



Public Sector Spectrum Release: Award of the 2.3 and 3.4 GHz spectrum bands

Statement and
consultation

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About this document

This document sets out Ofcom's decisions on a number of issues connected with the award of the 2.3 and 3.4 GHz spectrum bands, including the auction design and process; the coexistence of new and existing uses of the frequencies to be awarded; and the licence conditions we will attach to the spectrum.

Additionally, the document seeks stakeholder views on options for proceeding with the award in light of changes to market circumstances. This includes the option of reducing the volume of spectrum to be awarded.

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Section 1

Executive summary

- 1.1 This document is both a statement and a further consultation on an award of the 2.3 and 3.4 GHz spectrum bands.
- 1.2 The statement element of the document sets out Ofcom's decisions on a number of issues that have been the subject of earlier consultations, including the auction design and process; the coexistence of new uses of the frequencies to be awarded alongside existing uses in neighbouring bands; and the technical and non-technical licence conditions.
- 1.3 The consultation element invites responses from stakeholders on options for proceeding with the award in the light of potential changes in the mobile market.
- 1.4 The 2.3 and 3.4 GHz award bands will be released by the Ministry of Defence (MOD) as part of the Government's Public Sector Spectrum Release (PSSR) programme to make 500 MHz of spectrum available for civil use by 2020. The spectrum is likely to be of interest to mobile broadband operators.

Consultation

- 1.5 Since the publication of our earlier consultations, two announcements have been made which could change the nature of the mobile market: On 5 February 2015, BT announced its intention to acquire EE. Then, on 24 March 2015, it was announced that Hutchison Whampoa (owner of the H3G network i.e. 'Three') had reached agreement to acquire O2 from its current owner Telefonica. If the H3G/O2 transaction were to proceed, it would reduce the UK wholesale mobile market from four operators to three.
- 1.6 It is not Ofcom's role to decide whether it would be appropriate for these transactions to take place – this will be considered by the relevant competition authorities¹.
- 1.7 Ofcom's principal duty is to further the interests of consumers in relevant markets, where appropriate by promoting competition. We also have a duty to secure the optimum use of spectrum. In doing so, we consider it is important to have as many tools as possible at our disposal, particularly where market conditions may change.
- 1.8 We therefore seek the views of stakeholders on the *option* of withholding some of the available spectrum from the 2.3 and 3.4 GHz award. We would proceed with an auction of the bulk of the available spectrum and award any withheld frequencies at a later date, in light of market conditions.
- 1.9 We believe this option may be preferable to the alternatives of a) delaying the whole auction until market conditions are clearer; or b) proceeding with an auction of all the newly available spectrum regardless. We believe either of these alternatives could result in an inefficient use of spectrum.
- 1.10 Our initial thinking is that it may be appropriate to withhold around 60 MHz of the 190 MHz of spectrum available. However, we invite stakeholder views.

¹ The UK Competition and Markets Authority or the European Commission.

Statement on issues addressed in previous consultations

Auction design

- 1.11 Having considered responses to our November 2014 consultation we have decided to conduct the 2.3 and 3.4 GHz award using a Single Multi-round Ascending (SMRA) auction process. We have considered arguments in favour of alternative auction formats, including a Combinatorial Clock Auction (CCA). However, we have concluded that the additional complexity of a CCA process is not justified in this case.
- 1.12 The particular assumptions on which we based our recommendation for an SMRA format, and the severity of the residual risks of this format, would not be significantly affected if we decided to hold back some of the frequencies. Our decision on auction format will therefore stand, because the SMRA auction is sufficiently robust to cope with all anticipated circumstances.
- 1.13 We have revised our proposals on the lot sizes to be offered in the auction in light of consultation responses. We had proposed auctioning all the available spectrum in lot sizes of 5 MHz, because we believed this would ensure the greatest possible flexibility.
- 1.14 After careful consideration of responses, we still consider 5 MHz lots to be the best option for the 3.4 GHz band. This is because there are a range of potential uses of the spectrum in this band, and it remains appropriate for us to enable maximum flexibility.
- 1.15 However, in light of its likely use for LTE, we have decided that the 2.3 GHz spectrum will be awarded in 10 MHz lots. Our decisions on synchronisation for the 2.3 GHz band (see below) mean there is unlikely to be a need for any of the available spectrum to be used for guard bands to avoid interference. Therefore, 10 or 20 MHz channels are likely to be preferred. The award of 10 MHz lots means there is no need for us to have a minimum requirements option for the 2.3 GHz spectrum.
- 1.16 We have also finalised our decisions on a range of more detailed aspects of SMRA auction design including information disclosure; a ranking rule to assign standing high bids; activity rule; withdrawal rule; and eligibility ratio for switching between bands. We will proceed to draft regulations on the basis of these decisions. However, we recognise that some aspects may change in the process of drafting the regulations. We will consult on the draft regulations and we will note any significant alterations.

