHz
Germany	800MHz, 1800MHz, 2.1GHz and 2.6GHz	Caps: - T-Mobile and Vodafone: 2x10 MHz of 800 MHz - E-Plus and Telefónica: 2x15 MHz of 800 MHz - Entrants: 2x20 MHz of 800 MHz No caps on spectrum above 1 GHz
Ireland	800 MHz, 900 MHz and 1800 MHz	Proposed caps: - overall spectrum cap of 2x50 MHz across all three bands - sub-1 GHz cap of 2x20 MHz
Italy	800 MHz, 1800 MHz and 2.6 GHz	Caps: - sub-1 GHz cap of 2x20 MHz - 55 MHz on joint paired and unpaired 2.6 GHz spectrum
Netherlands	2.6 GHz	Caps: - for entrants: 40 MHz - for KPN: 20 MHz - for T-Mobile: 10 MHz - for Vodafone: 25 MHz
Norway	2.6 GHz	Cap of 90 MHz
Spain[30]	800 MHz, 900 MHz and 2.6 GHz	Caps: - 2x20 MHz of sub-1 GHz - 115 MHz on joint 1800 MHz, 2.1 GHz and 2.6 GHz spectrum
Portugal[31]	800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz	Caps: - 2x20 MHz of 800 MHz; - 2x5 MHz of 900 MHz (applied to wholesalers that already had spectrum at 900 MHz); - 2x20 MHz of 1800 MHz (including spectrum already held in the 1800 MHz band, prior to the auction); - 2x20 MHz of 2.6 GHz (FDD).
Sweden	800 MHz and 2.6 GHz	Caps: - 2x10 MHz of 800 MHz - 140 MHz of 2.6 GHz
Switzerland[32]	800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz	Caps: - 2x20 MHz of 900 MHz - 2x25 MHz of sub 1GHz - 2x35 MHz of 1800 MHz - 2x30 MHz of 2.1 GHz - overall cap of 2x135 MHz (on the paired spectrum)

A9.13 Spectrum caps have also been used extensively in other parts of the world. For example:

[29] http://www.rtr.at/en/tk/FRQ_2600MHz_2010_AU/F4_08_TenderDocumentation_2_6_GHz.pdf
[30] See also paragraph A9.64 below.
[31] http://www.anacom.pt/streaming/english_version_Auction_Regulation.pdf?contentId=1101807&field=ATTACHED_FILE
[32] The auction is scheduled for the first quarter of 2012. See http://www.news.admin.ch/message/index.html?lang=en&msg-id=39412.

9.13.1 in India a cap of 10 MHz was put in place for the auction of the 2.1 GHz band (in total 30 MHz of spectrum was available in most regions and 40 MHz in the remaining regions);

9.13.2 Hong Kong set a cap of 30 MHz on the acquisition of 2.3 GHz (90 MHz available) and 2.6 GHz spectrum (105 MHz available);[33]

9.13.3 New Zealand is considering[34] different options in relation to the cap for the 700 MHz auction (2x45 MHz available). The current proposal envisages a cap of 2x15 MHz, with provision for one party to be able to exceed the cap to acquire a 2x20 MHz block subject to additional conditions;[35] and

9.13.4 spectrum caps have also been widely adopted in Latin America countries (for example, in Brazil, Argentina, Chile and Mexico).[36]

A9.14 A number of regulators have also employed additional measures to stimulate and sustain competition. For instance, France adopted a hybrid auction/beauty contest format where bidders' offers were evaluated with respect to both price and commitments (in terms of hosting MVNOs and regional coverage). The award resulted in three operators committing to provide wholesale access.

A9.15 In The Netherlands the Ministry of Economic Affairs has decided to reserve 2x10 MHz at 800 MHz and 2x5 MHz at 900 MHz in the forthcoming auction for new entrants, with a cap of 2x10MHz on the amount that can be bought by any single new entrant.[37] A similar approach was adopted by Canada, which set aside 40 MHz for new entrants in the Advanced Wireless Services spectrum auction (1.7 GHz / 2.1 GHz) held in 2008. New entrants were defined as those with less than 10% of the national wireless market based on revenue.[38]

Update on the outcomes of international auctions

A9.16 Several European countries have already auctioned all or part of their newly available 800 MHz and 2.6 GHz spectrum. This sub-section briefly outlines the outcomes of these auctions, summarising information on prices of different bands and discussing some common features of the resulting spectrum allocations.

Prices of different spectrum bands

A9.17 As of December 2011, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Norway, The Netherlands, Portugal, Spain and Sweden have completed their 2.6 GHz auctions. Only six countries (France, Germany, Italy, Portugal, Spain and

[33] http://www.ofta.gov.hk/en/industry/broadband/presentation.pdf
[34] See Digital Dividend: Opportunities for New Zealand, Ministry of Economic Development, August 2011, http://www.rsm.govt.nz/cms/policy-and-planning/projects/digital-dividend-planning-for-new-uses-of-the-700-mhz-band/Discussion%20Document%20-%20PDF.
[35] The regulator is considering two alternative conditions: a 2x30 MHz sub-1 GHz spectrum cap or a requirement to sell a specified minimum quantity of spectrum holdings to a new entrant, should one present itself over the life of the management right.
[36] For a review of international experiences on spectrum caps see Arthur D Little Mobile broadband, competition and spectrum caps – an independent paper prepared for the GSM Association, January 2009.
[37] http://www.rijksoverheid.nl/ministeries/eleni/documenten-en-publicaties/kamerstukken/2011/10/06/kamerbrief-veiling-mobiele-communicatie.html
[38] See Policy Framework for the Auction for Spectrum Licences for Advanced Wireless Services and other Spectrum in the 2 GHz Range, Industry Canada, November 2007.

Sweden) have so far auctioned the 800 MHz band, although several others are planning to do so shortly. In some cases, spectrum in other bands, 900 MHz and 1800 MHz,[39] has been awarded jointly with 800 MHz and 2.6 GHz.

A9.18 Figure 9.2 shows the average auction prices. All prices are expressed in £ per MHz per head of population. The same data are shown in Figure 9.3 below.

Figure 9.2: Auction prices in European countries (£/MHz/pop)[40]

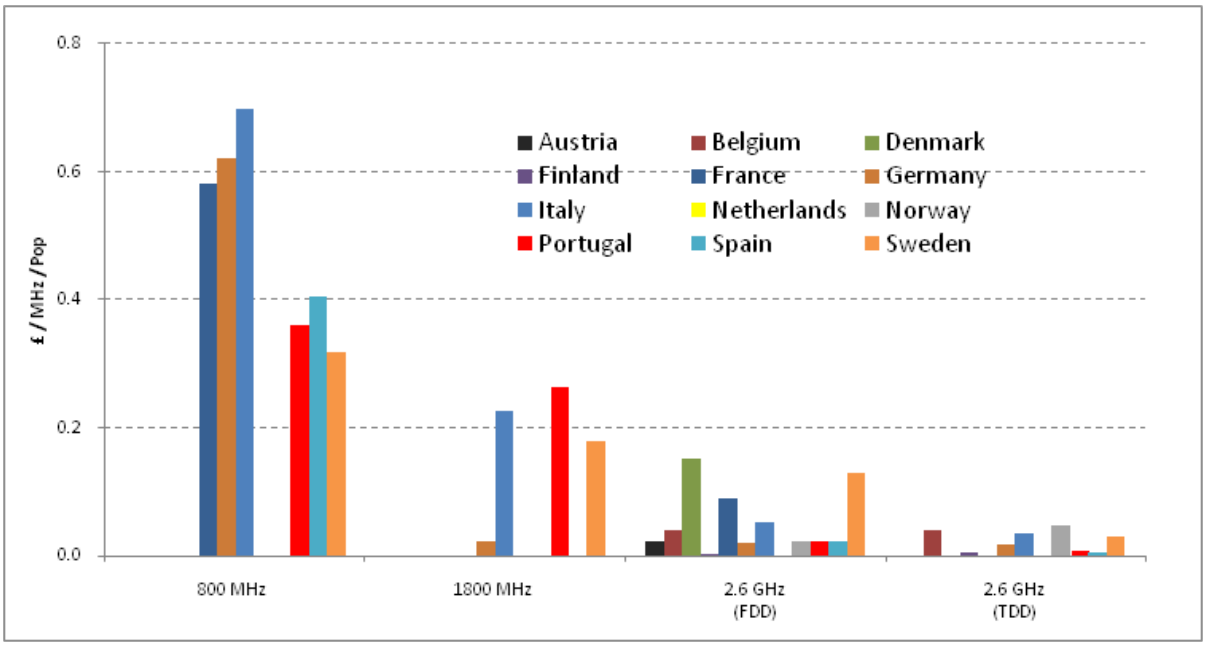
£/MHz/pop[41]	Date auction concluded	800 MHz	1800 MHz	2.6 GHz (paired, FDD)	2.6 GHz (unpaired, TDD)
Austria	October 2010			0.0212	
Belgium	November 2011			0.0396	0.0394
Denmark[42]	May 2010			0.1508	
Finland	November 2009			0.0027	0.0048
France	December 2011	0.5809			
	September 2011			0.0883	
Germany	May 2010	0.6217	0.0218	0.0192	0.018
Italy	September 2011	0.6993	0.2252	0.0510	0.0350
Netherlands	April 2010			0.0010	
Norway[43]	November 2007			0.0220	0.0460
Portugal[44]	December 2011	0.3616	0.2651	0.0241	0.0096
Spain	July 2011	0.4043		0.0229	
	November 2011				0.0061
Sweden[45]	March 2011	0.3174			
	October 2011		0.1788		
	May 2008			0.1287	0.0298
Average (simple)		**0.4809**	**0.1727**	**0.0400**	**0.0236**

A9.19 Prices for 800MHz spectrum have so far been highest in Italy, followed by Germany. Prices in Portugal and Sweden were approximately half the Italian and German levels. For 1800 MHz the Portuguese auction ended at the reserve price

[39] Auctions for 1800 MHz have so far taken place in Germany, Italy, Portugal and Sweden.
[40] For Austria and Denmark only the total price including both paired and unpaired 2.6 GHz spectrum is available. The average price for the 2.6 GHz bands (both FDD and TDD) has been calculated excluding the figures of Austria and Denmark.
[41] Exchange rate used to convert EUR (EUR) to Pounds Sterling (GBP): 0.855.
[42] Exchange rate used to convert Danish Kroner (DKK) to Pounds Sterling (GBP): 0.115.
[43] Exchange rate used to convert Norwegian Kroner (NOK) to Pounds Sterling (GBP): 0.089.
[44] Portugal's 4G spectrum auction ended at reserve prices for all frequencies (see J.P. Morgan Cazenove, Europe Equity Research, 1 December 2011)
[45] Exchange rate used to convert Swedish Kronor (NOK) to Pounds Sterling (GBP): 0.084.

but nonetheless raised the highest per MHz revenue per head of population, £0.26/MHz/pop, followed by Italy and Sweden, while the German auction ended at a significantly lower price, i.e. £0.02/MHz/pop. For 2.6 GHz paired spectrum, prices have so far been highest in Sweden (£0.13/MHz/pop) and in Denmark (£0.15/MHz/pop, although this is the average across paired and unpaired 2.6 GHz). This is significantly higher than elsewhere – in other European countries prices remained below £0.1/MHz/pop.[46] The unpaired 2.6 GHz spectrum has tended to be sold for less than the paired 2.6 GHz spectrum. The highest prices were in Italy, Norway and Belgium (£0.04-0.05/MHz/pop).

Figure 9.3: Price comparison of the European auctions (£/MHz/pop)[47]



A9.20 Figure 9.4 provides information on the prices raised in some of the recent auctions in non-European Countries.

[46] Denmark appears likely to have raised a similar price, but there is no data available on the 2.6 GHz prices distinct by paired and unpaired band.
[47] For illustrative purpose, we present the Austrian and Danish figures in the paired 2.6 GHz band (see footnote 40).

Figure 9.4: Auction prices in non-European countries (£/MHz/pop)

Country and spectrum auctioned	*Date*	**Price** *£/MHz/pop*
India[48] *2.1 GHz paired*	2010	0.094
Hong Kong[49] *2.6 GHz paired*	2009	0.214
Hong Kong[50] *850 MHz and 900 MHz*	2011	1.128
Singapore[51] *2.1 GHz*	2010	0.295
USA[52] *Broadband PCS*	2008	0.188
USA[53] *AWS1*	2008	0.062
South Korea[54] *800 MHz, 1800 MHz, 2.1 GHz*	2011	0.395

Spectrum allocation resulting from the auctions

A9.21 A number of common themes emerge from the auctions that have been carried out to date:[55]

- First, in the six countries that have sold the 2x30 MHz of spectrum available in the 800 MHz band, the spectrum has always been split equally among three bidders each winning 2x10 MHz despite the availability of smaller blocks of 2x5 MHz.

- Second, examples of new entry are limited and mostly of small scale. A number of fixed operators acquired regional licences for the paired 2.6 GHz spectrum in Spain; Ziggo and Tele2 acquired 2x20 MHz each at 2.6 GHz in the Netherlands; BUCD BVBA acquired 45 MHz in the unpaired band in Belgium; and, Intel and Pirkanmaan Verkko in Sweden and Finland, respectively, secured 50 MHz of the 2.6 GHz (TDD) band.[56]

- Third, there is still significant variation in the shares of spectrum held by national wholesalers even after the auctions. Figure 9.5 compares the share of (paired)

48 http://www.dot.gov.in/as/Auction%20of%20Spectrum%20for3G%20&%20BWA/BWA%20Auction%20Results/BWAauction.htm

49 http://www.ofta.gov.hk/en/industry/broadband/main.html

50 http://www.ofta.gov.hk/en/industry/850/p_success_bidding.pdf

51 http://www.ida.gov.sg/Policies%20and%20Regulation/20100903165006.aspx

52 http://www.comreg.ie/_fileupload/publications/ComReg1159.pdf

53 http://www.comreg.ie/_fileupload/publications/ComReg1159.pdf

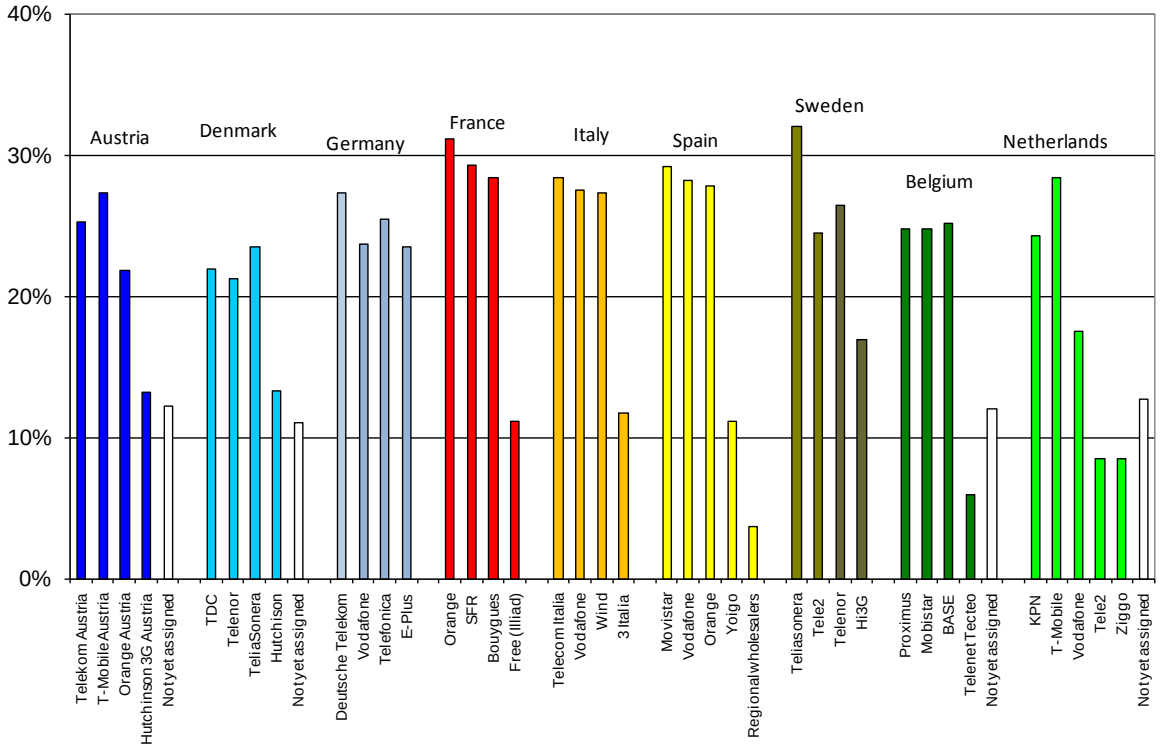
54 http://www.analysysmason.com/About-Us/News/Newsletter/did-sk-telecom-pay-too-much-in-the-south-korean-spectrum-auction/

55 We provide further details on the auction results for a number of European countries at the end of this annex.

56 In some cases binding caps may have prevented bidding for more 2.6 GHz thereby facilitating this new entry. For instance, in the Netherlands very stringent caps applied to three incumbents which *de facto* guaranteed entry also in the paired band (the three incumbents could collectively acquire no more than 55 MHz at 2.6 GHz).

spectrum of national wholesalers in most Western European countries with four or more wholesalers.[57]

Figure 9.5: Wholesalers' shares of paired mobile spectrum in European countries with four national wholesalers[58] [59]

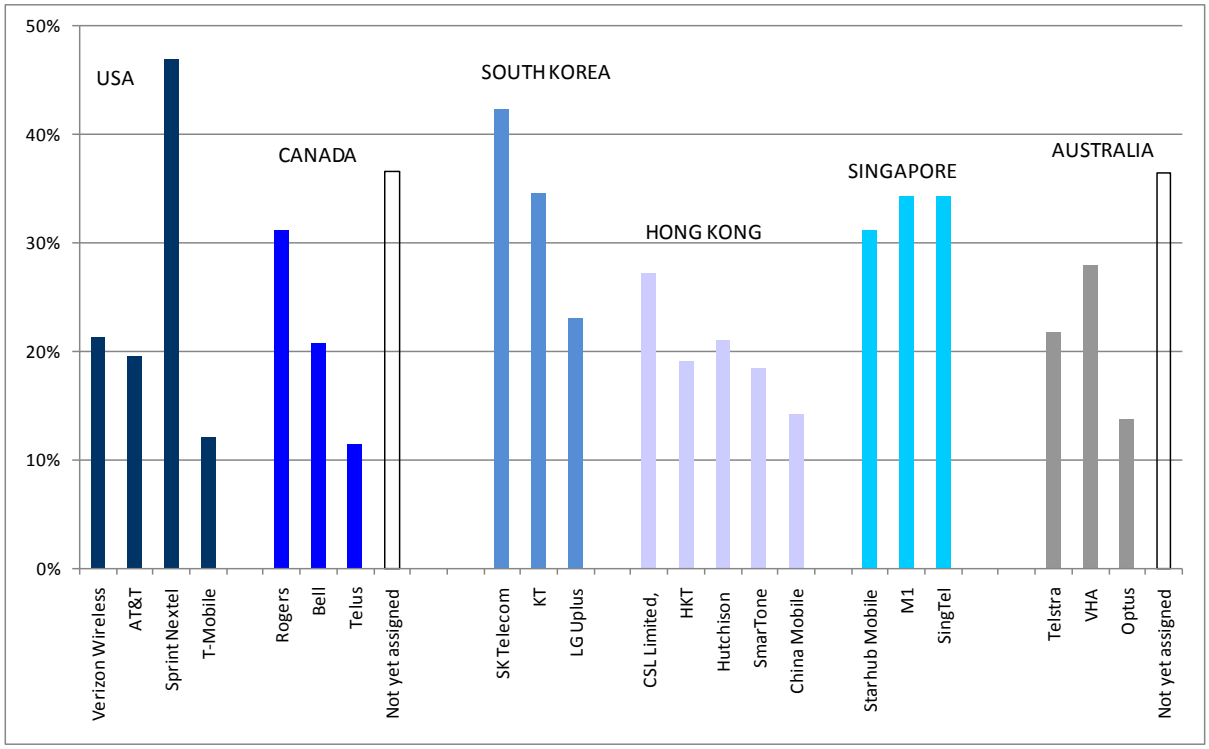


A9.22 While the difference between the smallest and the largest wholesalers is often considerable (except for Germany), the graph shows that it is unusual for a national wholesaler in these countries to have less than 10% of the available spectrum. The exceptions are the new entrants in Belgium and in the Netherlands, but these firms are likely to increase their share in the near future. Indeed, as we noted above, Telenet Tecteo has the option of buying the 2x4.8 MHz of 900 MHz spectrum and 2x10 MHz of 1800 MHz spectrum released by the other wholesalers (this would raise its share to 12%), and Tele2 and Ziggo may take advantage of the 2x15 MHz in the 800 MHz and 900 MHz that has been reserved to new entrants in the forthcoming auction.

A9.23 This outcome is broadly consistent with the (paired) spectrum shares in some non-European countries. Figure 9.6 shows wholesalers' holdings in USA,[60] Canada,[61] South Korea,[62] Hong Kong,[63] Singapore[64] and Australia.[65]

[57] Iliad (France) and Telenet Tecteo (Belgium) were awarded a licence to operate a 3G network only recently and they have not yet started to market mobile services. Similarly, in the Netherlands, Tele2 and Ziggo won 2x20 MHz of 2.6 GHz each in 2010 auction but they have not yet started to retail mobile services.
[58] The white bars represent the 800 MHz band not yet awarded.
[59] For Sweden we assumed that Telenor and Tele2 share equally the awarded 2x10 MHz spectrum at 800 MHz.
[60] Source: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-11-103A1.pdf.
[61] Source: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09949.html#s4.2.

Figure 9.6 : Wholesalers' shares of paired mobile spectrum in non-European countries[66] [67] [68] [69] [70]



A9.24 This shows that, in the countries we consider, all national wholesalers hold more than 10% of total paired spectrum.

A9.25 Looking more specifically at sub-1GHz spectrum, Figure 9.7 illustrates the sub-1 GHz spectrum shares of national wholesalers in the Western European countries with four wholesalers and where the 800 MHz auction has already taken place (Germany, Italy, Spain, Sweden and France).

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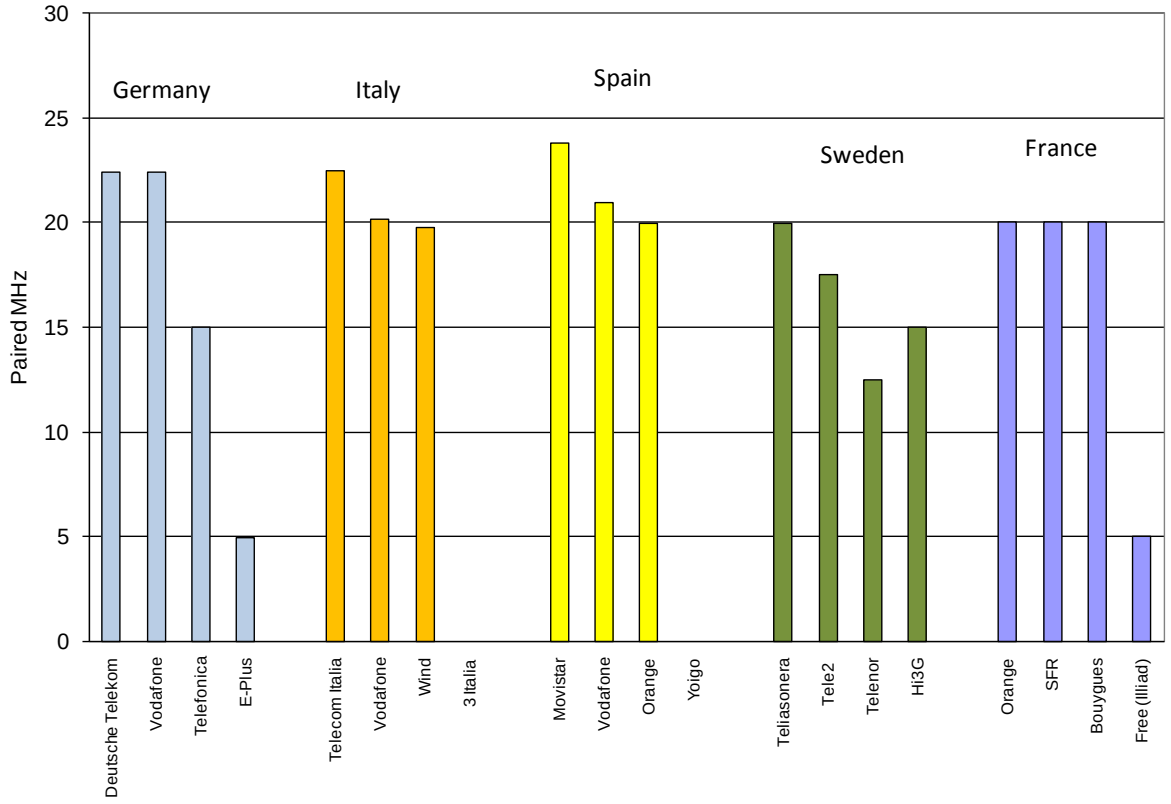
[62] Source: Morgan Stanley Research, Sep 13, 2011 - Telecommunications Services.
[63] Source: http://app1.ofta.gov.hk/apps/telecom_lic/content/lic_search.asp.
[64] Source: http://www.ida.gov.sg/doc/Policies%20and%20Regulation/Policies_and_Regulation_Level3/20060427175316/SpectrumRightAssignment_2011.pdf.
[65] Source: Morgan Stanley Research, Sep 28, 2011 – Australia Telecommunications.
[66] In the USA a large share of the total spectrum (around 30%) is held by regional wholesalers. Similarly, in Canada around 10% of total spectrum is held by regional wholesalers. In the Figure the spectrum shares are calculated based only on national wholesalers' holdings.
[67] Canada is planning to award 700 MHz spectrum (around 80-85 MHz) and 2.5 GHz spectrum (94 MHz) (see http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08551.html). Australia has yet to assign the 700 MHz band (90 MHz) and the 2.5 GHz band (140 MHz), together corresponding to around 37% of total spectrum available for mobile use.
[68] Sprint Nextel holds a majority interest in Clearwire. We then attribute Clearwire to Sprint Nextel when showing spectrum holdings.
[69] For simplicity we consider the entire spectrum available for mobile use as paired for USA and Canada, though some small parts of 700 MHz and *Advanced Wireless Services* (AWS) bands may be unpaired (e.g. in US the 700 MHz band consists of 58 MHz of paired and 12 MHz of unpaired spectrum).
[70] Also for Australia we consider the entire spectrum available for mobile use as paired although a small part of the 2.1 GHz band is unpaired.

Figure 9.7: Wholesalers' shares of sub-1 GHz spectrum in European countries[71]



A9.26 With the exception of Sweden where all four wholesalers hold significant shares of sub 1GHz spectrum, there is one wholesaler that has no (or very little) sub-1 GHz compared to its competitors. Iliad in France has 2x5 MHz of 900 MHz spectrum (see paragraph A9.7 above). E-Plus in Germany holds 2x5 MHz in the 900 MHz band, corresponding to 8% of the total spectrum below 1 GHz. 3 Italia in Italy and Yoigo in Spain have no holdings below 1 GHz, although as pointed out above 3 Italia might have access in the near future to a block of 2x5 MHz at 900 MHz freed by the other wholesalers as a condition for refarming.

A9.27 A similar situation can be observed in the USA where T-Mobile currently has no spectrum below 1 GHz.[72] In Hong Kong all five wholesalers have holdings below 1 GHz, although China Mobile has a significantly lower share compared to its competitors (around 9%). Countries with only three wholesalers tend to show more even distributions but significant asymmetries may still remain between the smallest sub-1 GHz holder and the other wholesalers. For instance, Optus' share of sub-1 GHz spectrum in Australia is around 17%, significantly lower than that of Telstra (47%) and VHA (36%). Similarly, Telus in Canada has a share of around 13%,[73] while Rogers and Bell have, respectively, 54% and 33% of the sub-1 GHz currently available.[74]

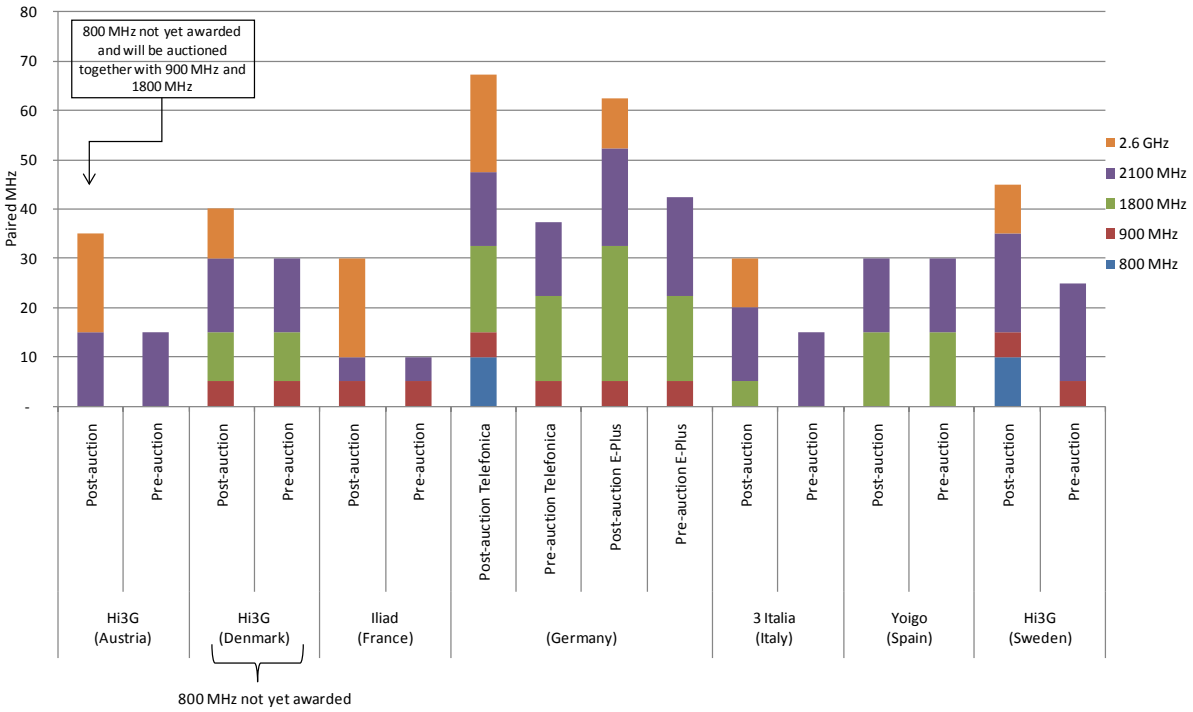
A9.28 We have also considered more directly the impact of auction outcomes on what appear to be the smallest incumbents in several European markets (namely Austria,

[71] See footnote 59.
[72] Except for one regional licence (in South Carolina) in the *Cellular* (850 MHz) band.
[73] The share calculation is based on the sub 1 GHz holdings of national wholesalers.
[74] See footnote 61.

Denmark, France, Germany,[75] Italy, Spain and Sweden). We have focused on those countries that have the clearest similarities with the UK mobile market either by virtue of the size of the market or the number of wholesalers.

A9.29 Figure 9.8 summarises and compares the paired spectrum holdings of the smallest incumbent in each country (before and after the auctions). In Austria and Denmark spectrum is still to be auctioned so the current holding of Iliad and Hutchison (both in Austria and in Denmark) could increase if they succeed in securing some spectrum at 800 MHz.[76]

Figure 9.8: Spectrum holdings of smallest incumbents – post- *vs* pre-auction



Focus at country level

Austria

A9.30 Austria has four national wholesalers: Telekom Austria, T-Mobile, Orange and 3G Austria. Telekom Austria is the largest operator with a subscriber share of 41.3%, followed by T-Mobile (30.8%), Orange (18.7%) and 3G Austria (9.2%).[77]

A9.31 In September 2010 the Telekom-Control-Kommission (TKK) completed the auction of the 2.6 GHz band. The total proceeds from the auction were €39m.

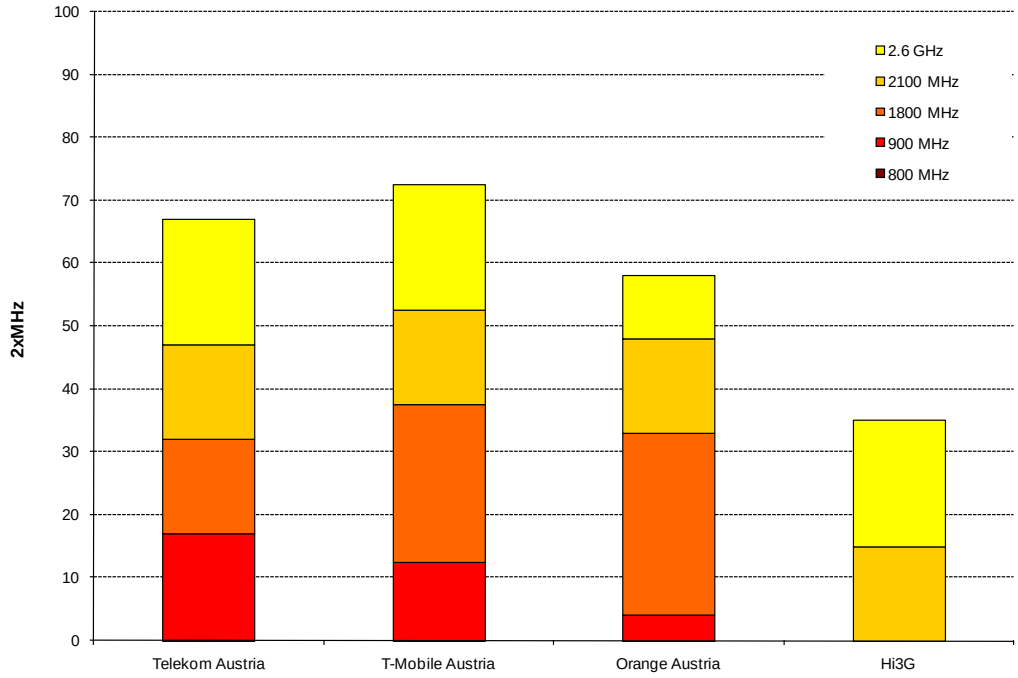
A9.32 The available spectrum was assigned as follows:

[75] For Germany we consider Telefónica and E-Plus as there is not a single wholesaler who is clearly smaller than the others. Telefónica and E-Plus are the two smallest wholesalers but they are rather similar in terms of market shares and spectrum holding (and they were so even before the auction).
[76] Also, Austria is planning to re-auction the 900 MHz and 1800 MHz bands together with 800 MHz spectrum. This could give further opportunities to Hi3G to increase its spectrum share.
[77] Source: http://www.rtr.at/en/komp/TKMonitor_3_2011/TM3-2011.pdf

- Telekom Austria acquired 2x20 MHz in the paired band and 25 MHz in the unpaired band for a total price of €13.2m;
- T-Mobile won 2x20 MHz for €11.2m;
- Orange acquired 2x10 MHz in the paired band and paid €4m; and
- Hutchison 3G Austria obtained 2x20 MHz in the paired band and 25 MHz in the unpaired band and paid €11m.

A9.33 Figure 9.9 shows wholesalers' (paired) spectrum holdings after the auction.

Figure 9.9: Spectrum holdings in Austria



A9.34 The combined award of 800 MHz, 900 MHz and 1800 MHz spectrum, in which a total of 2x140 MHz is available, is scheduled for September 2012.[78]

Belgium

A9.35 Belgium has three national wholesalers: Belgacom, Mobistar and KPN Group (Base). In June 2011 the telecoms regulator, BIPT, granted a 3G licence (2x15 MHz at 2.1 GHz) to a new wholesaler, NV Telenet Tecteo Bidco.

A9.36 In November 2011 Belgium held the auction for the 2.6 GHz band.[79] In total 155 MHz were assigned for total revenues of €77.8m. The auction concluded with the following assignments:

- Belgacom and Mobistar won 2x20 MHz each paying around €20m each;

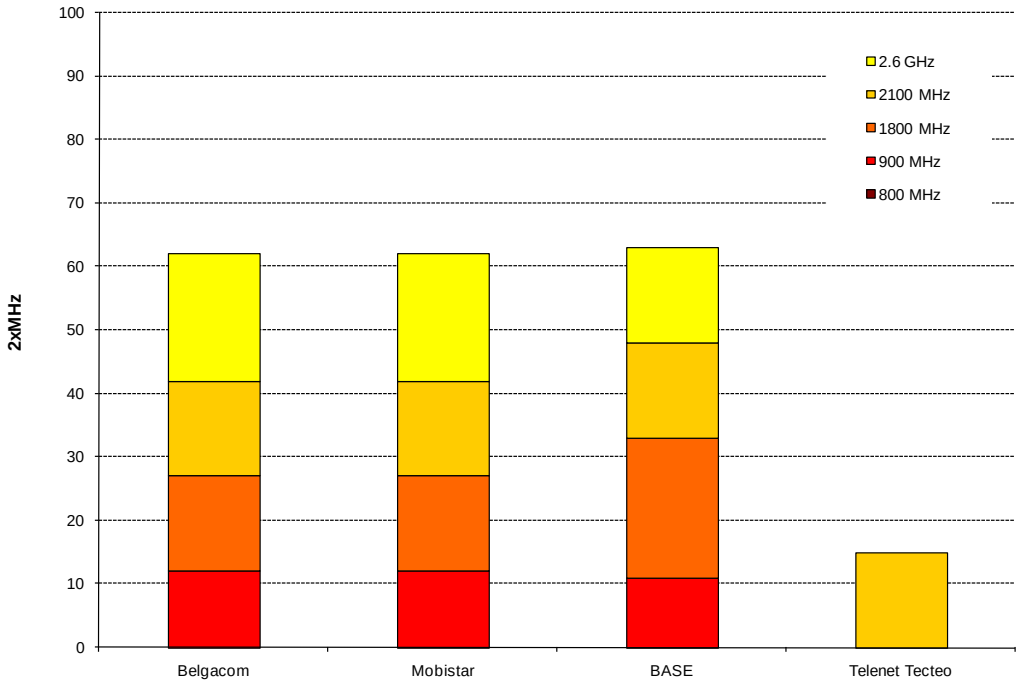
[78] Source: http://www.rtr.at/en/tk/FRQ_Auction2012_Info
[79] BIPT has not yet decided whether to allocate the 800 MHz band for the use of telecoms or broadcasting services.

- KPN Group (BASE) acquired 2x15 MHz for €15m; and
- BUCD BVBA, a new entrant Chinese company, acquired 45 MHz in the unpaired band paying €22.5m.

A9.37 While still to be confirmed, Telenet Tecteo Bidco is expected to exercise the option of acquiring the spectrum in the 900 MHz (2x5 MHz) and 1800 MHz (2x10 MHz) bands reserved for the fourth 3G operator.

A9.38 Figure 9.10 shows wholesalers' (paired) spectrum holdings after the auction.

Figure 9.10: Spectrum holdings in Belgium



Denmark

A9.39 Denmark has four national wholesalers, TDC, Telenor, Telia and Hi3G. TDC is the largest operator with a subscriber share of 43.9%, followed by Telenor (25.8%) and Telia (18.2%). Hi3G is the smallest and currently has a share of 6.2%.[80]

A9.40 In June 2010 the National IT and Telecom Agency issued licences in the 2.6 GHz band by auction[81]. The total auction revenues amounted to DKK 1b, corresponding to approximately £116m. The auction resulted in the following holdings:

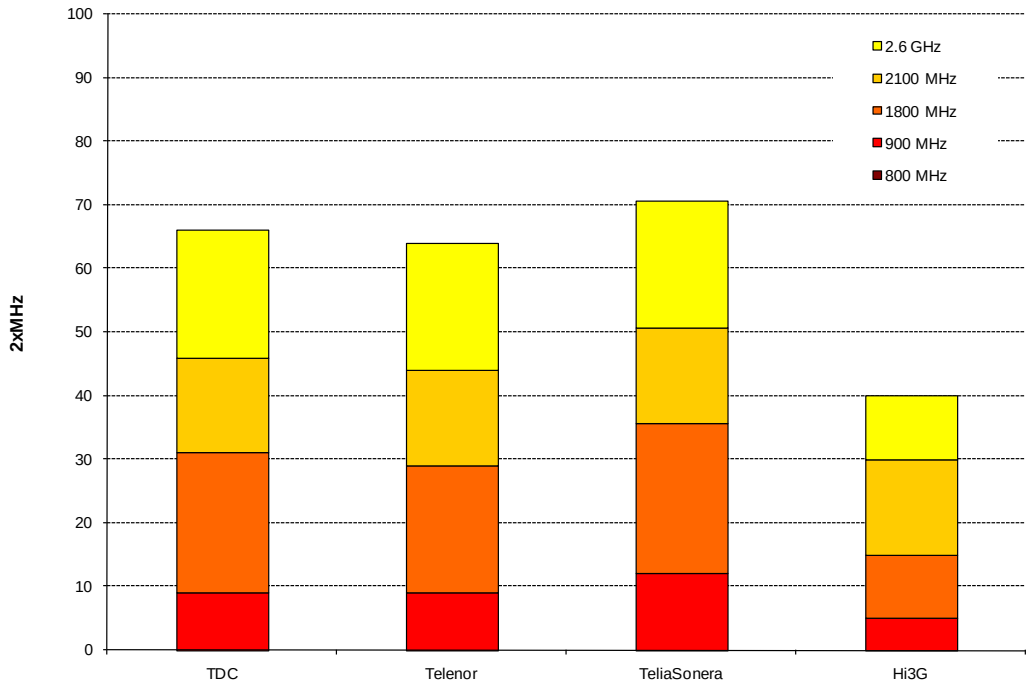
- TDC won 2x20 MHz for a price of DKK333m;
- Telenor and Telia obtained 2x20 MHz and 10 MHz in the unpaired band each, paying, respectively, DKK 333m and DKK336m; and

[80] The remaining share is split among more than 30 MVNOs.
[81] Auction for the 800 MHz band is planned in May 2012. The telecoms regulator is currently consulting on the auction rules and design (http://en.itst.dk/spectrum-equipment/Auctions-and-calls-for-tenders/800-mhz/public-consultation-over-draft-800-mhz-auction-documents).

- Hi3G obtained 2x10 MHz and 25 MHz in the unpaired band and paid DKK7m.

A9.41 Figure 9.11 illustrates the (paired) spectrum holdings of wholesalers after the auction.

Figure 9.11: Spectrum holdings in Denmark



France

A9.42 In France there are currently three national wholesalers. France Telecom (Orange France) has the largest share of subscribers (48%), followed by SFR (35%) and Bouygues (17%). Iliad (Free Mobile), which already holds a strong position in the fixed broadband market, was granted a mobile licence in 2010 but has not yet started to provide retail services.

A9.43 The French award for 2.6 GHz finished on 22 September 2011 and raised €936m. France adopted a hybrid auction/beauty contest format where operators' offers were evaluated with respect to both price and commitments (in terms of hosting MVNOs and regional coverage). The auction outcome was as follows:

- Orange France paid €287m for 2x20 MHz and committed to host MVNOs;
- Bouygues paid €228m for 2x15 MHz and committed to host MVNOs;
- SFR paid €150m for 2x15 MHz and made no commitment to host MVNOs; and
- Free Mobile (Iliad) paid €271m for 2x20 MHz and committed to host MVNOs.

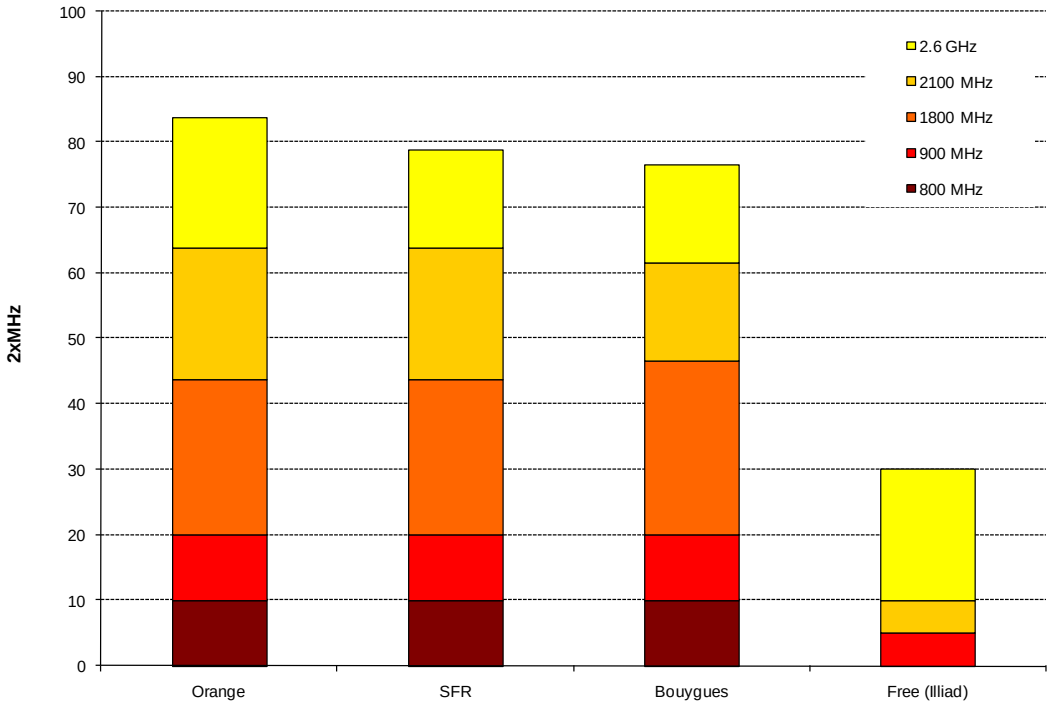
A9.44 The award for 800 MHz finished on 22 December 2011, again using a hybrid auction/beauty contest format. The auction outcome was as follows:

- Orange France Telecom paid €891m for 2x10 MHz, committed to host MVNOs and made a regional development commitment;
- Bouygues paid €683m for 2x10 MHz, committed to host MVNOs and made a regional development commitment; and
- SFR paid €1,065m for 2x10 MHz, committed to host MVNOs and made a regional development commitment.

A9.45 As part of the provisions of the 800 MHz award, any winner of 2.6 GHz spectrum that failed to win 800 MHz spectrum will be able to purchase wholesale access from the winner of the two middle blocks of the 800 MHz band. Free Mobile (Iliad) will be able to apply for roaming rights from SFR once its own 2.6 GHz network covers 25% of the population.[82]

A9.46 Figure 9.12 shows wholesalers' spectrum holdings in the paired bands after the 2.6 GHz and 800 MHz auctions.

Figure 9.12: Spectrum holdings in France



Germany

A9.47 Germany has four national wholesalers, T-Mobile, Vodafone, Telefónica and E-Plus. T-Mobile is the largest operator with a subscriber share of 34%, followed by Vodafone (32%), E-Plus (17.5%) and Telefónica (around 16.5%).

A9.48 Germany held an auction in May 2010 for several bands of spectrum (800 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz):

82

http://www.arcep.fr/index.php?id=8571&L=1&tx_gsactualite_pi1[uid]=1470&tx_gsactualite_pi1[backID]=1&cHash=80abfa005c

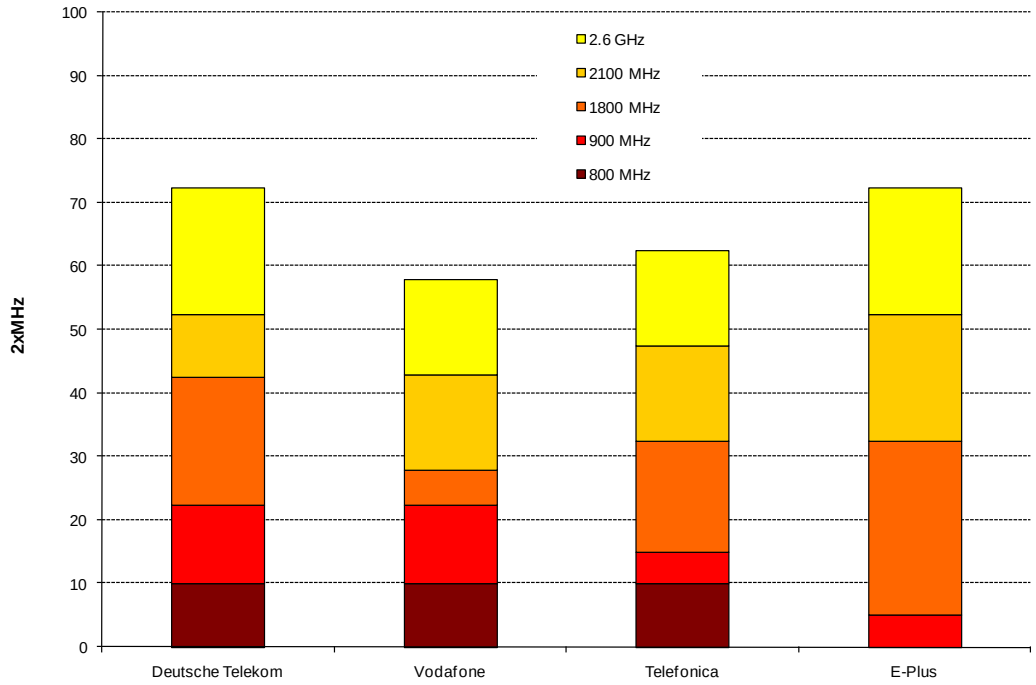
- 800 MHz band: 6 blocks of 2x5 MHz;
- 1800 MHz band: 5 blocks of 2x5 MHz;
- 2.1 GHz (paired): 4 blocks of 2x5 MHz;
- 2.1 GHz (unpaired): one block of 5 MHz and one block of 14.2 MHz; and
- 2.6 GHz: 14 blocks of 2x5 MHz in the paired part and 10 blocks of 5 MHz in the unpaired part.

A9.49 The auction resulted in the following holdings:

- 800 MHz: T-Mobile, Vodafone and Telefónica acquired 2x10 MHz each, paying overall €3.57bn (each operator paid an approximately similar price, € 1.2bn);
- 1800 MHz: T-Mobile acquired 2x15 MHz and E-Plus won the remaining 2x10 MHz for a total value of €104m;
- 2.1 GHz spectrum went to Vodafone (2x5 MHz), E-Plus (2x10 MHz) and Telefónica (2x5 MHz plus 20 MHz unpaired) for a total value of €360m; and
- 2.6 GHz spectrum was split among the four incumbents. Vodafone acquired the largest portion (65 MHz), T-Mobile and Telefónica obtained 45 MHz and 50 MHz respectively and E-Plus acquired the remaining 30 MHz. The total amount raised in the auction was €257m for the paired spectrum and €86m for the unpaired band.

A9.50 Figure 9.13 shows wholesalers' (paired) spectrum holdings after the auction.

Figure 9.13: Spectrum holdings in Germany



Italy

A9.51 Italy has four national wholesalers: the three largest incumbents (Telecom Italia, Vodafone and Wind) have a subscriber share of, respectively, 32.9%, 32.5% and 21.2%. H3G is the smallest player with a share of 9.6%.

A9.52 In September 2011 the Italian Government auctioned lots in four bands: 800 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz:

- 800 MHz band: six blocks of 2x5 MHz;
- 1800 MHz band: three blocks of 2x5 MHz;
- 2.1 GHz (TDD/unpaired): one block of 15 MHz; and
- 2.6 GHz: 12 blocks of 2x5 MHz in the paired band and two blocks of 15 MHz in the unpaired band.

A9.53 The auction for 800 MHz spectrum ended after 17 days with Telecom Italia, Vodafone and Wind acquiring 2x10 MHz each at prices just less than a billion Euros, well above reserve prices (+40%). In total, the auction raised €2.96bn.