Coexistence issues

- 1.17 Our February 2014 consultation identified the potential for interference from 2.3 GHz LTE mobile broadband to users of licence exempt spectrum in the nearby 2.4 GHz band (2400 to 2483.5 MHz). Uses of this band include domestic and commercial Wi-Fi, Bluetooth, ZigBee, some medical monitoring equipment and assistive listening devices (ALDs).
- 1.18 In all cases, we assessed the risk as very low and noted that if interference did occur it would be caused by licence exempt equipment 'listening in' to signals from outside its designated band, and not from LTE causing interference to the licence exempt band. Appropriately filtered equipment is not affected.

- 1.19 We conducted detailed further technical tests as a result of consultation responses, particularly in respect to Wi-Fi. We also engaged with a large range of stakeholders, including manufacturers and users of licence exempt equipment. This included making our test facilities in Hertfordshire available to makers of ALD equipment to test their systems. This will help them to update devices, if they feel it is necessary.
- 1.20 The results of all the additional testing, together with our further assessment, were published in our technical update document of December 2014, in which we confirmed our original proposals. We have now reached our final decisions.
- 1.21 For **Wi-Fi**, we have concluded that the likelihood of interference is very low and, even if it occurs, many users will not even notice. Further, there are suitable mitigations – including use of the alternative 5 GHz Wi-Fi band. We have therefore decided that no intervention in the market is necessary or justified. However, we will provide guidance to manufacturers/retailers recommending that they provide suitable information in installation guides and on packaging of femto cell equipment about suitable separation distances from Wi-Fi routers.
- 1.22 We have reached similar conclusions in respect to the other categories of licence exempt use of the 2.4 GHz band.
- 1.23 However, we considered in detail a further submission in respect to **Assistive Listening Devices** from the UK Children’s FM Working Group – a group involved in the education of deaf children. It did not challenge our testing or our conclusions in respect to the low impact on those with some hearing impairment. However, it said we had failed to understand the implications of actual deafness in children and their ability to learn. We subsequently met the group to discuss their concerns.
- 1.24 Having considered all the evidence we continue to believe the likelihood of any impact to ALDs is extremely low and no intervention is justified. However, in view of our increased understanding of issues affecting deaf children, we are planning to work with manufacturers to enable them to conduct ‘real life’ testing to establish the precise nature of any impact if it occurs.
- 1.25 We also confirm our proposals in respect to **civil maritime radar** and **aeronautical radar** close to the 3.4 GHz band; and in respect to coexistence with **satellite services**. Coordination is needed between 3.4 GHz LTE and aeronautical radar, but not with civil maritime radar or satellite services.
- 1.26 Coexistence with **naval systems** is still subject to finalisation with the MOD. We will require coordination zones around a number of key military locations, as per our consultation (Aberporth, St Kilda, Oakhanger, Colerne, Menwith Hill, Bude) plus some newly identified sites, including Boscombe Down, Warton and in Northern Ireland.

Technical licence conditions

- 1.27 In our February 2014 consultation we proposed that licensees could use a permissive mask to avoid interference between neighbouring users (i.e. without the need for a guard band) if there was full synchronisation between them. Alternatively, we said licensees would need to use a restrictive mask (i.e. with a need to use some of their spectrum for a guard band) if they chose not to use the preferred synchronised configuration.

- 1.28 In our December 2014 consultation, we proposed that an initial agreement was necessary for a number of reasons, including the timely deployment of networks following award of the spectrum. We consulted on two options:
- Option 1: We said we could mandate a TD-LTE frame *alignment* but leave it up to individual licensees whether to adopt the specified frame *structure*. This would allow a degree of flexibility. If a licensee chose not to adopt a specified structure they would need to use a restrictive mask.
 - Option 2: As an alternative, we said synchronisation could be achieved by mandating the full technical configuration compatible with TD-LTE, including the frame alignment and frame structure. In this case, all licensees would be able to use a permissive mask.
- 1.29 A majority of respondents favoured the greater flexibility afforded by option 1. However, other respondents argued strongly that efficient delivery of services required full synchronisation between operators. Having considered the responses carefully, we have decided there should be a different approach for the different bands.
- 1.30 For the 3.4 GHz band, with up to 150 MHz of additional spectrum available, we consider that this band should be synchronised. However we see no reason to deny licensees maximum flexibility if they wish to adopt different frame structures and use the restrictive mask. We therefore support option 1 for the 3.4 GHz spectrum.
- 1.31 With a maximum of 40 MHz of spectrum available in the 2.3 GHz band - and an optimal carrier size of 20 MHz for LTE - it makes sense to mandate full synchronisation in order a) to ensure the permissive mask is used in that band; b) that all the spectrum is deployed effectively/efficiently; and c) to facilitate the most timely roll-out of services.

Non-technical licence conditions

- 1.32 We received very few responses challenging our proposals on the non-technical licence conditions as set out in our November 2014 consultation. We have therefore decided to proceed on that basis. In summary:
- Licences will be issued for an indefinite period with an initial term of 20 years;
 - Licences to be issued on a non-exclusive basis;
 - The 2.3 GHz licences will cover Great Britain (i.e. England, Scotland and Wales, but not Northern Ireland)²;
 - The 3.4 GHz licences will cover the whole of the UK;
 - Licences will exclude territorial seas and areas of adjacent internal waters, although individual requests will be considered;
 - The spectrum will be tradable under the provisions of the Mobile Trading Regulations;

² N.B. Exclusion zones will apply in The Hebrides, Isle of Skye and The Small Isles

- There will be no coverage obligations or use-it-or-lose-it obligations placed on licences.

Section 2

Introduction

- 2.1 This document is both a statement and a consultation.
- 2.2 The statement element of the document sets out our decisions on issues for the 2.3 and 3.4 GHz spectrum award on which we have already consulted, including auction process and design, technical coexistence, and licence conditions.
- 2.3 The consultation element seeks stakeholder views on options for proceeding with the award in light of potential changes in the UK mobile market. In particular, the proposed acquisition of EE by BT; and the proposed acquisition of O2 by Hutchison Whampoa (parent company of mobile operator H3G). These transactions are subject to competition inquiries, with the final outcome uncertain at this stage.

Legal framework

- 2.4 The legal framework within which we must make our decisions was set out in both the February 2014 and November 2014 consultations. The full detail is not repeated here. However, it is worth highlighting the following aspects:

Principal duties under the Communications Act 2003

- 2.5 Our principal duties under Section 3 of the Communications Act 2003 are:
- to further the interests of citizens in relation to communications matters; and
 - to further the interests of consumers in relevant markets, where appropriate, by promoting competition.
- 2.6 In doing so, we have a duty to secure the optimal use of spectrum (Section 3(2)(a)); and a duty to take account of the different needs and interests of all current or potential users of the frequencies (Section 3(4)(f)).