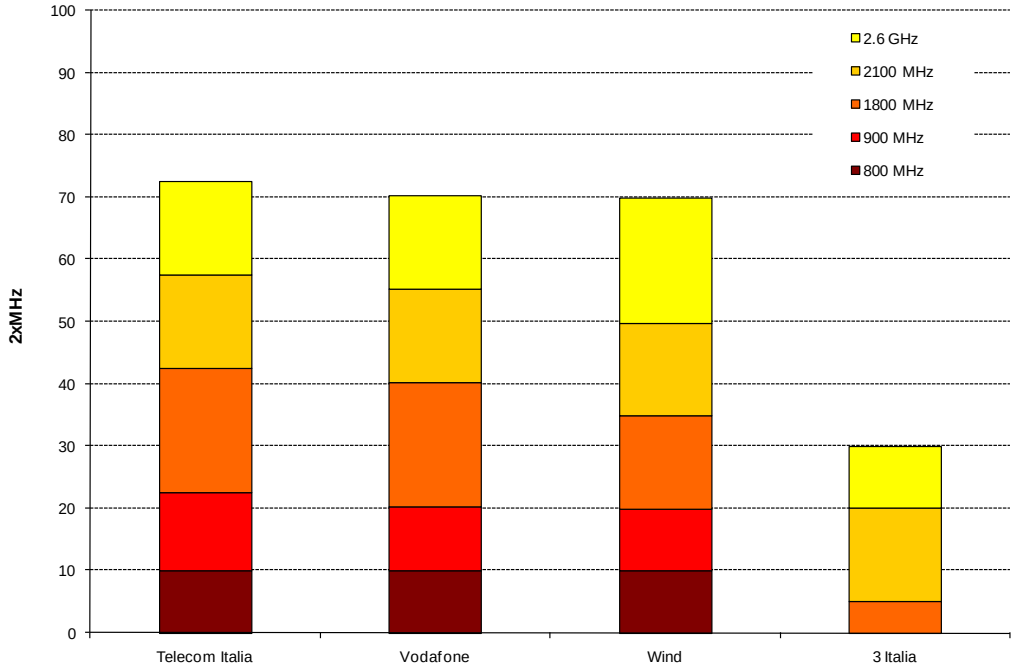
A9.54 The auction for the other bands finished few days later with the following results:

- 1800 MHz: Telecom Italia, Vodafone and H3G acquired 2x5 MHz each at broadly similar prices (€159m);
- 2.1 GHz (TDD): the block of 15 MHz went unsold; and

- 2.6 GHz: the four incumbents each won some spectrum, with Telecom Italia and Vodafone acquiring three blocks each, Wind four blocks and H3G two blocks. H3G also secured the all of the available unpaired spectrum (30 MHz). Telecom Italia and Vodafone spent around €108 to €109m each while Wind and H3G invested respectively €142m and €146m.

A9.55 Figure 9.14 shows wholesalers' (paired) spectrum holdings after the auction.

Figure 9.14: Spectrum holdings in Italy



The Netherlands

A9.56 In the Netherlands there are currently three national wholesalers. KPN with a share of 30 to 35% is the largest operator in terms of subscriptions. Vodafone and T-Mobile are the second and third largest with a share of, respectively, 25 to 30% and 20 to 25%.[83]

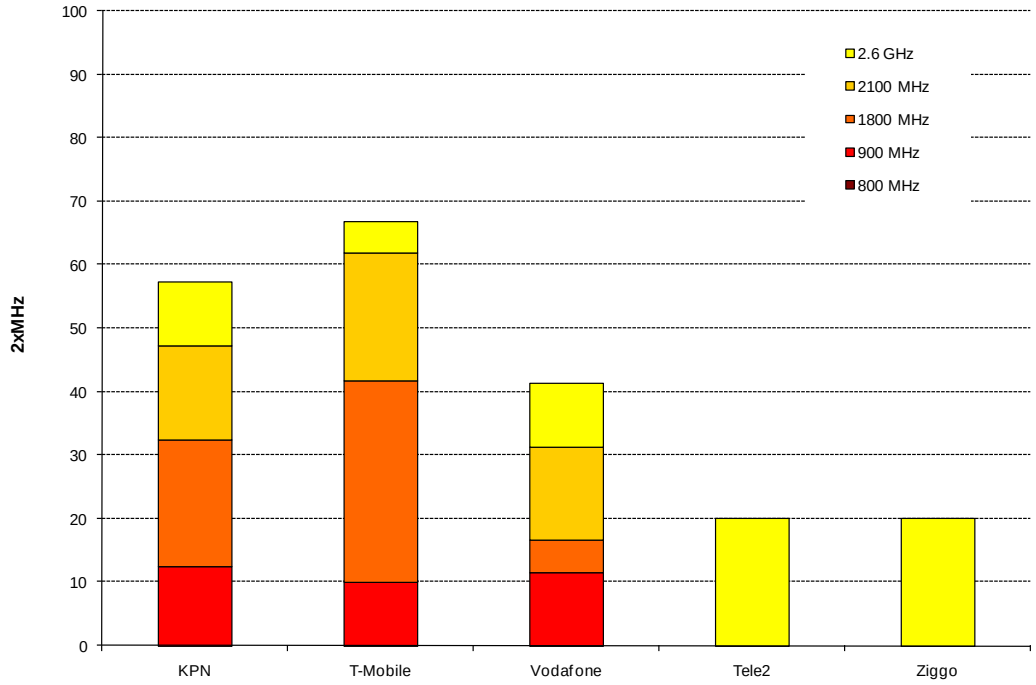
A9.57 The auction for the 2.6 GHz spectrum was held in 2010 and gave rise to the following assignments:

- KPN won 2x10 MHz for a price of €909,000;
- T-Mobile won 2x5 MHz for a price of €109,000;
- Vodafone won 2x10 MHz for a price of €200,000;
- Two new entrants, Tele2 and Ziggo, obtained 2x20 MHz each paying, respectively, €400,000 and €1m; and
- The unpaired 2.6 GHz went unsold.

[83] The remaining share is served by SPs and MVNOs (http://www.opta.nl/en/news/all-publications/publication/?id=3498).

A9.58 Figure 9.15 below shows wholesalers' (paired) spectrum holdings after the auction.

Figure 9.15: Spectrum holdings in the Netherlands



A9.59 The Government is planning to auction the 800 MHz, 900 MHz and 1800 MHz bands jointly in the second quarter of 2012.

Spain

A9.60 There are currently four national wholesalers in Spain: Telefónica, Vodafone, Orange and Yoigo. The latter (a 3G-only operator) entered the market only recently (2007) and currently has a small subscriber share (4.6%), though this is growing.

A9.61 In 2011 Spain awarded spectrum across four bands. The first award took place in May 2011, by beauty contest, for one block of 2x5 MHz of 900 MHz band (released by existing licensees and won by Orange) and for three blocks of 2x5 MHz of 1800 MHz that Yoigo won.[84]

A9.62 The second award was an auction that included the following spectrum:

- 800 MHz band: six blocks of 2x5 MHz;
- 900 MHz band: two blocks of 2x5 MHz;
- 2.6 GHz (paired): four national blocks of 2x10 MHz and three national blocks of 2x5 MHz, plus several regional blocks of 2x5 MHz and 2x10 MHz; and
- 2.6 GHz (unpaired): five national blocks of 10 MHz.

[84] Movistar and Vodafone were prevented from participating in the award, by beauty contest, of 2x5 MHz of 900 MHz. Similarly, operators that already had 1800 MHz spectrum (that is, Orange, Telefónica and Vodafone) could not participate in the beauty contest for the 2x15 MHz at 1800 MHz.

A9.63 This auction ended on 27 July 2011 with the following assignments:

- 800 MHz: Telefónica, Vodafone and Orange acquired 2x10 MHz each, paying overall €1.3bn;
- 900 MHz: Orange acquired 2x5 MHz for €169m (the second block went unsold);
- 2.6 GHz (paired): Telefónica, Vodafone and Orange acquired 2x20 MHz each (Vodafone acquired 2x15 MHz of national blocks and 2x5 MHz of regional lots), while the remaining regional blocks went to Jazz Telecom, ONO, Telecable, Telecomclm, Euskatel and R. Revenues for the 2.6 GHz band were €172m; and
- 2.6 GHz (unpaired): went unsold.

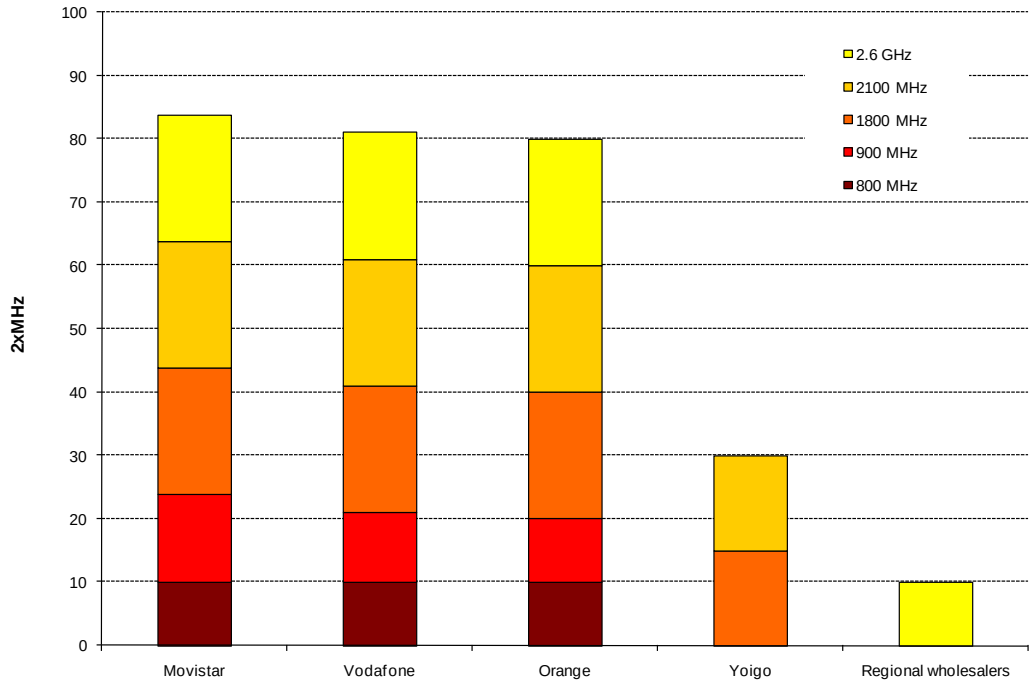
A9.64 Yoigo did not bid for any spectrum at 800 MHz, 900 MHz or 2.6 GHz and, as noted above, one block of 2x5 MHz of 900 MHz went unsold. Spain's Ministry of Communications indicated that the reason for the spectrum not being sold was that the top three operators reached their sub-1GHz spectrum caps. The unsold spectrum (both 900 MHz and 2.6 GHz unpaired) was re-auctioned, and spectrum caps raised to 2x25 MHz for the sub-1 GHz spectrum and to 135 MHz for higher frequencies[85] so as to allow Telefónica, Vodafone and Orange to participate in the auction. The re-auction resulted in:

- Telefónica obtaining the 2x5 MHz block of 900 MHz for €169m;
- Orange acquired 10 MHz of the unpaired 2.6 GHz spectrum for a price of €5.2m;
- Vodafone won 20 MHz of the unpaired 2.6 GHz for €10.4m; and
- Regional wholesalers obtained 10 MHz of the unpaired 2.6 GHz spectrum, paying overall around €800,000.

A9.65 Figure 9.16 illustrates the (paired) spectrum holdings that resulted from the recent awards.

[85] See http://www.mityc.es/telecomunicaciones/es-ES/Novedades/Documents/Pliego_segunda_subasta_espectro.pdf.

Figure 9.16: Spectrum holdings in Spain



Sweden

A9.66 In Sweden there are four national wholesalers, Teliasonera, Tele2, Telenor and Hi3G. The largest operator is Teliasonera with a subscriber share of 40%, followed by Tele2 (32%) and Telenor (17%). Hi3G is the smallest player in the market with a share of 9%.

A9.67 Sweden auctioned its 2.6 GHz spectrum in 2008 and its 800 MHz band in early 2011:

- The 800 MHz spectrum was acquired by Teliasonera, Net4Mobility (a joint venture of Tele2 and Telenor, two of the four wholesalers) and Hutchison's subsidiary with 2x10 MHz each.[86] The auction raised around SEK2b, with Teliasonera, Net4Mobility and Hi3G paying respectively SEK854m, SEK763m[87] and SEK431m;[88] and

- The 2.6 GHz (paired) was acquired by Teliasonera, Tele2, Telenor (2x20 MHz each) and Hi3G (who won the remaining 2x10MHz). The first three paid approximately SEK550-560m each. Hi3G paid SEK297m for its 2x10 block. Intel acquired the 50 MHz block of 2.6 GHz unpaired spectrum for SEK160m.

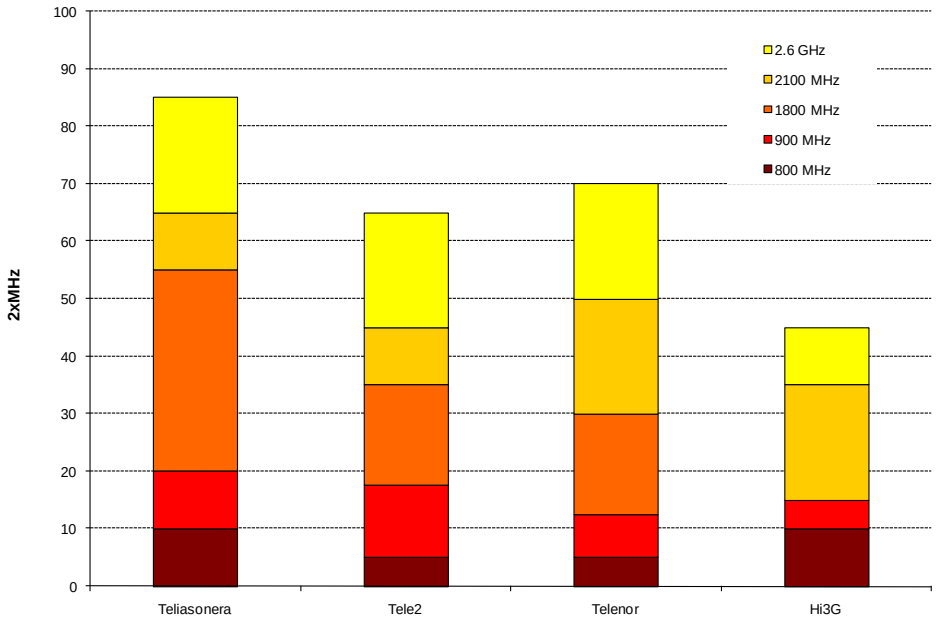
[86] In contrast to the outcomes in other European countries, the 'smallest' operator (Hi3G) was able to secure some 800 MHz spectrum. It is possible that the decision of Tele2 and Telenor, which are already partners in a 2.6 GHz network in Sweden through a joint venture called Net4Mobility, to bid jointly may have facilitated Hi3G access to the 800 MHz band.

[87] The licence awarded by Net4Mobility includes a commitment to spend SEK 300m on covering homes and businesses in remote areas of the country.

[88] Hi3G won the lowest frequency block of 2x10MHz for a price significantly lower than those paid by TeliaSonera for the middle block and by Net4Mobility for the highest block. This might reflect the fact that the lowest block in Sweden is subject to much more stringent technical restrictions in some parts of the country to avoid interference with DTT.

A9.68 The (paired) spectrum holdings of wholesalers after the auction are presented in Figure 9.17.[89]

Figure 9.17: Spectrum holdings in Sweden



[89] See footnote 59.

Annex 10

Summary of responses to our March 2011 competition assessment and Ofcom's comments

A10.1 This Annex sets out a summary of responses to the public responses to the competition assessment in our March 2011 consultation. We also received responses in which extensive sections were confidential. We do not make any reference to those here.

A10.2 This summary also includes an outline of Ofcom's response to the points raised or cross-references to the relevant parts of this Consultation, where a number of these issues are discussed in more detail.

A10.3 In addition, this Consultation includes separate annexes covering responses to our March 2011 consultation regarding our technical modelling and the re-farming of 900MHz and 1800MHz bands for UMTS and LTE. This Annex should be read in conjunction with the rest of this Consultation and the March 2011 consultation.

Issues raised in responses

A10.4 In terms of summarising responses, we have divided them into the following broad areas:

10.4.1 Market Definition

10.4.2 Competition distortion as a result of 2G Liberalisation

10.4.3 Importance of sub-1GHz spectrum relative to other frequencies

10.4.4 Amount and distribution of sub-1GHz spectrum

10.4.5 Use of 900MHz spectrum for LTE

10.4.6 Liberalisation of 900MHz and 1800MHz bands for LTE and WiMax

10.4.7 Equal spectrum shares

10.4.8 Desirability of at least four national wholesalers

10.4.9 Measures in auction for ensuring at least four national wholesalers

10.4.10 Strategic bidding

10.4.11 Spectrum as strategic asset and regulated access

10.4.12 Low power shared use of spectrum

10.4.13 Other issues

Market Definition

Summary of our position in March 2011 consultation

A10.5 In our March 2011 consultation we made it clear that we were not conducting a formal market definition exercise because the forward looking nature of the task made it impossible. Although all market definitions used in market reviews are forward looking to a degree, in this case the relevant products have not been launched and the time frames we are concerned with are much longer. An attempt at a formal definition would not therefore be fruitful. We also noted that some specific aspects of market definition would not affect our analysis, for example whether there is a business/residential split.

A10.6 Instead we considered how markets might develop in ways that could affect competition, taking current definitions as a starting point. We concluded that fixed line services did not act as a competitive constraint on mobile services and that this would be likely to continue, that mobile access and calls were likely to be part of the same market and that the market would remain national in its geographic scope.

A10.7 We also considered it likely that data services would continue to grow in importance and that this could, potentially, lead to separate markets emerging based on characteristics of the service. Specifically, we argued the following separate markets could emerge:

10.7.1 A high quality data market associated with reliable indoor coverage for data services.

10.7.2 A separate market associated with higher data speeds and better latency (delivered by LTE) which is distinct from a market associated with lower data speeds (delivered by 2G and 3G).

10.7.3 A division of the retail market into services that had priority over other services (e.g. a highly reliable business service compared to a lower priority consumer service).”

Summary of responses

A10.8 Several respondents commented on our candidate markets. Responses from Telefónica and Vodafone challenged our approach not to conduct a formal market definition analysis. Along with Everything Everywhere, they also disagreed that there is a sufficient distinction between services delivered by 3G and LTE technologies.

A10.9 Telefónica argued that Ofcom should have conducted a formal market review, taking the usual four year horizon as a starting point and then considering further projections from there. It argued that we had not considered demand-side substitution in any robust way or considered supply side substitution between sub1GHz spectrum and other bands.

A10.10 Telefónica argued that Ofcom needs to establish that 3G and 4G services were in separate markets (with no chain of substitution connecting them) and that sub-1GHz spectrum can lead to unmatchable advantages in particular markets. Telefónica argue that Ofcom must therefore demonstrate a break in chain of substitution on both demand and supply side. Telefónica noted that our Wholesale Broadband Access Market Review had considered market definition between

current and next generation products, which are comparable to the difference between 3G and 4G mobile services, and concluded they were part of the same market.

A10.11 Telefónica further argued that our conclusions were at odds with the recent T-Mobile/Orange merger decision by the European Commission, which found a single retail market (despite divergent spectrum holdings among national wholesalers) and focussed on the benefits of 2 x20 MHz contiguous spectrum not sub-1GHz holdings.

A10.12 Vodafone argued that we had not assessed the market according to well established principles of market definition and economic analysis and that, until this was done, it would be more prudent for Ofcom to conduct a competition assessment using established market definitions. Vodafone argued that our analysis did not meet the requirements of the European Regulatory Framework (e.g. no geographic definition was conducted on the proposed markets). Vodafone argued that the key issue was whether the auction design would create an outcome in which the market would be tipped in favour of a particular firm that is able to acquire a significant proportion of spectrum necessary for LTE. It argued that this assessment did not depend on market definition.

A10.13 Everything Everywhere argued there is no clear dividing line between 3G and LTE based services but did agree that sub-1GHz spectrum was crucial since consumers would demand good coverage particularly indoors. Everything Everywhere cited residential and business consumer research highlighting the importance of indoor coverage to customers[90]. (Everything Everywhere did not, however, explicitly state that services with indoor coverage could constitute a separate market.) Everything Everywhere also argued the M2M market would grow rapidly and that indoor coverage was important to compete in this segment.

A10.14 David Hall Systems agreed that there is a generic mobile market. However, they disagreed that all of our proposed markets will develop and said that other markets that we did not consider are possible. The development of markets has implications on the portfolios that national wholesalers must have to serve these segments.

Ofcom's response

A10.15 We discuss the role of market definition in our analysis in Section 2 of Annex 6.

A10.16 Regarding the Commission's analysis in the T-Mobile/Orange merger, as we said in the March 2011 consultation (paragraph 3.33 of Annex 6), our assessment of the possibility of a separate market emerging for high data speeds was consistent with the Commission's concerns about a 'bifurcation' in the market, with a single firm able to offer effective high speed services to consumers based on LTE technology.

Competitive Distortion as a result of 2G Liberalisation

Summary of Ofcom's previous position

A10.17 In our March 2011 consultation, we considered that there is a possibility that Vodafone and Telefónica might have a short term advantage with UMTS900 until LTE800 deployments constrain UMTS900's advantage. The risk of this was considered and taken into account by the Government in advance of its making the

[90] See page 20 of Everything Everywhere's consultation response.

Direction to Ofcom. This was in line with Ofcom's October 2010 Advice to the Government on 2G Liberalisation.[91] We did not consider this in our March 2011 consultation save to note that if there were to be a material delay to when LTE800 could act as a constraint on UMTS900, we retain the ability to reconsider this issue as necessary at the time.

Summary of responses

A10.18 Everything Everywhere argued that the recent liberalisation of 900MHz spectrum for UMTS in the hands of current licensees has created "a distortion of competition in 3G" and pointed out that the auction is an opportunity to prevent this extending into 4G.

A10.19 Everything Everywhere also argued that it was proposed that Vodafone and Telefónica would be prevented from acquiring 800MHz "and on that basis, it was agreed that a suitable remedy to balance Everything Everywhere's potential for 4G with Vodafone and Telefónica's 900MHz spectrum, would be for Everything Everywhere to divest 2x15MHz of 1800MHz." It argued the fact that Telefónica and Vodafone can now bid for the 800MHz to prevent Everything Everywhere from winning sub-1GHz after it has divested its 1800MHz spectrum "amounts to double jeopardy for Everything Everywhere."

A10.20 H3G argued that "one important function of the Combined Auction is to address any competitive distortions caused by the previous 900/1800MHz liberalisation decision". It argued that the "benefits [of liberalisation] have not been distributed evenly across the market and liberalisation has caused a fundamental shift in the balance of 3G capabilities of the various operators, without the benefit of a competitive process."

A10.21 H3G cited the example of Telefónica launching 3G services on 900MHz spectrum as evidence that distortion of competition is already happening. It argued that Ofcom is lawfully obliged to form a view on this distortion and apply measures to address this through the auction.

A10.22 Telefónica believed that there is "no legal basis for justifying any remedies" [Telefónica's emphasis] as a result of the 2G Liberalisation decision. Telefónica noted that if we wished to rely on matters relating to the decision, we would be required to consult again.

A10.23 Vodafone asserted that we concluded there was "little likelihood of a competitive distortion as a consequence of allowing Vodafone (and O2) to use its 900MHz spectrum for 3G", saying that we recognised that the merger put Everything Everywhere – and to some extent, H3G through its network sharing agreement – "in the strongest position in terms of network capability for providing UMTS services." It also argued that there is therefore no reason for Everything Everywhere or H3G to be "advantaged in the acquisition of sub-1GHz spectrum in order to correct for a current distortion caused by the re-farming decision."

Ofcom's response

A10.24 We remain of the view that there is a possibility that Vodafone and Telefónica might have a short term advantage with UMTS900 until LTE800 deployments constrain UMTS900's advantage, consistent with our October 2010 Advice to the

[91] http://stakeholders.ofcom.org.uk/consultations/spectrumlib/advice-to-government/

Government on 2G liberalisation. As we said in the March 2011 consultation, this risk was considered and taken into account by the Government in advance of its making the Direction to Ofcom to liberalise that spectrum.

A10.25 We have taken account of potential competition concerns arising from the distribution of sub-1GHz spectrum in Sections 3, 4 and 8 of Annex 6.

Importance of sub-1GHz Spectrum Relative to Other Frequencies

Summary of our position in March 2011 consultation

A10.26 In our March 2011 consultation, we recognised the particular importance of spectrum in the 800MHz and 900MHz bands – which we collectively termed "sub-1GHz spectrum" – for providing good quality mobile data services.

A10.27 We noted that sub-1GHz spectrum had technical advantages compared to spectrum in higher frequency bands and that this could result in improvements in the quality of coverage that sub-1GHz spectrum could provide, especially for data networks.

A10.28 We considered that a national wholesaler with only higher frequency spectrum may be able to overcome the coverage advantage of sub-1GHz spectrum by deploying additional sites, operating their network at a lighter loading or deploying in-building solutions, such as Wi-Fi or femtocell infrastructure. However, we did not believe that these approaches would allow a national wholesaler to practically overcome the coverage advantages of sub-1GHz spectrum and concluded that sub-1GHz spectrum may give an unmatchable technical advantage in terms of coverage.

A10.29 We recognised that a technical advantage in terms of coverage might not necessarily translate into a competitive disadvantage if consumers do not place sufficient weight on the locations where one network has a coverage advantage over another. However, given the prevalence current of indoor mobile broadband usage and the significant uncertainty surrounding consumer preferences in future markets, we considered that there is a risk that sub-1GHz spectrum may provide an unmatchable competitive advantage.

A10.30 We proposed that a national wholesaler is likely to require some amount of sub-1GHz spectrum in order to credibly offer high quality data services in a future mobile market, particularly for providing indoor coverage.

Summary of responses

A10.31 Everything Everywhere emphasised the importance of network coverage as a "key dimension on which operators compete in the UK" and cite a number of sources supporting the notion that in-building coverage is an important driver of customer satisfaction. Everything Everywhere also make the point that poor indoor coverage can damage the competitiveness of an national wholesaler for supplying wholesale access to MVNOs and to the M2M segment. Everything Everywhere explicitly state that there are areas "deep inside buildings, whether rural or urban, [that] can simply only be reached with sub-1GHz spectrum."

A10.32 Everything Everywhere also argued that, regardless of the overall proportion of indoor mobile usage, such usage will be experienced by all customers in practice. Therefore, the impact of indoor coverage will be even larger than overall usage

figures suggest, making sub-1GHz even more essential to providing a competitive customer experience.

A10.33 Whilst Everything Everywhere acknowledged the possibility of using Wi-Fi and femtocell solutions for providing deep indoor coverage, it expressed concerns regarding their limitations, citing issues around Wi-Fi congestion in public locations and questioning the feasibility of widespread femtocell deployments.

A10.34 Furthermore, Everything Everywhere argued that Ofcom has failed to consider the importance of sub-1GHz spectrum for coverage for mobile voice services. Everything Everywhere believes that voice will be "a key driver of revenues and customer utility over the next decade" and notes that it and H3G do not have access to sub-1GHz spectrum "with which to provide a voice solution to reach deep indoors from a practical deployment of outdoor macrocellular sites". Everything Everywhere go on to argue that even with access to 800MHz spectrum, it may be at a disadvantage for providing voice coverage compared to 900MHz national wholesalers since 800MHz spectrum will not be immediately suitable for providing voice services.

A10.35 Everything Everywhere also mentioned the importance of sub-1GHz spectrum for providing more cost-effective rural broadband coverage, but stops short of commenting on whether higher frequency spectrum can be a substitute in this regard.

A10.36 H3G argued that the liberalisation of the 900MHz band gives Telefónica and Vodafone a "clear competitive advantage" in terms of outdoor geographic and in-building coverage for mobile data services by virtue of their "extensive low frequency holdings".

A10.37 H3G also argued that this coverage advantage had existed for 2G services and improved consumer perception of the quality of coverage on Telefónica and Vodafone's networks. It goes on to argue out that this also translated into improved consumer perception of coverage for 3G services even when all national wholesalers were providing 3G services using 2.1GHz spectrum, a perception that has been exacerbated by 3G rollout at low frequency.

A10.38 Telefónica and Vodafone both opposed our point that sub-1GHz spectrum offered an unmatchable competitive advantage, provided that the sub-1GHz network was limited to 2x10MHz of spectrum. They argue that 2x10MHz of sub-1GHz is the relevant comparator given this is the maximum amount of 800MHz spectrum that they can acquire in the auction and that their 900MHz spectrum is not immediately suitable for LTE use. Given this condition, they each argue that the service provided by a sub-1GHz network can be practically replicated using additional spectrum and sites. In particular, they present evidence that it would be both possible and practical for an 1800MHz network to match – and in some locations, better – the performance of a sub-1GHz network, citing the site counts of existing networks and our previous technical evidence.

A10.39 Cable and Wireless agreed with our proposal that a national wholesaler would require sub-1GHz spectrum in their spectrum portfolio in order to provide a credible offering. It cites the "significant advantages for both wide area coverage and building penetration" that sub-1GHz spectrum provides and the importance of both of these to end users and, by extension, service providers such as itself.

A10.40 Ericsson also agreed that "there is a need for all operators to have access to sub-1GHz spectrum", citing rural range and urban building penetration as the advantages of the spectrum.

Ofcom's response

A10.41 We consider the importance of sub-1GHz spectrum relative to other frequencies in detail in Section 4, in Sections 3, 4 and 8 of Annex 6, and in Annex 7.

Amount and Distribution of sub-1GHz Spectrum

Summary of our position in March 2011 consultation

A10.42 In our March 2011 consultation, we considered the quantity of sub-1GHz spectrum that might need to be included in a minimum spectrum portfolio for the holder to be a credible national wholesaler.

A10.43 We compared the performance of a 2x20MHz sub-1GHz network against various multi-frequency networks containing smaller quantities of sub-1GHz spectrum with higher frequency spectrum. Making use of technical modelling results, we assessed the extent to which the multi-frequency networks could technically match the sub-1GHz network on three metrics of performance: coverage, speed and capacity.[92]

A10.44 With our technical results, we established that, for the metrics of coverage and speed, multi-frequency networks with as little as 2x5MHz of sub-1GHz spectrum could go a long way towards matching the technical capabilities of a 2x20MHz sub-1GHz network, especially if the multi-frequency networks are lightly loaded. Given this requirement for lighter loadings, we found that the multi-frequency networks had lower capacity when compared with the sub-1GHz network.

A10.45 From this, we concluded that the likelihood of an national wholesaler that had a portfolio containing only small amounts of sub-1GHz spectrum being at a material competitive disadvantage relative to one holding 2x20MHz of sub-1GHz spectrum depended very much on whether consumers placed a high value on the differences in speed at the edge of coverage.

A10.46 We recognised that the multi-frequency portfolios were at a capacity disadvantage, but did not conclude that this would leave a national wholesaler holding one of these portfolios to be at such a competitive disadvantage that they would cease to be credible. This is because we did not consider it all national wholesalers to need equal capacity to be effective competition and that it was sufficient for all to have enough spectrum to act as competitive constraints on one another. Additionally, we believed that there were feasible ways to overcome capacity disadvantages, such as offloading to small cells or the use of additional sites or spectrum.

Summary of responses

A10.47 Everything Everywhere argued strongly for 2x10MHz of sub-1GHz as the minimum that a national wholesaler requires to be credible. It stressed the importance of relative spectrum holdings when considering the potential credibility of national wholesalers with particular spectrum portfolios pointing out that our proposals, which include minimum spectrum portfolios containing only 2x5MHz of sub-1GHz spectrum, do not preclude a situation where two national wholesalers hold

[92] See Section 6 of Annex 6 of our March 2011 consultation for a detailed definition of these metrics.

2x27.4MHz of sub-1GHz spectrum, whilst the other two only hold 2x5MHz. In this situation, Everything Everywhere does not believe that the holders of the smaller amounts of sub-1GHz spectrum would be able to "exert a sufficient and sustainable competitive constraint" on the other two national wholesalers.

A10.48 In relation to coverage, Everything Everywhere argued that the data rates we used to determine that 2x5MHz of sub-1GHz spectrum can provide sufficient coverage were too low, given that consumers were likely to demand higher data rates in a future market. It argued that 2x10MHz of sub-1GHz spectrum will be necessary to deliver a sufficiently competitive service quality at cell edges.

A10.49 Additionally, Everything Everywhere argued that for data mobile data services delivered deep indoors, 2x5MHz of sub-1GHz spectrum would not provide enough capacity to ensure a sufficient quality of service is delivered to users. In this situation, it argued that capacity disadvantages cannot be overcome in the ways we suggested, since higher frequency spectrum is unsuitable for deep indoor coverage, whilst Wi-Fi and femtocells encounter issues relating respectively to congestion and logistics of mass deployment.

A10.50 Everything Everywhere also criticised our modelling approach for being "entirely theoretical" and based solely on technical requirements. It believes our analysis does not show that we have taken financial viability into account or assessed what degree of competitive constraint a national wholesaler must be able to exert to be considered credible. In particular, it argued that the loading level we used to justify 2x5MHz of sub-1GHz being sufficient for coverage is too low to be commercially viable, reasoning that the incremental increase in coverage and capacity would not cover the fixed costs of deployment.

A10.51 H3G argued that "low frequency spectrum of less than 2x10MHz is insufficient to support a national wholesale operator". It argued that minimum spectrum portfolios should include spectrum that is equivalent to 2x15MHz of 800MHz spectrum, including at least 2x10MHz of 800MHz spectrum.

A10.52 However, H3G argued that in practice, 2x10MHz of 800MHz spectrum is still insufficient to address the distortion in sub-1GHz spectrum since 2x15MHz of low frequency spectrum, which is held by Telefónica and Vodafone, can deliver "far higher data speeds" and "can be leveraged to provide optimum spectral efficiency with wider bandwidths of higher frequency spectrum" to facilitate greater overall network capacity.

A10.53 H3G also argued that we should ensure that each national wholesaler holds enough spectrum to support a "sustainable market share", which they specify as being 20%. They claim that this would require both 20% of total spectrum, as well as 20% of sub-1GHz spectrum. Consequently, it argued that this would require a minimum spectrum portfolio to include 2x15MHz of 800MHz spectrum.

Ofcom's response

A10.54 We consider the amount and distribution of sub-1GHz spectrum in detail in Sections 3, 4 and 8 of Annex 6.

Use of 900MHz spectrum for LTE

Summary of our position in March 2011 consultation

A10.55 In our March 2011 consultation we said that 800MHz and 900MHz spectrum were broadly equivalent and we treated them as the same throughout our analysis.[93] We considered that the result our technical modelling of 800 MHz spectrum would also apply to 900MHz spectrum.

A10.56 We said that we expected 900MHz spectrum to be used increasingly for 3G services following liberalisation but expected holders of this spectrum would defragment and refarm it for LTE if there is demand from consumers. We noted that future base station equipment would be more flexible and allow multiple standards to be employed simultaneously.

Summary of responses

A10.57 Vodafone argued that there are serious doubts that its 900MHz spectrum could be used for LTE in the medium or short term.

A10.58 Telefónica disagreed with our conclusion that 800 MHz and 900 MHz spectrum were broadly equivalent. It said that LTE900 had only been standardised[94] for use with up to 2x10 MHz of spectrum whereas LTE800 could also be used with 2x15 and 2x20 MHz. Because only the UK and Austria licence quantities of 900 MHz larger than 2x10 it is unlikely that there will be demand for LTE 900 standards with larger quantities to be developed. Telefónica also pointed to Ofcom's advice to the government which cites high costs of clearing 900 MHz spectrum (£440m to clear 2x10 MHz) and said that these estimates are likely to be low.

A10.59 Everything Everywhere noted that 'carrier aggregation' is a key feature of LTE Advanced, allowing national wholesalers to combine frequencies to achieve higher speeds. This aggregation is much easier between 800 MHz and 900 MHz spectrum than 800 MHz and higher frequencies and would allow Telefónica and Vodafone to use re-farmed spectrum along with 800 MHz to achieve high data rates.

Ofcom's response

A10.60 We consider the use of 900MHz for LTE in Sections 3 and 4 of Annex 6 and Annex 8.

Liberalisation of 900MHz and 1800MHz for bands LTE and WiMAX

Summary of our position in March 2011 consultation

A10.61 In our March 2011 consultation, we considered that allowing the 900MHz, 1800MHz and 2.1GHz spectrum bands to be used to deliver LTE services is likely to bring significant benefits to consumers.[95]

A10.62 We considered that this may result in a short term competitive advantage for holders of 1800MHz spectrum and acknowledged that the European Commission

[93] See paragraphs 5.70 to 5.72 of Annex 6 of the March 2011 consultation.
[94] Telefonica cites the 3GPP Release 10 air interface standard.
[95] Although we considered that WiMAX technology may also offer similar advantages, we felt that it was unlikely – given stakeholder plans at the time – that it would be deployed using this spectrum.

accepted commitments from Everything Everywhere's parent companies to divest some of their 1800MHz spectrum partly because of concern that Everything Everywhere could launch LTE at 1800MHz with a large contiguous channel. Given these commitments, we did not consider it necessary to take further measures before liberalisation of 1800MHz spectrum for LTE. Furthermore, we noted that once 2.6GHz becomes available, wholesalers will be able to deploy LTE in large contiguous bandwidths. When deployed in combination with sub 1GHz spectrum, the advantages of 1800MHz over 2.6GHz are likely to be matchable.

A10.63 We also considered that it was possible that the 900MHz spectrum could be liberalised for LTE use before the 800MHz spectrum is awarded and available for use on a wide scale basis. This might give holders of that spectrum a temporary advantage over holders of other spectrum. However, we did not consider that particularly likely given the information currently available to us on the timing for the development of LTE 900 equipment and the other availability of other spectrum, such as 800MHz, for the deployment of LTE.

A10.64 Given the distribution of 2.1GHz spectrum and the likelihood that LTE services will not be launched at 2.1GHz in the short term, we did not consider that liberalisation of this spectrum is likely to create any short term advantages.

Summary of responses

A10.65 Telefónica considered our proposals for immediate LTE liberalisation flawed. It provided arguments that it would be improbable for it or Vodafone to be in a position to deploy a competitive LTE network at 900MHz before 2020. On the other hand, it argued that Everything Everywhere would, in the case of a licence variation, be able to immediately deploy a 2x20MHz LTE network at 1800MHz and would be the only one to be able to do so. It pointed out that this would put Everything Everywhere in a position of Significant Market Power in the market for 4G services.

A10.66 Furthermore, Telefónica argued that we are under no legal obligation to vary 1800MHz licences to permit LTE deployment and that any such decision to liberalise for LTE would be unlawful as it would run counter to our duties. It cliamed that we have conducted no adequate competition assessment nor have we consulted properly on this issue.

A10.67 Telefónica also noted that the merger commitments on Everything Everywhere do not require them to make their divested spectrum available before 30 September 2015, which could lead to an extensive first mover advantage for it, were it to deploy an LTE network. Telefónica also argued that on Ofcom's own analysis a decision to liberalise the 1800MHz spectrum before the auction would give Everything Everywhere SMP on a 4G market. It stated that such a decision would be inconsistent with Ofcom's duties and therefore unlawful.

A10.68 H3G noted that Everything Everywhere has already received a large capacity uplift from 2G Liberalisation of 1800MHz spectrum and stated that it could "easily deploy 2x20MHz LTE at 1800MHz" and that its 2x45MHz holdings provide scope for it to gain from further technological developments[96] such that "Everything Everywhere may gain even greater (and possible unmatchable) speed advantages".

[96] Since 2x20MHz is currently the maximum bandwidth for LTE.

Ofcom's response

A10.69 We comment on liberalisation of 900MHz and 1800MHz for LTE in Section4.

Equal Spectrum Shares

Summary of responses

A10.70 H3G argued that a near-equal distribution of spectrum is desirable to maximize benefits for consumers since it removes or reduces the limit to competition caused by capacity constraints. H3G argues that given the high fixed costs incurred by any national wholesaler irrespective of their size, a national wholesaler needs to reach a 20% market share in order to achieve an efficient scale and be viable over the long run.[97] The 20% target and the alleged tight link between market and spectrum share support, in the view of H3G, the claim for "equalisation" of spectrum between national wholesalers.[98]

A10.71 H3G's argument supporting the need for a near-symmetric spectrum distribution is largely based on the analysis carried out by NERA into the effects of capacity constraints (see Annex 3 of H3G's response to the March 2011 consultation). The analysis runs through some standard theoretical models of oligopoly (specifically Cournot competition) and shows that capacity constraints tend to reduce competition and that redistributing capacity more evenly renders the market more efficient.

A10.72 H3G also claimed that Ofcom's Statement on Wholesale Mobile Voice Call Termination in 2011 suggested that the minimum efficient scale for a four-player market is 25% of the market.[99]

Ofcom's response

A10.73 We respond below initially to H3G's claim for equal spectrum shares. Then we comment on H3G's analysis of fixed costs and its claim about our Statement on Wholesale Mobile Voice Call Termination.

A10.74 Our response on equal spectrum shares falls into two parts. First, we do not agree that there is such a rigid relationship between spectrum shares and network capacity; and, second, even if capacity constraints are relevant it is only under strong assumptions that symmetric capacities produce the best market outcomes.

A10.75 On the first issue, in Sections 3 and 4 of Annex 6 we consider the share of spectrum required to be a credible national wholesaler, taking into account the relationship between spectrum shares and capacity (and the ways of increasing capacity other than more spectrum).

A10.76 On the second issue of symmetry, regarding the NERA analysis, the results presented are strongly affected by the simplifying and unrealistic assumptions that firms are identical except for their spectrum holdings and that there is a mechanical relationship between spectrum and network capacity (which is the first issue referred to above). In such a case, the model finds equal market shares are the optimal outcome, and therefore equal spectrum holdings are the best way to accommodate this. In reality, even in the absence of any capacity constraints firms'

[97] See paragraphs 191-198 of H3G's response.
[98] See paragraphs 203-208 of H3G's response.
[99] See paragraph 197 of H3G's response.

market shares may differ for several reasons, including different costs of production and/or different product quality. When this is the case, symmetric capacity allocation may fail to achieve an efficient output distribution across national wholesalers (this can easily be shown within the same basic framework by introducing some cost differences across firms).[100]

A10.77 Given the nature of the competition in the mobile sector we consider that the assumption of perfect symmetry is strong. Even assuming that spectrum is the only driver of network capacity, there are reasons to believe that symmetric spectrum shares are not necessarily optimal for consumers. In a dynamic and innovative market like the mobile sector, there is a wide scope for differentiation between national wholesalers:

- Service providers already tend to differentiate themselves by offering different products in terms of quality of services, bundle packages, pricing structures, etc. We expect this trend to continue in the future with service providers developing innovative offers to attract customers and foster the uptake of mobile data services;

- We also consider that national wholesalers may also compete on cost efficiency dimensions both at network level (technologies and network configuration) and at retail level (customer care, billing, etc.). This would, therefore, create differentiation even in terms of costs of provision.

A10.78 In such a context, benefits for consumers are maximized when they can have access to the best combination of services at the lowest prices. Ideally, national wholesalers' capacity should reflect their relative ability to attract demand so that customers are not constrained in their access to the offers that best meet their needs. Any predefined (symmetric) spectrum allocation can hinder such outcomes (assuming a rigid relationship between spectrum and capacity) and, ultimately, it would be to the detriment of customers. We also note that some form of asymmetry between rivals is a common feature of several competitive markets and would not normally be a cause for concern.

[100] To show this we consider the Cournot model proposed by NERA and we assume that the four existing firms have different marginal costs (firm A and B, have marginal costs equal to 1, while firm C and D have marginal costs of 5). These numbers are purely illustrative. In this setting, the Cournot equilibrium with no capacity constraints would be that firm A and B produces 26.4 each, firm C and D produces 22.4 each. The aggregate output would be 97.6 and the price 27.4. Suppose the total capacity available in the market equals the unconstrained market output and it is evenly allocated to firms (i.e. each firm holds a capacity of 24.4). Firm A and B are constrained and, thus, produce the maximum allowed by their spectrum endowment (24.4). Firm C and D, instead, are unconstrained and, therefore, set their output as a 2-firm Cournot duopoly of the residual demand left after the other competitors have saturated their capacity (each produces 23.7). This results in a market output of 96.3 less than the output under no capacity constraints. Clearly, a reallocation of capacity proportional to the unconstrained output equilibrium would allow each firm to produce its optimal output and, ultimately, it would yield a higher market output. In short, the highest market output is achieved through the capacity allocation that best approaches the unconstrained market equilibrium. Therefore, unless firms are identical along every competitive dimension, symmetric capacity distribution does not necessarily lead to the most efficient outcome.

A10.79 Finally, we note asymmetry in capacities tends to make collusion more difficult. As argued by Ivaldi et al. in a report for the EC:[101] "compared with a situation where all firms face the same capacity constraints, increasing the capacity of one firm at the expense of the others both increases the first firm's incentive to undercut the others and limits these other firms' retaliatory power. Overall, therefore, introducing such asymmetry hinders collusion." This result is supported by several other studies[102] and is consistently considered by the European Commission[103] as well as by the Office of Fair Trading (OFT) and the Competition Commission (CC) in the UK as a relevant factor in assessing the risk for coordinated effects resulting from mergers.[104] This is not to say that symmetry in capacity leads necessarily to collusion, but we consider that regulatory measures that artificially attempt to induce an equal capacity distribution across national wholesalers may have potentially detrimental consequences as they create conditions more conducive to coordination.

A10.80 As regards H3G's argument about fixed costs, we do not consider that a 20% minimum market share is a reliable conclusion. First, we consider that the extent to which a national wholesaler's costs are fixed with respect to its market share is exaggerated in H3G's analysis. For example, it takes network capital and operating costs as being "mostly fixed". However, whilst there are some fixed elements, these costs are variable to a material extent with the volume of traffic and the market share of the national wholesaler. Second, it appears that H3G treats "mostly fixed" costs as being entirely fixed. Third, any differences in average cost between operators with different market shares that arise from fixed costs become smaller as the volume of traffic grows. As set out in Section 3 of Annex 6, the volume of traffic has grown rapidly in recent years and is expected to continue to increase substantially..

A10.81 H3G's claim that our Statement on Wholesale Mobile Voice Call Termination found 25% market share to be a minimum efficient scale is plainly incorrect. First, we did not establish the minimum efficient scale in our Statement and indeed explicitly refrained from doing so:[105]

> "In the context of multi-product industries (e.g. mobile networks) with multiple cost drivers (i.e. coverage, subscribers, traffic) and outputs,

[101] Marc Ivaldi, Bruno Jullien, Patrick Rey, Paul Seabright, Jean Tirole (2003): "*The Economics of Tacit Collusion*", Report for DG Competition, European Commission (http://ec.europa.eu/competition/mergers/studies_reports/the_economics_of_tacit_collusion_en.pdf)

[102] Davidson and Deneckere (1984), (1990), Pénard (1997), Compte et al. (2002),

[103] For example, the EU Commission states in its Guidelines on the assessment of horizontal mergers that: "Firms may find it easier to reach a common understanding on the terms of coordination if they are relatively symmetric, especially in terms of cost structures, market shares, capacity levels and levels of vertical integration." (Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings, Official Journal C 31, 05.02.2004, pp. 5-18.)

[104] The OFT and the CC argue that asymmetries may impair the internal sustainability of the coordination because they potentially unbalance the incentive to deviate and retaliate of colluding firms. For this reason in assessing the sustainability of a coordinated behaviour the OFT and the CC consider: "whether there are significant asymmetries between firms—where this is the case, firms which are dissimilar to each other have weaker incentives to coordinate." (Merger Assessment Guidelines, A joint publication of the Competition Commission and the Office of Fair Trading (2010), http://www.oft.gov.uk/shared_oft/mergers/642749/OFT1254.pdf).

[105] Paragraph A6.98 in Wholesale mobile voice call termination, Statement, 15 March 2011: http://stakeholders.ofcom.org.uk/binaries/consultations/mtr/statement/MCT_statement.pdf

> estimating the minimum efficient scale would be a complex and disproportionate exercise."

A10.82 Second, we rejected the minimum efficient scale as the correct approach in that context:[106]

> "Even if it were reasonably easy to identify the minimum efficient scale, we do not believe this would be the conceptually correct approach to determining the level of unit costs for charge control setting. That is, the purpose of regulation is to mimic the outcome of a competitive market. While minimum efficient scale may be a useful indicator of the degree of contestability of a market, it is not the sole determinant of the equilibrium number of firms in a competitive market."

A10.83 Third, instead of the minimum efficient scale we based our cost modelling assumption of a 25% market share on the number of national wholesalers:[107]

> "Since 1994, there have been at least four – and from 2003 to 2009, five – national MCPs. Therefore, in the context of a hypothetical efficient network cost model built around 2G and 3G/HSPA infrastructure on a national scale, a choice between 20% or 25% is the appropriate range to consider for market shares."

A10.84 Fourth, as the above quotation shows, in our Statement on mobile termination we did not model the costs of a national wholesaler using LTE.

A10.85 Fifth, it is clearly invalid to seek to use Ofcom's cost modelling assumption in mobile termination to infer the minimum market share that a national wholesaler would need to achieve. Indeed Ofcom expressly noted that such an inference would not be appropriate:[108]

> "Moreover, simply because we are assuming a market share of 25%, it does not mean that we exclude the possibility that a firm could have a different market share and operate viably. In fact, given the range of business models we would expect different market shares just as we expect different operators to use different technologies."

Desirability of at Least Four National Wholesalers

A10.86 A number of respondents made comments regarding our conclusion that an auction outcome with four national wholesalers was desirable. We address them under the following headings:

- Representation of Ofcom's position
- The need for a competition assessment
- Evidence from the UK mobile sector

[106] Paragraph A6.99
[107] Paragraph A6.99
[108] Paragraph A6.100

- Evidence from other sources.

Representation of Ofcom's position

A10.87 Vodafone (paragraph 2 (i)) said it was concerned about "[t]he unsubstantiated assertion that an outcome from the auction resulting in a mobile market with three infrastructure providers is inherently damaging to competition and by implication consumers". Similarly, Everything Everywhere suggested that Ofcom's position was "that three national wholesalers do not create sufficient competition".

Ofcom's response

A10.88 These comments mischaracterise Ofcom's position in the March 2011 consultation. While we do not believe the consultation was ambiguous on this point, it is perhaps worth restating our position.

A10.89 We have identified the risk of competition concerns from outcomes in the auction that lead to a move from four to three credible national wholesalers as this could lead to a reduction in competitive intensity in the market. We discuss this in greater detail in Section 2 of Annex 6.

A10.90 However, we have not reached a definitive view that a consolidation from four to three national wholesalers would harm competition or consumers. It is possible, at least in principle, that some such consolidation would not be detrimental. This depends on the specific facts of the case such as the precise nature of the consolidation, the market position of each of the remaining national wholesalers and the prevailing circumstances. We do not know those facts, because we do not know what form such a consolidation would take. So we are not in a position to conduct a detailed merger-style assessment of consolidation. But an advantage of our approach is that any such consolidation after the auction would be subject to appropriate analysis under merger control[109] based on the precise form of that consolidation and the specific facts.

Need for a competition assessment

A10.91 Vodafone (paragraph 11) commented that Ofcom was effectively undertaking an analysis of the impact on competition of a change in the number of firms in the market, and this was akin to a forward-looking merger analysis. However, Vodafone said (paragraph 6) that our analysis did not satisfy the standard that would be expected of an NRA or competition authority undertaking such a review.

A10.92 Vodafone cited an ECJ case[110] to illustrate that the threshold for prohibiting a merger was a high one. It quoted ECJ as saying that a prospective analysis must be carried out with great care because it does not entail the examination of past events, for which often many items are available, but rather a prediction of events which are more or less likely to occur in future.

A10.93 Vodafone further cited judgements by the Competition Appeal Tribunal[111] (CAT) and the Irish Electronic Communications Panel[112] (IECP) to similar effect. It quoted the CAT's comment on the ECJ judgement as follows:

[109] Or other relevant provisions, such as a competition assessment in the case of a spectrum trade.
[110] Case C-12/03 P Tetra Lavel BV v Commission (2005).
[111] Hutchison 3G UK Ltd v Ofcom (2005) CAT 39, paragraph 32.

> "The case demonstrates (if it needs to be demonstrated) that theory and surmise is not enough. One must look to see how things operate in practice, and prove whatever has to be proved to an appropriate level of proof. It points out the need to be particularly careful in relation to that when one is considering future conduct."

A10.94 Vodafone also said that the CAT endorsed the view of the IECP.

A10.95 Everything Everywhere (page 68) noted that "Ofcom does recognise that the number of competitors is not the be all and end all of a competition analysis", and that "concerns do not arise in every case because the structure and dynamics of the markets in question are also important. However, Everything Everywhere stated that it fails to see where Ofcom has actually taken the structure and dynamics of the market into account. It added that "Ofcom's approach effectively ignores the relative strength of individual competitors and the importance of this in relation to whether a market is competitive".