Granting licences

- 2.7 In accordance with Section 10 and Schedule 1 of the WTA, Ofcom may grant licences in accordance with procedures prescribed in regulations made by Ofcom.
- 2.8 Ofcom has made general regulations in relation to licensing procedures (the Wireless Telegraphy (Licensing Procedures) Regulations 2010). Where Ofcom decides to award licences by auction, it makes specific regulations for those purposes, in accordance with Section 14 of the WTA. While this statement sets out our decisions on how we intend to award the 2.3 and 3.4 spectrum, the regulations will be subject to further consultation, and final decisions on how to award the spectrum will be set out in such regulations.

European Commission decisions relevant to the 2.3 GHz and 3.4 GHz band

- 2.9 On 21 May 2008, the European Commission adopted a decision (decision 2008/411/EC) which seeks to harmonise the conditions for the availability and efficient use of the 3400-3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the EU. On 2 May 2014, the

European Commission adopted Decision 2014/276/EU12, which amended Commission Decision 2008/411/EC, primarily in relation to the technical conditions in compliance with which the band should be made available. Any award of the 3.4 GHz band has to be compliant with the Commission Decision.

- 2.10 In relation to the 2.3 GHz band, ECC Decision (14)02 sets out harmonised technical and regulatory conditions for the use of the band 2300-2400 MHz for Mobile/Fixed Communications Networks. While the ECC Decision is not mandatory, the European Commission is currently working to issue a decision which will incorporate those technical and regulatory conditions. That decision will be mandatory and could be made in the autumn of this year.

The spectrum to be awarded

- 2.11 A total of 190 MHz of new spectrum will be released to Ofcom by the Ministry of Defence (MOD) as part of the Public Sector Spectrum Release (PSSR) programme to release or share 500 MHz of spectrum for civilian use by 2020. On our current timetable we expect to hold an auction in the later part of the 2015/16 financial year.
- 2.12 The full award frequencies to be released by the MOD comprise 40 MHz of spectrum within the 2.3 GHz band (2350-2390 MHz) and 150 MHz of spectrum within the 3.4 GHz band (at 3410-3480 MHz and 3500-3580 MHz). A further 40 MHz of spectrum in the 3.4 GHz band is currently held by UK Broadband Ltd (3480-3500 MHz and 3580-3600 MHz). If UK Broadband chooses to participate in the auction, the frequencies making up its current holding will change to enable all users of the 3.4 GHz band to have contiguous spectrum holdings.
- 2.13 The 2.3 GHz spectrum will be made available for new uses throughout Great Britain (i.e. in England, Scotland and Wales, but not in Northern Ireland)³. The 3.4 GHz spectrum will be made available throughout the whole of the UK.
- 2.14 Both of the award bands will be fully cleared of existing uses, apart from in a very few specific areas where there will be continued MOD use. There may also be some very limited use of the award spectrum for Programme Making and Special Events (PMSE) i.e. for wireless cameras (see below).

Future use of the spectrum

- 2.15 We expect the award frequencies to be of interest to mobile network operators (MNOs) and others involved with mobile broadband. The particular characteristics of the spectrum to be released, in terms of propagation and the penetration of signals, make it especially suitable for the latest long term evolution (LTE) mobile technologies:
- The 2.3 GHz spectrum has propagation characteristics very similar to the 2.6 GHz band already used for 4G;
 - The 3.4 GHz band may be valuable in providing additional options for network operators facing capacity pressures in other frequencies, either as capacity itself or as backhaul for small cells in other bands.

³ N.B. Exclusion zones will apply in The Hebrides, Isle of Skye and The Small Isles

2.16 Although high power LTE seems the most likely use of the spectrum, alternative uses will not be precluded if winning bidders have other plans (subject to compliance with technical parameters and consequent licence conditions).