A10.96 Everything Everywhere further commented that "[e]mphasising the number of players rather than the extent to which they can provide a credible competitive force is where Ofcom has gone wrong." "It concluded that "[r]ather than asking whether four competitors are necessary, Ofcom should be asking what is required to ensure a competitive market structure after the auction."

A10.97 Everything Everywhere also commented that:

> "The key issue over which Ofcom glosses in this analysis is that market structure is also important...As a simple example, a four player market with market shares of 40%, 40%, 10% and 10% would under many economic analysis be considered less competitive than a three player market with market shares of 33.3%, 33.3% and 33.3%. For example, one standard measure of market concentration (which can be considered as on proxy for competitiveness and is used as one indicator of this in relation to merger analysis…) is the Herschman-Herfindahl index (HHI) which would rate the latter market as more competitive…The HHI is therefore one of the leading examples of a concentration measure which attempts to compare the relative size of firms in a market as more important than simply counting competitors."

A10.98 Telefónica commented that:

> "Had we undertaken this process two years ago, perhaps five would have been the target – but time has demonstrated that a *sustainable* intensity of competition (rather than a finite number of competitors) is the more appropriate objective for a regulator;"

Ofcom's response

A10.99 We do not accept Vodafone's contention that the present discussion is effectively the same as a merger analysis: we are not considering a specific proposed consolidation, but rather the prospect that at some point in the future one of the current national wholesalers will exit the market as a consequence of failure to acquire sufficient spectrum of the right type in the auction. Given the different nature

[112] Decision No 02/05 of the Electronic Communication Appeals Panel in respect of appeal No: ECAP 2004/01, paragraph 4.23.

of the assessment we are undertaking and the additional uncertainty (relative to a merger situation) we consider that the approach adopted is appropriate.

A10.100 We agree that care is generally needed in considering future conduct. However, we also note that Vodafone's account of the CAT's views is misleading. It presents the CAT as interpreting the comments by ECJ and IECP as meaning that the threshold when considering future conduct is high. However, the CAT also commented that[113]

> "…we do not think that the remarks relied on by [H3G's Counsel] have the full effect he contends for. They sound a warning about the need to carry out proper assessments, and they provide for an understandable degree of caution where what is required is an assessment as to future conduct, as opposed to an evaluation of past conduct, but they do not flag a particularly high degree of probability …it seems to us that [H3G's Counsel] is in substance saying that future events, if part of a chain of events said to give rise to future dominance, have to be proved to be likely on a balance of probability. That is not necessarily a "high" test. In relation to paragraph 43 of the ECJ judgment, [H3G's Counsel] conceded that what was being referred to there is not a high degree of probability, but relative degrees of probability, which detracts from his strong case, and also said that what the court would do was look at the evidence carefully and evaluate whether it supported the conclusion drawn from it. That again is true, but it is not pointing to any particularly high degree of probability. The real position is that the evidence must be carefully looked at, and properly assessed."

A10.101 As the ECJ case cited by Vodafone suggests, a forward-looking analysis is potentially subject to much greater uncertainty than an ex-post analysis based on empirical evidence. This is true of merger assessment, but it is also true in the present case, where the post-auction market structure is much less certain than in a merger and we are looking 5 to 10 years beyond the auction. However, we are satsifed that, in the context of this uncertainty, the evidence has been carefully looked at and properly assessed.

A10.102 With regard to Everything Everywhere's comments that we have not taken market structure and dynamics into account, we disagree. As set out in Annex 6, our competition assessment considers a wide range of factors as sources of potential competition concerns. We agree that the number of competitors is not the be all and end all of competition analysis. But, especially in a highly concentrated market with high barriers to entry, it is a significant consideration.

A10.103 Turning to Everything Everywhere's comments regarding HHI, UK merger guidelines[114] note that:

> "As regards the HHI, the OFT may have regard to the following thresholds:[115] any market with a post-merger HHI exceeding 1,000 may be regarded as concentrated and any market with a post-merger HHI exceeding 2,000 as highly concentrated. In a concentrated market, a horizontal merger generating a delta of less than 250 is not likely to give cause for concern. In a highly

[113] Paragraph 31 – i.e. the paragraph preceding that quoted by Vodafone.
[114] Merger Assessment Guidelines, a joint publication of the Competition Commission and the Office of Fair Trading,.
[115] The Guidelines note that "These thresholds are in line with those in the European Commission's guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings—Commission notice 2004/C31/03)."

concentrated market, a horizontal merger generating a delta of less than 150 is not likely to give cause for concern."

A10.104 We note that:

a) In a market with four national wholesalers, the HHI is at least 2,500 – i.e. highly concentrated by the OFT's definition.

b) In a market with three national wholesalers, the HHI would be at least 3,333.

c) Our March 2011 consultation (Annex 6, Figure 4.15) showed market shares for wholesale mobile connections which indicate a HHI of over 3,200 (following the T-Mobile/Orange merger).[116]

d) Based on these shares, if the smallest national wholesaler (H3G) were to exit the market, and the remaining national wholesalers divided up its share proportionately, the HHI would rise by around 380.

In conclusion, HHI measures indicate that the wholesale market is highly concentrated, and a change from four to three national wholesalers would generate an increase in HHI (or "delta") substantially above the minimum level that could give cause for concern.

A10.105 We agree with Telefónica that in the past the view was taken that there should be at least 5 national wholesalers in the UK, e.g. as reflected in the reservation of spectrum for a new entrant in the 2.1GHz auction in 2000. The process to move from 5 national wholesalers to 4 was a specific consolidation, i.e. the T-Mobile / Orange merger to form Everything Everywhere, which was subject to assessment under merger control (and resulted in undertakings including the divestment of the 2x15MHz of 1800MHz). Under our approach we envisage a similar process of scrutiny for any similar consolidation after the auction to move from the current 4 to 3 national wholesalers (rather than it being the inadvertent outcome of the auction).

Evidence from the UK mobile sector

Competition in the UK market

A10.106 Vodafone commented that "the state of existing competition in the wholesale and retail access and mobile markets clearly must be the starting point to inform analysis". In this context Vodafone questioned whether Ofcom had given due regard to the available evidence. Vodafone also said (paragraph 28) that, had it done so, Ofcom could not have reached the conclusion articulated in the consultation document.

A10.107 Similarly, Everything Everywhere (page 64) referred to Ofcom's mobile sector assessment statement and noted that "Ofcom has previously consistently found that mobile wholesale and retail market[s] in the UK are effectively competitive and has found no evidence to undertake a market review of the mobile access and origination market."

A10.108 Everything Everywhere also commented that indicators of sector returns demonstrate that this is a competitive market: EBITDA for UK national wholesalers

[116] Based on Figure 4.1, the retail market would have a HHI of at least 1700.

has been below European benchmarks and has been falling, their ROCE has been below WACC, and also below European averages.

A10.109 Vodafone said that both the Commission (in the context of the T-Mobile / Orange merger – discussed below) and Ofcom had recently found the "retail mobile access and origination market" to be characterised by vigorous competition. In particular, Vodafone noted the presence of MVNOs who provide retail service by virtue of wholesale access arrangements with national wholesalers. Vodafone estimated that there are at least 16 MVNOs in the UK retail mobile market, accounting for around 11% of subscriptions. Vodafone commented (emphasis in original):

> "The presence of the number of these MVNOs and their ability to act as a credible source of competition to the MNOs is compelling evidence that the UK wholesale [sic] access and origination market is clearly effective."

A10.110 Vodafone argued (paragraph 20) that the MVNOs would not be able to play a significant role in driving competition if the terms of wholesale access arrangements were sufficiently uncompetitive or unattractive as to constrain the ability of these MVNOs to compete.

Ofcom's response

A10.111 We discuss competition in the UK market in Section 2 of Annex 6.

A10.112 We agree with Vodafone that the ability of MVNOs to compete effectively in the retail market is dependent on their ability to obtain competitive wholesale access arrangements. Because of this we consider that there is indeed reason to conclude that there is a risk to wholesale and retail competition if only three credible wholesalers survive.

A10.113 This is illustrated by the fact that – as Vodafone noted – Ofcom previously imposed an ex ante obligation upon Vodafone and O2 to provide wholesale national roaming services to H3G at the time of the 3G auction. At the time, Ofcom wished to ensure that there were *five* national wholesalers in the market (i.e. including H3G), and it had a concern that, with four other wholesalers, H3G would not be able to secure wholesale access on favourable terms. Any such concern is likely to be greater in a market with only three wholesalers.

The T-Mobile / Orange merger decision

A10.114 Vodafone (paragraph 21) stated that the T-Mobile / Orange merger has not affected competition in the wholesale access market. It added (paragraph 29) that:

> "From the Commission's readiness to accept remedies from the merging parties to preserve 3's viability as a competitor, Ofcom extrapolates this [sic] to make a broad assertion that "only three national wholesalers in UK mobile markets would be a concern"."

A10.115 Vodafone suggested (paragraphs 21 and 30) that H3G has not to date played a significant role in competing for the custom of wholesale access seekers. It concluded that "In practical terms, the number of credible competitors between whom wholesale access seekers are able to switch is three."

A10.116 Vodafone continued (paragraph 21):

> "Accordingly, if Ofcom's theory were borne out in reality, the incentives of the three remaining MNOs to compete for wholesale access seekers would have been diminished potentially to the extent that, *in extremis,* the outcome would have been a collective refusal to deal with such parties. However, this has not been the case. Nor has Ofcom adduced any evidence to the contrary.
>
> Were the auction to result in the emergence of three LTE infrastructure providers, there is accordingly no good reason to conclude that the existing vigorous competition that is evidently an established feature on the competitive landscape in the wholesale access and origination market would be emasculated in any way.
>
> Commercial real world evidence therefore illustrates the danger of seeking to advance a simple hypothesis that a three-player market is more likely to encourage conditions for coordination."

A10.117 Everything Everywhere commented that the T-Mobile/Orange merger is a "fact specific example which relates to the conditions of competition at the time of the merger and not in relation to the situation which may or may not exist after any auction". It added that the Commission's concern related to the specific detailed circumstances of competition in the market and the particular part played by H3G rather than a simple general conclusion that three networks does not create sufficient competition.

A10.118 Telefónica commented that Ofcom:

> "…is somewhat disingenuous when it suggests that the European Commission supports Ofcom's contention that a three player market is *a priori* a competition concern. In the Merger Decision the Commission was concerned that, in approving the merger it might (absent remedies) lead to a position whereby H3G was no longer viable by virtue of its RAN sharing agreement [paragraph 16]. An implicit five to three consolidation. The Commission's took no definitive position as to whether a three player outcome was to be avoided…The Commission's concern was purely to secure H3G's competitive position to that which was in place before the merger took place (i.e. that in authorising a five to four consolidation it did not inadvertently generate a five to three consolidation). Any four to three consolidation would need to be reviewed on its merits at the appropriate juncture."

Ofcom's response

A10.119 As we explain in Section 2 of Annex 6, Vodafone appears to have misconstrued the meaning of "national wholesalers", which includes self-supply as well as supply to MVNOs or other seekers of wholesale access. The current UK market is therefore characterised by four national wholesalers.

A10.120 We reject Telefónica's assertion that our presentation of the T-Mobile/Orange merger decision is disingenuous. Our current concern is to ensure that the auction does not inadvertently generate a consolidation to three national wholesalers. We do not take a definitive position as to whether an outcome with three national wholesalers is to be avoided, and such a consolidation – whether through merger or spectrum trading following the auction – would need to be reviewed on its merits. In that sense, the point we are considering is analogous to the Commission's concern,

as Telefónica has presented it, about the T-Mobile/Orange merger decision inadvertently leading to a further consolidation.

Role of H3G

A10.121 Vodafone (paragraph 2(ii)) expressed concern about "[t]he weight that Ofcom erroneously appears to attach to the role played by 3 in the market…" Vodafone suggests that Ofcom "albeit obliquely, considers that the continued presence of 3 specifically in the UK retail mobile market is beneficial to competition" (emphasis in original). Vodafone commented:

> "We note that Ofcom itself, as described in the last Competition Commission (the "CC") review of wholesale mobile termination rates, questioned the role that was played by 3 in the retail mobile market.:
>
> > *"It [Ofcom] did not accept that H3G was the only material source of competition in the retail market, characterising the claim that H3G was a maverick competitor as unproven and speculative." [CC report, paragraph 5.7.11]*
>
> The CC also endorsed Ofcom's doubts about the importance of 3 in the retail mobile market:
>
> > *"More broadly, we do not accept that H3G has been the only source of innovation in the market. The Interveners have given us evidence of a number of new products and pricing structures that they have introduced, demonstrating that the innovator's role is not exclusive to H3G." [CC report, paragraph 5.7.31]*

A10.122 In contrast, Everything Everywhere cited the Commission's decision in the T-Mobile / Orange case (paragraph 107):

> "Moreover, 3UK is considered by several market players as an important competitive force in the UK market and to be the most innovative MNO in the market. It has played a key role in driving innovation, particularly in the data segment, and lower prices for consumers […] The important role of 3UK on the UK market has also been acknowledged and confirmed by Ofcom."

A10.123 (We note that the Commission's decision continues (paragraphs 108-109):

> "The possible disappearance of 3UK or the degradation of its competitive position could consequently have a serious impact on the UK retail mobile communication market and would mean that the merger could in a worst case scenario lead to a concentration from 5 to 3 players.
>
> *Conclusion*
>
> In view of the above, the Commission informed the parties on 29 January 2010 that it had identified prima facie serious doubts as to the merger's compatibility with the common market in relation to the ability and incentives of the parties to eliminate 3UK as a competitive force in the UK mobile market.
>
> […]")

A10.124 Telefónica (footnote 38) commented that "[t]o the extent that the Commission discusses 3UK's importance to the UK market, it references Ofcom's view – making this a rather circular point".

Ofcom's response

A10.125 As the above quotation from the decision shows, the Commission did not merely note Ofcom's view about H3G's role. It also noted the views of several market players, and reached a conclusion on the basis of these views (Ofcom's and others') that the elimination of H3G as a competitive force could have a negative impact on the UK mobile market.

A10.126 The extent to which the Commission is concerned with a consolidation, rather than the elimination of H3G in particular, is not entirely clear from the text (such a distinction was not relevant in that context). But Ofcom has not, in any case, sought to argue that the presence of H3G is necessarily more beneficial to competition than another fourth national wholesaler.

A10.127 As regards the contributions of H3G and other national wholesalers to current and past competition in mobile services, we set out in Section 2 of Annex 6 the reasons why we consider that all four have provided strong competitive forces.

Evidence from other sources

International evidence

A10.128 Vodafone cautioned against relying on inferences from international comparisons, and commented that the CAT had expressed its reservations about the value or relevance of facts drawn from other markets.

A10.129 Vodafone also said that the examples cited by Ofcom were of limited value. It added that:

a) Compared to the UK, the situation in Spain had the critical difference that wholesale access arrangements had yet to be concluded at the time of the market review. By contrast there was "no evidence that a change in or migration to a new technology would alter the incentives of the current national wholesalers active in the market to enter into such an arrangement".

b) In Poland the most recent market review found the market to be competitive.

c) In Finland and Austria, MVNO activity was limited, unlike the case in the UK.

d) To the extent that any international comparison was relevant, the case of the Netherlands would appear to be the most instructive. Here, the Commission (in its decision in Case No. COMP/M.4748 T-Mobile/Orange Netherlands) approved a move from four to three players. In doing so "it placed considerable weight on the fact that the highly competitive wholesale access and origination market (with approximately 50 MVNOs having concluded wholesale access arrangements) would be unaffected by the transaction in light of the existing (and recent) evidence. This evidence demonstrated that the MNOs remaining on the market had continued to compete to conclude wholesale access arrangements with third parties wishing to operate on the retail access market."

A10.130 Everything Everywhere commented that Ofcom's analysis of these decisions in other markets:

> "[t]akes no account of any other potential differences in the market structure between the UK market (or the UK market as Ofcom might reasonably expect it to be after the auction) and the markets where competition complains were upheld. All of these cases involved a concern over collective dominance, a finding of which is highly fact specific and depends on the interactions between competitors…Such a finding is not simply based on the number of competitors."

A10.131 Everything Everywhere noted that in two of the mergers we considered, a three player market raised no competition concerns, and two others allowed a three player market to be created following certain remedies. It added that "[b]y definition, such remedies would be to ensure that three credible competitors were left and therefore implies that this is feasible." Everything Everywhere also commented that "[u]nder Ofcom's approach it would logically be just as reasonable to assume that the UK is more like those markets where the structure and the dynamics of the market meant that three competitors did lead to a competitive structure post merger".

A10.132 Telefónica noted that neither the German nor the Swedish 800MHz auctions guaranteed that four national LTE players would emerge from the process. In Germany, three national players emerged, and in Sweden four.

A10.133 H3G provided evidence (paragraphs 150-160) that effective 3G entry has been associated with lower mobile broadband price, better quality and greater penetration in Western Europe, and substantial consumer welfare benefits in the UK. It said that the countries that had seen effective 3G entrants had all benefitted from four national wholesalers competing in their mobile market (although in Spain (until recently) and Germany there had been four national wholesalers but no successful 3G entrants).

A10.134 More generally, H3G argued (paragraph 161) that in countries with four national wholesalers, consumers had benefitted from significantly lower prices for mobile voice (around 20% lower) and mobile broadband (almost 30% lower) services.

A10.135 H3G (paragraphs 170) cited the views of industry analysts who had linked competition to both the presence of a 3G-only national wholesaler (or H3G in particular) and the presence of four national wholesalers.

Ofcom's response

A10.136 In the March 2011 consultation we did not seek to rely on analysis in other markets (including auctions) to conclude on whether a particular increase in concentration would lead to competition problems. Our point was simply that increases in concentration have on a number of occasions – even if not every occasion - raised questions about competitive intensity, suggesting that a cautious approach is appropriate.

A10.137 As regards the T-Mobile / Orange Netherlands merger, the Commission noted that:

a) "all MNOs will continue to own unutilised spectrum capacity" post-merger (paragraph 52), and "in view of the progressing roll-out of UMTS networks and

handsets, all three MNOs will have even more capacity to make available to MVNOs and Service Providers who typically require only GSM capacity."

b) following its acquisition of Telfort, KPN had increased its activities on the wholesale market;

c) "in view of the structure of the Dutch mobile telephony market, MNOs withholding available capacity on the wholesale market would forego revenues which they cannot expect to compensate through higher retail revenues" (paragraph 56).

A10.138 So the existing and recent evidence to which Vodafone refers relates to the specific facts of the case. For example, firms with a large amount of spare capacity typically find it more difficult to collude, because of the greater gains from cheating on a collusive arrangement.

A10.139 On the Netherlands case we note that the Ministry of Economic Affairs has recently decided to reserve 2x10 MHz at 800 MHz and 2x5 MHz at 900 MHz in the forthcoming auction for new entrants, with a cap of 2x10MHz on the amount that can be bought by any single new entrant. This implies de facto that at least two entrants can have access to sub 1GHz following the auction. Also, the stringent caps set for the incumbents in the 2.6GHz auction favoured entry. As a result, two new wholesalers emerged from the auction, namely Tele2 and Ziggo, each acquiring 2x20 MHz.

A10.140 We agree with Everything Everywhere that the cases which we discussed were highly fact specific. Again, we are not arguing that a consolidation to three players would necessarily reduce competition – whether or not this is so would depend on the facts of the case (including the market structure after consolidation). Indeed under our proposed approach there would be the opportunity for any such consolidation after the auction to be considered by the relevant competition authorities.

A10.141 Regarding Telefónica's point about auctions in other countries, while we agree that the auction measures adopted in Germany and Sweden did not guarantee that at least four national wholesalers would have 800 MHz after the auction, we note that in both countries national regulators intervened to reallocate the 900 MHz band as part of the refarming process. This ensured that those wholesalers who did not initially hold sub 1GHz spectrum were assigned at least a block of 2x5 MHz at 900 MHz (i.e. E-Plus and Telefónica in Germany and Hi3G in Sweden).

A10.142 We also note that in August 2011, the US Department of Justice (DoJ) brought a civil action to prevent the merger of AT&T Inc and T-Mobile USA Inc. The DoJ noted that AT&T and T-Mobile were two of only four mobile operators with national networks which, together, accounted for over 90% of connections in the US.

A10.143 Among other points, DoJ:

a) Argued that business and government customers required services that were national in scope, and that the reduction in the number of bidders for business and government contracts to three or fewer significantly increased the risk of anticompetitive effects.

b) Considered that from a consumer perspective local areas may be relevant geographic markets. It noted that the parties competed head to head in at least

97 of the top "Cellular Market Areas"[117] and that in 96 of these the post merger markets would be highly concentrated (with a HHI above 2,500).

c) Said that the elimination of T-Mobile, as one of the four national competitors, would result in a significant loss of competition in consumer markets. As a result, concentration would increase in many local markets and competition was likely to be substantially lessened, resulting in higher prices, diminished investment, and less product variety and innovation.

d) Presented evidence that T-Mobile was important as an aggressive and innovative competitor, particularly due to its HSPA+ network and "disruptive" pricing plans. This evidence included internal AT&T documents showing that AT&T had felt competitive pressure from T-Mobile.

e) On the subject of coordination/collusion, said that:

> "The substantial increase in concentration that would result from this merger, and the reduction in the number of nationwide providers from four to three, likely will lead to lessened competition due to an enhanced risk of anticompetitive coordination. Certain aspects of mobile wireless telecommunications services markets, including transparent pricing, little buyer-side market power, and high barriers to entry and expansion, make them particularly conducive to coordination."

f) Also noted that the proposed merger would be likely to lessen competition through elimination of head-to-head competition between AT&T and T-Mobile, on the grounds that there was a substantial level of customer switching between the parties.

g) Considered that entry barriers were substantial.

h) Noted that the parties could not demonstrate "merger specific, cognizable efficiencies sufficient to reverse the acquisition's anticompetitive effects".

A10.144 The Federal Communications Commission (FCC) also assessed this merger between AT&T and T-Mobile USA and similarly concluded that "the Applicants have failed to meet their burden of demonstrating that the competitive harms that would result from the proposed transaction are outweighed by the claimed benefits. Staff thus finds, as has DOJ, that the proposed transaction would likely lead to a substantial lessening of competition...".[118]

A10.145 The DoJ's and FCC's assessments are based on the facts of a specific consolidation. Any consolidation from four to three in the UK would have different facts – although it would have at least some similarities to the US case, perhaps including the exit of an aggressive competitor, highly concentrated markets, the presence of market features conducive to coordination, and substantial entry barriers.

A10.146 The DoJ's and FCC's analysis illustrates that a four-to-three merger among national wholesalers can lead to competition concerns, which in that case were sufficiently serious for the DoJ to seek to block the merger.

[117] These are areas which the FCC has used to licence service providers and which, the DoJ said, often approximate the areas within which customers have the same competitive choices.
[118] Paragraph 5 in *Staff Analysis and Findings*, FCC, WT Docket No. 11-65, November 2011, http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db1130/DA-11-1955A2.pdf

A10.147 In the face of these competition concerns, in December 2011 AT&T abandoned its proposed acquisition of T-Mobile USA.[119]

Fixed-line markets

A10.148 Vodafone (paragraph 27) commented that evidence from fixed-line access markets does not assist in demonstrating the credibility of Ofcom's argument. It commented that the fixed market is distinct from mobile access markets, and that the nature of the product and the way in which competition occurs is likely to be very different from that of mobile markets. It added that in these markets Ofcom has typically been concerned with establishing whether an incumbent has significant market power where access to that provider's infrastructure is critical to aiding new entry. Vodafone said that this is "not remotely analogous" to the mobile access market where there has "always been a number of competing infrastructure providers between whom wholesale access seekers can switch".

A10.149 Everything Everywhere said that Ofcom's use of evidence from fixed market regulatory findings suffered from the same failing as its use of evidence from other EU mobile markets.

Ofcom's response

A10.150 Clearly, the experience in fixed markets was only one piece of evidence which we considered in our analysis.

A10.151 Access to upstream infrastructure is critical to aiding new entry in both fixed markets (as Vodafone notes) and in mobile markets. Similarly, in mobile markets, ongoing access to infrastructure on competitive terms is critical to sustaining effective retail competition. The common feature of both fixed and mobile markets is high barriers to upstream entry.

A10.152 The reason this has been less of a concern in mobile markets is (as Vodafone noted) because retailers have been able to switch between a number of providers. In some fixed markets competition concerns have tended to diminish as the number of wholesale providers increases. Our concern is that a decrease in the number of wholesale providers in the mobile market could lead to a decrease in competitive intensity.

Academic papers / theoretical analysis

A10.153 Everything Everywhere commented that the point that more competitors create more competition was uncontroversial, but Ofcom did not specifically relate conditions in the current UK market to the detail of the papers in order to support a specific number of required competitors.

A10.154 Everything Everywhere also commented that the Coate paper did not provide particularly strong support for "Ofcom's conclusion" that there should be four national wholesalers. It said this was "symptomatic" of Ofcom's approach and "illustrates how Ofcom's approach fails to provide a robust competitive analysis":

[119] See, for example, http://www.justice.gov/atr/public/press_releases/2011/278406.htm?utm_source=CPI+Subscribers&utm_campaign=333486a4a6-Tuesday_October_25_2011_new_template10_25_2011&utm_medium=email

a) Everything Everywhere commented that the paper itself notes that the cases it analyses have a natural bias towards mergers which were challenged.

b) It commented that "the paper is not saying that three players means that a market is not competitive, it is merely pointing out that of the cases in the FTC's files those which involved four to three mergers tended to be challenged" whereas five to four mergers tended not to be challenged.

c) It commented that a significant minority of cases was not challenged.

d) It noted that the analysis is not concerned with raw numbers of competitors. For example Coate looks at post-merger market share and other case specific factors.

A10.155 Everything Everywhere concluded that the paper does not find that markets with three competitors have been seen by the FTC as carrying a more significant risk to competition than those with four.

A10.156 H3G presented a report by NERA Economic Consulting which noted that, in a wide range of models, 3-firm markets were less competitive than 4-firm markets. NERA presented illustrative numbers showing, for a differentiated market, such a consolidation could lead to price increases of 17% to 25%, and output decreases of around 15% to 30%. NERA noted that in some models such a consolidation would not have an impact on competition, but these relied on assumptions – e.g. that firms set prices only once, or that there are no costs or barriers to market entry – which do not hold in the present case. NERA also considered the impact of capacity constraints from spectrum scarcity.

Ofcom's response

A10.157 Taking in turn Everything Everywhere's comments on the Coate paper:

a) The paper does not refer to a natural bias.[120] The paper is concerned with mergers which were challenged. Bias would only be an issue if it were seeking to draw conclusions about *all mergers*, or a wider group of mergers, which it is not.

b) We agree that the paper finds that four to three mergers tend to be challenged. To be clear, we did not present the paper as saying "that three players means that a market is not competitive", nor is this our view.

c) We agree that a significant minority of cases was not challenged, and this goes to the author's comment that in four to three mergers "facts are key", with which we agree.

d) Where possible we took account of case specific factors. For example, we took account of the high barriers to entry to be a national wholesaler in mobile services in the UK. Barriers or impediments to entry are an important consideration in the Coate paper, which finds for example that "If the merger leaves only three or fewer significant rivals in markets affected by impediments to entry, then the challenge probability remains above 90 per cent" (page 29). In contrast, the finding in the paper that "Lack of entry impediments often explains

[120] The word "bias" does not appear. Everything Everywhere may be referring to the comment that "[n]ot surprisingly, the data set skews heavily towards enforcement actions", but this is clearly not presented as a drawback of the data set.

the failure to challenge a transaction in highly concentrated markets" (page 37) is not relevant here - whilst the UK mobile market is highly concentrated, there are large barriers to entry instead of a lack of entry impediments.

Above we also consider possible changes in market shares and HHI. The current, i.e. pre-consolidation, HHI is over 3,200 and post-consolidation the HHI would be likely to increase by at least 380. The Coate paper finds that the challenge rate for markets with HHI at such a high level is significantly in excess of 90% (see Table 1 in the paper).

As to other case specific factors, given the different nature of the situation here compared to a merger, there are limits on the extent of the analysis since the precise form of the consolidation is not known.

A10.158 In contrast to Everything Everywhere's assertion, we consider that the paper does indeed find that markets with three competitors have been seen by the FTC as carrying a more significant risk to competition than those with four, especially in markets with high barriers to entry. Everything Everywhere's comments note that the paper does not find that markets with three competitors are necessarily harmful to competition, but this was not and is not our position.

A10.159 We agree with NERA that standard economic models demonstrate that an increase in concentration from 4 to 3 players may be expected to lead to significantly poorer consumer outcomes, albeit that the figures presented by NERA are illustrative and such models have limitations (e.g. they make simplifying assumptions).

Measures in Auction for ensuring at least Four National Wholesalers

Summary of our position in March 2011 consultation

A10.160 In our March 2011 consultation, we proposed a package of measures which we considered at that time to be appropriate and proportionate for achieving our aim of promoting effective competition at the national wholesale level. We believed that this objective might be achieved with measures to ensure at least four credible national wholesale service providers existed after the auction.

A10.161 We provisionally concluded that spectrum floors were the most appropriate and proportionate option for achieving our objective, in conjunction with the use of safeguard caps to guard against the risk of very asymmetric distributions of mobile spectrum which may result in future competition problems.

A10.162 Our spectrum floors involved a set of spectrum portfolios which we considered represented the minimum portfolios needed to be a credible national wholesaler. We proposed to only accept auction outcomes that ensured a least four entities held spectrum portfolios at least as large as one of the minimum spectrum portfolios:

Figure A10.1, Ofcom's proposals for Minimum Spectrum Portfolios in the March 2011 consultation

SPECTRUM FLOORS THAT SPECIFY A MINIMUM SPECTRUM PORTFOLIO									
OPTION 1					OPTION 2				
Each wholesaler must hold one of the following (or more):					*Each wholesaler must hold one of the following (or more):*				
	800MHz/ 900MHz	**1800MHz**	**2.6GHz**	**Total**		**800MHz/900MHz**	**1800MHz**	**2.6GHz**	**Total**
a)	2x5MHz	2x15MHz		2x20 MHz	a)	2x10MHz	2x15MHz		2x25MHz
b)	2x5MHz		2x20 MHz	2x25 MHz	b)	2x10MHz		2x20MHz	2x30MHz
c)	2x10MHz	2x10MHz		2x20 MHz	c)	2x15MHz	2x10MHz		2x25MHz
d)	2x10MHz		2x15 MHz	2x25 MHz	d)	2x15MHz		2x15MHz	2x30MHz
e)	2x15MHz			2x15MHz	e)	2x20MHz			2x20MHz

A10.163 We expressed a preference for the set of portfolios in Option 1, which would have a smaller influence on auction outcomes. However, we recognised that there were also arguments in favour of the portfolios in Option 2.

A10.164 We considered that in the very long term, very asymmetric holdings of spectrum may represent a risk to spectrum, especially for sub-1GHz spectrum. We therefore proposed safeguard caps which we believed still allowed for national wholesalers to obtain efficient spectrum portfolios.

A10.165 We proposed a safeguard cap on sub-1GHz spectrum of 2x27.5MHz. We preferred this to a cap of 2x22.5MHz, which we believed could impose significant costs by significantly constraining some bidders' ability to acquire sub-1GHz spectrum.

A10.166 We proposed a safeguard cap on overall spectrum holdings of2x105MHz of spectrum. We preferred this to a cap of 2x120MHz, as this would allow one bidder to acquire all of the 2.6GHz of spectrum. Whilst unlikely, we believed that this could lead to a material reduction of competition in the future.[121]

A10.167 Given these measures, we provisionally concluded that no further action was likely to be necessary given our then current view on market developments and the availability of 800MHz and 2.6GHz spectrum.

Summary of responses

H3G

A10.168 H3G agreed with our approach of both spectrum floors and total spectrum caps but suggested amendments to the compositions of the minimum spectrum portfolios and a reduction in the overall spectrum caps.

A10.169 H3G argued that when determining measures for the auction, we should ensure that:

- The auction will remedy the competitive distortion arising from 2G Liberalisation.

[121] See our March 2011 consultation for detailed rules on the spectrum bands that would count towards the overall cap.

- The spectrum awarded ensures four credible and sustainable national wholesalers.

- The auction will avoid spectrum being a source of competitive distortion in future.

A10.170 With this in mind, H3G argued that our measures should:

- "[R]emedy the competitive distortion arising from O2 and Vodafone's preferential access to low frequency spectrum", meaning that minimum spectrum portfolios were required to be equivalent to 2x15MHz of low frequency spectrum.

- "[R]edress the capacity from O2 and Vodafone's preferential access to low frequency spectrum", guaranteeing that at least four national wholesalers should have the ability to acquire 20% of total spectrum and 20% of sub-1GHz spectrum.

A10.171 As such, H3G argued that the minimum spectrum portfolios should be increased to at least 2x15MHz of 800MHz spectrum plus 2x20MHz of 1800 and/or 2.6GHz spectrum.

A10.172 H3G noted that Everything Everywhere already possesses total spectrum holdings over 20% and proposed that it should relinquish higher frequency spectrum on a 1:1 basis to guarantee itself sub-1GHz spectrum. H3G suggested this approach as a way to address the criticism of Everything Everywhere being guaranteed new spectrum despite its superior overall holdings.

A10.173 H3G argued that those eligible for minimum spectrum portfolios should be allowed to submit bids only for portfolios corresponding to their preferred choice from among the minimum spectrum portfolios, which it called 'bidder choice'.

A10.174 H3G also disagreed with our options for an overall spectrum cap. It points out that our preferred cap of 2x105MHz would represent 37% of total paired spectrum after the auction, a higher percentage than the largest share of paired spectrum available for data services before 2G Liberalisation.[122]

A10.175 H3G expressed a preference for "substantially equal spectrum holdings" but also suggested a reduction in the overall cap to 2x95MHz, which it noted would still allow Everything Everywhere to obtain another 2x30MHz of spectrum in the auction.

Vodafone

A10.176 Having already argued against sub-1GHz possessing unmatchable advantages, Vodafone disagreed with our spectrum floors, arguing that the impact of the spectrum floors would be to guarantee Everything Everywhere at least 2x5MHz of sub-1GHz spectrum.

A10.177 Vodafone also argued that a possible bifurcation of the market may occur as a result of Everything Everywhere purchasing 2x20MHz of 800MHz and 2x20MHz of 2.6GHz spectrum.

A10.178 Vodafone instead argued for an unconstrained auction, reasoning that those who do not obtain spectrum can simply conclude commercial wholesale agreements with successful bidders. Vodafone noted that we can intervene via wholesale

[122] Everything Everywhere's 2x20MHz of 2100MHz spectrum equated to 33% of the total 2x59MHz in the band.

access obligations on 800MHz spectrum, by either imposing this before the Auction or through ex post competition powers.

Everything Everywhere

A10.179 Everything Everywhere argued strongly that 2x10MHz of sub-1GHz spectrum was the minimum necessary to be credible national wholesaler and noted that some of the portfolios in our preferred Option 1 contain only 2x5MHz of sub-1GHz spectrum.

A10.180 It also noted that the portfolios in our Option 2 do not suffer from this deficiency in sub-1GHz spectrum. However, Everything Everywhere argued that the portfolios in Option 2 effectively reserve 1800MHz or 2.6GHz spectrum for Telefónica, Vodafone and H3G. It did not believe that any bidder possessed the ability or incentives to prevent Vodafone and Telefónica from acquiring this spectrum, if it was efficient for them to do so, so argued against Option 2 on the grounds that it would be disproportionate for achieving our objective of ensuring at least four national wholesalers.

A10.181 In addition, Everything Everywhere argued that 1800MHz spectrum was sufficiently similar to 2.6GHz spectrum that they should be included in equal amounts in the minimum spectrum portfolios.

A10.182 It therefore suggested the set of minimum spectrum portfolios be a modified version our Option 1 from the March 2011 consultation, with the portfolios containing only 2x5MHz of sub-1GHz spectrum removed and the others modified to include equal quantities of 1800MHz and 2.6GHz spectrum:

Figure A10.2, Everything Everywhere's proposals for amended Minimum Spectrum Portfolios[123]

	Sub-1 GHz	*1800 MHz*	*2.6 GHz*	*Total*
c)	*2x10 MHz*	*2x10 MHz*		*2x20 MHz*
d')	*2x10 MHz*		*2x10 MHz*	*2x20 MHz*
e)	*2x15 MHz*			*2x15 MHz*

A10.183 Everything Everywhere proposed that a tighter sub-1GHz cap could have a similar beneficial effect on competition and suggested that a 2x22.5MHz sub-1GHz cap could act as an alternative to its revised spectrum floors, saying that it was "agnostic as to which of these instruments Ofcom chooses to address its competition concerns".

A10.184 Everything Everywhere argued against our proposal for an overall spectrum cap and presented the following reasons why it did not think the cap was justified:

- It believed that above 1GHz spectrum was available in sufficient quantities such that four national wholesalers would be credible given the presence of spectrum floors. It believed this was especially true given that unpaired spectrum was also available and that there was increased international momentum for TD-LTE.

[123] Everything Everywhere also urged us to consider that unpaired spectrum could be included in the minimum spectrum portfolios.

- It believed our proposed cap of 2x105MHz, along with our auction rules (such as on eligibility points), limited its bidding flexibility and ability to respond to price changes during the primary auction rounds.

- It argued that the safeguard cap prevents Everything Everywhere from acquiring spectrum to launch new services as its existing 1800MHz spectrum still needs to be cleared for LTE services.

- The safeguard cap restricts Everything Everywhere's ability to serve its customers effectively by restricting its ability to maintain its current relative position in terms of overall spectrum in the market.

A10.185 Whilst it does not believe that there was a justification for an overall cap, it suggested that, if retained, it should be increased to the higher option we considered of 2x120MHz, which would ensure that Everything Everywhere is not discriminated against in its ability to bid in the auction.

Telefónica

A10.186 Telefónica did not disagree with our sub-1GHz spectrum cap. It accepted that sub-1GHz had benefits in rural areas and that over-concentration may lead to less competitive choice for rural consumers. It accepted the level of 2x27.5MHz since it equated to 42% of sub-1GHz spectrum, a figure consistent with a dominance assessment.

A10.187 Telefónica also did not disagree with our overall safeguard cap, since it equated to 36% of total spectrum, a figure consistent with a dominance assessment.

A10.188 Telefónica argued against our proposal of spectrum floors on that basis that they are:

- **Discriminatory –** Since we have not provided strong enough evidence to justify our reasoning that spectrum holdings *alone* would lead to unmatchable competitive advantages sufficient to distort competition, we have "no basis on which to discriminate between bidders and/or classes of bidders."

- **Disproportionate –** Due to the fact that Telefónica does not possess, nor can it accrue, an unmatchable competitive advantage through holdings of sub-1GHz spectrum; that 900MHz spectrum is not equivalent to 800MHz spectrum, so cannot be treated as equivalent to 800MHz spectrum in; and that Telefónica cannot act strategically in the auction process due to the auction design and the presence of spectrum caps.

A10.189 Telefónica also argued that by reserving certain spectrum lots for only some bidders, this may give rise to the award of spectrum at a discounted price which it alleged would constitute State aid.

Other respondents

A10.190 Cable and Wireless did not believe that we have taken sufficient steps to ensure all national wholesalers have sufficient holdings of sub-1GHz, reasoning that our proposals do not preclude a situation where each of Vodafone and Telefónica acquire 2x27.4MHz of sub-1GHz spectrum, whilst the other two are only left with 2x5MHz each.

A10.191 Steven Temple did not believe that 2x5MHz of 800MHz is sufficient for LTE services and believed that the consequences of our measures would be that H3G and/or Everything Everywhere possess only 2x5MHz of 800MHz after the auction. He believes that this would not deliver benefits for consumers or the UK.

Ofcom's response

A10.192 We consider in detail measures to promote national wholesale competition in Sections 6-8 of Annex 6 and we assess the evidence on refarming of 900MHz and 1800MHz in Annex 8.

A10.193 Regarding H3G's proposal of 'bidder choice', our proposals remain the same. If we reserve spectrum, we propose to specify a range of portfolios with the portfolio that is actually reserved being the one that maximises value (as expressed in auction bids), subject to meeting the constraint that one of the portfolios is obtained by an eligible bidder. The successful bidder for reserved spectrum will therefore be able to influence the portfolios it wins through the bids that it makes. We consider this is preferable to 'bidder choice' because it reduces the risk of an inefficient spectrum allocation. See the discussion under Option 4 in Section 8 of Annex 6.

A10.194 We have given careful consideration to Telefónica's assertion that our proposals might constitute State aid. Having done so, we are satisfied that our proposals do not give rise to State aid and this has been confirmed by Leading Counsel. Therefore, we do not consider that it is necessary to notify the European Commission of our proposals under Article 108 TFEU.

Strategic bidding

Summary of our position in March 2011 consultation

A10.195 In our March 2011 consultation we argued that there was a risk that certain national wholesalers could be excluded owing to strategic bidding. By 'strategic bidding' we meant that a bidder or bidders may deliberately buy more spectrum (paying more in the process) with the deliberate intention of excluding another from acquiring enough spectrum to remain a sustainable competitor in the market. We focussed in particular on the ability to foreclose access to sub 1GHz spectrum since we argued this was crucial for long term sustainability in the market.

Summary of responses

A10.196 Telefónica and Vodafone rejected the possibility of strategic bidding, while Everything Everywhere and H3G expressed concern about it.

A10.197 Telefónica contended that our combinatorial clock auction, by design, precludes strategic behaviour because a "strategic bidder" has no view of who is bidding on what and what effect his "behaviour" is having on the demand of other bidders (i.e. he cannot be sure it is having the intended anti-competitive effect). Telefónica reinforced its view by emphasising that the sub-1GHz cap means that it cannot acquire more than 2x10MHz of 800MHz so that what it does is not pivotal to the outcome for other parties.

A10.198 Vodafone argued that there would be no adverse effect on competition from having only three national wholesalers in the market, and that this means there would be no incentive to exclude a fourth firm. Vodafone also argued that the auction design prevents tacit collusion among bidders. It is hard for three bidders to coordinate to

exclude a fourth since it is impossible to tell during the auction if others are "playing their part". Vodafone also argued that the auction design means that a firm cannot adjust an attempt to exclude another bidder as the auction progresses; the design means the firm has to be committed from the start.

A10.199 Finally, Vodafone argued that Everything Everywhere can never be a victim of an attempt to exclude since it already has sufficient spectrum to launch a high speed network. It claimed that, if strategic bidding was a concern, Telefónica and Vodafone would be more at risk than H3G or Everything Everywhere.

A10.200 Everything Everywhere said it was very concerned that Telefónica and Vodafone would buy as much sub-1GHz spectrum as they could up to the spectrum cap in order to prevent H3G and Everything Everywhere from acquiring significant amounts.

A10.201 H3G agreed that other bidders had strategic incentives to exclude a fourth competitor.

Ofcom's response

A10.202 In this document for clarity we refer to 'strategic investment' to distinguish from other possible types of strategic bidding in the auction (such as strategic demand reduction). We discuss strategic investment in detail in Section 5 of Annex 6.

Spectrum as strategic asset and regulated access

Summary of our position in the March 2011 consultation

A10.203 In the March 2011 consultation we argued that spectrum was a strategic asset, which national wholesalers would want to hold directly. We noted that other assets, such as the rights to a particular handset, could in theory perform a similar role and allow a national wholesaler to gain influence in the market, including the ability to negotiate wholesale access. However, because national wholesalers account for a large proportion of retained revenue in the value chain (42%), we argued this would be limited.

A10.204 Our consultation discussed the possibility of two wholesale access conditions that could be attached to one or more spectrum licences: a "live" conditions that is constantly in force and a "dormant" condition that only comes into effect if certain criteria are met. Our provisional conclusion was that a live condition would be unnecessary since our proposals would ensure a competitive wholesale market, and a dormant condition would create too much regulatory uncertainty.

Summary of responses

A10.205 Everything Everywhere agreed that ex-ante wholesale access conditions are not appropriate, since they would distort commercial access negotiations. It is unclear at present how access conditions are best structured and the imposition of a simple cost-plus pricing rule would limit the ability to negotiate different tariff structures. Everything Everywhere also noted that existing levels of competition in the wholesale market have allowed many firms to negotiate access on reasonable conditions, including MVNOs and roaming agreements.

A10.206 Everything Everywhere also agreed that national wholesalers with a weak spectrum portfolio would be at a disadvantage when negotiating network sharing agreements.

A10.207 Vodafone disagreed with our analysis, saying that all evidence points to the idea that unsuccessful bidders can conclude a commercial wholesale arrangement with a successful bidder. Vodafone argued there is currently vigorous competition in the wholesale market with, in practice, only three competitors.

A10.208 Vodafone argued that, if Ofcom remains concerned about wholesale competition, there were more proportionate responses than minimum spectrum portfolios including reserving the right to intervene on an ex-post basis or including a wholesale obligation in one licence. Vodafone noted that Telefónica and Vodafone were required by Oftel to negotiate roaming agreements with H3G at the time of the 3G auction in 2000. These negotiations were concluded without the need for further intervention by Oftel.

A10.209 H3G agreed that wholesale access obligations were not needed as long as Ofcom continues to actively support the principle of ensuring four national wholesalers.

A10.210 C&WW argued it would not be proportionate or appropriate to include intrusive access obligations into the licences but did argue in favour of transparency obligations that require national wholesalers to publish details of their wholesale offer.

A10.211 UK Broadband argued an access obligation should only be introduced in the case of a proven market failure. However it argued that existing 2G and 3G national wholesalers should be required to provide national roaming to 4G licence holders on reasonable commercial terms.

A10.212 BT argued in favour of wholesale access obligations, saying that at a minimum there should be a reserve obligation triggered if four wholesalers do not emerge from the auction or if their behaviour does not support competition.

A10.213 The Institution of Engineering and Technology argued in favour of a wholesale access requirement. It argued that competition is trending in the wrong direction and that Ofcom needed to give itself the necessary tools to address this.

A10.214 Turquoise Mobile argued that ”regulated access conditions could be a useful fallback that Ofcom should perhaps ensure is available”.

Ofcom’s response

A10.215 We discuss spectrum as a strategic asset in Section 2 and the possibility of regulated wholesale access in Section 6 of Annex 6.

Low power shared use

Summary of our position in March 2011 consultation

A10.216 In our March 2011 consultation we considered the following options for promotion of retail competition through low power users:

- Aggregation of bids for low-powered use of the spectrum could address the coordination problem. We saw a strong case for aggregation of up to ten bids, for either 2x20MHz or 2x10MHz of 2.6GHz spectrum. We noted the risks that 2x10MHz would not be enough spectrum for low-powered use; conversely, there is a risk that if low power users only need 2x10MHz, then aggregating bids

across a larger block (2x20MHz) would require them to bid for more spectrum than then need, with the result that they would not win any spectrum.

- We noted a possible case for reserving spectrum, but noted that, given the uncertainty of benefits from entry by low power users, it was unclear whether reservation was appropriate and proportionate. In particular, we noted that other spectrum bands could be the focus for equipment for low power use. In addition, we considered the opportunity cost to reserving spectrum for low power use: there may be large benefits to holding large contiguous blocks for high power use. Reservation of 2x20MHz would reduce the number of 2x20MHz blocks for high power use, although reservation of 2x10MHz would not (because there is 2x70MHz of 2.6GHz paired spectrum available in total. We requested views on the merits of reserving some spectrum for low power use.

- We also considered the possibility of sharing 2x10MHz if low power users already had access to another 2x10MHz block.[124] For this purpose, Real Wireless modelled two shared usage scenarios. Under the full underlay approach, the number of locations, and power, which low power users could use would be limited by need to avoid interference to high powered use. The other approach was a hybrid – 2x10MHz available exclusively for low power use, and a further 2x10MHz available as underlay. We noted that the hybrid approach had open issues – such as the relative priority of low and high powered use, and how to manage interference and access.

Summary of responses

Responses in favour of support for low powered use

A10.217 BT, Virgin Media and C&WW said that some spectrum (at least 10MHz) should be reserved for low-powered 2.6 GHz use. They said that existing national wholesaler should not be allowed to bid, but did not explain why this was necessary.

Aggregation vs Reservation

A10.218 BT argued that aggregation of low powered bids would not be sufficient because (a) national wholesalers had an incentive to bid to exclude competition, (b) low powered users had a incentive to free-ride on the bids of other users, (c) the private values for low powered users were less than the benefits to consumers that they create and (d) low powered users would be deterred by the uncertainty surrounding their ability to negotiate roaming agreements.

A10.219 Similarly, Virgin Media argued that aggregating bids would not be effective since low-powered bidders would not know the bidding intentions of other low-powered bidders, and success would be dependent on other bidders remaining in the auction in each round. Virgin Media argued that bidders for high powered spectrum should not be allowed to bid for low powered spectrum, since they may bid to exclude competition and would have less interest in using the low-powered spectrum.

A10.220 C&WW argued that reservation was needed because, with bid aggregation, existing national wholesalers would still find it easy to outbid new entrants in order to exclude them from the market. If bid aggregation were relied on, C&WW favoured weighting the bids so that low-powered users only have to match a given percentage of the highest high-powered bid (a specific figure was not provided).

[124] March 2011 consultation, paragraphs 4.48 – 4.53.

Amount of spectrum needed for low powered use

A10.221 BT commented that reserving 2x20 MHz would allow the fastest broadband speeds and would make the management of interference easier. Virgin Media argued that, ideally, 2x20 MHz should be reserved but felt that a reservation of 2x10 MHz combined with shared use of a further 2x10 MHz could be sufficient.

A10.222 C&WW supported a hybrid approach of reserving 2x10 MHz for low powered use and allowing shared use of a further 2x10 MHz, but recognised that reserving 2x20 MHz would be hard to justify.

A10.223 The Institute of Engineering and Technology (IET) supported allowing low-powered users to co-exist with a high powered user in a 2x20 MHz block, as long as the high powered user was aware when bidding that this would be the case. The IET said that interference problems should be minimal and pointed to outcomes for Wi-Fi as demonstrating this.

Responses against support for low powered use

A10.224 The four national wholesalers opposed reserving of spectrum for low power use.

Uncertain benefits of low power use

A10.225 Everything Everywhere said that the experience of the DECT guard band, where only three out of 12 licence holders had launched a service, showed that a sub-national business model does not work. Vodafone, H3G and Arqiva made similar comments.

A10.226 Everything Everywhere also argued that, since Ofcom's proposals to ensure four national wholesalers would already guarantee a competitive market, MNOs would have little to gain by bidding to exclude low-powered users from acquiring 2.6 GHz spectrum. Reservation of the spectrum would also risk an inefficient allocation. Everything Everywhere did accept, however, that low-powered bids should be aggregated.

A10.227 Vodafone argued that, given the necessary power restrictions, national wholesalers could use Wi-Fi just as effectively. UK Broadband argued that specific measures to create sub-national RAN networks are not appropriate methods of promoting competition. It argued that in a competitive market trading and wholesale products should ensure low-powered products emerge if there is demand for them.

A10.228 Arqiva said that Ofcom should gain 'considerable assurances' from those seeking low-powered spectrum that it would be used for an early launch of services. Arquiva added that only a reservation of 2x10 MHz could be justified.

Loss of value from reserving

A10.229 Everything Everywhere, H3G and Arqiva argued that the uncertain value of low power use should be set against the certain, and substantial, opportunity cost of preventing high power use of this spectrum. H3G said the prices that 2.6 GHz spectrum had achieved in European auctions were evidence of its value in high power use.

Aggregation

A10.230 Everything Everywhere said that creating a mechanism for aggregating bids of low-powered users, so that they could bid against high-powered use, was a sufficient remedy. H3G accepted that there may be an argument for aggregating the bids of low-powered users providing it was done appropriately. No arguments were put forward against aggregating the bids of low-powered users.

Ofcom's response

A10.231 We discuss low power shared use in Section 9 of Annex 6.

Annex 11

Revised proposals for the auction rules

A11.1 This annex sets out our updated proposals for the auction rules. It includes a detailed description of the rules that relate to auction design. It does not cover other issues relevant to the award process and the auction regulations, such as the application and qualification process, the payment of deposits or potential penalties in case of breach of the rules.

A11.2 It is important to consider this annex in light of the proposals in section 4 on the competition assessment, section 5 on mobile coverage issues, and section 6 on our spectrum packaging proposals.