Previous documents

2.17 The statement element of this document follows the publication of three consultation documents in which we set out a number of proposals on various aspects of the award. The document summarises the evidence and analysis we presented in support of our proposals, but does not repeat the details in full. The relevant consultation documents are as follows:

- In October 2013, we consulted on a band plan for the 3.4 GHz spectrum and issued a 'Call for Inputs' to stakeholders on a range of issues including aspects of auction design; spectrum packaging; competition issues; coverage obligations; and 'use-it-or-lose-it' clauses⁴.
- In February 2014, we consulted on proposals for addressing the coexistence of LTE with users of adjacent spectrum bands⁵. In particular, we assessed the potential for interference between 2.3 GHz LTE and users of the licence exempt 2.4 GHz band (2400-2483.5 MHz) including Wi-Fi. We also considered other coexistence issues for the 2.3 and 3.4 GHz award, including issues for medical devices, satellites and radar. The technical analysis supporting our proposals was updated in a further document published in December 2014⁶. The February 2014 consultation also confirmed that band plans for both the 2.3 and 3.4 GHz spectrum would be consistent with time division duplex (TDD) arrangements⁷.
- In November 2014 we consulted further on a range of issues, including more detailed proposals on auction design and process, and on the technical and non-technical licence conditions⁸ we intend to apply. The November consultation also included our assessment of competition issues pertaining to a UK mobile network market with four national wholesalers.

2.18 We have already published decisions on some particular issues of relevance to the 2.3 and 3.4 GHz award. These are set out in the following documents:

*Public Sector Spectrum Release: Amateur use of 2310 to 2450 and 3400 to 3475 MHz*⁹. This document is a statement on our approach to use of the 2.3 and 3.4 GHz spectrum, and neighbouring spectrum, by amateur radio enthusiasts. We decided that amateur radio should not have continued access to the award bands after April 2015.

*Programme Making and Special Events: Strategy for video PMSE applications*¹⁰. This document addresses issues raised in the February 2014 consultation about the impact of the 2.3 and 3.4 GHz award on the amount

⁴ <http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/summary/2.3-3.4-ghz.pdf>

⁵ <http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf>

⁶ <http://stakeholders.ofcom.org.uk/consultations/pssr-2014/updated-analysis/>

⁷ Time division duplex is used to separate the outward and return mobile signals in the same frequency channel by time, rather than by use of different frequencies (frequency division duplex).

⁸ <http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz-auction-design/>

⁹ <http://stakeholders.ofcom.org.uk/consultations/public-sector-spectrum-release/statement>

¹⁰ http://stakeholders.ofcom.org.uk/consultations/pssr-2014/statement?utm_source=updates&utm_medium=email&utm_campaign=pmse-statement-oct14

of spectrum available for PMSE use, particularly for television coverage of sporting and other events. We have decided to allow access to both award bands through coordination with new licensees where there is a requirement for spectrum access to support peak demand events. The document says that by the time of the award, we will need to have come to a formal position on tenure in the 2200-2290 GHz band in order to fully support our strategy for video PMSE.

- 2.19 This document sets out our decisions on the outstanding issues on which we have consulted. We have reached our conclusions after careful consideration of the stakeholder responses we received.

Structure of the statement

- 2.20 The rest of this document is set out as follows:

Section 3 sets out our options for proceeding with the award. It explains why we may consider holding back some of the available spectrum from the 2.3 and 3.4 GHz auction;

Section 4 sets out our decisions on the way we should conduct the award process and on how the spectrum should be packaged for auction. It also sets out decisions on the proposed auction design;

Section 5 sets out our decisions on UK Broadband's holding in the 3.4 GHz award band, and how contiguity of holdings in the 3.4 GHz band might be achieved;

Section 6 sets out our decisions in respect to technical coexistence issues for LTE and users of spectrum adjacent to the 2.3 and 3.4 GHz award bands;

Section 7 sets out the non-technical licence conditions we will apply to the spectrum award;

Section 8 sets out the technical licence conditions we will apply, including our decisions on synchronisation between neighbouring users of the award frequencies.

Section 3

Consultation on options for proceeding with the award

- 3.1 In this section of the document we consider our options for proceeding with the 2.3 and 3.4 GHz award in light of potential changes in the UK mobile market. In particular, we seek the views of stakeholders on the possibility of holding back some of the frequencies available for award.