A11.3 In these three areas of our proposals, we have set out options for what the measures for the award might be. Several of these options have an impact on the auction rules. The four main examples are as follows.

a) Our approach to the competition assessment will determine whether it is appropriate to use the auction rules to implement such features as:

- a Competition Constraint on the outcome of the auction that would (if possible) restrict the outcome to one of those where a sufficient number of operators each win at least a certain minimum quantity of spectrum (a Minimum Portfolio Package – MPP); and/or
- caps on the amount of spectrum that bidders can win.

b) Our approach to concurrent low power use at 2.6GHz will determine whether there is a reservation for concurrent low power use only (and therefore effectively a separate category in which a fixed number of Lots are available) or whether we let potential concurrent low power users compete against other potential users for individual standard power Lots (creating a trade-off between the number of Lots available in two different categories).

c) Our approach to coverage issues will determine whether there is a coverage obligation, and if so, which spectrum it relates to. This has the potential to create additional categories of Lots.

d) Our approach to coexistence between future services in the 800MHz band and services in adjacent spectrum, such as existing DTT services below the 800MHz band, will determine how many categories of Lots there will be at 800MHz.

A11.4 Throughout this annex, we seek to make clear where different rules would be relevant depending on what policy option would apply in these areas.

A11.5 There are also a number of aspects of the proposed auction rules that are not sensitive to our proposed measures to promote competition, to address coverage issues or our approach to packaging of the available spectrum. This is true of:

a) the auction format (combinatorial clock auction with an assignment stage);

b) the requirement that Lots for a given bidder in each band be contiguous;

c) the Activity Rules i.e. the constraints on the amount and size (measured in eligibility points) of bids that bidders can make in each round given the bids they have made in previous rounds in the Principal Stage;

d) the rules for determining who the winners are and what prices they will pay; and

e) the information provided to applicants and bidders ahead of the bidding rounds and after each bidding round.

A11.6 The sequence in which we cover our proposals in this annex is as follows:

a) Policy objectives and choice of auction format.

b) Key terminology.

c) Overview of the structure of the auction.

d) Primary Bid Rounds.

e) Supplementary Bids Round.

f) Assignment Stage (where this involves further bidding).

g) Examples of how the Activity Rules apply.

h) Example of how the Competition Credit would apply.

A11.7 At specific points in the description, we include a discussion of key features in the auction design. We identify these under the caption heading 'key feature', to provide more detail in addition to the information set out in section 7.

A11.8 The proposed packaging and lot structure is discussed in section 6, see figure 6.10 in particular.

Policy objectives and choice of auction format

A11.9 The overall objective of the auction is to achieve an efficient allocation of spectrum, where bidders with the most valuable uses can win subject to promotion of downstream competition in providing services derived from spectrum use. In order to achieve efficient outcomes, the format needs to provide incentives for bidders to engage in straightforward bidding behaviour.

A11.10 There is likely to be uncertainty about the value of spectrum, both in terms of its absolute value and the relative value of spectrum in different bands. It is therefore important to provide an open auction mechanism in which price discovery can occur, allowing bidders to update their valuations in the light of updated estimates of market value. Such an approach reduces common value uncertainty, thereby reducing risk for bidders and enabling greater efficiency in the allocation of spectrum. However, at the same time it is important that the auction mechanism is robust to strategic behaviour. For these reasons we propose a similar approach to other recent Ofcom auctions where bidders can observe aggregate market-level data, but not the specific individual bidding activity of other bidders.

A11.11 The combinatorial clock format proposed provides a high degree of flexibility to implement various measures to promote downstream competition, including

spectrum caps, spectrum reservations and a requirement that a sufficient number of winners win at least one of their Minimum Portfolio Packages (MPPs) to become a prospective competitive national wholesaler. This final option can be accommodated within a combinatorial auction format by placing an explicit constraint – a Competition Constraint – on acceptable combinations of winning bids to ensure that the distribution of Lots amongst winners is consistent with pro-competitive measures.

A11.12 The combinatorial clock format, combined with one of our proposed second price rules, provides good incentives for straightforward bidding and allows bidders to follow simple bidding strategies that do not require them to second-guess the behaviour of rival bidders. It also allows the release of aggregate market level data to aid bidders in assessing the value of spectrum whilst allowing the control of information that could lead to gaming behaviour.

A11.13 The proposals described here include some modifications to the detailed rules of the combination clock auction format relative to previous Ofcom auctions and auction proposals. The Activity Rules for Primary Bid Rounds have been modified to provide greater opportunity for bidders to bid for their most preferred package of Lots at the prevailing Lot prices in each round. In particular, bids are no longer subject to a strict eligibility point-based activity rule, where once a bidder reduces its demand it is no longer able to bid subsequently for larger packages (i.e. those with a strictly greater number of eligibility points). Rather, it may be possible to bid again for a larger package (measured in eligibility points) having previously bid for a smaller one provided this is compatible with the preferences expressed in previous bids.

A11.14 At the same time, we propose to tighten somewhat the cap on Supplementary Bids in order to encourage more straightforward bidding in the Primary Bid Rounds. In particular, there will be an additional cap on Supplementary Bids (the Final Price Cap) that will limit the value that bidders may express for Packages of Lots that differ from the package bid for in the final Primary Bid Round. Any such bids will be capped relative to the highest bid made for the package bid for in the final Primary Bid Round and by reference to the Round Prices applying in the final Primary Bid Round. The Final Price Cap on Supplementary Bids should encourage more straightforward bidding during the Primary Bid Rounds, as bidders who find themselves bidding for a package that is not their most preferred one in the final Primary Bid Round may find that they are not able to make Supplementary Bids at the levels they would want.

A11.15 These changes to the Activity Rules should improve price discovery and encourage bidders to bid for their most preferred package in each Primary Bid Round. This should mean that the assessment of excess demand during Primary Bid Rounds (and the adjustment of Round Prices by the auctioneer in response) should provide a more informative estimate of the likely end-point of the Principal Stage. The Final Price Cap should also make it more likely that the final outcome of the Principal Stage is similar to the situation at the end of the Final Primary Bid Round. Bidders who submit bids in the Final Primary Bid Round should therefore be able to have greater confidence that they will win what they bid for in that round, albeit they may still have to submit a supplementary bid for that package in order to be certain of doing so.

A11.16 Where a Competition Constraint is used, it may affect the ultimate winning outcome of the auction and the prices paid. The prices of Lots in the Primary Bid Rounds should reflect the likely impact of this Competition Constraint if prices are to be

informative. To this end, our revised auction proposals now include a Competition Credit to be applied to qualifying bids during the Primary Bid Rounds, reducing the amount of a bid below the price of the package set by the current Round Prices for those bidders that are eligible to benefit from the Competition Constraint, to reflect the likely impact of that constraint.

A11.17 If some Lots are awarded on a frequency generic basis, then a mechanism is needed to determine which frequencies are allocated to each winner of those Lots. There are various possible mechanisms, such as bidding mechanisms and a role for negotiation between bidders. These alternatives are discussed in section 7. This annex discusses only those options that involve an Assignment Stage in which bidders are invited to bid for specific frequency ranges compatible with the outcome of the Principal Stage.

Key terminology

A11.18 The tables below provide a glossary of the most important terms used throughout subsequent sections when describing the auction rules. These terms are typically capitalised. We would suggest that the reader first read the description of the auction rules from Paragraphs A11.19 onwards, as they include detailed discussion of these terms, and use the following tables as a reference aid.

Figure A11.1: Key terms

Term	Explanation
Lot	Each individual spectrum block offered in the auction.
Generic Lot	A spectrum block that is not linked to a specific frequency range, but rather to a given bandwidth within a larger frequency range. The specific frequency range that will be assigned to each winner of a Generic Lot is determined in the Assignment Stage.
Lot Category	Each different type of Lot offered in the auction. Identical Generic Lots are grouped together within the same Lot Category.
Package	A combination of Lots, specified as the number of Lots in each Lot Category included in the Package.
Zero Package	The Package containing zero Lots in each Lot Category.
Package Bid	A bid for a Package. A Package Bid has an associated Bid Amount, which is the amount the bidder offers to pay for the Package to which the Package Bid relates. Bids for a Package are considered in their entirety, thus not exposing bidders to any risk of winning only a subset of the Lots included in a Package, unless they have also bid for such a subset in a separate Package Bid.

Term	Explanation
Bid Amount	The amount the bidder offers to pay for a Package in a Package Bid.
Zero Bid	A bid for the Zero Package, with a bid amount of zero.
Primary Bid Round	A round in the auction where the Auctioneer announces prices per Lot for each Lot Category and bidders are invited to submit a bid (a Primary Bid) for their preferred Package.
Supplementary Bids Round	A round in the auction that takes place after the Primary Bid Rounds have ended. In the Supplementary Bids Rounds bidders are able to submit multiple mutually exclusive bids (Supplementary Bids) for different Packages, provided that these bids are consistent with the Activity Rules of the auction.
Principal Stage	The stage in which the number of Lots in each Lot Category allocated to each Winner is determined. The Principal Stage comprises the Primary Bid Rounds and the Supplementary Bids Round.
Assignment Round	A round in the auction where the specific frequencies assigned to each winner of Generic Lots are determined. Winners of Generic Lots are guaranteed to win the bandwidth that corresponds to the Generic Lots won, and that Generic Lots in a frequency band will be assigned to each bidder on a contiguous frequency basis. Once the available frequency ranges that are consistent with contiguous assignments are established, bidders may be given the option to bid for specific alternative frequency ranges in accordance with their preferences.
Round Prices	The price per Lot for each Lot Category specified by the auctioneer in a Primary Bid Round.
Package Price	The total price of a Package in a Primary Bid Round. The Package Price is calculated as the sum of Round Prices of all Lots included in the package less any applicable Competition Credit (if the Competition Constraint on the outcome of the auction is implemented). The Package Price is the Bid Amount associated with the Primary Bid.
Permissible Package	For a specific bidder, a package for which the bidder may be permitted to bid that (i) satisfies the spectrum caps and other bidding constraints and (ii) in the event that the Competition Constraint is imposed, could possibly be a winning package for this bidder in some circumstances.

Term	**Explanation**
Package eligibility	For a Package of Lots, the sum of the eligibility points associated with all the Lots included in the Package.
Bidder eligibility	The bidder eligibility is one of the factors used to determine whether there are any applicable constraints on the packages a bidder may bid for in the Principal Stage. A bidder's eligibility in the first Primary Bid Round is determined before the first Primary Bid Round, by reference to the total amount of money that the bidder has on deposit with Ofcom at a specified point in time. After the first Primary Bid Round, the eligibility of the bidder in a round will be determined by reference to its eligibility and its Primary Bid in the preceding round.
Primary Bid	A bid for a Package, with a Bid Amount determined by prevailing Round Prices (and any applicable Competition Credit if there is a Competition Constraint), submitted in a Primary Bid Round. There are three possible types of Primary Bid for the purposes of the Activity Rules (described below): a Full Eligibility Primary Bid; a Constraining Primary Bid; and a Capped Primary Bid. This distinction does not have any impact on how the bids are evaluated in relation to the determination of Winning Bids.
Full Eligibility Primary Bid	A Primary Bid for a Package with eligibility *equal* to the bidder's eligibility in the round.
Constraining Primary Bid	A Primary Bid for a Package with eligibility *strictly smaller* than the bidder's eligibility in the round. Submitting a Constraining Primary Bid will result in: • a reduction in the bidder's eligibility, as the bidder's eligibility for the following round will be set to the eligibility of the Package the bidder bid for during the current round (or to zero if the bidder does not submit a Primary Bid); and • a Relative Cap on subsequent bids for packages with eligibility greater than the eligibility of the Package to which the Constraining Primary Bid relates.

Term	**Explanation**
Capped Primary Bid	A Primary Bid for a Package with eligibility *strictly greater* than the bidder's eligibility in the round. A bidder will only be able to submit such a bid if doing so is in accordance with the Relative Cap that applies to the Package. Submitting a Capped Primary Bid may require the bidder to increase bids for Packages for which the bidder has submitted a Constraining Primary Bid in earlier Primary Bid Rounds. Such raised bids are called *Chain Bids*.
Relative Cap	A cap (applying to some Supplementary Bids and all Capped Primary Bids) on the Bid Amount for a Package (call this X) with eligibility exceeding the bidder's current eligibility. The Relative Cap limits the amount by which a bid for Package X may exceed the highest bid that the bidder submits for the Constraining Package. The Constraining Package is that package for which the bidder submitted a Constraining Primary Bid in the last Primary Bid Round in which the bidder's eligibility was greater than or equal to the eligibility of Package X (the Constraining Round). The maximum difference is determined by the Round Prices that prevailed in the Constraining Round (see the definition of Stated Differential below).
Constraining Round	For a given Package subject to a Relative Cap, the last Primary Bid Round in which the bidder's eligibility was greater than or equal to the eligibility of the Package subject to the Relative Cap.
Constraining Package	For a given Package subject to a Relative Cap, the Package against which the Relative Cap is defined. The Constraining Package is the Package the bidder submitted a Constraining Primary Bid for in the last Primary Bid Round in which the bidder's eligibility was greater than or equal to the eligibility of the Package subject to the Relative Cap.
Stated Differential	The greatest permitted amount by which a bid for a Package subject to a Relative Cap may exceed the highest bid for its Constraining Package. The Stated Differential is equal to the difference in price between the Package subject to the Relative Cap and the Constraining Package at the Round Prices in the Constraining Round. Note that this differential may be positive or negative.

Term	Explanation
Chain Bid	An additional bid that a bidder is required to make in order to make a Capped Primary Bid. A Chain Bid for a Package Y is required if a bidder wishes to make a Capped Primary Bidder for a Package X for which Y is the Constraining Package and the Relative Cap that applies to Package X would not be met given the highest bid made so far for the Constraining Package Y. In this case, the required Chain Bid for Package Y would be for the minimum Bid Amount that would make the Capped Primary Bid for X consistent with the Relative Cap. A further Chain Bid for a Package Z will be required if that is the Constraining Package for Package Y, and the required Chain Bid for Y would not meet the Relative Cap with respect to the highest bid made so far for Package Z, and so on. Any required Chain Bids will need to be made in the same Primary Bid Round as the Capped Primary Bid to which they relate.
Closing Condition	The condition to be met for termination of the Primary Bid Rounds. The Closing Condition is met only if a provisional determination of Winning Bids results in at least one outcome where all bidders would be awarded no fewer Lots in each Lot Category than they bid for in the most recent Primary Bid Round.
Provisional Winner Determination (PWD)	The process of taking the bids received so far in the Primary Bid Rounds and performing a hypothetical winner determination to decide whether or not the Closing Condition is satisfied. The process uses an optimisation algorithm to identify possible combinations of Provisional Winning Bids (taking account of the Competition Constraint if implemented).
Compatible Tie	An outcome of the (Provisional or Final) Winner Determination in which every bidder would be allocated a Package that contains *at least* as many Lots in each Lot Category as the Package for which the bidder submitted a Primary Bid in the most recent Primary Bid Round.
Final Primary Bid Round	The last Primary Bid Round run, after which the auction proceeds to the Supplementary Bids Round.
Final Primary Package (FPP)	For each bidder, the Package of Lots for which the bidder submitted a Primary Bid in the Final Primary Bid Round. If the bidder does not submit a Primary Bid in the Final Primary Bid Round, the Final Primary Package will be the Zero Package.

Term	Explanation
Final Round Prices	The Round Price for each Lot Category applying in the Final Primary Bid Round.
Supplementary Bid	A bid for a package of Lots made in the Supplementary Bids Round.
Final Price Cap	A limit on the Bid Amount of any Supplementary Bid other than for the Final Primary Package. The Final Price Cap limits the Bid Amount relative to the highest bid the bidder submits for the Final Primary Package. A Supplementary Bid for a Package Z may not exceed the highest bid for the Final Primary Package (which may be a Supplementary Bid) by more than the Final Price Differential for Package Z.
Final Price Differential	The difference in price between a Package subject to the Final Price Cap and the Final Primary Package at the Final Round Prices. Note that this differential may be positive or negative.
Winner Determination (WD)	The process of taking a set of bids and determining which of those become Winning Bids. The process uses an optimisation algorithm to identify acceptable combinations of Winning Bids (taking account of the Competition Constraint if implemented).
Winning Bid	A bid that has been selected to win in the Winner Determination.
Winner / Winning Bidder	A bidder who has submitted a Winning Bid.
Base Price	The price to be paid by Winners of Lots in the Principal Stage. Base Prices are set to reflect the opportunity cost of allocating to a Winner the Lots it has won.
Additional Price	The price to be paid by Winners of specific frequencies in the Assignment Stage. When added to the Base Price, this determines the total price to be paid by a Winner. Additional Prices are set to reflect the opportunity cost (as reflected in Assignment Stage bids) of allocating a specific frequency range to a Winner.
Electronic Auction System (EAS)	The interface that enables bidders to participate in the auction and make bids over the internet.

Figure 11.2: Key terms applying only if there is a Competition Constraint

Competition Constraint	The requirement that a certain minimum number of bidders each win a certain minimum amount of spectrum (a Minimum Portfolio Package or MPP).
Minimum Portfolio Package (MPP)	For a specific bidder, a package of Lots that, if won by the bidder, would be sufficient for the bidder to count towards satisfying the competition constraint (provided that the bidder has opted in). A bidder may have more than one MPP, in which case the bidder counts towards satisfaction of the Competition Constraint if the above condition applies in respect of at least one of their MPPs. Different bidders may have different MPPs.
MPP Bidder	A bidder having one or more non-zero MPPs.
Opt-in Round	A single round in the auction, prior to the first Primary Bid Round, where MPP Bidders can choose to opt in to be eligible for being counted towards meeting the Competition Constraint, potentially benefiting from a Competition Credit. Opting in requires the bidder to submit bids at the reserve price for all of the bidder's MPPs (these are called Opt-in Bids).
Opt-in Bids	For a specific bidder, bids at the reserve price for all of the bidder's MPPs.
Opted-in Bidder	A portfolio bidder who has made Opt-in bids and may have a competition credit applied to its Primary Bids.
Competition Credit	For an opted-in bidder, a uniform credit applying to any package of Lots that includes one or more of that bidder's MPPs. This may vary by bidder and from round to round.

Stages to the proposed Combinatorial Clock Auction

A11.19 Bidding in a Combinatorial Clock Auction progresses in two distinct stages:

a) **The Principal Stage.** The function of the Principal Stage is to determine how many generic Lots bidders are allocated in each of the available Lot Categories and a Price for each winning bidder (its Base Price). The Principal Stage consists of:

- one or more **Primary Bid Rounds**, during which bidders bid for a Package of one or more Generic Lots in particular bands; and
- a **Supplementary Bids Round**, during which bidders can bid for many Packages of Generic Lots in particular bands, subject to constraints determined by their Primary Bids.

b) **The Assignment Stage.** Following the Principal Stage, the exact frequencies allocated to each one of the winners of Generic Lots in the Principal Stage are determined in the Assignment Stage.

A11.20 The purpose of the Primary Bid Rounds is to provide bidders with an opportunity to gather information about the demand for the Lots offered in the auction, and likely prices. The Primary Bid Rounds would typically last until the auction reaches prices for which there is no excess demand for any Lots offered in the auction.

A11.21 The Primary Bid Rounds allow bidders to update their estimates of market value and contributes to reduce common value uncertainty. Following the Primary Bid Rounds, bidders can then submit a full set of Supplementary Bids, subject to some restrictions derived from Activity Rules that provide incentives for bidders to reveal their true demand during the Primary Bid Rounds. All bids submitted during the Principal Stage are then taken into account for determining the Winning Bids.

A11.22 The Assignment Stage is only required for Lot Categories in which there is a minimum of two alternative frequency assignments that could be assigned to a Winning Bidder. In order to allow bidders to express their preferences for alternative frequencies, the Assignment Stage can take the form of a single round of bidding, where the Winners of Generic Lots from the Principal Stage can bid for their preferred options. This Annex describes only this option, although alternative options are possible.

A11.23 In addition, if a Competition Constraint is implemented, there would be an additional round in the Principal Stage, the Opt-in Round, where MPP Bidders would be asked to choose whether to opt in for counting towards meeting the Competition Constraint (and thus potentially benefit from a potential Competition Credit). Bidders opting in would be required to bid at reserve prices for all of their Minimum Portfolio Packages.

A11.24 Before the Principal Stage, we would determine a list of Permissible Packages for each bidder. The Permissible Packages would be those Packages which the bidder could possibly win, but not include those that could not win under any circumstances. Bidders would only be allowed to bid for their Permissible Packages.

A11.25 The assessment of Permissible Packages would take into account the spectrum caps and any other applicable bidding constraints. In addition, if a Competition Constraint is implemented, the determination of Permissible Packages would consider whether it would be feasible to award a bidder a Package and at the same time meet the Competition Constraint. Therefore, the determination of Permissible Packages would take place after the Opt-in Round.

Permissible Packages

A11.26 In this section, we describe the restrictions applying throughout the Primary Bid Rounds and Supplementary Bid Round to the Packages of Lots for which bidders may bid. In addition, the Primary Bid Rounds are governed by Activity Rules that affect the Packages a bidder may bid for in any particular round depending on previous Primary Bids submitted by the bidder. These Activity Rules are discussed subsequently in Paragraphs A11.99 to A11.143.

Spectrum caps

A11.27 We propose that all bids be liable to be subject to one or more spectrum caps as discussed in section 4 and annex 6.

A11.28 By way of example, under one option the proposed caps might be:

- 2x27.5MHz for spectrum under 1GHz for all bidders, including existing spectrum holdings of the bidder (the "Sub-1GHz Cap"); and

- 2x105MHz for spectrum in the 800MHz, 900MHz, 1800MHz, 2.1GHz (paired) and 2.6GHz (paired and unpaired) bands for all bidders, including existing spectrum holdings of the bidder (the "Overall Cap").

A11.29 The spectrum subject to the Sub-1GHz Cap would include all spectrum in the 800MHz and 900MHz bands.

A11.30 The spectrum subject to the Overall Cap would include:

a) all spectrum in the 800MHz, 900MHz, 1800MHz, and 2.1GHz (paired) bands, plus

b) all standard-power use paired spectrum in the 2.6GHz band (offered in Lot Category C), plus

c) 2x20MHz equivalent in respect of the 2.6GHz centre band (offered in Lot Category E).

A11.31 No bidder would be able to submit any bid for a Package of spectrum that would result in them exceeding any spectrum cap if the bid were to be a Winning Bid.

Contiguity requirement in each band

A11.32 We propose to set a contiguity requirement for bids in the 800 MHz band. As a consequence, a bidder would not be allowed to bid on Lot Categories linked to frequencies in the 800MHz band that are not adjacent to one another and thus could result in a non-contiguous assignment. The exact restrictions will depend on the final packaging chosen. The options for packaging are discussed in section 6.

A11.33 We also propose to set a contiguity requirement for bids in the 2.6GHz band. However, the requirement would not result in bidding restrictions within the Principal Stage. It would only lead to restrictions on the options available to Winners in the Assignment Stage.

Restrictions related to Lots in Lot Category D (2.6GHz paired low power)

A11.34 We propose that bidders are not able to bid for:

- more than one Lot in Lot Category D; or

- Packages containing more than 12 Lots in Category C and one Lot in Lot Category D.

Restrictions related to Lots in Lot Category E (2.6GHz unpaired)

A11.35 Subject to responses to this consultation, a bidder winning *n* Lots in the 2.6GHz unpaired band would have additional usage restrictions on the lowest 5MHz block, leaving *n-1* blocks available for standard use. The purpose of this restriction is to create guard blocks to manage risks of interference between adjacent users within the band. Consequently, we propose that bidders are not allowed to bid for Packages that contain only a single Lot in Lot Category E. In this case, any package containing Lots in Lot Category E would have to contain at least two such Lots.

Compatibility with the Competition Constraint

A11.36 If we implement the Competition Constraint, it will require that a sufficient number of bidders win at least one of their MPPs. In turn, this would limit the amount of spectrum available for other bidders. For this reason, it may be impossible for a bidder to win certain packages, as those packages might be incompatible with satisfaction of the Competition Constraint overall.

A11.37 For example, suppose that the Competition Constraint requires that two bidders win a MPP, and that the MPPs for each bidder include at least one Lot in a Lot Category with six Lots available. In this case, a bid including six Lots in this Lot Category could never be a Winning Bid.

Key feature A11.1: Bar on bids that cannot win

To prevent bidders from bidding on a Package they cannot win, we propose to determine (after the Opt-in Round if the Competition Constraint is implemented) the set of Permissible Packages that each bidder may bid for during the Principal Stage. The set of Permissible Packages may differ across bidders, due to bidders potentially having different MPPs and currently holding licences for spectrum that may be subject to spectrum caps.

The list of Permissible Packages for a bidder would consist of all possible Packages that:

- have an eligibility that does not exceed the initial eligibility of the bidder;
- could be awarded to the bidder without contravening the spectrum caps;
- respect the contiguity requirements in the 800MHz band detailed above;
- respect the requirements on Lots in Lot Categories D and E detailed above; and
- (if the Competition Constraint is implemented) could be awarded to the bidder and at the same time leave sufficient other spectrum for it to be possible to meet the Competition Constraint.

The Zero Package is always a Permissible Package. However, bidders

cannot specify a Bid Amount other than zero for the Zero Package. We call the bid for the Zero Package with a Bid Amount equal to zero the Zero Bid.

Each bidder would be notified of its Permissible Packages prior to the start of the Primary Bid Rounds. The Permissible Packages for each bidder would remain the same throughout the Principal Stage.

Opt-in Round

A11.38 The Opt-in Round would only be required if the Competition Constraint is implemented.

A11.39 The Opt-in Round would consist of a single round, run prior to the first Primary Bid Round in the Principal Stage. During the opt-in round, MPP Bidders with one or more non-zero Minimum Portfolio Packages would have the option to opt in for the purposes of counting towards meeting the Competition Constraint.

A11.40 MPP Bidders who opt in would be eligible to have a Competition Credit applied to their Primary Bids. MPP Bidders who decided not to opt-in, and bidders who already hold sufficient spectrum to be a National Wholesaler (for whom MPPs would not be defined and so opting in would not be an option) would not have any Competition Credit applied to their Primary Bids. The procedures for determining and applying Competition Credits are described in detail in Paragraphs A11.71 to A11.82 below.

A11.41 A bidder who wished to opt in would be required to make a bid at reserve price for each and every one of its MPPs. These would be binding bids that would be considered in the eventual determination of Winning Bids at the end of Principal Stage. Bidders would only be given the option to opt in if they have sufficient initial eligibility to allow them to bid for all of their MPPs.

A11.42 The decision to opt in has no effect on the bids that can be made during the Primary Bid Rounds and does not affect the Activity Rules that apply during the Principal Stage. Bidders who opted in would still be required to submit a Primary Bid in the first Primary Bid Round; however, the bidder would not be restricted to bidding for an MPP in the first Primary Bid Round, and therefore would be able to bid for any of the bidder's Permissible Packages (which could be larger than the MPPs).

A11.43 Subsequent to the Opt-in Round, we would determine the minimum number of bidders who must win at least one of their MPPs for the Competition Constraint to be met. This number would be the smaller of:

- the target number of MPP winners; and
- the number of Opted-in Bidders.

A11.44 Following the conclusion of the Opt-in Round, the number of opted-in bidders will be disclosed to all bidders before the start of the first Primary Bid Round.

A11.45 We propose that the opt-in round be conducted through the Electronic Auction System (EAS). The opt-in round would have start and end times in a similar manner to a Primary Bid Round or the Supplementary Bids Round.

Bidding in the Principal Stage

A11.46 Further bidding in the Principal Stage takes place in two parts, the Primary Bid Rounds and the Supplementary Bids Round. At the end of the Supplementary Bid Rounds, the winning combination of bids will be determined amongst all bids received during the auction. Bidders may not withdraw any bids; therefore, any bid submitted during the Opt-in Round, the Primary Bid Rounds or the Supplementary Bids Round may be selected as a Winning Bid.

A11.47 As explained above, prior to the first Primary Bid Round, we would provide to each bidder the list of Permissible Packages for which they may bid.

A11.48 Bidding in the Principal Stage would be subject to Activity Rules intended to prevent bidders from hiding their demand until late in the auction and thereby to promote price discovery and straightforward bidding behaviour. The proposed Activity Rules would constrain bidders when submitting bids in later rounds as a function of the Primary Bids submitted during earlier Primary Bid Rounds. The proposed Activity Rules are discussed in detail in Paragraphs A11.99 to A11.143 below.

Part 1 – The Primary Bid Rounds

A11.49 Bidding during this first part of the auction would proceed in discrete rounds, with all bidders being able to submit their bids for the round within the same fixed time window (subject to provisions for bidder-specific round extensions, details of which are not considered in this document but will be provided in the Information Memorandum).

A11.50 The Primary Bid Rounds would follow a clock auction format. Before the start of each Primary Bid Round, the auctioneer would announce a price per Lot for each Lot Category for that Primary Bid Round (the Round Prices). If a Competition Constraint is implemented, the auctioneer would also notify each Opted-in Bidder of the Competition Credit available to them in that round (which would apply to Packages that include at least one MPP for that bidder).[125] Bidders would be able to submit one single Primary Bid in each Primary Bid Round.

A11.51 A Primary Bid consists of a Package of Lots and a non-discretionary Bid Amount calculated automatically. The Bid Amount is the sum of the prices of all the Lots included in the Package less any applicable Competition Credit if the Competition Constraint is implemented.

A11.52 Competition Credits would only be available to Opted-in Bidders (i.e. bidders for which MPPs have been defined and who have opted in during the Opt-in Round) who are bidding for a Package that includes one of the bidder's MPPs. Competition Credits are only a feature of the rules if the Competition Constraint is implemented.

A11.53 In accordance with the Activity Rules, the Primary Bids submitted during the Primary Bid Rounds would limit the possibilities available to bidders for submission of bids in subsequent Primary Bid Rounds and in the Supplementary Bids Round.

A11.54 The Primary Bid Rounds would end when the Closing Condition is met. We would also be able to terminate the Primary Bid Rounds before the Closing Condition is met if we considered this to be necessary for the auction to achieve an efficient

[125]For clarity, throughout where we say that package A includes package B, then package A contains at least as many Lots in every Lot Category as package B.

outcome. The Closing Condition considers a provisional determination of winning bids given the bids received so far in the Primary Rounds. In essence, the Closing Condition requires that there is no excess demand in any Lot Category once the Competition Constraint (if applicable) is taken into account. The proposals for the assessment of Excess Demand are explained below.

A11.55 If there is Excess Demand for any Lot Category, then the Round Price of Lot Categories for which there is excess demand may be increased and a further Primary Bid Round may be run.

Scheduling Primary Bid Rounds

A11.56 Ofcom would specify in advance of the auction a minimum notice period that would be provided before the start of a Primary Bid Round and a minimum round duration. At the time at which the schedule for a Primary Bid Round is notified to bidders, each bidder would also be given information about:

- the duration of the round;
- the Round Prices for each Lot Category that would prevail in that round;
- if the bidder has opted in, the Competition Credit applying to that bidder in that round; and
- the bidder's eligibility for that Primary Bid Round (expressed as a number of eligibility points).

Determination of Excess Demand and Closing Condition

A11.57 At the end of each Primary Bid Round, a Provisional Winner Determination (PWD) is run on all bids received so far, which include:

- bids made in the current Primary Bid Round (including all Primary Bids and Chain Bids);
- all bids made in previous Primary Bid Rounds; and
- all Opt-in Bids made at reserve prices.

A11.58 The PWD would apply the same method as the final Winner Determination (described in detail in Paragraphs A11.144 to A11.164 below) to determine a provisional outcome, and therefore would require the Competition Constraint to be met if implemented.

A11.59 It is possible that the PWD may have ties. For some particular selection of tie, call the winning bids in the PWD the Provisional Winning Bids.

A11.60 A Compatible Tie is one in which every bidder would be allocated a Package that contains at least as many Lots in each Lot Category as the Package the bidder submitted a Primary Round Bid for in the round.

A11.61 The Closing Condition would require that there is at least one Compatible Tie. In the case that none of the outcomes of the PWD constitutes a Compatible Tie, then there is Excess Demand for at least one Lot Category. In this case, Ofcom would

typically increase the price for Lot Categories with Excess Demand and run a further Primary Bid Round.

A11.62 To assess which Lot Categories have Excess Demand, we propose to adopt the following rule. For a given outcome of the PWD, we define Total Demand in a Lot Category to be the sum across bidders of the greater of:

a) the number of Lots in that Lot Category included in the Primary Bid that the bidder submitted during the round (or zero if the bidder did not submit a Primary Bid); and

b) the number of Lots in that Lot Category in the bidder's Provisional Winning Bid.

A11.63 Where the Total Demand in a Lot Category exceeds the available supply of Lots in that Category in any one of the tied outcomes of the PWD, then that Lot Category would be deemed to have Excess Demand.

A11.64 The proposed definition of Total Demand takes account of the impact of potentially having to select a bid submitted during an earlier round as a Provisional Winning Bid in order to be able to satisfy the Competition Constraint (if implemented). Therefore, it takes into consideration the impact of the Competition Constraint on the supply of Lots that would be available to bidders who have submitted a Primary Bid for a non-zero Package during the round. The Closing Condition is therefore a requirement that it is possible to meet the Total Demand within the available supply.

A11.65 If Lot Category D (low-power paired 2.6GHz) is available in the auction on a non-reserved basis, then the assessment of Excess Demand for paired 2.6GHz Lots would need to consider that Lots in Lot Categories C and D are fungible. The PWD will consider the two alternative band plans for the 2.6GHz paired Lots (i.e. with or without Lot Category D). It would determine whether or not any category D Lots would be issued and, in the event they were, reduce the supply of category C Lots from 14 to 12. Therefore, Excess Demand for categories C and D should be assessed against the supply available in the band-plan selected by the PWD.

Key feature A11.2: Determination of Excess Demand in the Primary Bid Rounds

The proposed Closing Condition requires that the outcome of a Provisional Winner Determination using all bids received up to the end of a Primary Bid Round satisfies the condition that all bidders are allocated no fewer Lots in each Lot Category than they have specified in the Primary Bid they submitted in the round. This allows us to check whether all the Primary Bids submitted during a Primary Bid Round simultaneously become Winning Bids. If the Closing Condition is met, then the demand specified by bidders given the prevailing Round Prices can be accommodated, and therefore there is no Excess Demand; otherwise, there is Excess Demand in at least one Lot Category.

Competition Credit

A11.66 In the case that the Competition Constraint is implemented[126], we propose to use a system of Competition Credits to provide more accurate information about demand

[126] A possible alternative to the Competition Constraint could be to apply a bidder credit for certain bidders. This approach would involve some bidders receiving a fixed or relative reduction in the base price they would have to pay if they win. This approach could be selective, in the sense that only

during the Primary Bid Rounds. This would provide Opted-in Bidders with an estimate of the likely impact that the Competition Constraint could have on the prices they might have to pay.

A11.67 In the event that the Competition Constraint is not implemented, Competition Credits are not required; all other aspects of the rules for Round Prices and Primary and Supplementary Bids remain the same.

Key feature A11.3: Competition Credit

A Competition Credit would be determined for each Opted-in Bidder in each Primary Bid Round, after the auctioneer has set Round Prices for that round. The Competition Credit would then be applied when calculating the Package price for any Package that included at least one of the bidder's MPPs

The determination of the Competition Credit takes account of the bidding possibilities of Opted-in Bidders and how these change from one Primary Bid Round to the next. An increase in Lot prices that is caused solely by the demand from bidders who do not contribute towards meeting the Competition Constraint would not reflect the likely base price that an Opted-in Bidder benefiting from the Competition Constraint would ultimately have to pay. The Competition Credit offsets such price increases.

The Competition Credit would provide an estimate of the difference between the price of a MPP at the current Round Prices and its opportunity cost taking account of the requirement that it may be necessary to award this Package to an Opted-in Bidder for the Competition Constraint to be met..

A11.68 The Competition Credit for any particular Opted-in Bidder is determined as follows.

A11.69 First, we run a hypothetical winner determination that considers the following hypothetical bids:

- For each Opted-in Bidder, bids for any MPPs with eligibility equal to or lower than the bidder's eligibility for the Primary Round to which the Competition Credit applies, with a Bid Amount determined by the Round Prices in that same round;
- For each Opted-in Bidder, bids for any MPPs with eligibility greater than the bidder's eligibility for the Primary Round to which the Competition Credit applies, with a Bid Amount determined by the smaller of:
  - the Relative Cap that applies to bids on this MPP, if the bidder were to bid for its smallest (in terms of eligibility) Constraining Package at Round Prices; and
  - the price of this MPP at Round Prices.

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specific bidders might receive credits for certain packages. However, the credits would be pre-specified and announced to bidders prior to the auction. The value of bids actually made by the bidder would not be modified prior to determining winners. The process of winner determination and calculation of base prices would be exactly as in the main proposal (though without a Competition Constraint on the determination of winners). The bidder credit would be applied to the base price after the determination of winning bids and base prices. Therefore, bidders would need to anticipate the bidder credit they would receive if they win Lots when making their bid.

- For each Opted-in Bidder, the Zero Bid;

- A hypothetical standalone bid for each available Lot in each Lot Category at Round Prices, treating each such bid as if it were from a different notional bidder.

A11.70 These bids represent competition for Lots from Opted-in Bidders depending on their current Relative Caps and from other hypothetical demand at Round Prices. Let H1 be the total value of winning bids in the outcome of this hypothetical winner determination.

A11.71 We then run a second hypothetical winner determination that considers the same hypothetical bids, but with all the bids from the Opted-in Bidder under consideration reduced to the reserve price for the Package they relate to. Let H2 be the total value of winning bids in the outcome of this hypothetical winner determination.

A11.72 The Competition Credit for the Opted-in Bidder would then be calculated as the difference in the total value of winning bids in these two outcomes, H1 – H2.

A11.73 The resulting Competition Credit for this Opted-in Bidder would then be subject to a ceiling to ensure that the net price of any Package (i.e. after subtraction of the Competition Credit) does not decrease from one Primary Bid Round to the next. This ceiling is equal to:

- the Competition Credit calculated for this bidder in the previous Primary Bid Round; plus

- the smallest increase, across all MPPs for this bidder, in the Package price that results from increasing Round Prices this round relative to the previous Primary Bid Round.

A11.74 An example of the determination of the competition credit is provided in Paragraphs A11.200 to A11.250.

Information provided to bidders during Primary Bid Rounds

A11.75 At the end of each Primary Bid Round, Ofcom proposes to reveal to each bidder:

- the level of Total Demand and Excess Demand in each Lot Category;

- information about the Primary Bid (and any associated Chain Bids) submitted by the bidder in the last completed round;

- the eligibility of the bidder for the next round (if there is a need for a further Primary Bid Round); and

- the highest Bid Amount submitted by the bidder up to that point (which might be relevant for any deposit calls).

A11.76 Importantly, we will only reveal aggregate and excess demand in each category. Bidders will not receive any other information about the bids made by other bidders.

A11.77 If there is a need for a further Primary Bid Round, Ofcom will notify bidders of the Round Prices, and the start time and duration of this round. Each Opted-in Bidder would be informed of any Competition Credit it may apply to its bids, but not of the Competition Credit that might apply to other Opted-in Bidders.

A11.78 The EAS would include an auction history tool to allow bidders to view and download information about Total Demand and Excess Demand in each Lot Category in previous Primary Bid Rounds, and about their own bids.

A11.79 We may also publish aggregate information on our website from time to time during the Primary Bid Rounds, for example at the end of each day of bidding. Such information might cover Excess Demand and Lot prices for each Lot Category.

End of the Primary Bid Rounds

A11.80 The Primary Bid Rounds would terminate when the Closing Condition described above is met or earlier if we consider this to be in the general interest.

A11.81 The last Primary Bid Round is called the Final Primary Bid Round, and the Round Prices prevailing in the Final Primary Bid Round are called the Final Round Prices. The Package for which a bidder submits a Primary Bid in the Final Primary Round will define further constraints on the bids that the bidder may submit in the Supplementary Bids Round – we call this Package the Final Primary Package.

A11.82 After the Final Primary Bid Round, the auction will proceed to the Supplementary Bids Round.

Part 2 - Supplementary Bids Round

A11.83 The Principal Stage includes one further round of bidding, the Supplementary Bids Round, which occurs after the Final Primary Bid Round. During the Supplementary Bids Round bidders may bid for multiple mutually exclusive Packages, including Packages that they may not have bid for in any of the Primary Bid Rounds. Bidders are not required to make Supplementary Bids if they do not wish to do so.

A11.84 Bidders specify the Bid Amount for Packages they bid for in the Supplementary Bids Round. However, the Supplementary Bid on any Package for which a bidder has already bid must be greater than the highest bid made so far for that Package by that bidder. In addition, most Supplementary Bids will be subject to caps (all except possibly any Supplementary Bid for the bidder's Final Primary Package), which will set a maximum on the Bid Amount that the bidder can specify in relation to the bids for other Packages that the bidder submits, set in accordance with the Activity Rules.

A11.85 All bids received from bidders in the Opt-in Round, the Primary Bid Rounds and the Supplementary Bids Round are considered for the determination of winning bidders, Winning Bids, and prices to be paid by winning bidders.

Scheduling the supplementary round

A11.86 After the completion of the Primary Bid Rounds, Ofcom will announce the start time and duration of the Supplementary Bids Round. The minimum advance notice and minimum duration of this round will be set out in the Information Memorandum.

A11.87 Each bidder will be able to submit a single list of Supplementary Bids within the same fixed time window (subject to provisions for bidder-specific round extensions, details of which are not considered in this document but will be provided in the Information Memorandum).

Restrictions on Supplementary Bids

A11.88 There may be a limit on the number of Supplementary Bids that each bidder can make, although this is likely to be in the thousands rather than the hundreds. This will be determined by Ofcom depending on the details of the Lots available and announced in the Information Memorandum.

A11.89 The Bid Amount for each Supplementary Bid must be no less than the higher of:

- the sum of the reserve prices for all Lots included in the Package; and
- the bidder's highest bid for that package (if the bidder has submitted a bid for the package during the Opt-in Round or the Primary Bid Rounds).

A11.90 Supplementary Bids must conform with any Relative Caps and Final Price Cap applicable to each Package. These are set in accordance with the Activity Rules, described below in Paragraphs A11.99 to A11.143.

Activity Rules for the Principal Stage

A11.91 The proposed Activity Rules are intended to ensure that the preferences across different Packages expressed through a bidder's Primary and Supplementary Bids are consistent with the Primary Bids that the bidder previously made. They also discourage bidders from only revealing their demand late in the auction. As a result, the proposed mechanisms should strengthen incentives for straightforward bidding during the Primary Bid Rounds.

A11.92 The activity rules are based on an assessment of overall demand by a bidder across the various Lot Categories. This assessment uses an eligibility points system:

- Each Package has an associated number of eligibility points.
- Each bidder starts the auction with an initial eligibility, determined by the deposit lodged with Ofcom before bidding starts. The eligibility of each bidder in the first Primary Bid Round will be equal to the bidder's initial eligibility.
- During the Primary Bid Rounds, the eligibility of the bidder will be reduced if the bidder submits a Primary Bid for a Package with eligibility smaller than the bidder's eligibility in the round – in this case, the eligibility of the bidder after this round will be set equal to the eligibility of the Package for which it has just submitted a Primary Bid.
- Therefore, the eligibility of a bidder may stay the same or decrease over successive Primary Bid Rounds, but cannot increase.

Eligibility of a Package

A11.93 Each Lot Category in the auction has an associated number of eligibility points per Lot. The eligibility of a Package is calculated as the sum of:

- the eligibility points of all the Lots included in the Package, except for Lots in Lot Category E; and
- if the package includes *n* Lots in Lot Category E, the eligibility points associated with *n-1* Lots in Lot Category E.

A11.94 The special treatment of Lots in Lot Category E reflects the requirement that if a bidder wins *n Lots* in Lot Category E, then only *n-1* of these Lots are available for use under standard terms, with one Lot having more restricted usage conditions.

Types of Primary Bids

A11.95 In any Primary Bid Round, a bidder may submit a Primary Bid for any Permissible Package with eligibility equal to the bidder's eligibility in the round. We call such bids Full Eligibility Primary Bids. The eligibility of a bidder will remain the same for the following round if the bidder submits a Full Eligibility Primary Bid.

A11.96 A bidder may also submit a Primary Bid for a Package with eligibility smaller than the bidder's eligibility, in which case the bidder's eligibility will be reduced to the eligibility of the Package for which the bidder has submitted a Primary Bid. We call such bids Constraining Primary Bids.

A11.97 In some cases a bidder may also submit a Primary bid for a Package with eligibility greater than the bidder's eligibility in the round. However, any such bids must be consistent with the preferences that the bidder has expressed in previous rounds, in particular previous rounds in which the bidder dropped eligibility. Any such bid would be a Capped Primary Bid, and would be subject to a Relative Cap determined by the Constraining Primary Bid. The eligibility of a bidder will be maintained, but not increased, if the bidder submits a Capped Primary Bid.

A11.98 Bidders can submit a Zero Bid during the Primary Bid Rounds to indicate that they do not wish to make any further Full Eligibility or Constraining Primary Bids. In this case, the eligibility of the bidder will be set to zero for the following rounds. However, a bidder with zero eligibility may still be able to submit Capped Primary Bids and will still be able to submit Supplementary Bids.

Relative caps

A11.99 Relative Caps arise only as a result of a bidder dropping eligibility during the Primary Bid Rounds. Therefore, if a bidder does not drop eligibility in a given Primary Bid Round, no Relative Caps are created by its Primary Bid.

A11.100 The idea behind the Relative Caps is that when the bidder drops eligibility it is stating a preference to reduce its demand to a Package with lower eligibility given the price differentials between those packages that result from prevailing Round Prices. In particular, the bidder is indicating that it is not prepared to pay more than a certain amount extra for any larger package (where "larger" is measured in eligibility point terms). The Relative Cap prevents that bidder from subsequently returning to bid for any larger package at a greater premium than it had previously been unwilling to pay.

A11.101 This means that the difference in value between a Package subject to the Relative Cap and the Package for which the bidder submitted the Constraining Primary Bid associated with this package should not exceed the price difference between these two Packages in the round where the Constraining Primary Bid was submitted.

A11.102 In practice, for any Package subject to a Relative Cap, we therefore need to identify the first Primary Bid that resulted in the bidder's eligibility falling below the eligibility of the Package (the Constraining Primary Bid). The Relative Cap will be calculated in relation to this Constraining Primary Bid. We then use the following terminology:

- **Capped Primary Bid**: the bid that the bidder wishes to make in this current Primary Bid Round for a Package that exceeds its current eligibility.

- **Constraining Package**: the Package to which the Constraining Primary Bid relates.

- **Constraining Round**: the Primary Bid Round in which the bidder submitted the Constraining Primary Bid.

- **Stated Differential**: the price difference (taking account of any applicable Competition Credit) between the Package subject to the Relative Cap (i.e. the Capped Bid) and the Constraining Package in the Constraining Round. (The Stated Differential may be positive or negative.)

A11.103 The Relative Cap requires that the Bid Amount specified for the Capped Primary Bid not exceed the greatest bid that the bidder has submitted for the Constraining Package[127] plus the Stated Differential. Relative Caps apply to all Capped Primary Bids that a bidder may submit. They also apply to Supplementary Bids.

A11.104 All Supplementary Bids for Packages with eligibility greater than the bidder's eligibility in the Final Primary Bid Round are also subject to a Relative Cap calculated as follows. Let Y be the Constraining Package for Package X. Then, the Supplementary Bid for Package X may not exceed:

- the highest bid that the bidder submits for Y plus

- the Stated Differential between Y and X (i.e. the difference between the price of Y and X in the Constraining Round, taking into account any applicable Competition Credit).

Submitting Capped Primary Bids

A11.105 A bidder will only be able to submit a Capped Primary Bid on a Package if it is consistent with the Relative Cap applicable to this Package. This requires that the difference in price between this Package and the Constraining Package at prevailing Round Prices is not greater than the Stated Differential[128].

A11.106 A bidder who is able to submit a Capped Primary Bid may also be required to increase its bids for the corresponding Constraining Packages to a given minimum bid amount to ensure that the Capped Primary Bid is consistent with the applicable Relative Caps. Such bids are called Chain bids. The bidder would need to submit the Chain bids for these minimum Bid Amounts along with the Capped Primary Bid.

A11.107 Chain bids may in turn also be subject to a Relative Cap, so that placing a Capped Primary Bid would also require that all necessary Chain bids are consistent with the Relative Cap. This constraint requires that the difference in price between the Package for which a Chain bid is required and its Constraining Package at prevailing Round Prices is not greater than the corresponding Stated Differential.

[127] The bidder may, however, be allowed to submit a higher bid for the Constraining Package in the same round as the Capped Primary Bid – a Chain Bid – provided that this bid satisfies similar conditions..

[128] This is a simplified statement of the conditions under which a bidder may submit a Capped Primary Bid – see below for a more complete exposition.

A11.108 If the Bid Amount of one or more of the associated Chain Bids exceeds the price of the Package to which it relates at the current Round Prices (net of any applicable Competition Credit), then it would not be possible to make the Capped Primary Bid in the current round. However, this does not rule out the possibility that a Capped Primary Bid might be possible for the same Package in some later Primary Bid Round, depending on the subsequent evolution of Round Prices.

A11.109 We intend that the EAS will provide functionality to assist bidders in determining when Capped Primary Bids are feasible given the prevailing Round Prices and the Constraining Primary Bids submitted by the bidder in earlier rounds. When making a Capped Primary Bid, it would only be necessary for a bidder to enter the Package that is the subject of its Capped Primary Bid. Any required Chain Bids would be identified by the EAS and notified to the bidder before submission of the bids. At this stage, the bidder would have to confirm that it wished to submit not only the Capped Primary Bid but also all of the identified Chain Bids. If the bidder were unwilling to make any of the necessary Chain Bids, then that bidder would not be allowed to submit the Capped Primary Bid.

Chain bids

A11.110 The Bid Amount for a Chain bid will be set to the minimum Bid Amount necessary for the Capped Primary Bid to be consistent with the Relative Cap. This Bid Amount is calculated as follows.

A11.111 Let Y be the Constraining Package for the Relative Cap on Package X. Then, the Bid Amount required for the Chain Bid on Package Y is equal to:

- the Price of Package X at prevailing Round Prices; minus
- the Stated Differential (i.e. the difference in price between Package X and Package Y at the Round Prices prevailing in the Constraining Round).

A11.112 In turn, if a Chain Bid is also subject to a Relative Cap, then an additional Chain Bid would be required, for a Bid Amount calculated as follows.

A11.113 Let Z be the Constraining Package for the Relative Cap on Package Y. Then, the Bid Amount required for the Chain Bid on Package Z is equal to:

- the Bid Amount for the required Chain Bid for Package Y; minus
- the Stated Differential (i.e. the difference in price between Package Y and Package Z at the Round Prices prevailing in the Constraining Round).

A11.114 The EAS would identify any required Chain Bids necessary for a Capped Primary Bid to be consistent with the Relative Cap, and the bidder would only need to confirm that it wishes to submit the Chain Bids at the same time as the Capped Primary Bid.

Final Price Cap

A11.115 A further constraint on Supplementary Bids only, the Final Price Cap, results from the Primary Bid submitted by the bidder in the Final Primary Bid Round. We call the Package for which the bidder submits a Primary Bid in the Final Primary Round the Final Primary Package.

A11.116 The Final Price Cap limits the Bid Amount of all Supplementary Bids for any Package other than the Final Primary Package. The cap is the highest bid that the bidder submits for the Final Primary Package plus the price difference between the Package subject to the Final Price Cap and the Final Primary Package in the final Primary Bid Round. We call this price difference the Final Price Differential.

A11.117 Therefore, all Supplementary Bids for Packages other than the Final Primary Package are subject to the Final Price Cap. The Final Price Cap is calculated as follows. Let F be the Final Primary Package. Then, the Supplementary Bid for any other package X may not exceed:

- the highest bid that the bidder submits for F plus
- the Final Price Differential between X and F (i.e. the difference between the prices of X and F in the Final Primary Round, taking into account any applicable Competition Credit).

A11.118 The concept behind the Final Price Cap is similar to the Relative Cap. However, the Final Price Cap applies to all Packages other than the Final Primary Package regardless of their eligibility.

A11.119 The purpose of the Final Price Cap is to ensure that if a bidder submits Supplementary Bids for Packages other than its Final Primary Package, any incremental value that these bids express over the highest bid that the bidder submits for the Final Primary Package cannot exceed the Final Price Difference. A consequence of this rule is that bidders are limited in terms of submitting Supplementary bids for Packages they did not bid for in the final Primary Bid Round that could overturn the outcome achieved in the final Primary Bid Round. Therefore, a bidder can ensure it wins its Final Primary Package provided it makes a sufficiently high Supplementary Bid for this Package (and does not raise the amount of previous Primary Bids for other packages too much). We believe this is desirable as it provides greater certainty for bidders and improves price discovery.

Managing Caps in the Supplementary Bids Round

A11.120 Supplementary Bids for all Packages other than the Final Primary Package are subject to the Final Price Cap. In addition, any Supplementary Bid for any Package with eligibility greater than the bidder's eligibility in the Final Primary Bid Round are subject to Relative Caps.

A11.121 Because bidders have the option of submitting a Capped Primary Bid (i.e. a Primary Bid for a Package that is subject to a Relative Cap) in the Final Primary Round, and given that all bids for other Packages will be subject to the Final Price Cap, it is possible that bidders enter the Supplementary Bid Rounds with caps on all Packages. However, as all such caps are relative caps, it will still be possible for such a bidder to raise all of its bids provided that this is done 'simultaneously' such that the appropriate relativities between bids are preserved consistent with the applicable caps.[129]

A11.122 A bidder who faces caps on all its Supplementary Bids would enter the Supplementary Bids Round with a set of bids that is already consistent with the

[129] A bidder who has submitted the Zero Bid at some stage during the Primary Bid Rounds will however be unable to raise their bids beyond a certain limit since all their bids will need to comply with the Relative Cap relative to this Zero Bid.

caps, as the bidder would have already been required to submit any necessary Chain bids to ensure consistency with the Relative Caps. In order to raise the bid for its Final Primary Package (submit a Supplementary Bid for this Package), the bidder would then need to raise the corresponding Chain bids in order to satisfy all the constraints. The EAS will provide functionality to assist bidders in identifying the Chain bids that need to be increased if the bidder makes a Supplementary Bid for the Final Primary Package in such a case.

A11.123 If a bidder submits a Full Eligibility or a Constraining Primary Bid in the Final Primary Round, the Supplementary Bid Amount for its Final Package will be uncapped. However, if the bidder submits a Capped Primary Bid in the Final Primary Round, then all its Supplementary Bids will be capped (relatively by other bids).

A11.124 Bidders may submit a Supplementary Bid for any Permissible Package, provided that these bids are consistent with the applicable Relative Caps and the Final Price Cap.

A11.125 Examples of diverse situations that bidders could face in relation to the caps on their Supplementary Bids are provided in Paragraphs A11.184 to A11.199.

Key feature A11.4: the Activity Rules

The proposed Activity Rules provide a mechanism by which a bidder is able, and is incentivised, to bid for its most preferred Package of Lots at the prevailing Round Prices in each and every Primary Bid Round. The rules require that bids are compatible with the Relative Caps applicable to Packages with eligibility greater than the bidder's eligibility that result from the bidder's previous Primary Bids. The proposed rules depart from the rules used in previous Ofcom auctions, but provide valuable additional flexibility for Bidders as:

- first, it is possible for bidders to switch demand across Lot Categories from one Primary Bid Round to the next whilst maintaining overall Eligibility (i.e. when submitting Full Eligibility Primary Bids);
- second, bidders may reduce their overall demand (measured in eligibility points) without undermining their possibilities to bid again for Packages with greater eligibility if price differentials between different Lot Categories are reversed in subsequent rounds.

These rules allow a bidder always to bid for its preferred Package at a given set of Round Prices provided it has consistently done so in previous rounds. In addition, a Final Price Cap applies to Supplementary Bids for any Packages other than the Final Primary Package, in order to *incentivise* a bidder to bid for its preferred Package at the Round Prices prevailing in each Primary Bid Round.

The proposed Activity Rules are intended to improve demand revelation and price discovery during the Primary Bid Rounds. Overall, we expect that the proposed activity rules will provide a greater degree of certainty about the possible outcomes of the Principal Stage once the Primary Bid Rounds end:

- The possibility of submitting Capped Primary Bids allows bidders to bid for their most preferred Package of Lots at current prices in each and every Primary Bid Round. This means that bidders can switch back to bidding for Packages with greater eligibility in the event that

price differentials are reversed.

- At the same time, the Final Price Cap creates an incentive for bidders to bid for their most preferred Package in each round in order not to end up with a Final Price Cap that does not allow them to express their relative valuations fully.

Bidders must have sufficient flexibility to bid for the Package that they most prefer at the prevailing Round Prices in each Primary Bid Round if we are to impose the Final Price Cap. Otherwise, bidders could end up with a Final Price Cap that is tighter than the Relative Cap that applies to Packages with eligibility greater than their eligibility in the Final Primary Round. This would undermine the incentives for bidders to bid for their preferred Package during the Primary Bid Rounds, and could lead to bidders bidding for larger (but less attractive) Packages in order to maintain greater flexibility in the Supplementary Bids Round. A consequence is that the implementation of the Final Price Cap cannot be separated from allowing bidders to submit Capped Primary Bids.

Under the proposed Activity Rules, the eligibility of a bidder does not in itself determine whether the bidder can bid for a Package during the Primary Bid Rounds, but rather determines which Packages are subject to Relative Caps and which not. Whether or not a bidder can submit a Primary Bid for a Package with eligibility greater than the bidder's eligibility in the round depends on Lot prices and the bidder's history of previous Primary Bids. To be able to bid for a Package that exceeds a bidder's current eligibility, it is necessary for such a bid to be consistent with the preferences expressed through the earlier bids made by the bidder.

There is no necessity that a bidder uses the facility to make Capped Primary Bids unless it wishes to do so. However, failing to do so in the Final Primary Bid Round may result in the bidder being unable to express its full value for all Packages as result of the Final Price Cap.

For instance, suppose that a bidder starts by bidding for Package A, but this Package becomes too expensive relative to an alternative Package B and the bidder switches to bidding on Package B. Suppose that Package B has a smaller eligibility than Package A (for example, the bidder might need fewer Lots in a different band). Without the opportunity to make Capped Primary Bids, the bidder would not be able to bid again for Package A in the Primary Bid Rounds, even if in some future round Package B once again became relatively expensive compared with Package A.

In contrast, the proposed Activity Rules would permit such a bid provided that Lot prices have changed in a way that a bid for Package A can be made consistent with the Relative Cap. Specifically, the bidder will be able to switch back again if the price difference between Package A and Package B in a subsequent round is smaller than the price differential between the two Packages in the round when the bidder dropped eligibility.

In some cases, to make a consistent bid for Package A it may be necessary to raise a bidder's previous bids for Package B. Such bids are Chain Bids. They are additional bids associated with a Capped Primary Bid that raise previous bids for certain Packages already bid for in an earlier round. They are set at the minimum level necessary to ensure consistency with the Relative Caps.

If implemented, we intend the EAS to assist Bidders with the identification of possible Packages that can be subject to Capped Primary Bids and any associated Chain Bid(s) that may need to be submitted along with the Capped Primary Bid. Bid Amounts would be non-discretionary. There would typically be only a small number of such Chain Bids needed.

Determining the winners of the Principal Stage

A11.126 Following the Supplementary Bids Round, all bids received throughout the Principal Stage will be considered to determine the winning bids. These include all bids submitted:

- in the Opt-in Round (if the Competition Constraint is implemented);
- in the Primary Bid Rounds; and
- in the Supplementary Bids Round.

A11.127 Each bidder would also be considered to have submitted a Zero Bid (i.e. a bid of zero for a Package comprising no Lots) to represent the possibility of the bidder losing entirely.

A11.128 The selection of Winning Bids maximises the total value of Winning Bids, subject to:

- accepting at most one bid from each Bidder;
- ensuring that all the Lots included in the Winning Bids can be awarded given the available spectrum; and
- if implemented, the Competition Constraint being met.

A11.129 The process of selecting the winning bids on the basis of such an optimisation is called Winner Determination.

A11.130 If the Competition Constraint is implemented, it will require that a sufficient number of bidders win packages that include at least one of their respective Minimum Portfolio Packages (MPP). The number of bidders required to win a MPP would be adjusted in the event that an insufficient number of bidders have opted in for the Competition Constraint to be feasible.

A11.131 The prices that winning bidders would need to pay (Base Prices) would then be determined using an algorithm that identifies the opportunity cost that each winning Bidder and group of winning Bidders impose on other Bidders who are denied spectrum by virtue of the available Lots being allocated to the winning bidders.

Winner determination without the Competition Constraint

A11.132 We first describe the simpler case in which the Competition Constraint is not implemented.

A11.133 The winner determination process would select one bid from each bidder (which may be the Zero Bid) in order to maximise the total value of Winning Bids such that no more Lots are awarded than are available. In the event that low-power 2.6GHz

paired Lots are available with variable supply, this condition must also consider that if any D Lots are awarded, then only 12 C Lots will be available.

A11.134 If there is only one combination of bids that meet these criteria, this will be the winning outcome that determines the Winning Bids and Winning Bidders.

A11.135 In the event of any tie amongst multiple combinations of Winning Bids of equal total value, we propose that the tie-breaking rule maximises the similarities between the outcome of the auction and the Final Primary Packages of each bidder. We, therefore, propose where possible to select outcomes where winners do not win fewer Lots than they bid for in the Final Primary Bid Round. However, because the final outcome may differ from the outcome in the Final Primary Bid Round in more than one Lot Category, we propose to give greater weight to differences in Lot Categories with greater eligibility points.

A11.136 Under this approach, the tie would be selected amongst those which have the smallest sum, across bidders and across Lot Categories, of the larger of:

- the number of Lots in the Final Primary Package minus the number of Lots in the winning bid for that bidder; and
- zero (we do not penalise deviations that imply allocating more rather than fewer lots to a bidder).

weighted by the eligibility points per Lot of the relevant Lot category.

A11.137 If ties still remain after application of this first tie-breaking criterion the combination of winning bids would be selected amongst those that have the greatest number of winners. If ties still remain after application of this second tie-breaking criterion, the combination of winning bids would be selected at random from amongst the remaining ties.

Winner determination with a Competition Constraint

A11.138 If a Competition Constraint is applied, the combination of Winning Bids will have the additional constraint that a sufficient number of Winning Bidders are allocated at least one of their MPPs.

A11.139 For the purposes of counting the number of bidders that win a MPP, only Opted-in Bidders would be counted.

Determining base prices for Winning Bids in the Principal Stage

A11.140 Following the determination of Winning Bids in the Principal Stage, Ofcom would proceed to determine Base Prices. These would be the minimum prices to be paid by Winning Bidders for the Lots they would be allocated.[130]

A11.141 A separate Base Price would be determined for each Winning Bid (and thus for each Winning Bidder). Note that the Base Prices relate to the overall package of Lots won by Winning Bidders, not individual Lots within these packages.

[130] These are minimum prices because bidders may have to pay an additional price in order to win particular frequencies through the Assignment Stage.

A11.142 Base Prices will reflect the individual and collective opportunity costs of bidders winning spectrum. They are calculated such that if all Winners had specified a Bid Amount equal to the Base Price for their Winning Bid, and reduced the Bid Amount of all their other bids by the same extent, then:

- the outcome of the winner determination process would be the same as the outcome of the Principal Stage; and
- no winner could have lowered their Winning Bid Amount any further without changing the outcome of the winner determination process.

A11.143 Annex 12 sets out in detail the proposed methodology for calculating base prices.

End of Principal Stage

A11.144 Once we have determined the Winning Bids, the Winning Bidders and the Base Prices, we will announce the outcome of the Principal Stage to bidders.

A11.145 We will notify bidders individually of the Lots they have won and the applicable Base Price, and require them, if necessary, to increase their deposit to be no less than their Base Price. Once Winning Bidders have topped-up their deposits to this level, the following information will be released to all bidders and may be published by Ofcom:

- the identity of the Winning Bidders; and
- the number of Lots won in each of the categories by each Winning Bidder.

A11.146 Following this, specific frequencies would be assigned to all Winners based either on the allocation of specific Lots in the Principal Stage or the outcome of a follow-up process of assignment described in the following sub-section.

Assignment Stage

A11.147 The Principal Stage determines how many Lots each bidder receives in each Lot category. In the case of Lot Categories consisting of generic Lots which are not associated with specific frequencies, a further mechanism is required to locate winners from the Principal Stage at particular frequencies.

A11.148 There are a number of options for how the process of frequency allocation could be achieved:

- Negotiation between Principal Stage winners with Ofcom imposing a decision if no agreement is achieved before a specified deadline;
- Negotiation between Principal Stage winners with an Assignment Stage auction being run if no agreement is achieved before a specified deadline;
- Moving directly to an Assignment Stage auction after the conclusion of the Principal Stage.

A11.149 None of these alternatives has any effect on the rules for an Assignment Stage auction. In the event that pooling of winning Lots from the Principal Stage is allowed, it would only be permitted in cases where such pooling of winning Lots still permitted frequencies to be allocated as a single contiguous block. In such cases, the pooled interests would simply operate as a single bidder in the Assignment

Stage having won a certain number of Lots in total in each Lot Category in the Principal Stage. The Assignment Stage auction would not be otherwise affected.

A11.150 The Assignment Stage auction would consist of a single round of bidding, which will allow winners to express preferences for the specific frequencies at which their Lots might be located by submitting assignment bids for alternative assignment options. At the end of this stage, winning bidders will be assigned specific frequencies equal in bandwidth to the Lots in each Lot Category that they were allocated in the Principal Stage. Where a number of winners of the Principal Stage compete for the same frequency range in the Assignment Stage, the bidder who is allocated a contested frequency range may have to pay an additional price no greater than its assignment bid.

A11.151 In order for a Lot Category to appear in the Assignment Stage:

- there must be more than one Lot in the Lot category; and
- there must be at least two alternative assignment options for winners of spectrum in the Lot Category once the contiguity rule described below has been applied.

Contiguity rule

A11.152 The contiguity rule imposes a restriction on assignment options such that where a bidder is allocated Lots in Lot Categories that are adjacent to one another, assignment options will be limited to those that ensure that such a bidder's frequency assignment is in one contiguous block in each band.

Bidding in the Assignment Stage

A11.153 In the Assignment Stage, winners in the Principal Stage that have been allocated at least one Lot which has not automatically been assigned to specific frequencies are presented with the alternative frequency ranges available to them based on the package they have won in the Principal Stage. During the Assignment Stage, these winners have an opportunity to make an assignment bid in respect of each of the specific frequency ranges they could be assigned. Bidders that have been awarded one or more Lots in a Lot Category in the Principal Stage are guaranteed to win one of the specific frequency ranges in the relevant Lot Category equal in bandwidth to the Lots allocated to them in the Principal Stage regardless of the assignment bids they make. As such, bidders are not under any obligation to submit bids in the Assignment Stage, but may choose to do so if they wish.

A11.154 Each bidder will be provided with an electronic bid form listing the alternative frequencies ranges available to them given the Lots they won in the Principal Stage and the effect of the contiguity rule. Bidders may bid an amount for one or more of the assignment options.

A11.155 If a bidder does not enter a bid for one or more assignment options, it will be deemed to have entered a bid of zero for those assignment options.

Determining winners in the Assignment Stage

A11.156 The winning bids from the Assignment Stage will be determined for each Lot Category separately by selecting the combination of assignments of specific frequency ranges to winners that yields the greatest sum of winning Assignment Stage bid amounts. In the event of a tied outcome with more than one assignment

producing the same total value of winning bid amounts, the tie will be broken by selecting one of the tied outcomes at random.

Determining additional prices for winning bids in the Assignment Stage

A11.157 Following the determination of winning assignment bids in the Assignment Stage, Ofcom will proceed to determine the additional prices, that is, the amounts (over and above the base prices) to be paid by winning bidders for the specific frequencies they have been assigned.

A11.158 A separate additional price is determined for each winning bid (and thus for each winning bidder).

A11.159 Additional prices are calculated such that if all winners had specified a bid amount equal to the additional price for their winning bid, and reduced the bid amount of all other assignment stage bids they submitted by the same extent,

- the outcome of the winner determination process would be the same as the outcome of the Assignment Stage; and
- no winner could have lowered their winning bid amount any further without changing the outcome of the winner determination process.

A11.160 Additional prices are determined jointly for all winners in a single calculation similar to that used to determine base prices.

End of the Assignment Stage

A11.161 Following the completion of the Assignment Stage, each winning bidder will be told:

- the exact frequency ranges awarded to them; and
- the total price to be paid by them, which will be the sum of the base price for their winning bid in the Principal Stage and the additional price (if any) for their winning bid in the Assignment Stage.

A11.162 Bidders are required to pay the outstanding balance on their total price (taking account of any funds deposited with Ofcom during the course of the auction process if not forfeit) within a pre-specified timeframe, before a licence for frequencies assigned to the bidder in the auction is granted.

Completion of the award process

A11.163 Following the payment of licence fees and the grant of licences, Ofcom will complete the award process by publishing on its website details of all bids made in the Principal Stage and Assignment Stage by each Bidder, the names of all licensees, the details of the frequencies comprised in the licences awarded and the licence fees paid. We will also publish the names of any winning bidders that did not comply with the deposit requirements applicable in the award and that were therefore excluded from the award process in accordance with the auction rules. Where relevant, we will also publish details of the frequencies that would otherwise have been assigned to excluded bidders and the licence fees that they would have been required to pay.

A11.164 If one or more Lots are not awarded as part of the award process, we retain the discretion to award the remaining Lots through a separate award process.

Examples of how the proposed activity rules apply

A11.165 To shed further light on the discussion above, we present here some examples of a bidder bidding across a number of primary bid rounds and then making some supplementary bids. For simplicity, we suppose that only Lots in two categories, A and B, are offered in the auction, with attributes shown in Figure A11.3.

Figure A11.3: Lots available

Lot Category	Lots available	Eligibility points per Lot	Reserve per Lot (£ million)
A	5	2	2
B	5	1	1

A11.166 In the examples below, we use the notation B(*X*) to represent the greatest bid submitted by the bidder for package *X*.

Example 1: The bidder does not bid in the Final Primary Round

A11.167 Suppose that the bidder has the following valuations for different packages of Lots across these Lot categories:

Figure A11.4: Valuations for packages (example 1)

Package ID	Number of A Lots	Number of B Lots	Assumed valuation (£ million)	Activity of package
1	3	0	20.1	6
2	2	1	15	5
3	0	4	13	4

A11.168 In Figure A11.13 we provide an example of the implied cost and payoff for each one of the packages shown in Figure A11.12 for a given scenario of round prices. The bidder's preferred package (the one providing greatest payoff) in each round is highlighted in orange.

Figure A11.5: Bid submitted in the primary bid rounds (example 1)

Round	Round price for A Lots (£ million)	Round price for B Lots (£ million)	Package 1		Package 2		Package 3		Bidder eligibility in round	Eligibility associated with preferred package
			Price (£ million)	Payoff (£ million)	Price (£ million)	Payoff (£ million)	Price (£ million)	Payoff (£ million)		
1	2	1	6	14.1	5	10	4	9	6	6
2	3	1	9	11.1	7	8	4	9	6	6
3	4	1	12	8.1	9	6	4	9	6	4
4	5	1	15	5.1	11	4	4	9	4	4
5	5	2	15	5.1	12	3	8	5	4	6
6	6	3	18	2.1	15	0	12	1	4	6
7	7	3	21	-0.9	17	-2	12	1	4	4
8	8	3	24	-3.9	19	-4	12	1	4	4
9	8	4	24	-3.9	20	-5	16	-3	4	0
10	8	5	24	-3.9	21	-6	20	-7	0	0
11	8	6	24	-3.9	22	-7	24	-11	0	0
12	9	6	27	-6.9	24	-9	24	-11	0	0

Primary bids

A11.169 Assuming that the bidder always bids for the package that would provide the greatest payoff, we would expect the following bids:

Figure A11.6: Primary bids and required chain bids (example 1)

Round	Package bid for	Type	Chain of caps that apply to preferred package (£ million)	Required chain bids (£ million)
1	1	Full Eligibility	none	none
2	1	Full Eligibility	none	none
3	3	Constraining	none	none
4	3	Full Eligibility	none	none
5	1	Capped	B(3)+8 (relative cap from primary bid in round 3)	Bid of 7 for package 3; chain bid required.
6	1	Capped	B(3)+8 (relative cap from primary bid in round 3)	Bid of 10 for package 3; chain bid required.
7	3	Full Eligibility	none	none
8	3	Full Eligibility	none	none
9	0	Constraining	none	none
10	0	Full Eligibility	none	none
11	0	Full Eligibility	none	none
12	0	Full Eligibility	none	none

Supplementary bids

A11.170 In the supplementary bids round, the bidder can place additional bids. Any supplementary bid for a package must exceed the highest bid made for that package so far, and must respect both any relative caps and the final price cap that may apply to the package. As the bidder has not placed a bid in the final primary round, the relative caps are calculated in relation to the zero package, for which the bidder cannot bid any amount different than zero. Therefore, all the supplementary bids that this bidder may submit are subject to an absolute cap.

A11.171 The caps applicable to each package are shown in Figure A11.7. As the bidder has bid for its preferred package in all primary rounds, the bidder can bid its full valuation for all packages, as this is consistent with the relative caps and the final price cap.

Figure A11.7: Supplementary bids (example 1)

Package ID	Constraining Package				Final Price Cap			Supplementary Bid amount (£ million)	Applicable caps given Supplementary Bids submitted (£ million)
	Constraining Package	Constraining Round	Stated Differential (£ million)	Calculation of the cap (£ million)	Final Primary Package	Final Price Differential (£ million)	Calculation of the cap (£ million)		
1	3	3	12-4=8	B(3)+8	0	27-0=27	B(0)+27; as B(0)=0, this is an absolute cap of 27	20.1	13+8=21; 27
2	3	3	9-4=5	B(3)+5	0	24-0=24	B(0)+24; as B(0)=0, this is an absolute cap of 24	15	13+5=18; 24
3	0	9	16-0=16	B(0)+16; as B(0)=0, this is an absolute cap of 16	0	24-0=24	B(0)+24; as B(0)=0, this is an absolute cap of 24	13	16; 24

Example 2: The bidder places a Full Eligibility primary bid in the final primary round

A11.172 Suppose that the bidder has the following valuations for different packages of Lots across these Lot categories:

Figure A11.8: Valuations for packages (example 2)

Package ID	Number of A Lots	Number of B Lots	Assumed valuation (£ million)	Activity of package
1	3	0	30	6
2	2	1	27	5
3	0	4	27.1	4

A11.173 In Figure A11.9 we provide an example of the implied cost and payoff for each one of the packages shown in Figure A11.8 for a given scenario of round prices. The bidder's preferred package (the one providing greatest payoff) in each round is highlighted in orange.

Figure A11.9: Bid submitted in the primary bid rounds (example 2)

Round	Round price for A Lots (£ million)	Round price for B Lots (£ million)	Package 1		Package 2		Package 3		Bidder eligibility in round	Eligibility associated with preferred package
			Price (£ million)	Payoff (£ million)	Price (£ million)	Payoff (£ million)	Price (£ million)	Payoff (£ million)		
1	2	1	6	24	5	22	4	23.1	6	6
2	3	1	9	21	7	20	4	23.1	6	4
3	4	1	12	18	9	18	4	23.1	4	4
4	5	1	15	15	11	16	4	23.1	4	4
5	5	2	15	15	12	15	8	19.1	4	4
6	6	3	18	12	15	12	12	15.1	4	4
7	7	3	21	9	17	10	12	15.1	4	4
8	8	3	24	6	19	8	12	15.1	4	4
9	8	4	24	6	20	7	16	11.1	4	4
10	8	5	24	6	21	6	20	7.1	4	4
11	8	6	24	6	22	5	24	3.1	4	6
12	9	6	27	3	24	3	24	3.1	4	4

Primary bids

A11.174 Assuming that the bidder always bids for the package that would provide the greatest payoff, we would expect the following bids:

Figure A11.10: Primary bids and required chain bids (example 2)

Round	Package bid for	Type	Chain of caps that apply to preferred package (£ million)	Required chain bids (£ million)
1	1	Full Eligibility	none	none
2	3	Constraining	none	none
3	3	Full Eligibility	none	none
4	3	Full Eligibility	none	none
5	3	Full Eligibility	none	none
6	3	Full Eligibility	none	none
7	3	Full Eligibility	none	none
8	3	Full Eligibility	none	none
9	3	Full Eligibility	none	none
10	3	Full Eligibility	none	none
11	1	Capped	B(3)+5 (relative cap from primary bid in round 2)	Bid of 19 for package 3; as the bidder has already bid above this amount for this package in round 10, no chain bid required.
12	3	Full Eligibility	none	none

Supplementary bids

A11.175 In the supplementary bids round, the bidder can place additional bids. Any supplementary bid for a package must exceed the highest bid made for that package so far, and must respect both any relative caps and the final price cap that may apply to the package. As the bidder has placed an Full Eligibility primary bid in the final primary round, the supplementary bid on the package it bid for in the final primary bid round is uncapped.

A11.176 The caps applicable to each package are shown in Figure A11.11.

Figure A11.11: Supplementary bids (example 2)

Package ID	Constraining Package				Final Price Cap			Supplementary Bid amount (£ million)	Applicable caps given Supplementary Bids submitted (£ million)
	Constraining Package	Constraining Round	Stated Differential (£ million)	Calculation of the cap (£ million)	Final Primary Package	Final Price Differential (£ million)	Calculation of the cap (£ million)		
1	3	2	9-4=5	B(3)+5	3	27-24=3	B(3)+3	30	27.1+5=32.1 27.1+3=30.1
2	3	2	7-4=3	B(3)+3	3	24-24=0	B(3)+0	27	27.1+3=30.1 27.1+0=27.1
3	na	na	na	No cap applicable	3	na	No cap applicable	27.1	None

Example 3: The bidder places a Capped primary bid in the final primary round

A11.177 We now suppose that the bidder has the following valuations for the different packages of Lots:

Figure A11.12: Valuations for packages (example 3)

Package ID	Number of A Lots	Number of B Lots	Assumed valuation (£ million)	Activity of package
1	3	0	61	6
2	2	1	58.1	5
3	0	4	52	4

A11.178 In Figure A11.13 we provide an example of the implied cost and payoff for each one of the packages shown in Figure A11.12 for a given scenario of round prices. The bidder's preferred package (the one providing greatest payoff) in each round is highlighted in orange.

Figure A11.13: Bid submitted in the primary bid rounds (example 3)

Round	Round price for A Lots (£ million)	Round price for B Lots (£ million)	Package 1		Package 2		Package 3		Bidder eligibility in round	Eligibility associated with preferred package
			Price (£ million)	Payoff (£ million)	Price (£ million)	Payoff (£ million)	Price (£ million)	Payoff (£ million)		
1	2	1	6	55	5	53.1	4	48	6	6
2	3	1	9	52	7	51.1	4	48	6	6
3	4	1	12	49	9	49.1	4	48	6	5
4	5	1	15	46	11	47.1	4	48	5	4
5	5	2	15	46	12	46.1	8	44	4	5
6	6	3	18	43	15	43.1	12	40	4	5
7	7	3	21	40	17	41.1	12	40	4	5
8	8	3	24	37	19	39.1	12	40	4	4
9	8	4	24	37	20	38.1	16	36	4	5
10	8	5	24	37	21	37.1	20	32	4	5
11	8	6	24	37	22	36.1	24	28	4	6
12	9	6	27	34	24	34.1	24	28	4	5

Primary bids

A11.179 Assuming that the bidder always bids for the package that would provide greatest payoff, we would expect the following bids:

Figure A11.14: Primary bids and required chain bids (example 3)

Round	Package bid for	Type	Chain of caps that apply to preferred package (£ million)	Required chain bids (£ million)
1	1	Full Eligibility	None	none
2	1	Full Eligibility	None	none
3	2	Constraining	none	none
4	3	Constraining	none	none
5	2	Capped	B(3)+7 (relative cap from primary bid in round 4)	Bid of 5 for package 3; chain bid required.
6	2	Capped	B(3)+7 (relative cap from primary bid in round 4)	Bid of 8 for package 3; chain bid required.
7	2	Capped	B(3)+7 (relative cap from primary bid in round 4)	Bid of 10 for package 3; chain bid required.
8	3	Full Eligibility	none	none
9	2	Capped	B(3)+7 (relative cap from primary bid in round 4)	Bid of 13 for package 3; chain bid required.
10	2	Capped	B(3)+7 (relative cap from primary bid in round 4)	Bid of 14 for package 3; chain bid required.
11	1	Capped	Relative cap for package 1: B(2)+3 (relative cap from primary bid in round 3); Relative cap for package 2: B(3)+7 (relative cap from primary bid in round 4)	Bid of 21 for package 2; as the bidder already bid this amount for this package in round 10, no chain bid required. Bid of 14 for package 3; as the bidder already bid this amount (required chain bid) in round 10, no chain bid required
12	2	Capped	B(3)+7 (relative cap from primary bid in round 4)	Bid of 17 for package 3; chain bid required.

Supplementary bids

A11.180 In the supplementary bids round, the bidder can place additional bids. Any supplementary bid for a package must exceed the highest bid made for that package so far, and must respect both any relative caps and the final price cap that may apply to the package. As the bidder has placed a capped primary bid in the final primary round, all supplementary bids are subject to a cap that depends on the bids that the bidder submits for

other packages. However, the bidder is able to raise all these bids provided that the loose lock is maintained.

A11.181 The caps applicable to each package are shown in Figure A11.15. As the bidder has bid for its preferred package in all primary rounds, the bidder can bid its full valuation for all packages, as this is consistent with the relative caps and the final price cap.

Figure A11.15: Supplementary bids (example 3)

Package ID	Constraining Package				Final Price Cap			Supplementary Bid amount (£ million)	Applicable caps given Supplementary Bids submitted (£ million)
	Constraining Package	Constraining Round	Stated Differential (£ million)	Calculation of the cap (£ million)	Final Primary Package	Final Price Differential (£ million)	Calculation of the cap (£ million)		
1	2	3	12-9=3	B(2)+3	2	27-24=3	B(2)+3	61	58.1+3=61.1; 58.1+3=61.1
2	3	4	11-4=7	B(3)+7	2	na	No cap applicable	58.1	52+7=59
3	na	na	na	No cap applicable	2	24-24=0	B(2)+0	52	58.1-0=58.1

Example of how the proposed competition credit applies

A11.182 As in the previous example, suppose only Lots in two categories, A and B, are offered in the auction, with attributes shown in Figure A11.16.

Figure A11.16: Lots available

Lot Category	Lots available	Eligibility points per lot	Reserve per Lot (£ million)
A	5	2	2
B	5	1	1

A11.183 Further, suppose we have two Opted-in Bidders, and a Competition Constraint that requires one of the Opted-in Bidders to be awarded one of their MPP. Suppose that both Opted-in Bidders have the same MPPs, shown in Figure A11.17.

Figure A11.17: Minimum Portfolio Packages

Package ID	Number of A Lots	Number of B Lots	Activity of Package
1	3	0	6
2	2	1	5

A11.184 Consider the following evolution of Round Prices in the first four Primary Rounds, with the corresponding prices for each one of these MPPs in the absence of a Competition Credit, shown in Figure A11.18.

Figure A11.18: Round Prices (Competition Credit calculation example)

	Round Prices (£ million)		**Cost of Packages without competition credit (£ million)**	
Round	A Lots	B Lots	Package 1	Package 2
1	2	1	6	5
2	3	1	9	7
3	4	1	12	9
4	5	1	15	11

A11.185 Given these Round Prices, and assuming that both bidders submit a Primary Bid for the Package that would give them a greater pay-off at Round Prices, we would observe the following Primary Bids and resulting calculation of Competition Credits.

Round 1

A11.186 In the first round, the Competition Credit is zero for both Opted-in Bidders. Suppose that both Opted-in Bidders start the auction with eligibility of 6, and that in round 1 both bidders submit a Full Eligibility Primary Bid for Package 1. Therefore, we receive the following Primary Bids:

Figure A11.19: Primary Bids from Opted-in Bidders in round 1

Bidder	A Lots	B Lots	Bid Amount (£ million)	Package eligibility
Bidder 1	3	0	6	6
Bidder 2	3	0	6	6

A11.187 Suppose that there is excess demand and only for Lot Category A, and the Auctioneer raises the price of A Lots for round 2 to £3 million, leaving the price for B Lots unchanged.

A11.188 The calculation of the Competition Credit for each one of these two bidders requires solving the hypothetical winner determinations described in Paragraphs A11.77 to A11.81.

A11.189 The hypothetical winner determination is run over a hypothetical set of bids that include:

- bids from Opted-in Bidders for their MPPs;
- zero bids for the Opted-in Bidders;
- standalone bids for each single Lot available in the auction.

A11.190 The bids on MPPs from Opted-in bidders are capped at the cost of the Package given Round Prices, or potentially at a lower level if Relative Caps apply. Moreover, in the second hypothetical winner determination, the bids for the bidder to whom the Competition Credit calculation applies are lowered to the reserve price on the Package.

A11.191 Given this, and given that we only require one Opted-in Bidder to win a MPP, any outcome where we select:

- one MPP from an Opted-in Bidder; and
- standalone bids for each single Lot not included in this MPP

will provide the greatest possible value of winning bids given the selected MPP. This is because awarding an MPP to the other bidder would at most provide the value of this second MPP at Round Prices, and thus would be tied with the previous outcome.

A11.192 For this reason, we can solve the hypothetical winner determination by selecting the outcome that provides a greater total value of winning bids from the following four possible outcomes:

a) We allocate Package 1 to Bidder 1 and all remaining Lots at Round Prices;

b) We allocate Package 2 to Bidder 1 and all remaining Lots at Round Prices;

c) We allocate Package 1 to Bidder 2 and all remaining Lots at Round Prices;

d) We allocate Package 2 to Bidder 2 and all remaining Lots at Round Prices.

A11.193 The steps for calculating the Competition Credit are as follows.

A11.194 We first calculate the maximum bid that each one of the bidders would be able to submit for their MPPs in the event that the round 2 were the Final Primary Bid Round, and assuming that bidder's highest bid on their Final Primary Package was the price of the Package in the Final Primary Bid Round. As none of the bidders would face Relative Caps on their MPPs, bidders would be able to bid the full price of the Package in the Final Primary Bid Round. Therefore, the hypothetical bids from these bidders for the first hypothetical winner determination (to calculate H1 in Paragraph A11.78) are identical, and would be (for each bidder):

- A bid for Package 1 at the Round Prices set for round 2 (3 x £3 million = £9 million);
- A bid for Package 2 at the Round Prices set for round 2 (2 x £3 million + 1 x £1 million = £7 million); and
- The zero bid.

A11.195 We then calculate the value of allocating the Lots not included in each possible MPP at Round Prices:

- If Package 1 is allocated to satisfy the Competition Constraint, we are left with 2 A Lots and 5 B Lots. At the Round Prices set for round 2 this would generate a value of £11 million (calculated as 2 x £3 million + 5 x £1 million).
- If Package 2 is allocated to satisfy the Competition Constraint, we are left with 3 A Lots and 4 B Lots. At the Round Prices set for round 2 this would generate a value of £13 million (calculated as 3 x £3 million + 4 x £1 million).

A11.196 Therefore, the value associated with each one of the outcomes to the hypothetical winner determination listed in Paragraph A11.210 would be:

a) £9 million + £11 million = £20 million;

b) £7 million + £13 million = £20 million;

c) £9 million + £11 million = £20 million;

d) £7 million + £13 million = £20 million;

A11.197 All these solutions to the hypothetical winner determination are tied, and would result in a total value of winning bids (H1) of £20 million.

A11.198 The next step is to solve the hypothetical winner determination for each one of the Opted-in Bidders when reducing their own bids for MPPs to the reserve price on the Package. The reserve prices for these Packages are equal to the prices of these Packages in round 1, therefore:

- Reserve for Package 1 = £6 million;
- Reserve for Package 2 = £5 million.

A11.199 We can then calculate the outcomes listed in Paragraph A11.210 when the bids for MPPs from Bidder 1 are reduced to reserve:

a) £6 million + £11 million = £17 million;

b) £5 million + £13 million = £18 million;

c) £9 million + £11 million = £20 million;

d) £7 million + £13 million = £20 million;

A11.200 The optimal solutions to the hypothetical winner would be c) and d), which still result in a total value of winning bids (H2 for Bidder 1) of £20 million. Therefore, the Competition Credit for Bidder 1 in round 2 would be set to H1 - H2 = £20 million - £20 million = 0.

A11.201 Similarly, we can calculate the outcomes listed in Paragraph A11.210 when the bids for MPPs from Bidder 2 are reduced to reserve:

a) £9 million + £11 million = £20 million;

b) £7 million + £13 million = £20 million;

c) £6 million + £11 million = £17 million;

d) £5 million + £13 million = £18 million;

A11.202 The optimal solutions to the hypothetical winner would be a) and b), which still result in a total value of winning bids (H2 for Bidder 2) of £20 million. Therefore, the Competition Credit for Bidder 2 in round 2 would be set to H1 - H2 = £20 million - £20 million = 0.

Round 2

A11.203 Suppose that in round 2 we receive the following Primary Bids:

Figure A11.20: Primary Bids from Opted-in Bidders in round 2

Bidder	A Lots	B Lots	Bid Amount (£ million)	Package eligibility
Bidder 1	3	0	9	6
Bidder 2	0	4	4	4

A11.204 Note that Bidder 2 submits a Constraining Primary Bid for a Package with eligibility smaller than the eligibility associated with any of its MPPs. This means that bids for any of its MPPs will be subject to a Relative Cap. The Stated Differentials on the two MPPs will be equal to the price of the MPP in the Constraining Round minus Price of the Constraining Package in the Constraining Round, and thus are calculated as follows:

- for Package 1, (3 x £3 million) – (4 x £1 million) = £5; and
- for Package 2, (2 x £3 million + 1 x £1 million) – (4 x £1 million) = £3.

A11.205 Suppose that again there is excess demand and only for Lot Category A, and the Auctioneer raises the price of A Lots for round 3 to £4 million, leaving the price for B Lots unchanged.

A11.206 The steps for calculating the Competition Credit are as follows.

A11.207 We first calculate the maximum bid that each one of the bidders would be able to submit for their MPPs in the event that the round 3 were the Final Primary Bid

Round, and assuming that bidder's highest bid on their Final Primary Package was the price of the Package in the Final Primary Bid Round. These may now differ for the two Bidders.

A11.208 We start with Bidder 1, who does not face a Relative Cap on its MPPs. Therefore, Bidder 1 would be able to bid the full price of the each MPP in the Final Primary Bid Round. Therefore, the hypothetical bids from Bidder 1 for the first hypothetical winner determination (to calculate H1 in Paragraph A11.78) would be:

- A bid for Package 1 at the Round Prices set for round 3 (3 x £4 million = £12 million);
- A bid for Package 2 at the Round Prices set for round 3 (2 x £4 million + 1 x £1 million = £9 million); and
- The zero bid.

A11.209 Second, we calculate the maximum bids that Bidder 2 can make for its MPPs. Suppose that Bidder 2 bids for its smallest Constraining Package (for which it submitted a bid in round 2) at the Round Prices set for round 3, which is equal to £4 million (calculated as 4 x £1 million). Then, bids for its MPPs would be capped to this amount plus the Stated Differential for each one of the Packages. Therefore, the hypothetical bids from Bidder 2 for the first hypothetical winner determination (to calculate H1 in Paragraph A11.78) would be:

- A bid for Package 1 at the maximum allowed for by the Relative Cap, equal to £4 million + £5 million = £9 million);
- A bid for Package 2 at the maximum allowed for by the Relative Cap, equal to £4 million + £3 million = £7 million); and
- The zero bid.

A11.210 We then calculate the value of allocating the Lots not included in each possible MPP at Round Prices:

- If Package 1 is allocated to satisfy the Competition Constraint, we are left with 2 A Lots and 5 B Lots. At the Round Prices set for round 3 this would generate a value of £13 million (calculated as 2 x £4 million + 5 x £1 million).
- If Package 2 is allocated to satisfy the Competition Constraint, we are left with 3 A Lots and 4 B Lots. At the Round Prices set for round 3 this would generate a value of £16 million (calculated as 3 x £4 million + 4 x £1 million).

A11.211 Therefore, the value associated with each one of the outcomes to the hypothetical winner determination listed in Paragraph A11.210 would be:

a) £12 million + £13 million = £25 million;

b) £9 million + £16 million = £25 million;

c) £9 million + £13 million = £22 million;

d) £7 million + £16 million = £23 million;

A11.212 The optimal solutions to the hypothetical winner would be a) and b), which would result in a total value of winning bids (H1) of £25 million.

A11.213 The next step is to solve the hypothetical winner determination for each one of the Opted-in Bidders when reducing their own bids for MPPs to the reserve price on the Package. The reserve prices for these Packages are equal to the prices of these Packages in round 1, therefore:

- Reserve for Package 1 = £6 million;
- Reserve for Package 2 = £5 million.

A11.214 We can then calculate the outcomes listed in Paragraph A11.210 when the bids for MPPs from Bidder 1 are reduced to reserve:

a) £6 million + £13 million = £19 million;

b) £5 million + £16 million = £21 million;

c) £9 million + £13 million = £22 million;

d) £7 million + £16 million = £23 million;

A11.215 The optimal solution to the hypothetical winner would be d), which would result in a total value of winning bids (H2 for Bidder 1) of £23 million. Therefore, the Competition Credit for Bidder 1 in round 3 would be set to H1 - H2 = £25 million - £23 million = £2 million.

A11.216 Similarly, we can calculate the outcomes listed in Paragraph A11.210 when the bids for MPPs from Bidder 2 are reduced to reserve:

a) £12 million + £13 million = £25 million;

b) £9 million + £16 million = £25 million;

c) £6 million + £13 million = £19 million;

d) £5 million + £16 million = £21 million;

A11.217 The optimal solutions to the hypothetical winner would be a) and b), which still result in a total value of winning bids (H2 for Bidder 2) of £25 million. Therefore, the Competition Credit for Bidder 2 in round 3 would be set to H1 - H2 = £25 million - £25 million = 0.

Round 3

A11.218 Suppose that in round 3 we receive the following Primary Bids:

Figure A11.21: Primary Bids from Opted-in Bidders in round 3

Bidder	A Lots	B Lots	Bid Amount (£ million)	Package eligibility
Bidder 1	3	0	10	6
Bidder 2	0	4	4	4

A11.219 Note that the Competition Credit is applied to Bidder 1's bid, as this bid is for a MPP.

A11.220 Suppose that we continue to have excess demand only for Lot Category A, and the Auctioneer raises the price of A Lots for round 4 to £5 million, leaving the price for B Lots unchanged.

A11.221 The steps for calculating the Competition Credit are as follows.

A11.222 We first calculate the maximum bid that each one of the bidders would be able to submit for their MPPs in the event that the round 4 were the Final Primary Bid Round, and assuming that bidder's highest bid on their Final Primary Package was the price of the Package in the Final Primary Bid Round. These may now differ for the two Bidders.

A11.223 We start with Bidder 1, who does not face a Relative Cap on its MPPs. Therefore, Bidder 1 would be able to bid the full price of the each MPP in the Final Primary Bid Round. Therefore, the hypothetical bids from Bidder 1 for the first hypothetical winner determination (to calculate H1 in Paragraph A11.78) would be:

- A bid for Package 1 at the Round Prices set for round 4 (3 x £5 million = £15 million);
- A bid for Package 2 at the Round Prices set for round 4 (2 x £5 million + 1 x £1 million = £11 million); and
- The zero bid.

A11.224 Second, we calculate the maximum bids that Bidder 2 can make for its MPPs. Suppose that Bidder 2 bids for its smallest Constraining Package (for which it submitted a bid in round 2) at the Round Prices set for round 4, which is still equal to £4 million (calculated as 4 x £1 million). Then, bids for its MPPs would be capped to this amount plus the Stated Differential for each one of the Packages. Therefore, the hypothetical bids from Bidder 2 for the first hypothetical winner determination (to calculate H1 in Paragraph A11.78) would be:

- A bid for Package 1 at the maximum allowed for by the Relative Cap, equal to £4 million + £5 million = £9 million;
- A bid for Package 2 at the maximum allowed for by the Relative Cap, equal to £4 million + £3 million = £7 million; and
- The zero bid.

A11.225 We then calculate the value of allocating the Lots not included in each possible MPP at Round Prices:

- If Package 1 is allocated to satisfy the Competition Constraint, we are left with 2 A Lots and 5 B Lots. At the Round Prices set for round 4 this would generate a value of £15 million (calculated as 2 x £5 million + 5 x £1 million).
- If Package 2 is allocated to satisfy the Competition Constraint, we are left with 3 A Lots and 4 B Lots. At the Round Prices set for round 4 this would generate a value of £19 million (calculated as 3 x £5 million + 4 x £1 million).

A11.226 Therefore, the value associated with each one of the outcomes to the hypothetical winner determination listed in Paragraph A11.210 would be:

a) £15 million + £15 million = £30 million;

b) £11 million + £19 million = £30 million;

c) £9 million + £15 million = £24 million;

d) £7 million + £19 million = £26 million;

A11.227 The optimal solutions to the hypothetical winner would be a) and b), which would result in a total value of winning bids (H1) of £30 million.

A11.228 The next step is to solve the hypothetical winner determination for each one of the Opted-in Bidders when reducing their own bids for MPPs to the reserve price on the Package. The reserve prices for these Packages are equal to the prices of these Packages in round 1, therefore:

- Reserve for Package 1 = £6 million;
- Reserve for Package 3 = £5 million.

A11.229 We can then calculate the outcomes listed in Paragraph A11.210 when the bids for MPPs from Bidder 1 are reduced to reserve:

a) £6 million + £15 million = £21 million;

b) £5 million + £19 million = £24 million;

c) £9 million + £15 million = £24 million;

d) £7 million + £19 million = £26 million;

A11.230 The optimal solution to the hypothetical winner would be d), which would result in a total value of winning bids (H2 for Bidder 1) of £26 million. Therefore, the Competition Credit for Bidder 1 in round 4 would be set to H1 - H2 = £30 million - £26 million = £4 million.

A11.231 Similarly, we can calculate the outcomes listed in Paragraph A11.210 when the bids for MPPs from Bidder 2 are reduced to reserve:

a) £15 million + £15 million = £30 million;

b) £11 million + £19 million = £30 million;

c) £6 million + £15 million = £21 million;

d) £5 million + £19 million = £24 million;

A11.232 The optimal solutions to the hypothetical winner would be a) and b), which still result in a total value of winning bids (H2 for Bidder 2) of £30 million. Therefore, the Competition Credit for Bidder 2 in round 4 would be set to H1 - H2 = £30 million - £30 million = 0.

Annex 12

Revised proposals on pricing methodology for base price determination

Introduction

A12.1 We review the responses on the choice of pricing rules in section 7. We explain in that section why we continue to think that both a Vickrey-nearest pricing rule and a linear reference pricing rule would be suitable for this auction.

A12.2 In this annex, for ease of reference and to clarify details of the linear reference rule, we set out the details of each pricing rule. However, we start by discussing general features that apply to both rules.

A12.3 Similar principles apply to both the Principal Stage of the auction, in which a base price is determined for each winning bidder, and the Assignment Stage, where an additional price is determined for each winner.

Second price rules

A12.4 Both the linear reference rule and the Vickrey-nearest rule are **second-price rules**. They determine a price to be paid by each winning bidder on the basis of opportunity cost, rather than winners simply paying the amount of their winning bid.

A12.5 Specifically, each winning bidder, and each group of winning bidders, is required to pay at least the opportunity cost of the lots it is awarded. Opportunity cost is the cost of the spectrum awarded to a winner being denied to others. Within the auction, opportunity cost is reflected in the bids submitted by bidders other than the winner. Specifically, it can be measured by the value that a winner (or, more generally, a group of winners) denies to other bidders by virtue of being allocated their winning package of lots. This approach of pricing by reference to generalised opportunity cost is known as **core pricing** and has been used in previous Ofcom auctions.

A12.6 The requirement to pay at least opportunity cost is applied both to individual winners and also collectively to each and every group of winning bidders. In a combinatorial auction with bids for packages of lots, it is possible that a group of winners might impose a collective opportunity cost on other bidders that exceeds the sum of the individual opportunity costs that each of those winners causes. For example, this situation arises in the case of two winners, where there is no alternative demand from other bidders for the winning package of each winner individually (i.e. if the winning package were not awarded to one of these bidders then there is no other bidder who wants it) but there is alternative demand for a larger package that could be created by combining the winning packages of both winners. In this case, the two winners jointly impose an opportunity cost on those bidders failing to win this larger package. This sets a floor on the amount that the two winners must in total pay.

A12.7 Opportunity costs can be determined by considering the hypothetical annulment of the bids of a winning bidder or group of winning bidders. Removing the bids of a particular bidder (or group of bidders) and re-determining the winners will typically

lead to a reduction in the total value of winning bids. However, it might be possible to reallocate the lots freed by removing the winning bidder(s) to other bidders. Therefore, the reduction in the total value of winning bids will often be strictly less than the sum of the original winning bids of the removed bidders (and certainly never greater), as the winning combination of bids can be re-optimised. Opportunity cost can then be defined as the amount of the bidder's original winning bid (or sum of the winners' winning bids if considering opportunity cost for a group of bidders), less the amount by which the total value of all winning bids would be reduced if that bidder's bids were removed (with winning bids re-determined).

A12.8 For example, suppose that a winner only won as a result of a tiebreak and that there was another losing bidder with a bid of the same amount for that package. In that case, if the winner's bids were hypothetically removed, the loser could be swapped into the winning combination of bids and the original total value of winning bids preserved. Therefore, the opportunity cost of the winner is the entire amount of its winning bid in this case. Conversely, if there were no alternative demand for these lots, then the opportunity cost would be zero (and the reserve price would set a floor on the price).

A12.9 If a Competition Constraint is implemented (i.e. that a sufficient number of bidders win at least a Minimum Portfolio Package), then opportunity cost needs to be evaluated taking into account this constraint. The underlying principle that opportunity costs may be determined by considering the hypothetical annulment of some bids is unchanged. However, a Competition Constraint may affect the magnitudes of opportunity costs.

A12.10 For example, it could be that in some cases the Competition Constraint can only be satisfied if some lots are allocated to a particular bidder. In such case, there may be no opportunity cost associated with those lots, as there may be no alternative but to allocate those lots to that bidder. Notice that it is possible that this situation could apply to only some of the lots that a bidder wins (i.e. those constituting a Minimum Portfolio Package), rather than the entire package won.

A12.11 Prices will be set as low as possible subject to the requirement that winners pay at least their individual and joint opportunity costs and subject to winners paying at least reserve prices. Specifically, the sum of the base prices across winners will be minimised subject to the constraints that each winner and possible set of winners pays at least its relevant opportunity cost. Such sets of prices (one for each winner) are known as **minimum revenue core prices** (MRC prices). Each set of MRC prices has the same total revenue.

A12.12 Minimum revenue core pricing has the consequence that jointly winning bidders pay the lowest possible amount such that, if they had bid that amount for their winning package (and corresponding lower amounts for other packages), then they would still win this package; however, they would not have won if they had bid any less than this. Both the Vickrey-nearest rule and the linear reference rule have this property. This encourages straightforward bidding behaviour, as bidders pay only what they need to win, not necessarily the amount that they bid.

Selection of a set of base prices

A12.13 In some cases, these requirements alone may be insufficient to determine a unique price for each winning bidder. There may be many sets of minimum revenue core prices.

A12.14 This situation may arise where a group of winners collectively beat other bids for some set of lots. In such a case, the amount that the group of winners as a whole should pay may be determined by the group's collective opportunity cost, but the amount that each individual member of the group needs to pay may be indeterminate (though there will typically be limits on the possible ways in which this total payment can be split). In these situations, a further rule is needed to select unique base prices from amongst the various possible sets of minimum revenue core prices.

A12.15 The linear reference rule and the Vickrey-nearest rule differ only in how a unique base price for each winner is selected in such cases. Both rules pick a set of prices (one for each winner) from amongst the lowest prices compatible with each winner and group of winners paying at least their opportunity cost. However, they employ different criteria for making this selection from amongst the minimum revenue core prices.

A12.16 The Vickrey-nearest rule picks those base prices that are closest to the individual opportunity cost of each winning bidder (the so-called Vickrey prices). The linear reference rule picks base prices that result in winning prices being as close as possible to approximate market-clearing prices for each lot category that are uniform (i.e. the same for each winner) and linear in quantity (the same for all lots within the category).