Background

- 3.2 Our earlier consultations on the 2.3 and 3.4 GHz award set out plans to auction all of the spectrum to be released by the MOD in both the 2.3 and 3.4 GHz bands – namely, 40 MHz in the 2.3 GHz band (2350-2390 MHz) and 150 MHz in the 3.4 GHz band (at 3410-3480 MHz and 3500-3580 MHz).
- 3.3 Our November 2014 consultation included a competition assessment of the award based on there being four national wholesalers in the market (EE, H3G, O2 and Vodafone). We expressed our preference for applying a safeguard cap of 37% on the overall volume of mobile spectrum that any operator could hold. We said this competition measure would avoid the risk of an outcome where there were very asymmetric spectrum holdings. However, we also invited views on an alternative cap of 33%, and on proceeding with no cap.
- 3.4 Since publication of that consultation, BT has announced its intention to acquire EE; and Hutchison Whampoa (owner of the H3G network i.e. 'Three') has reached agreement to acquire O2 from its current owner Telefonica. If the H3G/O2 transaction were to proceed, it would reduce the UK wholesale market from four operators to three.
- 3.5 The proposed BT acquisition of EE is already the subject of a competition inquiry by the Competition and Markets Authority (CMA). The H3G/O2 transaction will need to be notified to the European Commission, which will then conduct a separate competition inquiry. This inquiry may take at least six months or longer and completion of the transactions – if approved - may take until the second half of 2016.

Impact on the 2.3 and 3.4 GHz award

- 3.6 It is not Ofcom's role to decide whether the proposed BT/EE and/or H3G/O2 transactions should go ahead. However, as outlined in the previous section (section 2) our principal duty (amongst others) is to further the interests of consumers in relevant markets, where appropriate by promoting competition. In carrying out our functions, we also have a duty to secure the optimal use for wireless telegraphy of the electro-magnetic spectrum. These are primary considerations when awarding spectrum.
- 3.7 We have considered whether we should place the 2.3 and 3.4 GHz award on hold until the outcome of the proposed transactions in the mobile market are determined. However, this may not be the best option because:

- The spectrum is available now and is unused. A delay of a year or more to the award – which might suggest an effective delay of up to two years before the frequencies are actually used – does not represent an efficient use of spectrum;
 - Our stakeholder engagement suggests there is demand for the spectrum, even though the current uncertainty may make it more difficult for some of the potential bidders to value the spectrum;
 - There is no guarantee that the market environment will be certain after the conclusion of any EC (or CMA) inquiry. There may never be a ‘perfect time’ to award the spectrum.
- 3.8 We believe our duties may be best achieved by bringing as much new spectrum into use as soon as possible. However, we also need to be aware of the potential impact that market changes may have on both spectrum efficiency and on competition.
- 3.9 In an uncertain market environment, we believe our objectives are best achieved by having as many regulatory tools as possible at our disposal in order to give ourselves maximum flexibility to respond to likely and potential future changes.

Our proposal

- 3.10 Our proposal is to give ourselves the additional *option* of withholding some of the 2.3 and/or 3.4 GHz spectrum from the auction - and award it instead at a later date.
- 3.11 There are a number of uncertainties as a result of the proposed BT/EE and H3G/O2 transactions – not least in terms of resulting spectrum holdings. If we decided subsequently to adopt the option to hold back some of the spectrum, the retained frequencies could be used as one tool (amongst others) to assist in addressing any competition concerns that may arise, or to promote competition as appropriate. Spectrum held back from the award could, for example, help us to address concerns about overly concentrated holdings, if this proved necessary at a later date.
- 3.12 The option of retaining some spectrum therefore represents an alternative competition measure to the earlier proposal for a safeguard spectrum cap – but one which can be adapted as conditions dictate. It may be much less appropriate for us to use a spectrum cap mechanism to address competition concerns in a scenario where the market (and consequently spectrum holdings) may change at short notice - and possibly at the same time as the auction. We therefore propose that there should be no spectrum cap in circumstances where we decide to proceed with an initial award of a reduced amount of spectrum without delay.
- 3.13 We also have two other options: to proceed with the award as currently planned (i.e. by awarding all the available 2.3 and 3.4 GHz frequencies); or to delay the whole auction to a later date. At this stage we do not know which option will be the most appropriate. However, it remains our intention to award (at least) the bulk of the 2.3 and 3.4 GHz frequencies as planned.
- 3.14 In considering the volume of spectrum which we may hold back, we need to balance the advantages of bringing currently unused spectrum to the market as soon as possible against the greater flexibility that withholding larger amounts of spectrum may give us. Our initial thinking is that we might wish to consider holding back around 60 MHz of the 190 MHz of newly available spectrum, but we will consider this further in the light of stakeholder comments.