Determination of linear reference prices

A12.17 This section sets out in detail how linear reference prices are determined. We first provide a description of the method without using any mathematical notation, then set out the technical details at the end of the section. The approach described here applies in equal measure to both the Principal Stage and the Assignment Stage.

Overview

A12.18 The linear reference price method finds a particular set of *linear prices* that are close to market clearing prices. By a linear price, we mean a price per lot applying to a particular lot category that is uniform across each winning bidder and does not vary according to what other lots a bidder wins.[131] We then choose winning prices from amongst possible sets of minimum revenue core prices to minimise the difference between the winning prices and the price of winning packages at these linear reference prices.

A12.19 Market clearing prices are linear prices (i.e. a uniform price per lot for each category) with the property that, if each bidder demanded its most preferred package given its bids, then total demand would exactly match the available supply of lots.[132] We define the most preferred package as the package which maximises a bidder's surplus (i.e. the difference between the bid amount and the cost of package) at these linear prices across all the bids that the bidder has made.

[131] Therefore, there is one linear price for each lot category applying to all bidders, as opposed to base prices and additional prices, where one price is determined for each winner.

[132] In the case that there is a trade-off between the number of category C lots and category D lots, then there is not a fixed supply of lots in each category. The subsequent definition of a metric for measuring how far linear prices are from market clearing applies equally well in the case that there are trade-offs in the supply of lots in different categories.

A12.20 In a combinatorial auction where bids are made for packages of lots, there is no guarantee that such a set of market clearing prices will exist. The difficulty is that there may be no way of setting uniform per lot prices for all bidders such that all available lots are allocated. For example, increasing linear prices may cause a bidder to switch from a larger to a smaller package reducing its demand by many lots. This may prevent there being linear prices at which demand and supply can be exactly matched. Nevertheless, it is still possible to define a notion of *approximate* market clearing prices in the following way.

A12.21 Given a particular auction outcome, we may ask whether a particular set of linear prices for each lot category *rationalises* that outcome, in that each bidder would prefer to purchase its winning package at these prices rather than some other package. At such prices and on the basis of the preferences expressed through the bids received, each bidder would not prefer to have won something different from what they did win (including losing bidders having not won anything). In other words, if these prices were set in a Primary Bid Round, then bidders would be expected to bid for what they have won. Clearly if an auction outcome involves all available lots being allocated, then if linear prices exist that rationalise such an outcome, such linear prices will be market-clearing prices by definition.

A12.22 As discussed above, it cannot be guaranteed that a set of linear prices can be found with these properties. However, it is possible to choose linear prices that satisfy this condition as closely as possible. To formalise the notion of 'as closely as possible', we define an **excursion** for each bidder, which quantifies the maximum extent to which any particular set of linear lot prices fails to rationalise the auction outcome for that bidder as the bidder would not prefer its winning package at those prices.

A12.23 Specifically, in the case of winning bidders this excursion is defined as the maximum amount by which the payoff of any of their losing bids (i.e. the difference between the amount bid and the total price of all the lots included in the bid) exceeds the payoff of their winning bid, for the particular set of linear lot prices being considered. Where the payoff for their winning bid is at least as great as the payoff for all of their losing bids, the excursion is zero, as the bidder's most preferred package is its winning package at these prices.

A12.24 Linear prices would ideally be set such that losing bidders would prefer to receive no lots given these prices. However, at some prices this might not the case and there will be an excursion. We can define the excursion for losing bidders in the same manner as for winning bidders. For losing bidders the excursion is the greatest amount by which any of their losing bids exceeds the total price of all the lots included in the bid, for the particular set of linear lot prices being considered. The excursion is zero if none of their (losing) bids has a positive payoff.

A12.25 Given this definition, the excursion for each bidder is the maximum extent to which the proposed linear lot prices are unable to explain the auction outcome for that bidder, in that the bidder is not winning its most preferred package at the prevailing prices. By adding up the excursions of all bidders, the **total excursion** provides an overall metric of the extent to which linear prices fail to rationalise the auction outcome, in the sense that one or more bidders are not receiving what would be their most preferred package at these prices given the bids they made.

A12.26 Because the excursion for each bidder is zero or positive, if the total excursion is zero, this means that the linear prices fully rationalise the auction outcome, in that every bidder would prefer to receive its winning package (given the bids made) at

these prices. However, there may be no linear prices that result in a zero total excursion. In such a case, the linear reference prices are chosen to minimise the total excursion subject to certain requirements described below.

A12.27 The first requirement that we impose on the linear reference prices is that the total of the linear reference prices for all lots sold should be the same as the total revenue achieved by all sets of MRC prices. This ensures that the final linear reference prices will (in a sense) represent an average of the prices paid by winning bidders.

A12.28 The second requirement that we impose on the linear reference prices is that they should be one of those sets of linear lot prices that minimise the total excursion across all bidders.

A12.29 The effect of this condition is that the linear reference prices are approximate market clearing prices. They are prices at which the outcome of the auction is approximately consistent with the bidders choosing the package they have been awarded if faced with a common price per lot for each category, so demand and supply are balanced (subject to any unsold lots in the winning outcome not being allocated). However, we can only achieve approximate consistency, as there are cases in which it is not possible to match demand and supply using only linear prices that are common across all bidders.

A12.30 If there is more than one set of linear lot prices which minimise the total excursion, the linear reference prices are the set of linear lot prices from amongst this group which are closest to reserve prices in relative terms. This condition is guaranteed to identify a unique set of linear reference prices in all cases.

A12.31 Notice that this definition of excursions (and the approach of minimising total excursions) applies equally well to both the Principal Stage and the Assignment Stage. In the Principal Stage, one linear price is set for each lot category. In the Assignment Stage, one linear price is set for each frequency block available (with bids being for packages of frequency blocks). In both cases, we can define an excursion to be the greatest amount by which the surplus of any package bid for exceeds the surplus associated with the winning package.

Technical description

A12.32 In this subsection, we give a formal description of the procedure described above for determination of the linear reference prices. This procedure applies equally to both the Principal Stage and the Assignment Stage (with certain minor caveats noted below due to reserve prices being zero in the Assignment Stage), so we describe both applications of the procedure together.

A12.33 We adopt the following notation. There are K categories of lots for allocation labelled $k=1,...,K$ and there are s_k lots awarded in category k. For the Principal Stage, these are just the lot categories. For the Assignment Stage, winners and prices are determined for each band in turn. For one particular band, the relevant lot categories are the specific frequency blocks available in that band (of which there is one lot available for each category).

A12.34 There are I bidders labelled $i=1,\ldots,I$. Bidder i makes bids (β_{ij},x_{ij}) where β_{ij} is the bid amount of the j^{th} bid and x_{ij} is the package of lots bid for. For the Principal Stage, each bidder's set of bids conventionally includes a zero bid (i.e. a bid of amount

zero for an empty package) representing the possibility of that bidder losing. Let (β_i^*, x_i^*) be the winning bid of bidder i (which will be the zero bid in the case of losing bidders). For the Assignment Stage, a bidder must win exactly one frequency assignment corresponding in size to the number of lots won in the Principal Stage, so no zero bid is added.

A12.35 Let a_k denote the linear reference price of a lot in category k and a the vector of linear reference prices. Let ρ_k be the reserve price for lot category k and ρ the vector of reserve prices.

A12.36 We assume throughout this subsection that at least one lot is allocated in each category, otherwise the linear reference price is not determined. Therefore, in the event that all lots in some category are unallocated in the winning outcome, that category should be dropped from the analysis below (and the number of categories K reduced accordingly).

A12.37 The first step in the determination of linear reference prices is to find the vectors of linear lot prices which are solutions to the following linear programme:

$$\min_{\alpha} \sum_{i=1}^{I} \max_j \left[(\beta_{ij} - \alpha \cdot x_{ij}) - (\beta^\star - \alpha \cdot x_i^\star) \right]$$

s.t.

$$\sum_{i=1}^{I} \alpha \cdot x_i^\star = R$$

$$\alpha_k \geq \rho_k \quad \forall k$$

where R is the total revenue requirement on the linear reference prices. This is the minimum revenue over all core prices (i.e. the common revenue associated with all MRC price vectors).

A12.38 This linear programme identifies the sets of linear lot prices that minimise the total excursion, subject to the total price of the winning packages at these linear lot prices equating to the total revenue associated with all prices in the minimum revenue core. We also require that the linear lot prices are higher than their respective reserve prices.

A12.39 In the case that there is fungibility between the C and D lot categories, then the linear reference price for the D category should be subject to the additional constraint that it is at least one-fifth of the linear reference price for the C category. This constraint arises because otherwise it would be efficient not to award 10 D lots, but create 2 more C lots instead.

A12.40 If there is more than one set of linear prices which minimise the sum of maximum excursions over bidders, the linear reference prices are chosen to be that set which minimise the sum of squared differences *relative* to reserve prices.[133] Specifically, the linear references need to satisfy

[133] The weights in the objective function are chosen such that it is unaffected by sub-division or recombination of lots. For example, it has the property that if we sub-divided each of the lots in a category into two lots and halved the relevant reserve price, then the linear reference price would halve too. Therefore, the objective function is scale-free.

$$\min_{\alpha_k} \sum_{k=1}^{K} s_k \rho_k \left(\frac{\alpha_k}{\rho_k} - \lambda \right)^2$$

$$\alpha_k \geq \rho_k \quad \forall k$$

where this optimisation problem has the further constraints of the previous linear programme and the requirement that an optimum of that linear programme is achieved. Here s_k is the total number of lots awarded in category k and

$$\lambda = \frac{R}{\sum \rho_k s_k}$$

is the common multiple that needs to be applied to the reserve prices to obtain revenue R.

A12.41 In the case of the Assignment Stage, all reserve prices are zero. The objective above needs to be slightly modified to reflect this, giving equal weight to each lot category and making linear reference prices as similar as possible. For the Assignment Stage the objective is simply

$$\min_{\alpha_k} \sum_{k=1}^{K} (\alpha_k - \lambda)^2$$

where

$$\lambda = \frac{1}{K} \sum_{k=1}^{K} \alpha_k$$

is the mean price of each lot category (i.e. each specific frequency block in the band).

Determination of base prices from the Principal Stage

A12.42 We now describe the overall process for determination of the base prices in the Principal Stage, using the linear reference pricing approach for selecting from amongst multiple sets of MRC prices (if this situation occurs). Again, we first provide a qualitative description of the procedures and then a more formal mathematical description.

A12.43 Base prices are the unique set of prices, one for each winner, which fulfil the following four conditions:

i) **First condition:** the base price of a winning bid must be no less than the total of the reserve prices of the lots in the winning bid package, but no greater than the winning bid amount.

ii) **Second condition (core prices):** the set of base prices must be sufficiently high that each winner and group of winners pays at least its opportunity cost. This means that there is no alternative bidder, or group of bidders, who expressed

through their bids a willingness to pay more than any winner or group of winners (and would be able to win those lots and still satisfy the Competition Constraint). If there is only one set of prices that meet the first and second conditions, these are the base prices for the Principal Stage.

iii) **Third condition (minimum revenue core prices):** If there are many sets of prices that fulfil the first and second condition, only those set(s) of prices that minimise(s) the sum of base prices across winning bidders are selected. If there is only one set of prices satisfying these three conditions, these are the base prices for the Principal Stage.

iv) **Fourth condition:** If there are many sets of prices that satisfy the first three conditions, the (unique) set of such prices that minimises the sum of squared differences between the price for each winner and the linear reference price for that winner are the base prices. Linear reference prices are determined using the procedures described in the previous section. If the Vickrey-nearest rule is used, then distance from the Vickrey prices is minimised instead (discussed at paragraphs A12.53 and following below).

A12.44 In applying the second condition, it is necessary to take into account the Competition Constraint, if this is applied. In particular, this affects the definition of opportunity cost, as certain winners may need to win at least some of their lots in order to satisfy the Competition Constraint, reducing the opportunity cost. This is reflected in the formal definition given below.

A12.45 Relative to the Vickrey-nearest rule previously used by Ofcom, only the last condition of the base price determination changes through the use of a different reference point.

Technical description

A12.46 We will use the same notation as before and set out in paragraphs A12.33 and following above. In addition, let p_i be the base price for bidder i.

A12.47 Core prices are prices p_i for each bidder i which satisfy the following conditions:

$$\begin{aligned} \sum_{i \in C} (\beta_i^\star - p_i) &\leq V(I) - V(I \setminus C) \qquad \forall C \subset I \\ p_i &\leq \beta_i^\star \qquad \forall i \\ p_i &\geq \rho \cdot x_i^\star \qquad \forall i \end{aligned}$$

where $V(I)$ is the total value of winning bids if all bidders I are included and $V(I\backslash C)$ is the total value of winning bids if all the bids of bidders in a set C are excluded.

A12.48 The first condition says that each coalition of bidders C pays at least its collective opportunity cost. The second requirement is that prices do not exceed bids and the third that they exceed the cost of the package won at reserve prices.

A12.49 This condition applies in the same form whether or not a Competition Constraint is applied. However, in the event that a Competition Constraint is applied, we need to define the value of winning bids on excluding some bidders, $V(I\backslash C)$, appropriately to reflect the impact of the Competition Constraint on opportunity costs. In particular if the set C contains any opted-in bidders, then bids for all of their MPPs at reserve

price (and the zero bid) should remain, but all other bids (including any bids for MPPs at greater amounts) should be excluded. No change is needed for bidders who did not opt-in or who do not have MPPs; if such bidders are in the set C, then all their bids are excluded from the winner determination.

A12.50 Let M be the set of price vectors $(p_1,\ldots,p_I)$ satisfying these conditions and which also minimise the total revenue Σp_i. These price vectors are the MRC prices. Let R be the common minimum revenue across all these MRC prices.

A12.51 To select from the set of MRC price vectors, we minimise the Euclidean distance from the reference point set by pricing the winning packages at the linear reference prices (where the derivation of linear reference prices uses the procedure described above at paragraphs A12.17 and following):

$$\min_{p} \sum_{i=1}^{I} (p_i - \alpha \cdot x_i^{\star})^2$$
$$s.t.$$
$$(p_1, \ldots, p_I) \in M$$

A12.52 All price vectors in the minimum revenue core M have total revenue R. Pricing the winning packages at the linear reference prices also produces total revenue R. Therefore, geometrically, the problem is one of finding the closest point in M to the winning prices implied by the linear reference prices within the plane of all prices raising revenue R. This problem has a unique solution for the base prices.

Base price determination with Vickrey-nearest rule

A12.53 If a Vickrey-nearest rule is used to select from amongst multiple sets of MRC prices, the final step of the procedures above is replaced by a rule that minimises distance from Vickrey prices, rather than the linear reference prices. Otherwise, the procedure is unchanged.

A12.54 The Vickrey price of a winning bidder is that bidder's individual opportunity cost. This is the difference between that bidder's winning bid and the reduction in the total value of winning bids that results from excluding that bidder and re-determining the winning bids (with the same treatment of MPP bids as described above in the case of opted-in bidders when a Competition Constraint applies).

A12.55 Using the notation above, the Vickrey price $p^v{}_i$ of bidder *i* is equal to

$$p_i^V = \beta_i^{\star} - V(I) + V(I \setminus \{i\})$$

A12.56 To select from the set of MRC price vectors using the Vickrey-nearest rule, we solve

$$\min_{p} \sum_{i=1}^{I} (p_i - p_i^V)^2$$

subject to the prices p_i being MRC prices.

Determination of additional prices from the Assignment Stage

A12.57 We now describe the procedure for determination of additional prices in the Assignment Stage. Following the Assignment Round, a winner determination is run separately for each band and additional prices determined for that band. Each band is considered separately for these purposes.

A12.58 In the Assignment Round, bidders may submit bids for various assignment options. Each assignment option is a contiguous frequency block, corresponding in total size to the number of lots won in the Principal Stage. There is no compulsion to submit bids for any assignment option. Any assignment option not receiving a bid will be treated as having received a bid of zero, as the bidder has expressed no preference for that assignment option.

A12.59 For the purposes of determining winners in the Assignment Round, the relevant lot categories are the individual frequency blocks (with one lot available for each). Bids for assignment options should be considered as bids for packages of frequency blocks. Given this interpretation, the procedures for determining winning bids and additional prices are very similar to those for the Principal Stage with two minor differences. First, there are no reserve prices in the Assignment Round. We have already discussed at paragraph A12.41 that this requires a minor modification of the procedure for determining linear reference prices. Also, constraints on winning prices arising from reserve prices can be ignored (although additional prices still need to be non-negative).

A12.60 Second, in the Assignment Stage winners are guaranteed to win the number of lots that they were allocated in the Principal Stage. The Assignment Stage simply determines which frequency assignment a winner receives; they must receive some assignment. Therefore, in determining winning bids, no 'zero bids' should be included to represent the possibility of a bidder losing. This affects the definition of opportunity cost. In particular, in the Assignment Stage, opportunity cost is defined to be loss of value to other bidders that results from a winner (or group of winners) making bids above zero for their assignment stage options and expressing a preference for particular frequency blocks.

A12.61 With these provisos, the same four conditions can be used to characterise additional prices:

i) **First condition:** the additional price of a winning assignment must be non-negative and not greater than the winning bid amount.

ii) **Second condition (core prices):** the set of additional prices must be sufficiently high so that each winner (and group of winners) pays at least the opportunity cost arising from bidding more than zero. This means that there is no alternative bidder, or group of bidders, who expressed through their bids a willingness to pay more than any winner or group of winners. If there is only one set of prices that meet the first and second conditions, these are the additional prices for the Assignment Stage.

iii) **Third condition (minimum revenue core prices):** If there are many sets of prices that fulfil the first and second condition, only those set(s) of prices that minimise(s) the sum of additional prices across winning bidders are selected. If there is only one set of prices satisfying these three conditions, these are the additional prices for the Assignment Stage.

iv) **Fourth condition:** If there are many sets of prices that satisfy the first three conditions, the (unique) set of such prices that minimises the sum of squared differences between the additional price for each winner and the linear reference price for that winner are the additional prices. If the Vickrey-nearest rule is used, then distance from the Vickrey prices is minimised instead.

Technical description

A12.62 The description of the procedures for the Principal Stage applies subject to redefining $V(I \backslash C)$, the optimised value of winning bids on excluding some set of bidders C. In the case of the Assignment Stage, all the bids of the bidders in the set C are retained, but set to zero. Thus opportunity cost is defined relative to the counterfactual that the bidders in the group C expressed no preference amongst any of the frequency assignments.

Linear reference prices vs. Vickrey-nearest prices

A12.63 In this section we briefly consider the differences between the linear reference pricing approach and the Vickrey-nearest approach. It is important to recognise that the two methods are more similar than they are different. They both determine prices for winning bids that are minimum revenue core prices, as explained above. They also both pick prices from amongst the set of minimum revenue core prices to minimise distance (measured by a sum-of-squares of price differences across bidders) from some reference point. The only difference is in how this reference point is calculated.

A12.64 The differences in the behaviour of these two pricing rules should not be characterised necessarily as advantages or disadvantages. They have somewhat different properties and the choice between them depends on the weight accorded to various objectives.

Incentive effects

A12.65 The two approaches have somewhat different properties with regard to the incentives they create for bidders, which we consider in this subsection. Our concern is whether a bidder might have an incentive to bid other than straightforwardly in order to lower the price paid for its winning package.

A12.66 With both second price rules, bidders typically do not pay an amount equal to their winning bid, but rather a lower amount determined by the pricing algorithm. Therefore, neither pricing rule gives rise to an acute incentive to under-report valuations as would arise with a simple first price (pay-what-you-bid) rule. Nevertheless, it is possible that a bidder could affect the reference point used to select from amongst the minimum revenue core prices and so affect the price it might pay. This linkage may give rise to incentives to bid other than straightforwardly (other than simply in accordance with value).

A12.67 By way of introduction, it is important to recognise that the only pricing rule that gives pure incentives to bid at value is a Vickrey pricing rule. This sets prices equal to the unilateral opportunity cost of each winning bidder. With a Vickrey pricing rule, it is a dominant strategy for a bidder to bid its true valuation for each package, as the price that the bidder will pay if it wins depends only on the bids of other bidders

and not on its own bids; this means that it is optimal to bid at value regardless of the bidding strategies adopted by rivals.[134]

A12.68 However, the simple Vickrey pricing rule is well known to have major deficiencies. In particular, in a package auction, it does not consider that a bidder may lose to a *group* of rivals, rather another single bidder.[135] This means that there may be losing bidders prepared to pay more for the lots allocated to the winners than the winners are paying. This is a highly unsatisfactory feature and is a key reason for the use of core pricing, which ensures that every winner and group of winners pays at least its (individual or joint) opportunity cost. Informally, core pricing can be thought of as achieving an outcome which would not be upset by counter-offers from losing bidders in a hypothetical open out-cry process (allowing for the possibility that groups of bidders might put such a counter-offer). In contrast, Vickrey pricing would not be robust to such counter-offers from losers in general settings.

A12.69 In certain simple situations, Vickrey prices can be core prices and, if this occurs, there is a unique core price for each winner (i.e. the Vickrey price). In particular, if bidders have made bids that demonstrate diminishing returns – so that adding successive lots to a package have diminishing incremental valuations – then this situation can occur. However, in a package auction, bidders may have synergistic valuations, where adding additional lots to a package increases the valuation of other lots in that package. In these more complex situations, Vickrey prices may lie outside the set of core prices.

A12.70 This means that, in the setting of a package auction, there is a tension between ensuring that each winner pays a sufficient amount to ensure that losers had not bid more for the same combination of lots and ensuring that winners are given incentives to report their valuations truthfully when bidding. With any core pricing rule we have to accept that there will be some (at least theoretical) incentive to bid differently from true value.

A12.71 Different MRC pricing rules – such as the linear reference rule and the Vickrey-nearest rule – have somewhat different properties in terms of how they affect bidding incentives, as we consider now.

A12.72 A commonly considered example of the problems with the Vickrey-nearest rule is where two bidders win small packages (call them A and B) against a rival bidding for a large package that combines the two smaller ones (call this AB). Suppose that the 'large' bidder bids an amount p_{ab}, whereas the 'small' winners bid p_a and p_b respectively, where $p_a+p_b>p_{ab}$ so that the small bidders are prepared to pay more in aggregate. Suppose also that $p_{ab}>p_a$ and $p_{ab}>p_b$. This means that on hypothetically eliminating one of the small bidders, it is then optimal to reallocate both lots to the large bidder. On this assumption, the winner of A has a Vickrey price (i.e. an individual opportunity cost) of $p_{ab}- p_b$ and the winner of B has a Vickrey price of $p_{ab}- p_a$.

A12.73 The amount of each winner's winning bid does not affect its *own* Vickrey price, as this depends only on the bids of rival bidders. However, it does affect the Vickrey price of the other winner and so can shift the reference point against which the

[134] We are ignoring the complications created by common value uncertainty here and simply supposing that we can treat bidders as having private values.

[135] Consider the example introduced in paragraph A12.6. Here two bidders for small packages jointly beat a sole rival bidder for a larger package consisting of all lots in both smaller packages. The individual opportunity cost for each winner is zero. However, at these prices the loser bidding for the large package would prefer to have won.

minimum distance selection of core prices is made. This is the source of the possible incentive to bid differently from true value.

A12.74 In particular, core pricing requires that two winners pay p_{ab} in total. It can be easily verified[136] that the sum-of-square distance from the Vickrey prices is minimised if the winner of A pays $½(p_{ab}-p_b+p_a)$ and the winner of B pays $½(p_{ab}-p_a+p_b)$. This means that for every £1 that a winner lowers its bid, its winning price falls by 50p. For small reductions in bid, the impact on the probability of winning creates a second-order loss, but there is a first order gain.[137] Therefore, there is a *marginal* incentive to lower the winner bid.

A12.75 We must be careful about drawing general conclusions from this example however. It is important that the two 'small' winners are in effect forming an implicit coalition to beat the 'large' rival. This is the source of the incentive to reduce the winning bid, as each winner would like to free ride on the other winner, trying to get the other winner to take a greater part of the burden of paying sufficient *jointly* to beat the 'large' bidder. With the Vickrey-nearest rule, winning as a part of a coalition is necessary for a bidder to enjoy a benefit from lowering the bid made for the winning package below valuation. In practice, it is likely to be extremely difficult for a bidder to be able to assess the probability of winning as part of such a coalition in a complex auction where there are many lot categories, many packages and many bidders. Therefore, the previous example is rather unrealistically simple, and in practice incentives to reduce winning bids are likely to be significantly muted by uncertainty over the auction outcome.

A12.76 The linear reference rule, by contrast, has the property that the linear reference prices are not affected by winning bids. By definition, the excursion for a winning bid is zero. As a result, modifying the amount of a winning bid – assuming the change is sufficiently small that the bid remains winning – will not affect the linear reference prices. This is a potentially useful advantage of the linear reference rule as there is no incentive to reduce the amount of a winning bid.

A12.77 However, there may be losing bids made by winning bidders for which the bid amount will affect the linear reference prices. As in the previous discussion, we focus on where there are *marginal* incentives to modify bids as these are likely to be the most relevant consideration for bidders, as it allows manipulation of winning prices at low risk.

A12.78 If we look at one particular bidder, there are two possible cases. First, it may be that the bidder has no non-zero excursion associated with any bid that it has made. This means that it would have chosen its winning package at the linear reference prices. In such a case, the bidder typically cannot affect the linear reference prices at the margin by modifying any of its bids by a small amount.[138]

[136] This entails a equal sharing of the amount by which winning prices need to rise above the Vickrey prices of the two winners in order for them to pay p_{ab} in total.

[137] This point about risk-free gains is made by Erdil and Klemperer (2010) "A New Payment Rule for Core-Selecting Package Auctions", Journal of the European Economic Association, vol: 8, issue 2-3, pp537–47.

[138] There is a potential non-generic case in which the excursion on one losing bid is just at the point of becoming positive. In this case, there may be an incentive to increase this bid if it is for lots not involved in the bidder's winning bid in order to raise the linear reference prices for lot categories that the bidder does not want.

A12.79 Second, the bidder may have some non-zero excursion associated with one of its losing bids. In this case, there is one losing bid for some package that has the greatest excursion amongst all the losing bids.[139] This is the excursion for that bidder which contributes to the total excursion across all bidders that needs to be minimised by the choice of linear reference prices. *Marginally* changing the bid amount for this losing package by a small amount typically does not affect the linear prices.[140] In order to affect the linear prices, it is necessary to change bid amounts by some discrete amount such that the losing bid determining that bidder's excursion changes.

A12.80 Therefore, we can see that marginal (i.e. small) changes in losing bids typically do not affect linear reference prices. However, it is possible that larger discrete changes might do so, or smaller changes in the non-generic case where truthful bidding leads to a number of losing bids with equal excursions.

A12.81 So is there an equivalent under the linear reference rule to the strategy discussed earlier of 'small' winners in an implicit coalition trying to shirk the collective burden of beating a 'large' aggregating bidder? This is certainly possible, but it involves a winner raising its bids on lot categories its does not want – that are not in its winning package – in order to raise the linear reference price on those lot categories. In our earlier example, the winner of A has an incentive to make bids above value for the lots in the B package but not in the A package, in order to raise the linear reference price of the lot categories that it does not want.[141] This may benefit the bidder if it is winning as part of an implicit coalition with a winner of those lots.

A12.82 The linear reference rule therefore creates different incentives for making bids that differ from true value. Whereas the Vickery-nearest rule can create an incentive to reduce winning bids, the linear reference rule can create an incentive to increase losing bids (provided these do not involve lots contained in the bidder's winning bid). However, the incentives for marginal deviations from truthful bidder appear to be relatively weaker in the case of the linear reference rule.

A12.83 For both pricing rules, the incentive for deviation from value-based bidding are likely to be significantly muted by the complexity of the auction in terms of the number of lots categories, number of potential packages and number of bidders. This makes it difficult to assess the probability of being a coalitional winner, which is a key determinant of the benefit of deviating from straightforward bidding. In the case of linear reference pricing, there are also a greater number of dimensions that affect the formulation of an optimal deviation from straightforward bidding.

[139] For simplicity, ignore the non-generic case where a number of losing bids may have equal excursions.
[140] We ignore the non-generic case that two losing bids have exactly the same excursion.
[141] This point was raised by Prof Ian Jewitt in a submission on behalf of Telefonica made in the consultation responses to the proposed auction rules for the combined award of 800MHz and 2.6GHz spectrum issued by Ofcom in March 2011.

Annex 13

Annual Licence Fees: further discussion

Introduction and summary

A13.1 In the March 2011 consultation, we set out initial proposals for how to implement the requirement under the Government Direction to revise fees for 900 MHz and 1800 MHz licences after completion of the auction so that they reflect the full market value of the spectrum. We explained that we believed that for these purposes full market value meant the market price that would arise in a well functioning spectrum market, such that supply equals demand. We would not attempt to set Annual Licence Fees (ALF) conservatively in light of the available information and we would not discount them relative to our assessment of full market value.

A13.2 We received a number of responses regarding our proposals. The majority focused on the general principles and the implementation of the Direction, but we also received some responses regarding more detailed aspects such as the comparability of spectrum bands and the methodology for converting upfront auction fees into annual payments.

A13.3 In this consultation we focus on the comments on the use of auction information to derive ALF, reflecting the obligation in the Direction to have particular regard to the sums bid for licences in the auction when revising the 900 MHz and 1800 MHz licence fees. In light of the comments received, our updated thinking is to consider three sources of information to estimate the full market value of 900 MHz and 1800 MHz spectrum:

- the bids made and licence fees paid in the combined award, using the linear reference price methodology described in the March 2011 consultation (whether or not this is the pricing rule used in the award);
- an alternative approach to estimating full market value from bids in the auction which we term the Additional Spectrum Methodology; and
- amounts paid in auctions in other countries for the same or similar spectrum, which may inform the relative value of different frequencies as well as their market value.

A13.4 As in the March 2011 consultation, it is important to stress that our provisional conclusions set out here will have to be reviewed after the auction, when we will consult specifically on the revision of ALF on 900 MHz and 1800 MHz spectrum. Nonetheless we consider that it is likely to be helpful for stakeholders to understand in advance of the auction our likely approach and therefore we have included a discussion of the key issues raised in response to our March 2011 consultation. We propose to cover other aspects of the process for determining ALF and corresponding consultation responses following the award when we will finalise all details.

A13.5 The remainder of this annex is structured as follows.

a) We consider comments on the principle of linking ALF to bids and prices in the auction and the potential for this adversely to affect bidding incentives in the auction.

b) We describe our revised thinking on the approach that we should take.

c) We then provide clarifications on other issues that stakeholders raised involving more detailed or related aspects of the approach to setting ALF and its implementation.

Link between auction information and ALF

A13.6 To investigate the main issues regarding ALF raised in responses, we:

a) provide a summary of our March proposals;

b) summarise responses on this issue, i.e. the risk of reduced auction efficiency from a mechanistic link between bids in the auction and ALF;

c) review the basis for the comments using a simple example; and

d) consider the implications for how to set ALF.

Our March proposals envisaged using bids and prices in the auction to determine ALF subject to the auction being sufficiently competitive

A13.7 In the March 2011 consultation we described a number of different sources of information that could be used to determine the full market value of 900 MHz and 1800 MHz spectrum. We identified the following:

a) bids made and licence fees paid in the auction for the 800 MHz and 2.6 GHz spectrum;

b) amounts paid in auctions in other countries for the same or similar spectrum;

c) estimates derived from technical and cost modelling; and

d) estimates derived from spectrum trades for 900 MHz and 1800 MHz spectrum in the UK or potentially in other countries.

A13.8 At paragraphs A11.7 to A.11.17 of the March 2011 consultation, we considered the strengths and weaknesses of each of these sources of information. From that assessment, we provisionally concluded that, if the auction was sufficiently competitive, the amounts bid and licence fees paid in the auction were likely to provide the most reliable basis for estimating the full market value of 900 MHz and 1800 MHz spectrum.

A13.9 In that case, we proposed that:

a) ALF would vary linearly with the amount of spectrum for each category of spectrum;

b) ALF for 900 MHz spectrum would be based on linear prices for suitable lots at 800 MHz; and

c) ALF for 1800 MHz would be based on a simple average of linear prices for suitable lots at 800 MHz and for paired lots (standard power) at 2.6 GHz.

A13.10 The proposal was subject to us reviewing the auction information in order to establish whether it was reliable and appropriate to use it in this way.

Several responses raised concerns regarding the use of auction information to establish ALF particularly if the information was used mechanically

A13.11 A number of responses commented on our provisional view that the auction prices were likely to provide the most reliable source of information for the purposes of setting ALF. Some expressed support and one stakeholder invited us to implement the new fees quickly. However, several of those who commented on the ALF proposals questioned the role of auction prices for the purpose of determining the fees. They were particularly concerned about the risks they considered were associated with a mechanistic link between auction prices and ALF, or the possibility that bids would necessarily form part of the calculation of ALF.

A13.12 The risk identified results from the scope for the link to affect bidders' bidding incentives, leading holders of 900 MHz and 1800 MHz licences to shade their bids in order to seek to secure a lower ALF. This could result in an inefficient allocation of spectrum.

A13.13 In addition to a mechanistic link between bids and ALF, one respondent was also concerned about the discretion that Ofcom might wish to exercise in determining whether auction information was suitable to set ALF. The respondent saw a potential issue in Ofcom effectively deciding whether an auction had been effectively competitive, and the impact that this might have on how bidders behaved in the auction with potential knock-on effects for ALF.

A13.14 We consider the potential distortion of bids and auction outcomes below.

A mechanistic link between auction prices and ALF may create incentives for bid shading and affect the auction outcome but there are other considerations

<u>Numerical example – initial simplifying assumptions where ALF would be zero if the price of 800 MHz was zero</u>

A13.15 A numerical example can help to illustrate this point. For the purpose of the example, although this was not our proposal in the March 2011 consultation, we assume that there is a mechanistic link between auction prices and ALF, both for simplicity and to use an extreme case of linkage between auction prices and ALF as a reference point. In the numerical example we focus on the link between the auction of 800 MHz spectrum and ALF for 900 MHz Similar principles will also apply to the use of auction information in setting ALF for 1800 MHz:

- Suppose that bidder 1 holds 2x10 MHz of 900 MHz spectrum and competes for 2x10MHz of 800 MHz spectrum against bidder 2 which does not hold any 900 MHz spectrum.

- When bidder 1 bids in the auction for 2x10 MHz of 800 MHz spectrum, it considers the value it attributes to winning the 800 MHz spectrum and using it as part of its overall portfolio, the price it could pay for it and the effect that its bids would have on the ALF it will pay for its 900 MHz holding.

- The effect that bidder 1's bids have on ALF is equal to the expected difference in ALF caused by its bids, i.e. the expected difference in ALF with and without bidder 1's bids, which would be the difference in the auction price of 800 MHz spectrum with and without bidder 1's bids if there was a purely mechanistic linkage between the price of 800 MHz spectrum and the ALF for 900 MHz spectrum.

- As for any bidders in the auction, the 900 MHz holder has an incentive to bid up to the point at which it still receives a positive surplus from its bid winning. That is it will bid for 2x10 MHz of 800 MHz of spectrum as long as:

  - Net surplus from bidding on 800 MHz spectrum = (Value from winning 2x10 MHz of 800 MHz – Price for 2x10 MHz of 800 MHz) – (Price of 2x10 MHz of 800 MHz as proxy for 900 MHz ALF– Expected ALF on 900 MHz without own bids) >0.

A13.16 The first term in the equation above is the same for other bidders for 800 MHz who do not hold 900 MHz, i.e. the expected value of 800 MHz net of the auction price. The second term reflects the additional consideration that bidding on 800 MHz may affect the ALF for 900 MHz, i.e. the difference in ALF with and without the bidder's own bids.

A13.17 Bidder 2 instead only considers the value it attributes to the 800 MHz spectrum minus the auction price it would pay if it won. Any effect on ALF is directly not relevant to it, because bidder 2 does not hold 900 MHz spectrum and does not have to pay ALF for it.

A13.18 Table 13.1 sets out some assumptions for a simple numerical example. These assumptions are initial ones that we have designed to illustrate circumstances in which a mechanistic linkage between the auction price for 800 MHz and ALF for 900 MHz can lead to an inefficient allocation. In subsequent tables, we develop this example with further assumptions.

A13.19 Under the initial assumptions in Table 13.1, bidder 1 is assumed to have a value for 800 MHz substantially above bidder 2 (1,900 compared with 1,000) and so would acquire the 800 MHz spectrum in an efficient allocation.[142] In the absence of any bids by bidder 1, bidder 2 would obtain the 800 MHz spectrum for a price of zero (assuming a reserve price of zero) and we assume that ALF is also zero in this case. This is unrealistic but we explore below the implications of more reasonable assumptions. Table 13.1 shows the net surplus of each of the two bidders, with bidder 2 setting the price at 1,000 as the losing bidder (second price rule).

[142] Abstracting from any other relevant considerations such as the allocation changing the strength of competition in mobile services.

Table 13.1: Numerical example with two bidders and zero ALF without own bid

	A	B	C = A – B	D = B	E	F = D – E	G = C – F
	Value of 800MHz	Auction price of 800MHz	Surplus on 800MHz	ALF for 900MHz with own bid[143]	ALF without own bid	Increase in ALF caused by own bid	Net surplus
Bidder 1	1,900	1,000	900	1,000	0	1,000	-100
Bidder 2	1,000		0	n/a	n/a	n/a	0

A13.20 In this case, if bidder 1 were able accurately to estimate bidder 2's value for the 800 MHz lot, it would not bid for the 800 MHz spectrum and the lot would be assigned to bidder 2 even though bidder 2 values the spectrum less highly than bidder 1.[144] By not bidding, bidder 1's net surplus would be zero (zero on 800 MHz and zero ALF). This is an improvement of 100 compared to bidding (for which the net surplus is -100 as shown in the Table above).

A13.21 Given the specific circumstances of this example, the ALF derivation causes an inefficient allocation of spectrum.[145] It is therefore important to consider:

i) the strength of the link between bids for 800 MHz and ALF for 900 MHz; and

ii) the circumstances that could lead to an inefficient allocation of spectrum.

A13.22 Below we discuss two important and more realistic modifications to the initial numerical example: first, where ALF without the bidder's own bids is greater than zero; and second, where are more than two bidders.

Numerical example - ALF without own bids that is greater than zero

A13.23 Modifying the example above, we now assume that bidder 1 expects ALF without its own bids to be at least equal to 200 rather than zero. Since ALF on 900 MHz is intended to reflect full market value, this value must be greater than zero (as long as 900 MHz has any value to potential holders). The reason for an expectation of an ALF of at least 200 may, for example, be because there is a reserve price on 800 MHz of 200. Table 13.2 shows the implication of this change in assumption about the expected level of ALF without bidder 1's own bids.

[143] Assuming a mechanistic linkage between the auction price for 800MHz and ALF for 900MHz.
[144] Throughout the numerical examples here and below we assume that, if surplus to the bidder is zero, it will still make the bid.
[145] Note that in this example we assume that bidder 1 bids for a quantity of 800MHz spectrum that is equivalent to the amount of 900 MHz spectrum that it holds. In practice, the bidder may bid for a quantity of 800MHz spectrum which is smaller than the amount of 900MHz that it holds. This means that the possible distorting effect of bidding on 800MHz spectrum could be larger.

Table 13.2: Numerical example with two bidders and ALF without own bid of 200

	A	B	C = A – B	D = B	E	F = D – E	G = C – F
	Value of 800MHz	Auction price of 800MHz	Surplus on 800MHz	ALF for 900MHz with own bid	ALF without own bid	Increase in ALF caused by own bid	Net surplus
Bidder 1	1,900	1,000	900	1,000	200	800	100
Bidder 2	1,000		0	n/a	n/a	n/a	0

A13.24 In this case, when the price of the 800 MHz spectrum reaches 1,000 in the auction, bidder 1 will continue to bid for the spectrum, because its net surplus is now positive at 100. The difference from the initial example in Table 13.1 is that the increase in ALF for 900 MHz caused by bidder 1 bidding on 800 MHz at an auction price of 1,000 is now smaller, because ALF would be 200 (not zero) even if bidder 1 did not bid at this price.

A13.25 As a result, bidder 1 will outbid bidder 2, because at prices above 1,000 it still has a positive surplus, while bidder 2 will have dropped out. Bidder 1 will therefore win the 800 MHz spectrum, and the allocation of spectrum will be efficient.

A13.26 These examples show some of the situations in which the bids of firms that will have to pay ALF ("ALF payers"), bidder 1 in the example, may be affected:

- When the auction price is below the level of ALF that ALF payers expect without their own bids (for example because the auction price is below other likely benchmarks), there is no distortion to bids. This is because when an ALF payer's bid is below the expected ALF, it knows that the level of ALF is likely to be the same with or without its bids.

- When the auction price exceeds the level of ALF that ALF payers expect without their own bids, there is a potential for a distortion because an increase in an ALF payer's bid may increase the level of ALF. However, the second numerical example (shown in Table 13.2) illustrates that the potential effects on incentives do not necessarily affect the auction outcome. Even though the auction price (1,000) is well above the level of ALF without bidder 1's own bids (200), the auction results in an efficient allocation of 800 MHz spectrum to bidder 1. The reason is that in this example:

  - the additional value of 800 MHz to bidder 1 over bidder 2 (i.e. 1,900-1,000 = 900) is larger than

  - the difference between the auction price above which bidder 2 drops out (i.e. its value of 1,000) and the level of ALF without bidder 1's own bids (200), i.e. 1,000 – 200 = 800.

A13.27 Put simply, from an ALF payer's perspective, the higher the value of ALF without its bids, the less value there is from reducing bids to minimise increases in ALF. As a result, setting an absolute minimum value for ALF for 900 MHz, for example in line with reserve prices for 800 MHz, would reduce bid shading incentives from the link between auction prices and ALF.

Numerical example - more than two bidders as well as ALF without own bids that is greater than zero

A13.28 ALF payers also know that other competitors can affect the value of ALF. This is because the highest losing bidder sets the price for the 800 MHz lot and this sets the value of ALF for 900 MHz spectrum (under the circumstances of the example as it is assumed that ALF of 900 MHz = 800 MHz auction price for the same quantity of spectrum). To illustrate this point, we now assume that there is also a third competitor in the auction, bidder 3, which values 2x10 MHz of 800 MHz spectrum at 900 (i.e. less than bidder 2) and which does not hold any 900 MHz spectrum.

A13.29 We make the following additional assumptions.

a) The auction price increases in increments of 100 in each round of bids. We initially consider the round in which the 800 MHz lot price has reached 900; it was 800 in the previous round and it will be 1,000 in the next round.

b) Bidder 1 expects that ALF without its own bid will be at least equal to the bid of the highest losing bidder.

c) After each round, the auctioneer informs bidders of the aggregate level of demand for the lot.

A13.30 Table 13.3 shows surpluses for each of the three bidders in the round under consideration on the basis of the information available in that round. In the previous round (with a round price of 800), all three bidders bid.

Table 13.3: Numerical example with three bidders and round price of 900 (surpluses as expected during the current round on the basis of previous rounds)

	A	B	C = A – B	D = B	E	F = D – E	G = C – F
	Value of 800MHz	Round price of 800MHz	Surplus on 800MHz	Max. ALF on 900MHz with own bid	Min. ALF without own bid in that round	Max. Increase in ALF caused by own bid	Net surplus
Bidder 1	1,900	900	1,000	900	800	100	900
Bidder 2	1,000		100	n/a	n/a	n/a	100
Bidder 3	900		0	n/a	n/a	n/a	0

A13.31 In this round, with the price at 900, bidder 1 knows that, if it does not bid, ALF will be at least 800. This is because in the previous round, at a price of 800, all three bidders bid. Even if both of the other bidders dropped out in the current round (price of 900), the highest losing bid and the final auction price would be at least 800. Thus we assume that the minimum value of ALF as a result of this round in the case where bidder 1 does not bid is 800.

A13.32 Bidder 1 also knows that if it *does* bid, it could increase ALF to 900. If both of the other bidders drop out, then the auction would close and the highest losing bid would be at least 800. However, if bidder 1 has bid, and one of the other bidders also remains active and bids at 900, then the auction will not close at a price below

900. Thus we assume that the maximum value of ALF in this round in the case where bidder 1 bids is 900.

A13.33 Hence the *maximum* effect that bidder 1 can have on the value of ALF by bidding in this round is to increase ALF by 100 (and the actual effect could be lower).

A13.34 Bidder 1 discovers that in fact all three bidders bid at a price of 900. Moving onto the next round (at a price of 1,000), it updates its beliefs about ALF to reflect the fact that at least one other bid for the lot was equal to 900 in the previous round and (as a result of its bidding in this round) ALF could be up to 1,000, as shown in Table 13.4.

Table 13.4: Numerical example with three bidders and round price of 1,000 (surpluses as expected during the current round on the basis of previous rounds)

	A	B	C = A – B	D = B	E	F = D – E	G = C – F
	Value of 800MHz	Round price of 800MHz	Surplus on 800MHz	Max. ALF on 900MHz with own bid	Min. ALF without own bid in that round	Max. Increase in ALF caused by own bid	Net surplus
Bidder 1	1,900	1,000	900	1,000	900	100	800
Bidder 2	1,000		0	n/a	n/a	n/a	0
Bidder 3	900		-100	n/a	n/a	n/a	-100

A13.35 At a price of 1,000, bidder 3 will stop bidding because 1,000 exceeds its valuation. Therefore, in the following round (when the price is 1,100), bidder 1 knows that one of the other bidders dropped out at a price of 1,000 so there are only two bidders left. Hence if bidder 1 does not bid, the auction will close and ALF will be set at 1,000. If bidder 1 *does* bid, it knows that one of the other bidders may also continue to bid, so ALF could increase to 1,100. However, it is still profitable for bidder 1 to continue bidding as shown in Table 13.5.

Table 13.5: Numerical example with three bidders and round price of 1,100 (surpluses as expected during the current round on the basis of previous rounds)

	A	B	C = A – B	D = B	E	F = D – E	G = C – F
	Value of 800MHz	Round price of 800MHz	Surplus on 800MHz	Max. ALF on 900MHz with own bid	Min. ALF without own bid in that round	Max. Increase in ALF caused by own bid	Net surplus
Bidder 1	1,900	1,100	800	1,100	1,000	100	700
Bidder 2	1,000		-100	n/a	n/a	n/a	-100
Bidder 3	900		-200	n/a	n/a	n/a	-200

A13.36 The outcome with three bidders in this numerical example is that bidder 1 wins the 800 MHz spectrum, which is the efficient allocation. The existence of a third competitor (with a value for 800 MHz 100 below bidder 2's value) means that the minimum level of ALF is much higher than in the previous examples, as the highest losing bid is at least as high as the value of that bidder (i.e. 900).

A13.37 The maximum increase in ALF caused by bidder 1's own bids in each round is 100 (the round price increment) while at least one other bidder is still active. The additional value of 800 MHz to bidder 1 over the next highest bidder is larger than this increase in ALF. Therefore, in this example the distortion of bidder 1's bidding incentives is weak and insufficient to alter the allocation of spectrum.

A13.38 So far, the example has assumed that bidder 1 makes a choice in each round whether to continue bidding or to drop out. However bidder 1 could also choose not to bid at all. With good information about the valuations of its rivals, this would in fact be an irrational choice. If bidder 1 had decided not to bid in the auction and let bidder 2 win the spectrum, then bidder 1 would have to pay an ALF equal to 900, the valuation of bidder 3, rather than 1,000, the valuation of bidder 2. Bidder 1 would also have forgone the profit from winning 800 MHz equal to its value for it of 1,900 less the price it would have had to pay to win it of 1,000. Hence the comparison of not bidding versus bidding shows that not bidding would lead to a loss of 800.

A13.39 With less good information about its rivals' valuations – as could be the case when considering whether to bid prior to the auction – choosing not to bid might in principle be a rational decision and might be more strongly influenced by the potential effect on ALF. However, this would need to involve a significant misperception. Even if bidder 1's assessment was somewhat inaccurate, it might still select a bidding strategy that led to an efficient outcome. For example, if it thought that both bidder 2 and bidder 3 had different valuations from their true valuations, of say 1,200 for bidder 2 and 700 for bidder 3, then it would expect:

- to have to pay 1,200 to win the 800 MHz lot;
- to pay 1,200 in ALF with its own bids or 700 without its own bids; and
- to have a resulting surplus of (1,900 – 1,200) – (1,200 – 700) = 200 by bidding.

It would therefore choose to bid.

A13.40 The reason that the auction allocates spectrum efficiently in the numerical example above is that the valuations of bidders 3 and 2 are sufficiently close compared to the excess of bidder's 1 value over the next highest. Hence, if bidder 2's valuation is higher compared to bidder 3, the risk of an inefficient allocation rises. Even if bidder 1 has full information about the valuations of its rivals, once bidder 2's valuation rises above 1,400 (all other things being equal), the bid-shading incentive on bidder 1 is sufficient to lead to an inefficient auction outcome. This 'breakeven point' (at 1,400) is shown in Table 13.6.

Table 13.6: Numerical example with three bidders including bidder 2 with a value of 1400

	A	B	C = A – B	D = B	E	F = D – E	G = C – F
	Value of 800MHz	Price of 800MHz	Surplus on 800MHz	Max. ALF on 900MHz with own bid	ALF without own bid in that round	Max. Increase in ALF caused by own bid	Net surplus
Bidder 1	1,900	1,400	500	1,400	900	500	0
Bidder 2	1,400		0	n/a	n/a	n/a	0
Bidder 3	900		-600	n/a	n/a	n/a	-500

A13.41 At this break-even point the gap between the values of bidders 1 and 2 is the same as between bidders 2 and 3. At any value of bidder 2 below 1,400 (holding constant both bidder 1's and 3's values) the auction would result in the efficient allocation of 800 MHz to bidder 1 even with a mechanical linkage to ALF. At valuations for bidder 2 above 1,400, bidder 1 prefers not participate at all because of the effect of its participation on ALF.

A13.42 If there is an inefficient allocation, a measure of the size of the inefficiency is the gap between the bidder with highest value (bidder 1 in the examples) and the value of the winner of the auction for the 800 MHz lot. This is on the basis that the private values of the bidders are well correlated with the social value (which also includes the benefits to consumers). Therefore, although there is a greater the risk of an inefficient allocation the higher is bidder 2's value compared to bidder 1, the size of any inefficiency is smaller.

Implications of a mechanistic link between auction prices and ALF

A13.43 These examples show that a mechanistic link between auction prices and ALF can create incentives for ALF payers either to shade bids or not to bid at all. In some circumstances however, the incentives may not distort the allocation of spectrum. ALF payers would be likely to engage in strategic demand reduction through bid shading only if they believe that they can affect the level of ALF and that they can improve their surplus. However, as shown in the example above, their scope to achieve both can be limited by other considerations even if the only source of information to set ALF is the level of bids in the auction. This is for two reasons:

a) First, if there is a pre-defined floor for ALF, then any pay-off from not bidding or shading bids would be more limited.

b) Second, if there are several bidders and their valuations are relatively close to each other, then the price set by the losing bidder would be unlikely to change materially whether or not an ALF payer shaded its bids or did not participate. Indeed, in such circumstances an ALF payer shading its bids in the hope of reducing ALF would have the potential consequence of losing without a material offsetting benefit to it of a reduction in ALF. If so, there would be little incentive for the ALF payer to shade its bids.

A13.44 Furthermore, the circumstances required for bidders to be incentivised to behave in a way that could result in an inefficient allocation are ones in which the size of any inefficiency would itself be limited, even if it were to occur.

A13.45 Hence, although it is not clear that bid-shading incentives from a mechanistic link between ALF and bids in the auction are likely to be strong in practice, we recognise that there is a potential issue in principle, as highlighted in Table 13.1 for example.

A13.46 We have therefore updated our thinking on how a range of sources of information could play a role in estimating full market value and developing ALF proposals following the auction and we have identified a potential new methodology to assess information based on bids in the auction. We set out our thinking below.

Our view of full market value and sources of information suitable to set ALF in light of responses

There was general support for our interpretation of full market value

A13.47 Respondents generally agreed with our interpretation of the meaning of full market value in the Direction, which we set out at paragraph A13.1 above. To the extent that it is relevant to the definition of full market value, the only differing view in responses that might relate to this interpretation was the suggestion to use our approach to setting AIP in order to determine revised ALF. We consider this point below in relation to the sources of information that are relevant to the calculation of revised ALF.

We continue to see an important role for the main data sources we identified in March 2011

A13.48 Our March proposals identified four sources of information that could be used to estimate the full market value of the 900 MHz and 1800 MHz spectrum. These were:

a) bids made and licence fees paid in the UK auction for 800 MHz and 2.6 GHz spectrum;

b) amounts paid in auctions in other countries for the same or similar spectrum;

c) estimates derived from technical and cost modelling; and

d) information derived from spectrum trades for 900 MHz and 1800 MHz spectrum in the UK or potentially in other countries.

<u>Bids in the UK auction, including for 1800 MHz</u>

A13.49 At the time of the March 2011 consultation, we considered that bids in the UK auction of the 800 MHz and 2.6 GHz bands would be a particularly useful source of information for estimating the full market value of the 900 MHz and 1800 MHz bands if the auction was sufficiently competitive. This was because the bands were generally substitutes.

A13.50 We considered it highly unlikely that relinquished spectrum would be available in the auction and we could not know whether Everything Everywhere's 1800 MHz divestment would be available in the auction.

A13.51 We now clarify that if the divested 1800 MHz spectrum were available in the auction, we would expect to include bids for it as part of any auction information we

might consider for the purpose of assessing ALF. This information might be sufficient for the purpose of using bid information to inform the ALF for other 1800 MHz spectrum, or it might be part of a wider pool of relevant bids, as one of a range of sources of information.

A13.52 Several respondents raised the concern regarding bid-shading incentives that we discuss above, while others were in favour of using bid data from the UK auction to set ALF subject to the auction being competitive. In some cases, respondents supported the principle of using UK bid data to revise ALF in principle, but they also considered that changes to the details of how we proposed to use bids would be important (e.g. to reflect differences between bands).

A13.53 As discussed above, we acknowledge the potential risk for the efficiency of the auction, at least in principle, from using bids made and licence fees paid in the auction as a single source of information for the purpose of setting ALF for 900 MHz and 1800 MHz spectrum, where ALF payers' bids might influence the ALF they pay. We propose below a way to mitigate this potential risk.

A13.54 Even before taking account of our proposal to mitigate further the potential risk from a link between bids and ALF, we continue to be of the view that bids in the UK auction are likely to be an important source of information if the auction is competitive. Notwithstanding that the Direction requires us to have particular regard to the sums bid for licences in the auction, bids in the auction would in any event be likely to provide an important indication of the full market value of spectrum. Furthermore, we can see no scope to get data of a similarly high relevance from other UK market transactions. No other auction of mobile spectrum of similarly large scale has taken place in the last decade, and nor do we expect another similar auction in the near future.

Licence fees paid in mobile spectrum auctions internationally

A13.55 In the March 2011 consultation, we explained our view that information from non-UK auctions for similar spectrum would play a helpful part in assessing the market value of spectrum in the UK. We noted that we would need to treat this information carefully in light of differences between international and UK markets and also to take into account whether these auctions were competitive.

A13.56 The use of international auction data also attracted opposing views. H3G argued that, if the UK auction was not competitive, then we should use data from other auctions of the same or comparable spectrum to set ALF. It argued that recent mobile spectrum auctions in Germany and Hong Kong would provide suitable benchmarks.

A13.57 Telefónica referred to the Competition Commission's determination on mobile phone wholesale voice termination charges to support the view that seeking to use information from international auctions would be particularly difficult and unlikely to be sufficiently robust.[146]

A13.58 The views that the Competition Commission and other parties expressed related to the specific econometric analysis that experts had put forward in the context of that

[146] Competition Commission. Determination on mobile phone wholesale voice termination charges, 16 January 2009, available at http://www.competition-commission.org.uk/appeals/communications_act/mobile_phones_determination.pdf. Telefonica cited paragraph 2.5.50.

case. We note the arguments made in that context on the merits of using information from international spectrum auctions to infer information for the UK. We will take these points into account if we use similar approaches to consider whether to draw inferences for UK spectrum values. This is consistent with the view we set out in our March 2011 proposals.

A13.59 In any case, we recognise that interpreting and using international benchmarks requires care. We also note that the specific nature of information that results from a market process is relevant here just as it is for UK auction prices. In that sense, international auction results have the potential to be a helpful part of our overall approach, when taking due account of differences between the UK and comparable markets for which data is available.

Technical and cost modelling

A13.60 Our March 2011 consultation recognised that spectrum value estimates derived from technical and cost modelling are subject to a considerable margin of error, especially in relation to technologies that are in the early stages of commercial deployment such as LTE. As a consequence, we proposed that we should only use such estimates alone if there were no credible alternative.

A13.61 Vodafone considered that it would be appropriate to use our methodology for determining opportunity cost and thereafter setting AIP to set ALF and that this would also address the issue of bid shading incentives. Vodafone argued that we could then use the bids made in the auction as a cross-check.

A13.62 However, as in the March 2011 consultation we do not consider that this approach would give sufficient weight to the best source of information on full market value, and as a result would be likely to produce less reliable estimates. This approach could potentially lead to ALF rates that appeared out of line with full market value as inferred from the auction, if the auction appeared to be sufficiently competitive and auction prices were significantly above, or below, values derived from modelling. Vodafone did not suggest potential ways for addressing such challenges. In such circumstances we would be inclined to place greater weight on the market information from the auction to estimate full market value which is subject to larger error margins. This puts into question the benefit of undertaking the complex technical and cost modelling task in the first place.

A13.63 We therefore do not currently envisage relying on technical and cost modelling, as we expect that more appropriate (market-based) information will be available. However, we would review the possible use of such modelling if there were reasons for considering it was likely to be more reliable than other sources of information.

Prices from private sales of rights to use spectrum

A13.64 We did not receive specific comments on the potential use of information from relevant spectrum trades following the March 2011 consultation.

A13.65 As we set out in that document and in contrast to publicly available information from auctions, information from private transactions for mobile spectrum that may exist today is unlikely to be helpful in estimating full market value for the purpose of setting ALF. There are three reasons. First, there may be no relevant trades in the timeframe for setting ALF. Second, even if there were one or more trades, we might not be able to obtain price information for the transaction, as there is no requirement on parties to a spectrum trade to submit it to us. Third, for trades in the

UK, the ALF that the trade might potentially inform would apply following the trade, so that any acquirer would be likely to reflect their expectation of future ALF in the price they paid.

A potential additional source of information from bids in the auction that does not incorporate the ALF payer's bids: Additional Spectrum Methodology

A13.66 In response to the potential concern discussed above regarding the potential impact of ALF payers' bids on the ALF they pay, we have developed a potential additional source of information which relies on information from the auction and which excludes bids from ALF payers.

A13.67 The objective of this approach is to obtain an estimate of the opportunity cost of each holder of 900 MHz and 1800 MHz spectrum retaining their holding, in light of the bids made in the auction and in a way that is not directly influenced by the bids of the licensee whose spectrum value we are assessing.

A13.68 The intended method for estimating the full market value of 800 MHz, 1800 MHz and 2.6 GHz spectrum would be to calculate the additional amounts that bidders would be willing to pay for additional 800 MHz, 1800 MHz and 2.6 GHz spectrum if it had been available in the auction (as a proxy for the 900 MHz and 1800 MHz spectrum that could have been made available in the auction but wasn't).

A13.69 For example, since we are interested in estimating the full market value of the 900 MHz spectrum retained by each of Telefónica's and Vodafone, and the 1800 MHz spectrum retained by each of Everything Everywhere, Telefónica's and Vodafone (and potentially also the acquirer of the 1800 MHz spectrum to be divested by Everything Everywhere), it might be appropriate to consider:

a) the additional amount that bidders other than Telefónica would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x15 MHz of 800 MHz spectrum (as a proxy for the 2x17.4 MHz of 900 MHz spectrum retained by Telefónica);

b) the additional amount that bidders other than Vodafone would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x15 MHz of 800 MHz spectrum (as a proxy for the 2x17.4 MHz of 900 MHz spectrum retained by Vodafone);

c) the additional amount that bidders other than Everything Everywhere would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x45 MHz of 1800 MHz spectrum (as a proxy for the 2x45 MHz of 1800 MHz spectrum retained by Everything Everywhere);

d) the additional amount that bidders other than Everything Everywhere would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x45 MHz of 2.6 GHz spectrum or an additional 2x20 MHz of 800 MHz spectrum and 2x25 MHz of 2.6 GHz spectrum (as a proxy for the 2x45 MHz of 1800 MHz spectrum retained by Everything Everywhere);

e) the additional amount that bidders other than Telefónica would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x5 MHz of 2.6 GHz spectrum (as a proxy for the 2x5.8 MHz of 1800 MHz spectrum retained by Telefónica);

f) the additional amount that bidders other than Vodafone would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x5 MHz of 2.6 GHz spectrum (as a proxy for the 2x5.8 MHz of 1800 MHz spectrum retained by Vodafone).

A13.70 The calculation of these additional bid amounts would in each case proceed as follows (for ease of exposition we describe the situation in the case of the first example above in the previous paragraph).

i) The baseline bid amount for the calculation would be the total amount of the winning bids taking account of all bids made less the amount of Telefónica's winning bid (if any). The calculation would involve bid amounts and not prices, as under this approach involving a hypothetical spectrum supply, bids set the opportunity cost.

ii) The baseline spectrum on offer would be all of the spectrum that was on offer in the auction (whether sold or not) less the amount of spectrum in Telefónica's winning bid (if any); i.e. all of the spectrum on offer that was not won by Telefónica.

iii) We would then add to this baseline spectrum an additional 2x15 MHz of 800 MHz spectrum (hypothetical) as a proxy for the 2x17.5 MHz of 900 MHz spectrum retained by Telefónica.[147]

iv) We would then calculate which combination of bids from bidders other than Telefónica would win, if it had been this larger total amount of spectrum that had been on offer in the auction, and the total amount of those bids. For the avoidance of doubt, there would not be any further bidding for this purpose. This calculation would involve solely bids made by bidders during the auction itself.

v) The additional amount that bidders other than Telefónica would be willing to pay for the additional spectrum hypothetically on offer would then be the difference between this new total bid amount and the original baseline total bid amount.

A13.71 We would apply these five steps to each of the cases set out above at paragraph A13.69.

A13.72 One advantage of this approach to estimating the full market value of spectrum is that, to first order at least, it creates no incentive for the holders of 900 MHz and 1800 MHz spectrum to shade their bids in the auction as a result of any impact that their bids might have on the future level of ALF for the spectrum they retain. If we based ALF for retained spectrum solely on these estimates then the calculations are such that the bids made by each holder of 900 MHz and 1800 MHz spectrum would have no direct impact on the revised ALF that they would each pay.

A13.73 However the approach may raise interpretation challenges because the estimates it generates could well be non-linear in the quantity of spectrum retained, and even for the same quantity of spectrum retained, the estimates might differ between bidders, e.g. between Telefónica and Vodafone who currently hold the same amount of 900 MHz spectrum.

[147] If there were multiple categories of 800MHz spectrum, then we would need to decide which category or categories of 800MHz lot to increase in number. No equivalent question arises in respect of 2.6GHz spectrum, where the single relevant category is that of paired lots for individual use at standard powers.

A13.74 We have also considered whether this approach could raise different issues for bidder incentives. We have not identified clear downsides of that nature but will keep this under review and we would welcome any feedback from stakeholders on this point.

A13.75 For these reasons, we would not intend to use this approach in isolation but would expect that it could, alongside others, form part of the pool of information that we would use in order to take a view on the appropriate fees that should apply consistent with the Direction.

Our updated thinking is to use three sources of information to estimate full market value

A13.76 Based on the above assessment of the properties of different potential sources of information, our updated thinking is to consider the following in order to estimate the full market value of 900 MHz and 1800 MHz spectrum:

i) the bids made and licence fees paid in the combined award, using the linear reference price methodology described in the March 2011 Consultation, provided the auction is sufficiently competitive;

ii) an alternative approach to estimating full market value from bids in the auction which we term the Additional Spectrum Methodology; and

iii) licence fees paid in auctions in other countries for the same or similar spectrum, which may, inter alia, inform the relative value of different frequencies.

A13.77 Each of these sources of information has advantages and disadvantages, as discussed above. We propose to determine the precise approach to revising ALF following a further consultation after the auction. In doing this, we will have particular regard to the sums bid in the auction, as required by the Direction.

Respondents raised other issues of principle and of detail on which we seek to provide clarifications

A13.78 In addition to the impact of a link between bids and ALF, responses to the March 2011 consultation also included a number other comments. These were concerned with the risks that our proposed methodology could:

a) constitute State aid because of fees for ALF payers relative to their competitors;

b) raise issues because of the difficulty in comparing different spectrum bands;

c) potentially distort bidding incentives under the linear reference rule for the calculation of auction prices;

d) be inconsistent with our views in the Strategic Review of Spectrum Pricing (SRSP)[148] regarding the risk of distortion of bidding incentives in an auction where auction prices may impact on fees for other spectrum that some bidders or potential bidders hold;

[148] Statement published on 17 December 2010 at http://stakeholders.ofcom.org.uk/binaries/consultations/srsp/statement/srsp-statement.pdf.

e) be inconsistent with the European regulatory framework, which requires spectrum fees to reflect the need to make optimal use of that spectrum and be, among others, proportionate and justified; and/or

f) affect the scope for Everything Everywhere to conclude a private sale of its 1800MHz divestment ahead of the auction, given that we are proposing to set out our decision on ALF for 900 MHz and 1800 MHz spectrum after the conclusion of the auction.

A13.79 We consider most of these points below. We will deal with the remaining points (such as the comparability between bands) when we consult on the revision of ALF after the auction.

We are satisfied that our proposed approach does not give rise to State aid

A13.80 Telefónica argued that bids in the auction are more expensive for ALF payers than for other bidders. This is because bids in the auction will determine how much an ALF payer needs to pay for rights to use spectrum available in the auction if it wins any, and will also determine the level of ALF it has to pay on 900 MHz and /or 1800 MHz it holds. The respondent argued this would constitute State aid.

A13.81 H3G argued that there was a risk of State aid in favour of ALF payers. The risk would materialise if ALF failed to reflect advantages from 900 MHz spectrum such as the first mover advantage H3G considered it provides to its holders from the ability to use 3G technology which has been available for some time at 900 MHz

A13.82 We are satisfied that our proposals do not give rise to State Aid either in favour of non-ALF payers or ALF payers. In any event, with respect to Telefónica's concern we note that it is efficient for an ALF payer to pay increased ALF as a result of its own bids in the auction to the extent that the bids in the auction provide a better estimate of full market value, as this would lead to a more efficient level of ALF. Inefficiency only arises from the potential effects of bid-shading which is discussed above. Further, we also note in relation to the point raised by H3G that we are proposing to set ALF at our estimate of full market value and not at a discount.

The proposed linear reference pricing rule is unlikely to raise incentive issues in practice

A13.83 In a report submitted by Telefónica, Professor Ian Jewitt raised some concerns regarding incentives that might exist under the proposed linear reference pricing rule. We discuss these comments at Annex 12 and explain why we think that the issues are unlikely to materialise in practice.

A13.84 We also note that the Vickrey-nearest pricing rule is also an option under our proposals. We could use that rule for the purpose of determining prices in the auction and the linear reference price rule under one of our methodologies for estimating full market value as an input to our revision of ALF. This would be as part of the wider set of methodologies we are proposing to use, such that we believe that any potential distorting incentives linked to a pricing rule are unlikely to be a concern for the purpose of setting ALF or more generally.

Our March 2011 proposals are consistent with our Strategic Review of Spectrum Pricing (SRSP)

A13.85 In its submission, Vodafone voiced concern that the conditions that we defined in the SRSP for when it is not appropriate to use auction prices apply in this case. Specifically it referred to the link between bids and ALF, and quoted paragraph 3.105 of the consultation on spectrum pricing we published in March 2010.[149]

A13.86 We were clear in the SRSP that direct observations of market prices are highly relevant as indicators of spectrum market values. We adopted a principle under which we will take account of observed market valuations from auctions and trading alongside other evidence where available when setting spectrum fee levels. However, such market valuations will be interpreted with care and not applied mechanically to set reference rates and AIP fees.[150] Our proposals in the March 2011 Consultation were consistent with this SRSP approach, which our updated thinking reinforces.

Our proposals are consistent with the European regulatory framework

A13.87 Vodafone also queried whether our March 2011 consultation proposals might be inconsistent with Ofcom's duties under the European regulatory framework relevant to spectrum management.

A13.88 Vodafone made the following main arguments:

a) that we have previously set spectrum licence fees using a methodology known as "administrative incentive pricing" (AIP) on the basis that this methodology would promote the efficient use of spectrum by giving incentives for spectrum to be allocated to those who value it the most;

b) that we did not explain why we had proposed setting the revised fees for the spectrum in question using a different methodology from AIP other than because of the provisions of the Direction;

c) that if the Direction was the reason for our proposal to move to a new fee setting methodology, we would have to be satisfied that the new approach (and implicitly therefore the provisions of the Direction) was consistent with our duties under the Common Regulatory Framework Directives, as European law takes precedence over domestic law in the case of any contradiction between the two;

d) and that, as a result, we must interpret the Direction in a way that does not result in the bidding process in the auction being distorted by virtue of our proposals in relation to the revision of annual licence fees, so as to ensure that competition is not distorted in the mobile market.

A13.89 We consider that our proposals for calculating ALFs, which amongst other things take account of article 6 of the Direction, are compatible with our statutory duties

[149] See SRSP consultation published on 29 March 2010 at http://stakeholders.ofcom.org.uk/consultations/srsp/. Paragraph 3.105: "Linking AIP directly to auction prices may distort bidding incentives. For example, if bidders expect the AIP fees they pay on some of their spectrum to be revised in light of the auction price of spectrum they are bidding for, they may have an incentive to bid less aggressively. In addition, if the direct link between AIP and auction prices affects some bidders' valuations but not others' (for instance, if only some bidders are subject to AIP on their other spectrum holdings), auction results might be distorted".

[150] See SRSP statement, paragraphs 4.263 and 4.310.

under the domestic and EU legislative framework. As we have said, we will consult on our exact proposal for calculating ALFs after the auction.

A13.90 As we set out in the March 2011 consultation, the Direction requires Ofcom, after the completion of the auction, to revise the annual licence fees paid for 900 MHz and 1800 MHz spectrum. When preparing its Direction, the Government consulted on the policy as part of its Digital Britain initiative[151] and on its implementation through a draft Statutory Instrument.[152] This led to the requirement for us to revise ALF to reflect full market value, having particular regard for bids in the auction.

A13.91 Regarding Vodafone's concern that our approach as proposed might distort bidding in the auction, we consider the risk to be low. As is clear from the March 2011 consultation and the discussion in this section, we do not propose to adopt a mechanistic link between ALFs and prices paid in the auction and for the avoidance of doubt our March 2011 proposals did not include such a mechanistic link. Rather we intend to use various sources of information to determine full market value for these purposes. However, in light of concerns expressed by some respondents as regards the potential impact on bidding incentives of the specific methodology for deriving estimates of full market value from bids in the auction that we set out in our March 2011 consultation.

A13.92 We have developed an additional approach which we might use alongside other estimates.[153]

Impact of policy for revising ALF on trading of the 1800 MHz divestment

A13.93 Two respondents argued that uncertainty regarding the value of ALF may affect firms' incentives to trade spectrum. In the absence of full information on ALF ahead of the auction, uncertainty would affect the scope for parties to make an accurate assessment of the value of spectrum due to become subject to ALF in future. The respondents were concerned that it could reduce the scope for Everything Everywhere to trade the 1800 MHz it has committed to divest in advance of the auction. One respondent thought that, under the March 2011 proposals, Everything Everywhere's decision as to whether to sell the 1800 MHz divestment privately in advance of the auction or to relinquish it for award in the auction would be affected by its expectation of the average price of 800 MHz and 2.6 GHz in the auction relative to the likely price of 1800 MHz if it were sold in the auction.

A13.94 It is of course axiomatic that there will be a degree of uncertainty about the level of ALF until we decide what it will be. However, this flows from the Direction under which we are obliged to set revised ALF *after* the auction and to have particular regard to the sums bid for licences *in* the auction. We are therefore unable to remove all uncertainties ahead of the auction.

A13.95 However, we are keen to make available as much relevant information as we can on our intended approach to deriving ALF ahead of the auction and we welcome suggestions from stakeholders regarding what additional information we may be able to provide ahead of the auction, bearing in mind the provisions of the Direction.

[151] See http://webarchive.nationalarchives.gov.uk/20100511084737/interactive.bis.gov.uk/digitalbritain/.
[152] See http://www.legislation.gov.uk/ukdsi/2010/9780111500767/introduction.
[153] Furthermore, contrary to Vodafone's suggestion, both in the March 2011 consultation and in this document we explain why, in the relevant circumstances, we do not favour relying on technical and cost modelling, the approach we have traditionally used to set AIP.

Next steps to the final milestone of making implementing regulations

A13.96 Our proposal is to review the overall approach for the implementation of article 6(1) and 6(2) of the Direction in light of responses to this and the previous consultation and, after completion of the award, to put forward proposals for specific levels of ALF in a further consultation.

A13.97 In light of responses to the consultation on specific ALF levels, we will then set out our decision in a statement and publish the regulations implementing this decision in draft for statutory consultation. Finally, we will make the regulations that will bring into force new fees for 900 MHz and 1800 MHz spectrum.

A13.98 If new developments led to a delay in the award of the 800 MHz and 2.6 GHz bands, we would also expect to consider whether to update current fee levels for 900 MHz and 1800 MHz spectrum ahead of the auction. We would therefore consider whether it might be suitable to introduce interim revised ALFs ahead of fully implementing the Direction after the auction.

Annex 14

LTE Technical Modelling Revised Methodology

A14.1 Annex 14 will be published separately.

Annex 15

Summary of responses on technical issues (including relevant responses to TLC con doc) and Ofcom's comments

Introduction

A15.1 Ofcom issued consultations on the award of 800 MHz and 2.6 GHz in March 2011 and June 2011. Both consultations included technical elements and we received a number of comments from stakeholders on these elements. This annex sets out a summary of the comments that we received and our analysis of the points raised.

Comments on the technical performance modelling in the March 2011 consultation

A15.2 In the March 2011 consultation we provided a set of results on technical performance modelling for deployment of networks in various quantities of spectrum in the 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz bands. This section considers the comments that we received on various aspects of the modelling and the assumptions that lay behind it. The results of the revised modelling are presented in Annex 7 and the modelling methodology in Annex 14.

Propagation model

A15.3 Vodafone raised doubts about the use of the Extended Hata propagation model to compare different frequency bands due to the breakpoints in the model at 1500 MHz and 2000 MHz and concluded that that model generally overestimates the frequency exponent (the instantaneous rate of change of pathloss with frequency) that applies between a lower frequency and a frequency close to the 2000 MHz boundary, and the propagation loss in the simulated area would not vary with frequency by as much as Ofcom suggested in the March 2011 consultation. Vodafone proposed the use of a constant frequency exponent for a given clutter type across the range of frequencies considered.

A15.4 Vodafone's comments on the applicability of the Extended Hata propagation model placed most emphasis on the value of the rate of change of path loss with frequency ("frequency exponent" in dB/decade) in the model. However there are a significant number of other terms in the Extended Hata Model expression used in the calculation of path loss, and it is important to look at the model as a whole rather than just one aspect of it. Following receipt of this comment we conducted our own analysis of the effect of adopting the 900 MHz path loss exponent for the frequency block from 1500 MHz to 1800 MHz, and this suggested a difference in the 1800 MHz propagation loss amounting to less than 2dB compared to that calculated using the usual Extended Hata figures. This figure is not significant compared with the uncertainties that can arise in propagation modelling in general.

A15.5 We accept that for site build purposes operators may opt to use bespoke models to obtain the highest possible accuracy. Such models are not available to us.

A15.6 The Extended Hata Model has been calibrated based upon a wide set of path loss measurements and has been subject to extensive peer review both within academia and industry. It is widely accepted and has been extensively used in regulatory studies by many national regulators and in studies for international bodies such as CEPT and ITU. We consider it the most appropriate model available to Ofcom. We have therefore retained the Extended Hata model in the revised modelling that we have presented in the present document.

A15.7 Vodafone additionally commented on the clutter type used in the technical modelling in the March 2011 consultation. The Extended Hata model has three clutter categories: Urban, Suburban and Open. Vodafone correctly deduced that we had used the Open clutter type for rural areas. However, it also referred to the definition of the Open clutter model in origins of the Extended Hata model. In Vodafone's view, the rural areas in our simulation area to the west of London would have been better described as "quasi-open" land as defined by the Telecommunications Industry Association and others. The path loss for "quasi open" areas would be higher than for truly open areas so Vodafone saw the potential for overestimation of coverage in our March 2011 technical modelling.

A15.8 Ofcom reviewed the comments about clutter types. The Extended Hata propagation model only gives us a choice of Urban, Suburban and Open clutter types. However, because we are concerned with the relative differences in propagation between the frequency bands rather than absolute values, we are content that the impact of using "open" rather than "quasi-open" would be small. We concluded that there are benefits to using a well established propagation model so for the present analysis we have decided to continue with the use of Extended Hata and we expect that only a small absolute impact from the difference between "open" and "quasi-open" clutter types.

A15.9 One further comment from Vodafone concerned the standard deviation of the propagation loss modelled by Ofcom in the March 2011 consultation. Vodafone queried why we had used the following formula, which we stated was from Saunders and Aragon-Zavala[154]:

$$\sigma_s = 0.65 \cdot \log(f_c)^2 - 1.3 \cdot \log(f_c) + A$$

where *A* is a clutter-dependent constant. Vodafone noted that we had not explained why we had used this formula in preference to other available formulae for standard deviation. In particular, Vodafone requested that we justify why we had used a formula with greater frequency dependence than the formula for standard deviation of propagation loss in Recommendation ITU-R P.1546-4:

$$\sigma_L = K + 1.3 \cdot \log(f)$$

where *K* is again a clutter-dependent constant.

A15.10 We have examined the sensitivity of our model to the use of the shadow fading standard deviation formula in Recommendation ITU-R P.1546-4 as opposed to the one we used for the modelling for the March 2011 consultation. Figures A15.1 and A15.2 show results for the use of each of these formulae. We have provided results on the basis of the 'Max var' case defined in Annex 7. 'Max var' is based on a high dependency of median building penetration loss with frequency and high building

[154] "Antennas and Propagation for Wireless Communication Systems", S. Saunders & A. Aragon-Zavala, John Wiley and Sons

penetration loss standard deviation. Annex 7 also defines 'Min var', which combines, amongst other things, zero dependence of median building penetration loss with frequency and low building penetration loss standard deviation.

Figure A15.1: Sensitivity of results to shadow fading standard deviation formula
Single-user throughput vs % Delivery addresses
West London, 8000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth

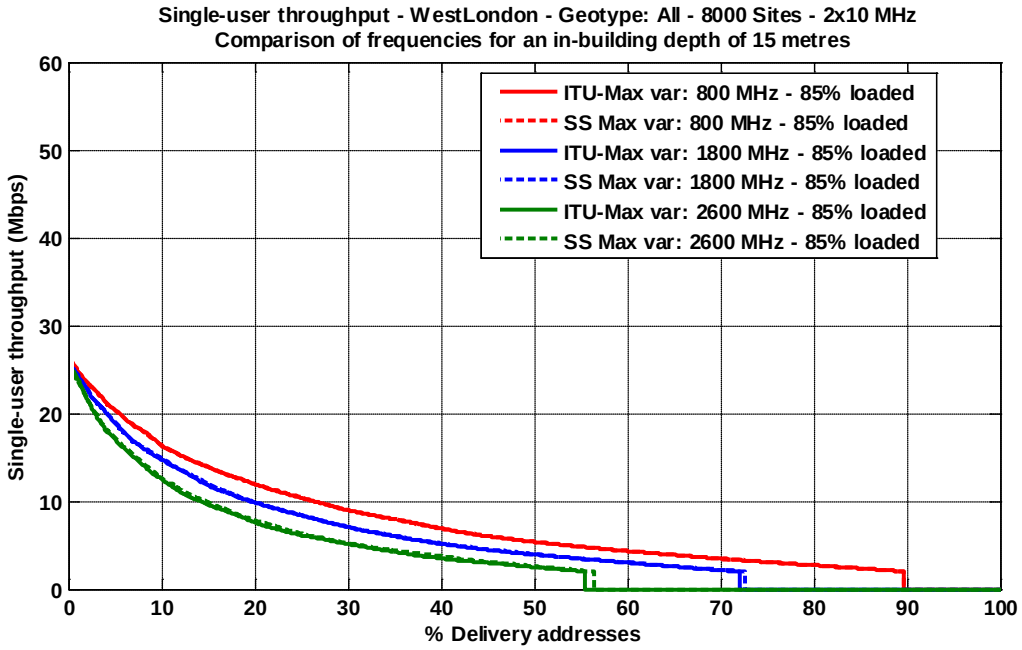
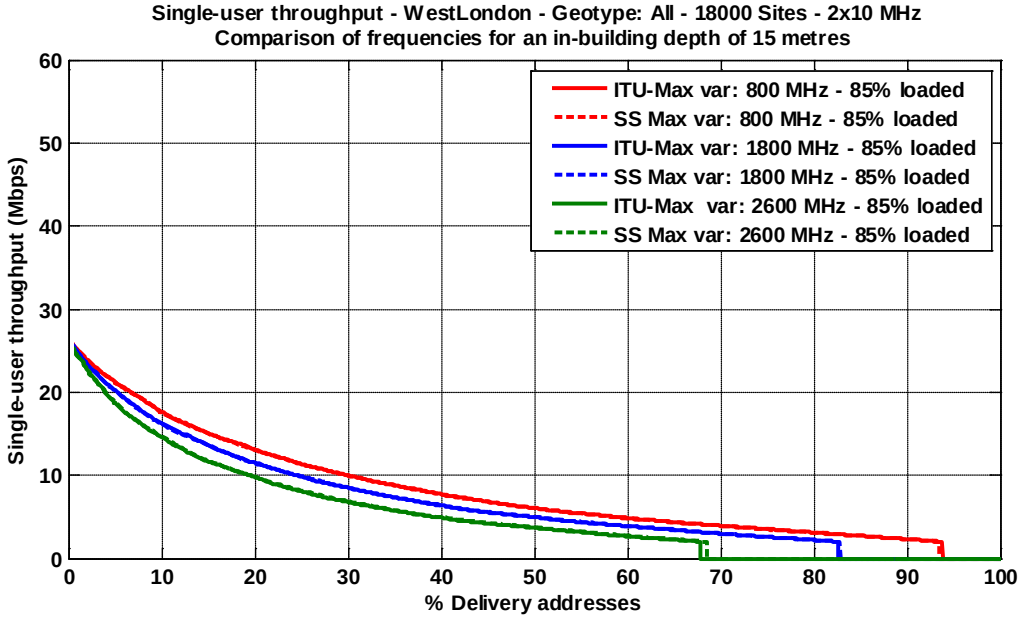


Figure A15.2: Sensitivity of results to shadow fading standard deviation formula
Single-user throughput vs % Delivery addresses
West London, 18,000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth



A15.11 On the basis of these results, we concluded that adopting the ITU-R P.1546-4 formula leads to only a very minor difference in our results. There being no strong argument one way or another for the choice between the two formulas, for our

revised modelling we have decided to adopt the one from ITU-R P.1546-4 as suggested by Vodafone.

Base station locations used in the modelling

A15.12 Vodafone noted that in the March 2011 consultation we had stated that the base station locations that we used in our modelling were representative of existing operators' macro networks, but queried whether the site locations for smaller deployments were selected as strict subsets of the largest deployment (equivalent to 20,000 sites nationally), or whether the selected sites are optimised for each size of deployment, since constraining site locations for a given network size would have been likely to lead to sub-optimal deployments.

A15.13 In our March 2011 modelling the smaller deployments were selected as strict subsets of the largest deployment (i.e. the superset) and the selected sites were not optimised. We agree that that process could lead to a sub-optimum deployment for any particular synthetic network. However, the objective of both the March 2011 modelling and the revised modelling in the present document has been to examine the relative performance of networks at different frequencies rather than absolute performance, and our March 2011 modelling compared the performance of networks with the same number of sites.

A15.14 We did review the method of generating the locations of sites in the synthetic network and we have adopted a revised algorithm for generating synthetic networks. Nevertheless, for the reasons outlined above, we believe that the results are not particularly sensitive to the method of generating sites in a synthetic network. The revised algorithm is set out in Annex 14.

Uplink limitations

A15.15 One confidential response commented that in the March 2011 consultation, when we modelled the multi-frequency approach to offset limited sub-1 GHz frequency allocation, we had not considered the impact of terminal power constraints that would limit the uplink and would therefore particularly impact coverage in the higher frequency bands. This response suggested that as a result of uplink limitation, the 2 Mbps service would only cover a sub-set of the cell area.

A15.16 The results set out in the present document are for downlink performance only. In order to explore the possibility of results being invalidated by deficiencies in the ability of the UE to communicate with the base station using the uplink we have conducted a link budget analysis. For the uplink we assumed that the maximum power (23dBm) is transmitted over one resource block to give maximum range, and assume that this gives a high enough data rate for the required control and acknowledgement data. We concluded that for the vast majority of cases presented in this consultation the performance is not impaired by uplink limitations, with uplink and downlink at worst being very finely balanced.

Channel quality estimation

A15.17 One confidential response commented that our March 2011 modelling had neglected degradations due to dynamic load variations with time, i.e. from one Transmit Time Interval (TTI) to the next; this implies that link performance at low load could be poorer than we had modelled due to CQI estimation error.

A15.18 We can confirm that the Ofcom modelling presented in the March 2011 consultation dealt with static loads and did not incorporate dynamic load variations. However, discontinuous traffic could have two effects:

b) discontinuous traffic will cause a significant change in the interference profile between one TTI and the next, meaning that scheduling decisions made based on one TTI may subsequently be potentially invalid; and

c) the scheduling of differing service needs in non-full buffer situations may vary linearly with bandwidth, in particular giving better performance at wider bandwidths.

A15.19 Our revised technical modelling has implemented a different signal to interference and noise ratio (SINR) to throughput mapping. We consider that this mapping function is a conservative approach and that it accounts for degradations caused by poor CQI estimation.

Signal to interference and noise ratio (SINR): SINR to throughput mapping function and SINR cut-off

A15.20 The technical model used in the March 2011 consultation calculated the SINR values on a resource block basis for a number of test points (terminal locations). The SINR values were then mapped to throughput values using a mapping function. For that consultation, the mapping function used was an attenuated and truncated form of the Shannon bound as taken from Annex A, Section A.1 of 3GPP TR 36.942.

A15.21 One stakeholder commented that we had assumed in the March 2011 consultation that some data throughput could be achieved with SINR as low as -10dB but not taken account of whether the downlink control channels could operate at -10dB SINR. It noted that a terminal would need to decode the least robust control channel, the physical downlink control channel (PDCCH), before any data can be received on the physical downlink shared channel (PDSCH). The response cited a conference paper which had indicated that this control channel becomes unreliable for SINR below -5dB, so we could have been overestimating the coverage that LTE could achieve if we had assumed that there could be significant data throughput for SINR values down to -10dB.

A15.22 We based the SINR cut-off point of -10dB on work in 3GPP TR 36.942 in the March 2011 consultation. However, other work in 3GPP has indicated that system coverage is limited by the PDCCH, and has used target values for the required energy-per-symbol to noise ratio (Es/No) that are close to the -5dB value that was cited in the consultation response. There are techniques available that would increase the power of individual control channels, so that the PDCCH could have up to 3dB higher SINR than the overall wideband signal. However, we cannot predict whether these techniques will be used in practice. We have therefore provided modelling results in Annex 7 using the previous SINR cut-off of -10dB as well as an SINR cut-off of -5dB to create a range in the analysis.

A15.23 One response commented that in the March 2011 consultation we had assumed that 2×2 MIMO would be used across the whole cell in our model. However, the respondent did not believe that would be the case, and that open loop diversity would be applied by most vendors, resulting in 2×2 MIMO only in good conditions and transmit diversity in poor conditions towards the cell edge.

A15.24 One confidential response commented that in the March 2011 consultation we had overestimated throughput by 67% because we had not taken the implementation margin of 0.6 into account and a further 30% because we had also incorrectly applied the relationship in Equation (13) from that consultation as total user bit rate in total bandwidth rather than (as intended) bit rate in the bandwidth associated with actual used resource blocks. The compounded effect would therefore have been an overestimate of capacity by 117%.

A15.25 We have revised the SINR to throughput mapping function in the revised modelling in Annexes 7 and 14. Our approach now uses the downlink SINR to throughput mapping function from 3GPP TR 36.942, Annex A Section A.1 (i.e SIMO) for the main results: we consider that this mapping function is representative of the performance of current implementations. We consider that the mapping is representative of a 2 × 2 LTE downlink which automatically selects the optimum SIMO/MIMO mode for the given channel conditions.

A15.26 The implementation margin of 0.6 was taken into account in the spectral efficiency curve given in Annex 8 of the March consultation document. The spectral efficiency curve also took into account a factor of 2 to account for a 2 × 2 MIMO system. The respondent was correct in pointing out that spectral efficiencies should be applied to the occupied bandwidth for each resource block (180 kHz) rather than total bandwidth for each resource block (200 kHz), and this is this has been corrected for the revised modelling presented in this consultation document.

Building penetration loss

A15.27 Vodafone commented that in the March 2011 consultation we had not provided new reference material to justify our assumptions on building penetration loss, but had justified our choice of values for the base case by comparing these to the best fit straight line through a set of building penetration loss measurements compiled from public sources. Its view was that the use of this linear regression was not appropriate because the collated measurements were for different buildings measured at different frequencies using different methodologies. Vodafone suggested that that we should have computed the regression curves individually for each building, and then computed the average of the slopes and intercepts for each of these regression curves to determine the best fit line through the data. It observed that our assumptions for the building penetration loss at depth 2+ showed a frequency dependence of 14.8dB per decade between 800 MHz and 1800 MHz and 18.6dB per decade between 800 MHz and 2.6 GHz. Vodafone's own analysis, taking most of the sources that we used and averaging the slopes of the regression curves through each researcher's results, found only weak frequency dependence of building penetration loss at 1.6dB per decade.

A15.28 In the modelling for the March 2011 consultation we based the values for building penetration loss on those used in previous Ofcom publications155,156, for which the relevant frequencies were 900 MHz, 1800 MHz and 2100 MHz. Returning to these publications we can see that Figure 25 in Annex 13 of the mobile liberalisation consultation (2009) does indeed show a best fit line. However, that line was for indicative purposes only (showing the central assumption from the 2007

[155] Application of spectrum liberalisation and trading to the mobile sector – A further consultation, Annex 13, Ofcom, 13 February 2009

[156] Advice to Government on the consumer and competition issues relating to liberalisation of 900 MHz spectrum for UMTS, Annex 5, Ofcom, 25th October 2010

mobile liberalisation work) and played no part determination of the building penetration loss values that were used for the 2009 consultation.

A15.29 The building penetration loss values used for mobile liberalisation work in 2009 included a wider variation of mean building penetration loss with frequency and also included a variation with clutter type. These values were derived after extensive consultation with mobile network operators. Ofcom was not able to publish data and views were supplied on a confidential basis. Nevertheless, examination of operator data shows that the frequency dependence of "rising at a higher rate" appears to be on the high side, and this gradient along with the gradient for base case was used in calculation of the mid-way values for the March 2011 consultation.

A15.30 Given the sensitivity of the results to the values of building penetration loss we have subsequently considered that it would be prudent to adopt a range for our current analysis. Therefore, we have now examined results for

- no rise in mean building penetration loss with frequency; and
- rapid rise in mean building penetration loss with frequency.

A15.31 If we had applied an extrapolation based on a linear dependence on frequency, the assumption for building penetration loss at 2.6 GHz would be over-estimated in comparison with data supplied in confidence by mobile network operators for the 2009 consultation. We believe that extrapolation based on building penetration loss with a linear dependency on log(f) is more suitable for derivation of values at 2.6 GHz.

A15.32 Vodafone also commented that in the March 2011 consultation we had assumed, without justification, that the standard deviation of the building penetration loss is frequency dependent for depth 2+ but not clutter dependent. Vodafone suggested that its own measurements indicate that the standard deviation of the building penetration loss is proportional to the median building penetration loss value, and that it is unusual for the standard deviation of building penetration loss to be more than one third of the median.

A15.33 We recognise that this modelling convention will occasionally produce negative total building penetration losses. In reality, there could possibly be a gain observed upon penetrating a building as a result of multipath effects, but it might not occur as often as suggested by this modelling. We considered Vodafone's reported results trend carefully and conducted a literature survey including comparison of results from recent IEEE publications[157,158]. Those results generally show that the building penetration loss standard deviation is in almost all cases larger than one third of median building penetration loss and does not provide any evidence that we should adjust the standard deviation to reduce or eliminate the probability of a gain. The GSM900 measurement results of Ferreira et al also show that negative attenuation can occur, particularly for higher floors.

[157] Ferreira L., Kuipers M., Rodrigues C. and Correia L.M., "Characterisation of Signal Penetration into Buildings for GSM and UMTS", *3rd International Symposium on Wireless Communication Systems,* Sept. 2006, pp. 63 – 67.

[158] Plets D., Joseph W., Veerloock L., Tanghe E., Martens L., Deventer E. and Gauderis H., "Influence of Building Type on Penetration Loss in UHF Band for 100 Buildings in Flanders", *Antennas and Propagation Society International Symposium, 2008, AP-S 2008,* pp. 1 – 4, IEEE.

A15.34 One confidential response commented that this type of simulation approach, based on average indoor penetration and what it described as a modest distribution, would not effectively capture areas of deep indoor coverage which are very difficult to reach due to building construction and practical site locations, and that experience indicates that that such difficult-to-reach indoor areas are far more common than the modelling suggests. However, the respondent did not propose alternative building penetration loss values for our revised modelling.

A15.35 We discuss the range of assumptions for frequency dependence of building penetration loss in Annex 14, and in Annex 7 we report results based on two cases: 'Min var' and 'Max var'. 'Min var' combines, amongst other things, zero dependence of median building penetration loss with frequency and low building penetration loss standard deviation. 'Max var' is based on a high dependency of median building penetration loss with frequency and high building penetration loss standard deviation.

Frequency dependence of antenna characteristics

Frequency dependence of base station antenna gains

A15.36 Vodafone commented that in the March 2011 consultation we had not taken account of the frequency dependence of antenna gains, noting that this provides a benefit in higher frequency bands, where the gain is higher for given physical dimensions. Vodafone estimated the difference between 800 MHz and 1800 MHz amounted to 2.5dB additional gain in the higher frequency band and that the gain at 2.6 GHz was 3.6dB higher than the gain at 800 MHz. As the base-station EIRP per 180 kHz resource block was assumed constant by Ofcom at 45dBm in the March 2011 consultation, Vodafone concluded that Ofcom had assumed a lower RF power into the antenna input at higher frequencies.

A15.37 A further confidential comment stated that the cost of deployment at 800 MHz would be higher for operators without existing 900 MHz spectrum. This is because they would need larger antennas than they currently use, improvements in structural strength of existing masts, and they would have a sub-optimal site grid, since this would be based on planning for 1800 MHz or 2.1 GHz.

A15.38 Our analysis, both in the March 2011 consultation and in Annex 7, has assumed that base stations radiate at a uniform maximum power spectral density close to the maximum licensed power. A level of 45dBm EIRP per 180 kHz resource block would be equivalent to 59dBm/5 MHz EIRP or 62dBm/10 MHz EIRP. Because the EIRP is set at a common value for the modelling of both bands, the base station antenna gain does not impact downlink performance, although we accept that it might have an impact on the required base station power into the antenna in different frequency bands. We conclude that differences in antenna gain are therefore not relevant for downlink calculations. We do recognise that there is a cost implication in the lower frequency bands, which may come from the requirement for base station equipment with higher rated power and/or physically larger antennas in order to achieve a particular radiated power, compared to the equivalent requirements in higher frequency bands. However cost has not been considered in our technical analysis. We also consider that the site grid of a network operator that was based on an 1800 MHz or a 2.1 GHz deployment should not be a disadvantage for deployment at 800 MHz since it is likely to have more sites than a 900 MHz network.

Frequency dependence of base station antenna beamwidths

A15.39 Telefónica commented on our modelling in the March 2011 consultation that it would have expected similar base station antenna characteristics for all the bands that we had modelled. It indicated that antennas for LTE800 are likely to be wideband antennas covering both 800 MHz and 900 MHz in place of GSM900 antennas, and therefore longer than antennas for LTE1800/2600. As such, Telefónica concluded that the antennas should have similar characteristics for horizontal and vertical beamwidth and antenna gain.

A15.40 Paragraphs A15.36 and A15.37 considered base station antenna gain and concluded that this was not relevant for downlink calculations. For the question of beamwidth, the technical modelling for the March 2011 consultation used horizontal and vertical beamwidth values based on a multi-band antenna extrapolated to 2.6 GHz. It does appear unlikely that a multi-band antenna would cover the whole frequency range from 800 MHz to 2.6 GHz, so our revised modelling uses fixed horizontal and vertical beam-widths for all frequencies. These values we have used for the revised modelling are

Antenna horizontal beam-width: 65.0°
Antenna vertical beam-width: 7.5°

A15.41 We carried out a sensitivity analysis on the impact of changing from frequency-dependent antenna beamwidth values to fixed antenna beamwidth values. Figures A15.3 and A15.4 show results for the change of assumption from frequency-dependent antenna beamwidth to fixed antenna beamwidth for the 'Max var' and 'Min var' cases. These results suggest that the change to a fixed beamwidth independent of frequency is likely to have only a minor impact on the results.

Figure A15.3: Sensitivity of 'max var' results to BS antenna horizontal and vertical antenna beamwidths
Single-user throughput vs % Delivery addresses
West London, 18,000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth

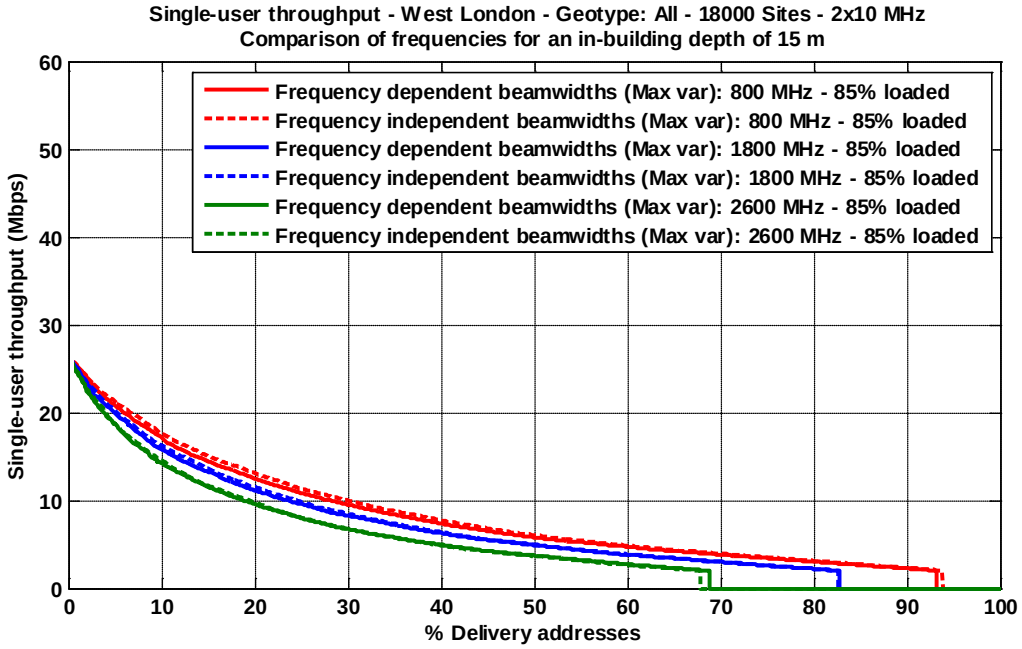
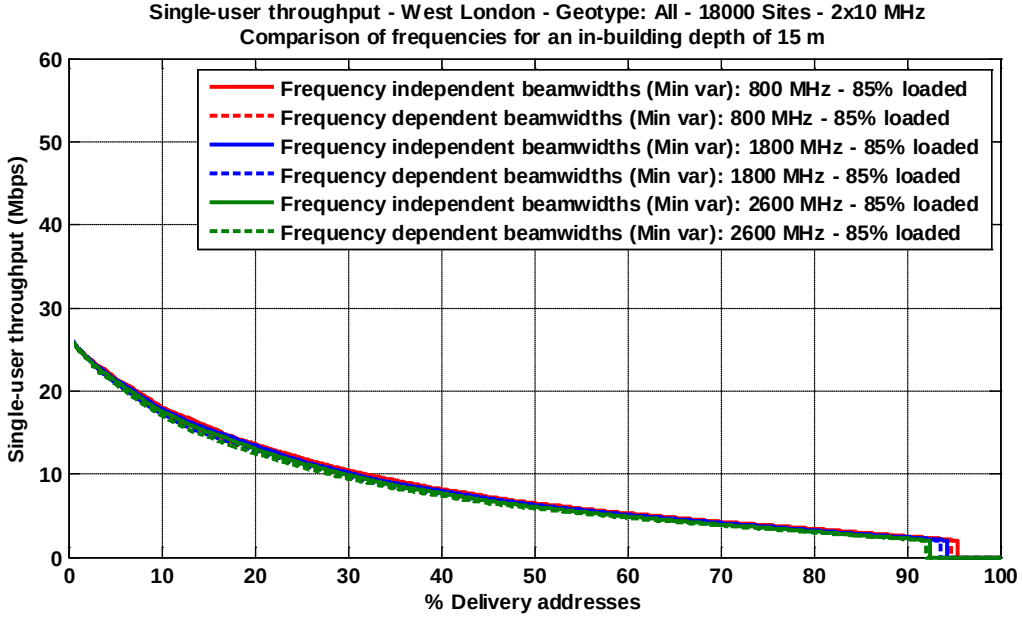


Figure A15.4: Sensitivity of 'Min var' results to base station antenna horizontal and vertical antenna beamwidths
Single-user throughput vs % Delivery addresses
West London, 18,000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth



Frequency dependence of terminal antenna gains

A15.42 Vodafone commented on Ofcom's assumption in the March 2011 consultation that the terminal antenna gain would be 0dBi across all of the frequency bands in the model, which it believed could be achievable at 1800 MHz and 2.6 GHz but was unlikely to be achieved at 800 MHz due to the potential for LTE bandwidths up to 20 MHz. Also it noted that multi-band terminals will often use a single antenna for several frequency bands, and indicated that wideband antennas are inherently less efficient at lower frequencies. Vodafone suggested that we should have assumed that a wideband antenna with 0dBi gain at 2.6 GHz would have -0.5dBi gain at 1800 MHz and -1.6dBi gain at 800 MHz.

A15.43 We agree that the difference in terminal antenna gain should be incorporated into our modelling. In our revised modelling in Annex 7 we have used the same relative antenna gains that Vodafone proposed but our model uses 1800 MHz as the 0dBi reference. As a consequence, the antenna gain values in Table A15.1 are applied in our model.

Table A15.1: Terminal antenna gain values used in our revised technical modelling

Frequency band	Terminal antenna gain
800 MHz	-1.1dBi
1800 MHz	0dBi
2.6 GHz	+0.5dBi

A15.44 We carried out a sensitivity analysis on the impact of changing from fixed antenna gain to frequency-dependent antenna gain on our modelling results. Figures A15.5 and A15.6 show a set of curves for both assumptions for the 'min var' and 'Max var' results.