- 3.15 We realise that withholding a relatively small volume of high frequency capacity spectrum in this way is not likely to be sufficient on its own to address all potential competition concerns. However, we believe it may be a useful element among the range of regulatory tools which might be available to us.

Auction design

- 3.16 We have considered whether the option of withholding some spectrum for award at a later date might have an impact on our choice of auction format.
- 3.17 In the next section of this document (section 4) we set out our reasons why proceeding with proposals for a Single Multi-round Ascending auction (SMRA) – as we proposed in the November 2014 consultation – also represents a good fit for an auction with less spectrum, and can deliver an efficient outcome.
- 3.18 Our decisions on the detailed implementation of the SMRA – i.e. the choices we make about how the format works in practice – are unaffected by the prospect of a possible partial award.

Consultation process

- 3.19 In light of the narrow focus of this additional consultation – i.e. on the option of withholding some of the 2.3 and 3.4 GHz spectrum - we will allow stakeholders one month to submit responses. Subject to our consideration of those responses, this timescale gives us the best chance of proceeding with the award with minimal delay. We still anticipate being able to award the spectrum in the 2015/16 financial year.
- 3.20 The closing date will therefore be 26 June 2015.

Consultation questions

Question 1: What are your views on our proposal to introduce the option of holding back some of the spectrum from the auction?

Question 2: Do you have any views on an appropriate amount of spectrum to hold back to allow sufficient flexibility to address potential competition concerns? Please explain your reasoning.

Section 4

Award process and auction design

- 4.1 In this section, we set out our decisions on how the 2.3 and 3.4 GHz spectrum bands will be awarded.
- 4.2 For simplicity, when discussing the number of available lots, the text below is written on the basis that all of the available spectrum will be included in the award. The particular assumptions on which we based our recommendation for an SMRA format, and the severity of the residual risks of this format, would not be significantly affected if we decided to hold back some of the frequencies. The auction design is sufficiently robust to cope with a smaller amount of spectrum being awarded. The decisions set out below will therefore stand.
- 4.3 In setting out our decisions, we first summarise the responses we received to proposals set out in our November 2014 consultation. A more detailed account of the points submitted – together with our more detailed analysis of those points - is presented in annex 4 of this document.
- 4.4 We will proceed to draft regulations on the basis of the policy we set out in this section. However, we recognise that some aspects may change in the process of drafting the regulations. We will consult on the draft regulations and we will note any significant alterations from the policy stated here.
- 4.5 In November 2014, we included an annex to our consultation that set out the illustrative auction procedures. We have updated these procedures in light of the changes we have made to the auction design, and include them as annex 5 to this statement. The revised illustrative auction procedures include examples to help clarify the changes set out below.

Overall award process

- 4.6 As noted in the previous section, Ofcom has a duty to secure the optimal use of radio spectrum. This will usually be the highest value use in financial terms. As described in our Spectrum Management Statement¹¹, we therefore have a preference for allowing market based mechanisms - such as an auction - to determine the outcome of an award.
- 4.7 Our November 2014 consultation set out proposals for a single auction of both the 2.3 and 3.4 GHz bands. We said that whilst lots in the 2.3 and 3.4 GHz bands are not likely to be seen by bidders as perfect substitutes, they were to some extent substitutable at some prices. Holding a combined auction therefore made sense from a bidder's point of view. It would be also administratively convenient and cost-effective to have an auction of both bands at the same time.
- 4.8 We said we did not expect that holding a combined auction would delay the award of either band. We therefore planned to award both bands as soon as was practical. We said we expected to make the award in the second half of the financial year 2015-16.