Figure A15.5: Sensitivity of 'Max var' results to terminal antenna gain
Single-user throughput vs % Delivery addresses
West London, 8000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth

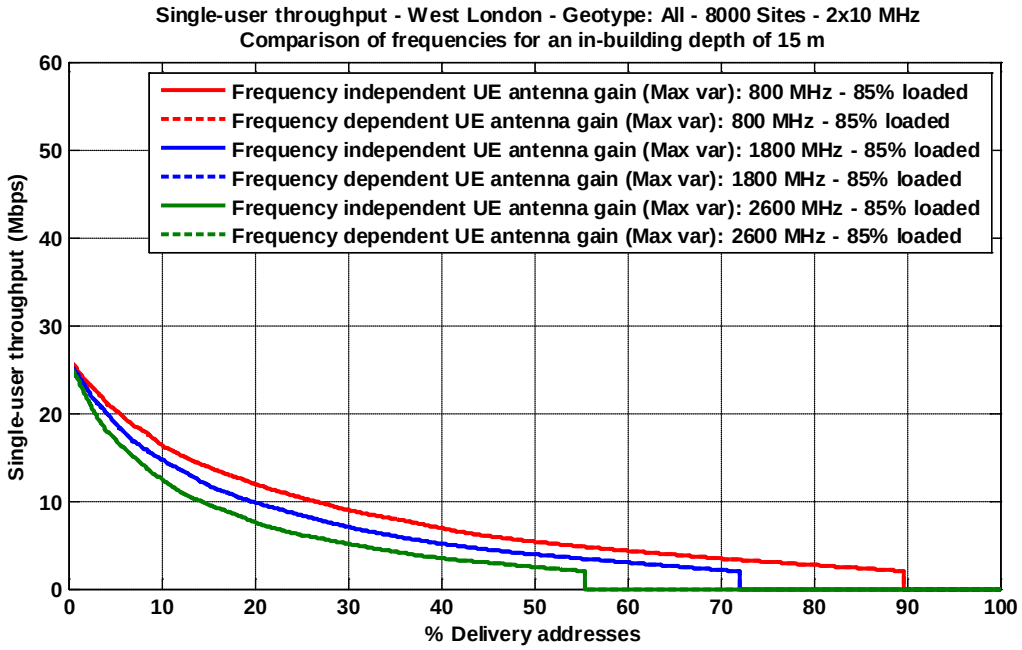
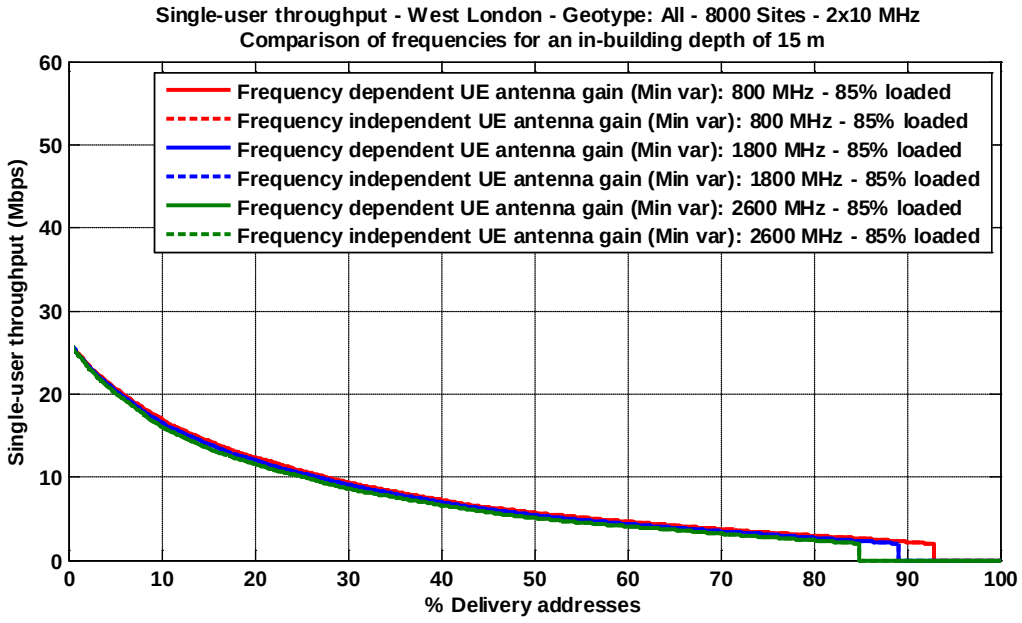


Figure A15.6: Sensitivity of 'Min var' results to terminal antenna gain
Single-user throughput vs % Delivery addresses
West London, 8000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth



A15.45 We concluded from these results that changing from fixed antenna gain (frequency independent antenna gain) to the different terminal antenna gain values in Table A15.1 would not have a significant impact on the modelling results.

Terminal noise figure

A15.46 Telefónica commented on the assumption in the March 2011 consultation for the noise figure in 800 MHz terminals. It indicated that in lower frequency bands,

particularly those with small duplex separation between the uplink and downlink blocks, the tight filtering constraints cause the terminal noise figure to be much higher than in the higher frequency bands, which tend to have much larger duplex separation. Telefónica UK reported that it had observed this effect recently when comparing noise figure measurements of UMTS terminals operating in the 900 MHz and 2.1 GHz bands. It therefore suggested that 13dB might be a more appropriate assumption for studies involving the 800 MHz band. Telefónica additionally commented that it was surprised that the additional results that Ofcom provided for 13dB noise figure showed minimal difference in the results from the 10dB noise figure assumption.

A15.47 We understand the link between narrow duplex frequency separation and raised noise figure to be a result of noise added by uplink transmissions. However, both in the March 2011 consultation and in the present document, we are interested in modelling the downlink-dominated performance. In these scenarios, uplink traffic volumes are sufficiently small compared with downlink volumes that the degradation due to uplink noise can be considered negligible on average.

A15.48 Ofcom noted Telefónica's comment that adjustment of the noise figure assumption from 10dB to 13dB resulted in minimal difference in the results for single user throughput speeds vs percentage of population in the March 2011 modelling. The reason for this is that the SINR values in our model were likely to be interference limited, which is what we would expect for a generally densely populated area, so there would have been little impact from an increase in terminal noise. For this reason, we do not consider it appropriate to adopt a different UE noise figure for 800 MHz in the revised modelling. Nevertheless, we did recognise that 3dB increase in the terminal noise figure could potentially lead to a reduction in coverage in noise limited environments, so we could expect it to have a more significant effect for high building penetration losses. We therefore looked at the impact of these two assumptions for terminal noise figure on the results for single user throughput for the relevant 'high' building penetration loss scenarios. Figure A15.7 shows the sensitivity of 'Max var' results for 15m depth inside a building, assuming a 2×10 MHz network of 8000 sites with 85% loading and terminal noise figure of 10dB or 13dB. Figure A15.8 shows the same for a network of 18,000 sites.

Figure A15.7: Sensitivity of 'Max var' results to terminal noise figure
Single-user throughput vs % Delivery addresses
West London, 8000 sites, 2×10 MHz bandwidth, 15% network loading, 15m depth

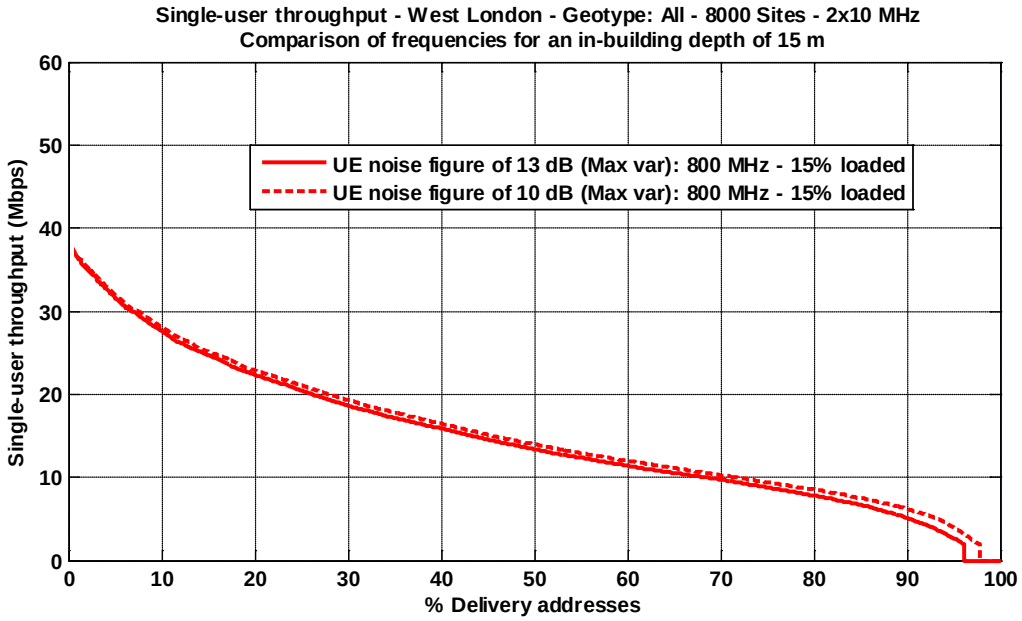
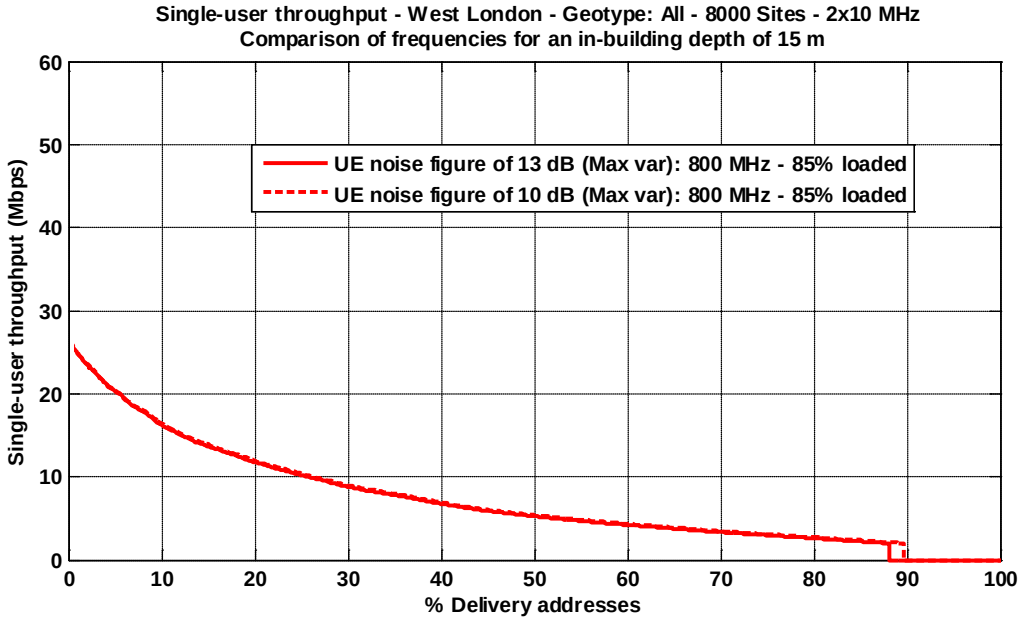


Figure A15.8: Sensitivity of 'Max var' results to terminal noise figure
Single-user throughput vs % Delivery addresses
West London, 8000 sites, 2×10 MHz bandwidth, 85% network loading, 15m depth



A15.49 As these graphs illustrate, the modelling is not significantly impacted by the choice of 10dB or 13dB terminal noise figure.

Network loading

A15.50 One confidential response questioned the loading assumptions in our March 2011 modelling. It noted that we had looked at a reference "serving" cell operating at 85% loading and the rest of the network at a much lower level of 15%. The response was

of the view that this scenario was highly hypothetical and unsuitable for modelling how networks would perform in reality, since it assumed that the serving cell is the only cell in the network where the majority of the cell resources are in use, while the rest of the network is far less important and can be loaded to only 15%. The respondent commented that every cell in the network is a serving cell to customers within that cell, and therefore proposed that in the analysis the load on the reference cell and the wider network should have been the same.

A15.51 We consider that the statistical nature of traffic distribution, particularly when the network is relatively lightly loaded makes it very likely that there will be cells supporting a heavy instantaneous load surrounded by others supporting a much lighter load. Our March 2011 modelling covered a range of network loadings from 15% to 85% to look at the capabilities of a cell given a particular network loading; it would not have been reasonable to artificially limit the capability of that cell to ensure equal serving cell and network loading.

A15.52 The same response also commented on our March 2011 modelling of the 800 MHz carrier as operating at 15% loading. It noted that if the loading assumption were changed, as proposed in A15.50, it would be necessary to reduce the reference cell's average power from 85% to 15%; the impact of this change would be to more than halve the range at which an LTE800 cell could serve a customer at 1Mbit/s and prevent a 5 MHz LTE800 network from serving any customers at 2Mbit/s with 90% confidence. This would lead to greater impact on the area and population covered to a particular data rate than our March 2011 results would suggest.

A15.53 There are two points here: the percentage loading on the serving sector and the transmit power assumption. In our modelling of the 800 MHz serving sector, we set the serving sector loading at 85%, and not 15%. In our March 2011 modelling, the loading assumption of 15% applied only to the interfering cells. In regard to the transmit power assumption, we used reduced power on the interfering cells and sectors to model the interference from 15% loaded cells and sectors, whereas within the serving sector, we set each resource block providing the downlink traffic to full power. Since the serving sector resource blocks were not at reduced power, the loading assumptions would not have had any impact on the range at which the LTE800 cell could serve 2Mbit/s.

A15.54 The confidential response also commented that if the March 2011 calculation of user data rate assumed a service cell loading of 85% then it would not be appropriate to assume zero interference from Set B sectors up to 33% network loading. Telefónica also commented that it did not expect vendors to implement the fractional loading scheme proposed by Ofcom in the March 2011 consultation, and expected random loading across the cell. We have also determined that the algorithm we had used for the calculation of other cell interference based on intelligent resource allocation contained an error. However, that error was unlikely to have materially affected the results. Also, in response to the concerns over our March 2011 assumptions on loading, we have produced new results for two loading assumptions: random loading and an intelligent loading algorithm (based on a modified algorithm). The revised approaches for calculation of user data rate are set out in Annex 14.

A15.55 One confidential response questioned Ofcom's assumptions of 85% of traffic on 20 MHz of 2.6 GHz and 15% of traffic on 5 MHz of 800 MHz. It indicated that that for coverage purposes, a multi-frequency 800 MHz/2.6 GHz network would need to assign a greater proportion of traffic to the 800 MHz layer than we had modelled. In

addition, it suggested that with this understanding, at least 10 MHz of sub-1 GHz would be needed to avoid congestion on 800 MHz.

A15.56 The comments in A15.55 relate to the modelling assumptions that we set out for the March 2011 consultation. We have now substantially revised our modelling of networks in 800 MHz and 2.6 GHz and set out new results in Annex 7 of the present document.

A15.57 Telefónica commented that it did not understand how network load could be held constant independent of throughput and number of users in the March 2011 modelling. Our response is that this is simply a reflection of how we set up the technical modelling, i.e. that it was based on fixed load figures.

A15.58 Telefónica also commented that for equal site numbers and equal market shares, operators would be expected to load their networks to the same amount. It indicated that network operators typically plan their downlink loading to be above 60%, therefore Telefónica considered it unsound for us to have assumed that networks would be running at loading below 20%.

A15.59 For the case of networks that operate only in a single frequency band, the assumptions in A15.58 might be reasonable. However, we consider that in the case of multi-band networks there is no reason why network load cannot be managed asymmetrically to optimise performance. Therefore we believe that that it is reasonable for us to include loading of a network within an individual frequency band at levels below 20%.

Calculation of overheads

A15.60 Telefónica commented on the speed charts in the March 2011 consultation. It indicated that it did not believe that the peak throughput of a 10 MHz system would be exactly 50% of that of a 20 MHz system because of the increased common channel overhead and the reduction in frequency diversity for the smaller bandwidth.

A15.61 We agree that there will be a reduction in frequency diversity for smaller bandwidths compared to the larger bandwidths, and while this will not affect peak throughputs it could have an impact in multi-user scenarios. Our revised capacity modelling set out in Annexes 7 and 14 now includes frequency domain packet scheduling. On the question of overheads, Table A15.2 shows our calculation of the overhead for 5 MHz, 10 MHz, 15 MHz and 20 MHz bandwidths:

Table A15.2: Calculation of overheads

	Overheads (%)				
	Number of MIMO streams (s = 2)	Number of resource blocks (RB)			
		5 MHz 25 RB	10 MHz 50 RB	15 MHz 75 RB	20 MHz 100 RB
Reference signals	4*s*/84	9.52	9.52	9.52	9.52
Physical Downlink Control Channels (PDCCH)	(2 × 12 - 4*s*) / (2 × 84)	9.52	9.52	9.52	9.52
Primary and Secondary Synchronisation Channels (PSCH/SSCH)	(6 × 2 × 1 × 12) / (10 × 84*n*)	0.69	0.34	0.23	0.17
Physical Broadcast Channels (PBCH)	(6 × 4 × 12) - 4*s*) / (40 × 84*n*)	0.33	0.17	0.11	0.08
Total		20.07	19.56	19.39	19.3

Where *n* = number of resource blocks

A15.62 It is apparent that the proportion of overheads varies with bandwidth, so that the peak throughput for a 10 MHz channel is not exactly that of a 20 MHz channel. However, the difference is relatively small and we therefore use a common figure of 20% to account for overheads.

Comments on technical licence conditions for 800 MHz spectrum

Limits on unwanted emissions below 790 MHz

A15.63 Commission Decision 2010/267/EU provides three possibilities for base station unwanted emission limits in the spectrum below 790 MHz. The consultation on technical licence conditions proposed to adopt the lowest level of emissions (designated “Case A” in Decision 2010/267/EU) for all base stations.

A15.64 Several stakeholder responses suggested that Case A limits were insufficient to protect DTT. However, these responses were not accompanied by any supporting technical analysis of where any inadequacies lay or quantifying the potential improvements from any alternative limits.

A15.65 Ofcom’s proposals, set out in the DTT coexistence consultation, are that the cases where the Case A limits do not provide adequate protection should be addressed with targeted measures aimed at resolving the particular coexistence scenario, rather than a blanket imposition of alternative emission limits. We were not persuaded by the information provided in responses that there was evidence to justify deviation from the limits set out in the Commission Decision.

A15.66 In contrast to the above responses, Vodafone suggested that Case A limits are too stringent for areas where channels 59 and 60 are not used by DTT and proposed the following limits for those areas:

- Case C limits for channel 60
- Case B limits for channels 58 and 59

- Case A limits for channel 57 and below

A15.67 Vodafone questioned the need to reduce emissions to Case A levels in areas where DTT is not currently using channels 59 and 60, and stated that equipment costs would be higher for base stations that needed to meet the Case A limits. This suggestion to relax the unwanted emission limits is based on the premise that the DTT plan is not expected to change. We consider that there are potential risks in setting adjacent band conditions on this basis if there is any possibility that the DTT channel usage might need to change.

A15.68 In conclusion, we are not minded to make particular exceptions to the proposals for emission limits below 790 MHz and for the Case A limits to apply to all base stations.

Maximum in-band power limit for 800 MHz

A15.69 Several responses to the June 2011 consultation commented that our proposed in-band power was higher than the value modelled in the DTT coexistence consultation. Our proposal for the maximum in-band power limit was 61dBm/5 MHz, while the DTT coexistence modelling assumed that base stations would operate at a level of 59dBm/10 MHz. The difference in the bandwidths would imply 5dB difference between the base station power that we modelled for DTT coexistence and the ceiling that we proposed in the consultation on Technical Licence Conditions.

A15.70 Following the closure of the consultations, we undertook additional modelling to look at coexistence between DTT and base stations operating at 61dBm/5 MHz, which is equivalent to 64dBm/10 MHz. The outputs of this modelling work and further analysis of the DTT coexistence issues continue to support the proposals put forward in the June 2011 consultation that the maximum in-band power limit should be set at a level of 61dBm/5 MHz. We expect to present the results of our additional modelling of DTT coexistence in a further technical report to be published in February along with a further statement and/or consultation on the DTT Coexistence issue.

A15.71 Vodafone's response suggested that we consider higher power for areas where the top few channels are not used for DTT. We believe that this approach would present risks if there is any possibility that the DTT channel usage might need to change. We are therefore not proposing to permit the use of power levels above 61dBm/5 MHz in any locations.

A15.72 We were also asked to clarify our understanding of the total power permitted in the case of equipment with multiple antennas, e.g. MIMO equipment. The Commission Decision is explicit on this point: in general, and unless stated otherwise, the block edge mask levels (including in-block power) correspond to the power radiated by the relevant device irrespective of the number of transmit antennas, except in the case of transition requirements for base stations, which are specified per antenna. Therefore the in-block power limit is specified per base station sector.

Short range devices in spectrum above 863 MHz

A15.73 A number of stakeholders commented on the potential interference from mobile broadband applications in the 800 MHz into short range devices, including alarm systems, using spectrum above 863 MHz. The matters raised in those responses, together with further work undertaken for Ofcom, have been considered in an

Information Update on *Use of Short Range Devices alongside mobile broadband services operating in the 800MHz band*[159], published on 30 November 2011.

Programme making and special events usage in spectrum adjacent to the 800 MHz band

A15.74 Several stakeholders commented on potential interference to wireless microphones operating above 863 MHz (channel 70) and wireless microphones in channel 60 and below. These matters are also considered in the Information Update.

A15.75 JFMG pointed out that the consultation on technical licence conditions did not cover use of the 800 MHz centre gap. This is because we do not have any concrete plans for the centre gap at this point in time. When we are ready, we will bring forward proposals for how this spectrum can be made available.

Comments on technical licence conditions for 2.6 GHz spectrum

Coexistence with radar use of spectrum above 2700 MHz

A15.76 We received several stakeholder comments seeking more detail and information on the radar remediation programme. In particular, stakeholders wanted to understand what timing they should expect, since this would potentially impact on any plans for deployment or roll-out.

A15.77 BT expressed a preference for a solution involving coordination between radar sites and mobile network base stations rather than imposing more stringent requirements on unwanted emission levels than those in the standards. However, it raised some concerns about the practicability of coordinating large numbers of low power base stations with radar sites. BT also suggested that the unwanted emission limit should be relaxed for small cells because they have low antenna gain and are likely to be located indoors.

A15.78 The Commissioners of Irish Lights (CIL) advised that it maintains four Racons in Northern Ireland, and had some concerns that 2.6 GHz base stations might be sited close enough to cause interference. CIL sought coordination with base stations that were planned to be located within possible interfering distance of its Racons.

A15.79 Arqiva expressed some concern about the permanent requirements on coordination and queried why the coordination requirements should apply to the whole band, in particular the unpaired spectrum which is 80 MHz away from the radar band.

A15.80 Telefónica commented that UK airports are likely deployment areas for in-building and small cell LTE systems. However, it expected that the indoor placement would be beneficial when considering impact of unwanted emissions into radar. Telefónica therefore expressed a strong preference for a coordination approach and referred to our Information Update published on 11 December 2009 and suggested that a 1km coordination or exclusion zone would be over-restrictive and would lead to inefficient use of spectrum.

A15.81 Telefónica also queried the 10km to 15km distances that we had included in our description of likely permanent coordination obligations. It suggested that with the propagation conditions of 2.6 GHz and the unwanted emission limit of -45dBm/MHz

[159] http://stakeholders.ofcom.org.uk/binaries/consultations/tlc/annexes/Update.pdf

EIRP a coordination distance of a few hundred metres would be sufficient. One confidential response believed that further information was required to be able to comment on the practicality of more stringent out of block emissions than -45dBm/MHz.

A15.82 Two responses expressed concerns over the practicality of Ofcom's suggestion that there may be a need for measures that would require a 2.6 GHz licensee to 'switch off' their 2.6 GHz terminal stations close to a radar or for terminal stations to be powered down if that radar is suffering harmful interference. Telefónica indicated that the only way to achieve this would be to prohibit base stations from providing coverage in these locations because there would be no way of preventing terminals from transmitting on the 2.6 GHz band if there is sufficient 2.6 GHz LTE coverage present. It indicated that such geographic restrictions would have to be clearly specified and limited, and once set down, there would be no basis for future radar systems to benefit from such exclusion zones.

A15.83 We do not dispute the comments above on the approaches that operators would need to follow to prevent terminals from transmitting in the 2.6 GHz spectrum. However, if there is evidence that mobile terminal transmissions in 2.6 GHz would pose a risk to the operation of these radars, it would be appropriate for us to put these measures in place to address this situation. We expect that it should be possible to force multi-band terminals to hand over to a different frequency band (i.e. not 2.6 GHz) within the operator's spectrum portfolio and we are also continuing work to understand the nature of any risk from mobile terminal unwanted emissions into the 2.7 GHz radar spectrum.

A15.84 Three expressed some concern at the potential for a radar coordination zone to be interpreted as prohibition on base station installations in the area; this would affect availability of 2.6 GHz services and the value of the spectrum. Three also indicated that additional restrictions on base station power within 15km of a radar site could require an increased density of base stations. Three's view was that the current information gives a high degree of uncertainty about the impact of coordination obligations and emission limits, and it sought the provision of information at the earliest opportunity on any proposed restrictions within 15km of radar sites and the timing of the regional upgrades to ATC radar sites.

A15.85 One confidential response proposed that the radar remediation programme should take the opportunity to re-plan radar channel allocations to provide greatest frequency separation between radar systems and base stations in the 2.6 GHz band to minimise the required roll off of additional filtering.

A15.86 We have provided an update on the radar remediation programme and related matters raised in the above comments in Section 3 of the present document.

A15.87 NATS provided a number of comments: on the example propagation model (ITU-R Recommendation P.452, 0.01% time), NATS wished to understand the justification behind this level of time percentage being used for assessing interference into radar systems; NATS also sought clarification on how or whether cumulative effects of additional uncoordinated interference into the 2.7 GHz band, e.g. ultra-wideband or other underlay applications, had been taken into account in assessing the adequacy of an unwanted emission level of -45dBm EIRP. NATS also pointed out that some of its radar systems are locations other than airports, and that radars located at airports are not necessarily owned or operated by the airport operator.

A15.88 A comment from NATS into the March 2011 consultation also indicated some differences between the values for radar system antenna gain used in the first Real Wireless report and those in Recommendation ITU-R M.1464-1[160], and that some of the towers employed by NERL are up to three times the height used by Real Wireless. The radar parameters in the first Real Wireless report were used for the purpose of modelling interference from radar systems into low-power 2.6 GHz cells. While the set of values provided in Recommendation M.1464-1 was considered, as the report notes, they were adjusted following discussions with the Ofcom S band radar team to align with typical commercially available ATC radars in the UK. In the case of radar antennas mounted at greater height than the modelling assumption, this might imply a greater distance over which 2.6 GHz applications could be affected by interference from those particular installations.

A15.89 NATS also expressed concern about the potential for emissions from low-power access points to cause interference to radar. NATS was concerned that licensing would be at network level and that the low-power access points incorporate a degree of autonomy with regard to load sharing and management of interference between low-power networks. NATS indicated that the expected obligations on licensees to protect radar use would need to apply to both standard power and low-power licences. We were mindful of the need for low power base stations to comply with the technical conditions on unwanted emissions above 2700 MHz. We therefore commissioned the study from Real Wireless on this issue which was published alongside the June 2011 consultation. This indicated that there are a number of optimum frequencies within the 2.6 GHz band for placement of low power spectrum block, but placement at the uppermost frequency block would present difficulties in meeting the unwanted emission limits that would be needed to protect radar.

2.6 GHz TDD restricted blocks: use of alternative block edge mask

A15.90 Arqiva, BT and Cable&Wireless were supportive of our proposed technical conditions for the use of the alternative block edge mask for restricted block TDD base stations. These technical conditions required a height restriction to a maximum 12m and a separation distance of 160m between a TDD base station using the alternative block edge mask and the nearest macrocell base station. We also received a confidential comment that the conditions might not be sufficient to protect FDD operation in some deployment scenarios. We were not presented with new evidence on the circumstances in which the technical conditions would not be sufficient, nor the degree of potential degradation arising from interference occurrences. We are therefore not minded to revisit the technical modelling work that developed these conditions.

A15.91 We also received two views on the matter of timing of deployment of restricted block base stations using the alternative mask. One stakeholder sought assurance that once a TDD alternative mask base station was deployed, the neighbouring operator could not subsequently require its removal when their FDD network expanded, i.e. if they installed a new FDD base station within 160m of the TDD base station. Another stakeholder was concerned that our proposals would mean that an area could become sterilised for the operator who doesn't deploy first.

[160] Recommendation ITU-R M.1464-1: *Characteristics of radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and meteorological radars in the radiodetermination service operating in the frequency band 2700-2900 MHz*

A15.92 We understand that there is a potential for conflict over this issue. However, we take the view that the technical conditions that we proposed in the June 2011 consultation will provide a good basis for operators to understand where they stand when they come to install equipment. We have considered the concern that an operator who deployed first could be forced to remove base stations following new deployments in the adjacent frequency block. We therefore propose to clarify in the Information Memorandum that any standard power base station could receive interference if it is installed closer than 160m to a restricted block TDD base station, installed at an earlier time, that uses the alternative block edge mask in an adjacent frequency block.

Information sharing for the purpose of establishing minimum separation distances for protection from 2.6 GHz TDD restricted blocks

A15.93 There was general agreement from most of those who responded on this point to the approach of sharing base station location information for coordination between the FDD network and TDD base stations using the restricted block alternative mask. One confidential response did not support the proposals and raised doubts about the potential accuracy of location information. We received no proposals for alternative ways of achieving the requirement for a minimum separation distance between restricted block base stations using the alternative mask and standard power base stations in the adjacent frequency block.

A15.94 Our assessment of the comments that we received is that there are no technical reasons that would prevent two operators coordinating to ensure that their base stations met the conditions on placement. We therefore plan to include the placement conditions set out in the June 2011 consultation as a requirement for use of the alternative block edge mask, while including the clarification set out in paragraph A15.92.

Standard power 2.6 GHz licence conditions: maximum in-band power limit

A15.95 In its response to the June 2011 consultation, Vodafone proposed to increase the 2.6 GHz in-block EIRP limit to 62dBm/5 MHz for base stations equipped with MIMO. Vodafone provided analysis to support its contention that the effect of blocking from a base station equipped with MIMO is around 1dB below that from a base station with a single transmit antenna. It suggested that Ofcom could relax the EIRP limit as envisaged in the Commission Decision: "*Member States can relax this limit to 68dBm/5 MHz for specific deployments e.g. in areas of low population density provided that this does not significantly* increase the risk of terminal station receiver blocking." Vodafone proposed that MIMO installations could be covered by the category of specific deployments and indicated that its analysis had shown that this increase does not significantly increase the risk of blocking.

A15.96 We did not include a specific question on the proposed 2.6 GHz in-band power limit in the consultation because it is set out as a requirement in the Commission Decision, and we did not propose to relax the limit for specific deployments. Having considered Vodafone's proposal, we are still not minded to propose any relaxation of the 2.6 GHz base station in-band power limit.

Comments on technical licence conditions for low power 2.6 GHz

Hybrid approach outlined in the March 2011 and June 2011 consultations

A15.97 The March 2011 consultation set out the potential for dedicated low power spectrum, where either 2×10 MHz or 2×20 MHz of paired spectrum in the 2.6 GHz band could be available for sharing between several licensees for provision of low power services. Recognising that dedicating spectrum for low-power licences would mean reducing the quantity of spectrum available for standard power usage, it also introduced the concept of hybrid spectrum: 2×10 MHz dedicated to low power only and a further 2×10 MHz shared with a standard power licensee, subject to certain conditions to manage the potential interference into the standard power network. At the time of the March 2011 consultation, we noted that there were still several open issues on the matter of low power and hybrid options.

Preference for dedicated or hybrid spectrum for low power licences

A15.98 In the June 2011 consultation we sought views on specific options for providing spectrum for low-power applications. One aspect of this was whether to dedicate 2×10 MHz or 2×20 MHz as low power spectrum, and then a question of whether to follow a hybrid approach of 2×10 MHz dedicated spectrum and 2×10 MHz shared with a standard power operator.

A15.99 The respondents that expressed support for the idea of making spectrum available for low power applications generally preferred the option that resulted in the greatest quantity of low power spectrum. This also means that the hybrid approach was preferred ahead of 2×10 MHz dedicated.

A15.100 Several respondents reiterated their comments from the March 2011 consultation that no spectrum should be set aside for low power applications, whether dedicated or hybrid. Additionally, those stakeholders expressed their opposition to the hybrid approach, citing concerns over the feasibility of sharing spectrum between low power networks and a standard power network and the likelihood of interference to the standard power network. These concerns are discussed in detail in the section dealing with the specific proposals for ways in which a hybrid approach could be implemented. Three stakeholder responses stated a preference for hybrid without providing supporting explanation.

A15.101 In conclusion, where responses provided reasons, they only supported a hybrid approach as a possible means to increase the quantity of low power spectrum; given the choice they would prefer the same quantity of dedicated low power spectrum. Only three stakeholders stated their outright support for hybrid over dedicated spectrum but they provided no additional information that would suggest to us where they saw the additional benefits.

Possible implementation of hybrid approaches for low power: spectrum sensing and geolocation

A15.102 The June 2011 took forward the options that were first outlined in the March 2011 consultation on a hybrid approach that could allow low power networks to access 2×20 MHz of spectrum, where 2×10 MHz of that would be shared with a standard power network. We set out two options for this hybrid approach that we could implement in order to enable the coexistence between the low power networks and the standard power network. Under a geolocation approach, we would set a

minimum separation distance between low power base stations and the nearest standard power base station. The other approach was based on spectrum sensing techniques that would use the capabilities of the low power base stations and terminals to determine the usage of the spectrum by the standard power network and then implement any necessary power back-off to avoid causing interference to the standard power network.

A15.103 Most of the responses on this question expressed opposition to the potential spectrum sensing approach. Two responses were broadly supportive of the spectrum sensing approach: Cable&Wireless referred back to its comments to the March 2011 consultation in which it supported an approach based on the use of measurement of various characteristics of LTE. ip.access had also confirmed in its response to the March 2011 consultation the technical capability of femtocells to perform network listen operation and then adjust their transmit parameters. It had indicated the development for 3GPP Release 10/11 of capability for LTE terminals to make measurements that can be used for optimisation, and suggested that macrocell and microcell deployments could also have network listen functionality.

A15.104 BT proposed an alternative approach for hybrid. It suggested that coexistence between low power and standard power should be managed by limiting low power networks to 15dBm EIRP in the shared 10 MHz block and cautioned against reliance on non-standardised techniques, such as location databases and carrier sensing power back-off. BT also disagreed with the assumption lying behind the spectrum sensing approach that the standard power network would have priority.

A15.105 One confidential respondent foresaw problems if the only spectrum made available for low power was shared with a standard power network. It suggested that standard power use would effectively render the low power licensees use of the spectrum impractical in many locations. Although our proposal envisaged that 10 MHz dedicated spectrum would always be available for low power, this comment does suggest a degree of concern at the potential coexistence difficulties in a block shared between low power and standard power.

A15.106 Vodafone's response expressed concern that we had apparently not decided on the relative priority for access to hybrid spectrum between low power and standard power networks. It therefore concluded that there might be only 2×50 MHz usable standard power spectrum. Vodafone also drew attention to the tentative nature of the proposals on technical licence conditions for hybrid spectrum in the June 2011 consultation and areas where it identified that additional detail on the hybrid approach was necessary. It stated that without this detail it could not give a final view on the technical feasibility of the hybrid approach.

A15.107 Vodafone drew parallels between the spectrum sensing approach outlined in the Real Wireless report and the detection-only approach to white space implementation in UHF TV spectrum, and it recalled that Ofcom had already concluded that implementation of detection-only devices for that band was likely many years away. It also noted that in the spectrum sensing approach, 2×10 MHz of spectrum was effectively underlay spectrum, and suggested that our conclusions on the full underlay approach (that it presented challenges for protection of the standard power operator and in ensuring low power operators could provide an adequate level of service) therefore also applied in the case of hybrid and we should not pursue it further.

A15.108 Telefónica suggested that overlapping low power and standard power carriers would lead to "near-far" interference situations, i.e. where a standard power

customer receives interference from a nearby low power base station at a higher power than the wanted signal from the standard power network, due to the relative difference in path loss from the two base stations.

Ofcom's proposed way forward on hybrid low power spectrum

A15.109 We are no longer proposing the geolocation or spectrum sensing options for hybrid low-power spectrum. Instead of the hybrid approach we have identified a possible alternative model of a geographic division between rural and non-rural areas for access to the additional 2×10 MHz of low power spectrum. Our thinking on this is set out in Section 4.

Frequency placement of low power 2.6 GHz blocks

A15.110 In the June 2011 consultation we referred to technical analysis of the requirement to meet conditions on unwanted emissions into the radar spectrum above 2700 MHz and into the spectrum below 2620 MHz, particularly for the case of low power access points. The analysis suggested that there were optimal frequencies within the band where low power base stations would be less likely to require additional measures in order to meet the licence requirements on unwanted emissions outside the operating band. Away from these optimal frequencies, low power base stations could use measures such as additional filtering or power back-off to meet the unwanted emissions requirements. We asked for views on the preferred frequency placement for low power licences.

A15.111 Those stakeholders that were supportive of dedicated low power spectrum indicated agreement with the analysis in the technical report. Several other responses suggested that any low power blocks should be placed in the unpaired spectrum at 2570-2620 MHz rather than the paired spectrum, on the grounds that paired 2.6 GHz spectrum had a higher value than unpaired spectrum.

A15.112 The assignment of 2.6 GHz spectrum, including any low power blocks is considered in Section 6 of this document.

Views on the number of low power 2.6 GHz licences

A15.113 The technical report accompanying the June 2011 consultation set out an analysis of the practicality of multiple low power licensees providing overlapping coverage in a shared frequency block. The modelling indicated how the availability of radio resources number to an individual operator is reduced as more operators attempt to provide service in an area, and we provided a summary in the consultation.

A15.114 BT generally agreed with the Real Wireless analysis of the reduction in individual resources as the number of operators in a location increased. However, its response to this information was to suggest that our March proposals for up to ten low power licences needed to be reconsidered. BT proposed to reducing the potential for interference between low power networks by subdividing the low power licences into two categories:

- Three licences with a maximum permitted base station power of 30dBm EIRP, proposed as suitable for outdoor or indoor coverage
- Seven licences with a maximum permitted base station power of 10dBm EIRP, proposed as suitable for indoor coverage.

A15.115 BT's proposals for the three outdoor licences align with the power limit that we proposed for the low power, and so should permit deployment in outdoor public spaces and campus or business park environments, as well as lower power deployments in indoor public spaces and office locations and uncoordinated residential deployments. Its proposals for the indoor licences are within the range that would provide coverage in residential locations, office environments and other indoor public areas.

A15.116 In reviewing the proposals for two categories of low power licence, we took into account several factors. We observed that the predicted reduction in radio resources available to individual networks occurs when multiple operators want to occupy the same space, so this will not be a national issue but will occur in the most popular locations, i.e. those locations where the highest number of licensees wishes to provide service. According to the modelling undertaken by Real Wireless for the March 2011 consultation, a low power licensee operating at the lower level of 10dBm EIRP could still provide coverage at outdoor public spaces, but coverage into buildings in the campus and business park scenarios might present a challenge. We therefore considered that the 10dBm low power licence category could restrict licensees' flexibility but it might not have significant impact in reducing the incentive to install systems in those most popular locations. Finally, we noted that cooperation in managing the shared low power spectrum is intended to be provided through a code of practice on engineering coordination, so use of spectrum in the most popular locations is a particular scenario that the code of practice would need to address. As a result of these considerations, we do not intend to split the low power licences, and we will retain a single category with a maximum power limit of 30dBm EIRP.

A15.117 In its response to our March 2011 consultation, Skype saw no intrinsic reason to restrict shared usage to a limited number of licensees and preferred shared usage to be limited by technical requirements to ensure satisfactory operation in the block. Skype also doubted that shared use of a spectrum block would require the power limit to be so stringent that they would require low power use in all circumstances and locations. Skype proposed a general authorisation, i.e. licence-exemption, for the frequency block dedicated to shared use and a further general authorisation on shared use of further (standard power) frequency blocks in 2.6 GHz, subject to conditions on mutual interference management to be agreed amongst the users.

A15.118 The Institution of Engineering and Technology (IET) response to our March 2011 consultation proposed that we allow licence-exempt low-power systems to share 2×20 MHz paired spectrum with a standard power network, where the standard power network operator has bid for the licence for that block in the knowledge that such low-power devices may exist in significant numbers. The IET proposed that under such circumstances the appropriate technical conditions were a maximum antenna height of 10m and maximum power of 30dBm EIRP, subject to a requirement for low-power systems to implement spectrum sensing and power back-off. The IET further suggested that it would be useful if provision could be made for the each small cell to be able to declare its location, power output policy and average and peak power output to a nominated service provider.

A15.119 We had not proposed a licence-exempt model for the provision of spectrum for low-power applications, and the IET and Skype responses were the only inputs that we received that proposed this approach. The IET indicated that its proposal would enable consumers to enjoy services based on small cells in the widest range of circumstances. However, it did not specify why these benefits required a licence-exemption model and why they could not be delivered by our proposed approach of

licensing several network operators to share access to a block of spectrum. Skype suggested that its proposal for a general authorisation approach arose from its conclusions on the different market outcomes in the UK and the Netherlands when these countries made spectrum at the top of the 1800 MHz band available for shared use.

A15.120 We understood the IET proposals to be effectively the full underlay approach that we outlined in the March 2011 consultation, but without any limit on the number of autonomous low-power networks. The same applied to part of the Skype proposal, which suggested a general authorisation on shared use of the standard power blocks between the individual standard power licensee and general authorisation users. Skype did not address coexistence with the standard power networks in its response whereas the IET contended that there was minimal likelihood of interference from licence-exempt small cells into the macro network, or between licence-exempt small cells, citing evidence from the May 2009 report for Ofcom on the Utilisation of Key Licence-Exempt Spectrum Bands, and the use of Wi-Fi in 2.4 GHz. We were unable to reconcile the suggestion that the likelihood of interference was minimal with the technical modelling that Real Wireless presented in its report that accompanied the March 2011 consultation. The Real Wireless report had not modelled a licence-exempt approach but it did look into the option of licensing several low-power operators as an underlay to a standard power licensee. The Real Wireless report stated that if the low-power spectrum block were provided on an underlay basis with a high power licence, there would be several scenarios where interference between the systems could be significant, and where mitigation techniques would be required. It concluded that an underlay approach would present interference and coordination challenges. It should be noted that adding licence-exemption of base stations into this scenario would complicate matters further: we could not rely on any interference mitigation that depended on coordination amongst the low-power operators or between the standard power operator and low-power operators. We therefore considered that there were a number of risks associated with allowing low-power base stations to operate on a licence-exempt basis as an underlay to a standard power network and did not pursue this option.

A15.121 Skype stated that the Real Wireless report accompanying the March 2011 consultation did not support our proposal to limit the number of networks accessing a shared block of spectrum. Real Wireless performed additional technical modelling on the impact on network performance in the case of several networks providing coverage in a location and we presented these results in the June 2011 consultation on technical licence conditions. These results make it clear that performance is impacted if a large number of networks attempt to provide service in a location. While the proposed code of practice on engineering coordination would provide a route for licensees to manage this situation amongst themselves, licence-exemption would not allow for such a mechanism. We were therefore not minded to pursue exemption of low power networks in a shared block.

Low power 2.6GHz licence conditions

A15.122 We proposed the technical conditions in Tables A15.3 to A15.5 for the low power shared access licences:

Table A15.3: Block specific requirements – base station in-block EIRP limit for low-power shared access blocks for outdoor antenna placement

Frequency range of in-block emissions	Maximum mean in-block power
Downlink use of low-power shared access paired frequencies	30 dBm EIRP

Table A15.4: Low-power base station antenna placement

Location	Maximum antenna height
Outdoor locations	12m
Indoor locations	No height restriction

Table A15.5 In-block requirements for low-power shared access terminal stations in the 2.6 GHz band

Frequency range of in-block emissions	Maximum mean in-block power
Uplink use of low-power shared access paired frequencies	23 dBm EIRP

A15.123 Additionally, out of block emission limits would be set at the levels provided in the Commission Decision 2008/477/EC. We received a number of comments from stakeholders on these proposals, which we address in the following sections.

Maximum height for low power outdoor antenna installations

A15.124 Two stakeholders suggested that it is not necessary to include a maximum outdoor height in the low power licences, and this condition might constrain certain applications or deployments. There were two reasons provided: BT suggested interference would be managed by reducing the number of licensees so that only three of them had sufficient power to provide outdoor coverage, while a confidential respondent suggested that the operator would instinctively move the base station to a lower height if it was subject to interference.

A15.125 We stated earlier that we do not intend to reduce the number of 30dBm licensees for interference management purposes. The rationale of a very limited number of potential interferers would not therefore apply. The point about the prevention of excessive levels of incoming interference deserves further consideration. Interference from multiple terminals into a single base station is quite a different scenario from interference from multiple base stations into terminals. It does not necessarily follow that the interference received at a base station is indicative of the cumulative interference in locations in or adjacent to its intended coverage area. Therefore we believe that there is a case for a backstop maximum antenna height that would serve to limit the interference impact of individual outdoor base stations.

Low power block edge mask

A15.126 Vodafone did not agree with use of the same block edge mask as standard power licences. It suggested that these out of block power limits would be inadequate for the protection of adjacent networks from low power base station interference because such devices will be located nearer to terminals of other networks than CEPT assumed for its development of block edge masks.

A15.127 The block specific requirements for base stations in the Commission Decision for the 2.6 GHz band were developed in CEPT Report 19. We reviewed this CEPT Report for indications about the applicability of the block edge mask. CEPT Report 19 states that its deployment assumption for 2.6 GHz includes macrocell, microcell and picocell deployments, and we observe that picocells are covered by the 3GPP specifications for local area base stations. 3GPP TS 36.104 states: "Local Area Base Stations are characterised by requirements derived from Pico Cell scenarios with a BS to UE minimum coupling loss equal to 45 dB." Given this low value for minimum coupling loss and that the rated output power for local area base stations defined in 3GPP is less than or equal to 24dBm (for one transmit antenna port), we consider that this covers the category of low power licences.

A15.128 Our other consideration was that the harmonised standards applicable to base stations for the 2.6 GHz band all include requirements on adjacent channel leakage power ratio. Any low power base station that is CE marked by compliance with the harmonised standard will have out of band emissions much lower than those required by the Commission Decision. Femtocells and other low power base stations placed on the European market could be deployed both by low power networks and by standard power licensees. Any concerns about the suitability of the block edge mask for non-macrocell deployments therefore apply equally to the use of such devices by standard power licensees or low power licensees. No respondent raised any concern about the technical conditions applicable to deployment of femtocells within standard power networks.

A15.129 In conclusion, we were not convinced that the use of low power base stations by low power licensees or by standard power licensees would invalidate the block edge mask in Commission Decision 2008/477/EC or require us to impose separate technical conditions.

Code of practice on engineering coordination for 2.6 GHz low power

A15.130 We proposed that sharing of the low power spectrum in locations where several licensees wished to provide service should be managed by a code of practice on engineering coordination, to be agreed amongst the low power licensees. Where respondents commented on this point, they agreed with our proposal that a code of practice is the appropriate approach to manage coexistence between low power licensees.

Other general comments on low power networks

A15.131 The Federation of Communication Services (FCS) and Turquoise Mobile proposed in their responses to the March 2011 consultation that Ofcom should ensure that measures were taken to facilitate roaming between national and sub-national networks to encourage hub and spoke radio use. They did not provide any indication of particular consumer benefits from the hub and spoke model, or how roaming between standard power and low power networks would encourage this approach.

A15.132 Intel Corporation (UK) suggested that shared access may be difficult to implement. It supported efforts to accommodate low power systems assisting broadband roll-out and coverage but placed a priority on standard power licensed services and, in its response to the March 2011 consultation it expressed a view that Ofcom should not reserve spectrum for this application. Intel stated that it was important to ensure that interference issues are manageable.

A15.133 Intellect also responded to the March 2011 consultation that the process of setting the number of licences and framing the technical licence conditions needed to ensure that interference issues are manageable. Intellect did not want low-power to unduly constrain the provision of standard power services, and was concerned that interference management must not require UK-specific implementations in terminal devices.

A15.134 Samsung was concerned that low power proposals must not lead to a requirement for UK-specific terminals. Our proposals had been made on the basis that it should be possible to use standard unmodified terminals. However, we recognise that the spectrum sensing option that we had outlined for the hybrid approach placed particular requirements on terminals to take measurements of characteristics of another LTE network, and there may have been uncertainty over the feasibility of including these as technical conditions on licensees.

A15.135 The BBC generally supported initiatives to promote the deployment of high efficiency LTE femtocells. Its view was that LTE femtocells have advantages over alternative approaches based on Wi-Fi which it suggested would suffer congestion, poor MAC efficiency, increased terminal cost and impact on terminal battery life. The BBC's interest in this matter derived from its provision of content that is consumed via mobile broadband. In particular, it held the view that a small cell approach was a more effective way of enabling broadband access for large numbers of users who are deep indoors, and where coverage from external base stations may be marginal.

Comments on exemption of terminal stations

800 MHz and 2.6 GHz terminals

A15.136 In the June 2011 consultation we proposed to proceed with the approach that terminal stations operating in the 800 MHz and 2.6 GHz bands should be exempt from a requirement for individual licensing provided that they comply with certain technical parameters which we outlined in Section 8 of the June 2011 consultation. As we indicated at the time, those parameters are consistent with the usage studied during the development of CEPT Reports 19, and 30 covering these bands and with the power limits in Commission Decision 2008/477/EC. We also proposed a set of technical conditions for exemptions of LTE and WiMAX terminals in 900 MHz and 1800 MHz, in line with implementation of Commission Decision 2010/267/EU and the usage studied in CEPT Reports 40 and 41.

A15.137 We received a number of supportive comments on this question Arqiva, BT, Cable&Wireless, Intel, Samsung, Three, Vodafone and one confidential response agreed with the proposal that we should proceed with the approach that terminal stations complying with the relevant technical parameters be exempted from the requirement for individual licensing.

A15.138 The responses from APWPT, BEIRG, Mr B Copsey, Ei Electronics, Great Circle Design and one confidential response did not support the proposal to exempt terminals complying with the relevant technical parameters from requirement from individual licensing. The BBC also proposed that we defer decisions on exemption until interference mechanisms to SRD and cable TV are understood. The stakeholders that were opposed to licence-exemption for terminals cited concerns about the potential for interference from terminals into short range devices in the spectrum above 862 MHz.

A15.139 The response from Great Circle Design was concerned about fixed or portable terminals operating at 35dBm in the 800 MHz band. We can confirm that the power limit of 35dBm/(5 MHz) EIRP for fixed or installed terminal stations only applies to the 2.6 GHz band; for 800 MHz the maximum in-block power limit for fixed or installed terminal stations is 23dBm EIRP.

A15.140 Terminals that would be exempted from licensing would be mobile devices that were placed on the European market and operated under the control of the mobile network. A requirement for individual licensing for mobile terminals is unlikely to influence the usage patterns of these devices but would simply introduce an administrative burden. As such, we take the view that requiring mobile subscribers to obtain licences for individual terminals that are operated under the control of the network would not have a material impact on the likelihood of interference into adjacent services.

900 MHz and 1800 MHz terminals

A15.141 Vodafone commented that in paragraph 8.9 of the June 2011 consultation, the technical conditions for exemption of LTE and WiMAX terminals should not refer to EN 301 908-14 and EN 301 908-22, because these standards are for base stations not terminals. That paragraph quoted the full definition of LTE and WiMAX from Commission Decision 2011/251/EU but we agree that the exemption regulations should only reference the terminal standards (EN 301 908-1, EN 301 908-13 and EN 301 908-21).

A15.142 We published the Notice of Ofcom's proposals for changes to the licence exemption of Wireless Telegraphy Devices161 on 20 October 2011, which refers to IR 2087 for technical conditions for LTE and WiMAX terminals. IR 2087 references EN 301 908-13 and EN 301 908-21 for the 900 MHz and 1800 MHz terminal transmit spectrum.

Comments on changes to 900 MHz and 1800 MHz licences

A15.143 In Annex 6 of the June 2011 consultation, we set out some proposals for how we intended to implement Commission Decision 2011/251/EU, which amended Decision 2009/766/EC. We propose to consider the responses on these issues outside of our proposals on the auction, in accordance with our obligations under the Directives and the Wireless Telegraphy Act 2006, in the first quarter of 2012.

Comments on other matters

UMTS 900 licence conditions

A15.144 Telefónica suggested that the condition that "the UMTS centre frequency must be 2.5 MHz or more inside the permitted frequency bands" prevents the use of the highest 3GPP downlink carrier, and proposed amendment of this condition. We considered UMTS technical conditions to be outside the scope of the consultation and therefore do not plan to make any proposals for change to 900 MHz UMTS.

[161] http://stakeholders.ofcom.org.uk/consultations/notice-wireless-telegraphy/

Coverage obligations

A15.145 We received a suggestion in the responses to the consultation on technical licence conditions that the coverage obligation for 2Mbit/s data, currently proposed on the basis of percentage of UK population and UK indoor locations, should instead be set at a regional geographic level. Our proposals on coverage obligations are covered in Section 5.