¹¹ <http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf>

Spectrum packaging and stages of the auction

4.9 In our November 2014 consultation we proposed that frequencies in the 2.3 GHz and 3.4 GHz spectrum bands should be auctioned in lot sizes of 5 MHz.

4.10 We said the different characteristics of the 2.3 and the 3.4 GHz band warranted separate categories in the auction. We therefore proposed there should be one category of 2.3 GHz lots and one category of 3.4 GHz lots. While there may also be some value differences within the bands, we said these could be addressed through the assignment stage of the auction.

4.11 We proposed an overall auction process as follows:

- Interested persons would be required to **apply** for the grant of a licence;
- Applicants would need to **qualify** to participate in the award process. An applicant may be disqualified where Ofcom determines that it is not fit to hold a licence. Applicants may also be disqualified in connection with bidder groups;
- The first stage of the auction is the **principal stage**, consisting of a number of rounds. The principal stage results in the determination of the winning principal stage bids and the **base price** for each winning principal stage bid. At this stage, lots within each category are considered to be generic and so bidders do not bid for specific frequencies;
- The second stage of the auction is the **assignment stage**, whereby actual frequencies are assigned to the winning bidders from the principal stage. The assignment stage allows bidders to express a preference for a particular part of the band. For the 2.3 GHz band we will only consider assignments in contiguous blocks. We will also consider only assignments of contiguous blocks in the 3.4 GHz band if UK Broadband participates in the auction (see section 4). If UK Broadband does *not* participate in the auction, in most circumstances bidders will be able to express a preference for a contiguous assignment. The assignment stage results in the determination of the winning assignment stage bids and the **additional price** for each winning assignment stage bid;
- The final stage is the **grant stage**, whereby Ofcom grants the licence to the winning bidder(s). The initial licence fee payable by a winning bidder is equal to the total of the base price and the additional price for each winning assignment stage bid.

4.12 We asked two questions on these points in the 2014 consultation:

*Do you agree with our proposals for categories and lot sizes in the auction?
If you disagree please provide evidence for your position.*

Do you have any other comments or views relating to the overview of the spectrum?

Consultation responses

4.13 Only one respondent suggested a different approach to our overall award process. The Institution of Engineering and Technology (IET) urged us to treat the 2.3 and 3.4 GHz awards differently because the two bands were markedly different in terms of potential future use.

- 4.14 No other respondent challenged our proposal for a combined award of the 2.3 and 3.4 GHz bands. Nor was there any other challenge to our proposal that there should be two categories - one for each band – or that lots within the two bands should be generic in the principal stage. All of those respondents who commented on the overall award process, apart from the IET, therefore supported our proposals.
- 4.15 Our proposals for 5 MHz lots in both bands were supported by UK Broadband, EE and a confidential respondent. The confidential respondent noted that all bidders were likely to require spectrum in quantities greater than 5 MHz, but outcomes where bidders target 15 or 25 MHz were plausible. This would be precluded if a larger lot size were adopted.
- 4.16 However, other respondents suggested larger lot sizes were more appropriate. BT and Angie supported 10 MHz as this would lead to a more efficient outcome. Huawei went further, and suggested that lots of 40 MHz were much more useful for IMT deployments. There were no deployments anywhere in the world based on 5 MHz bandwidths, and 10 MHz bands were only deployed where there had been migration from other technologies.
- 4.17 H3G (Three) agreed with our proposals for 5 MHz lot sizes for the 2.3 GHz band, but said that 10 MHz lots should be considered for the 3.4 GHz band because there was much more spectrum available in that band. It was likely that an operator would only be interested in acquiring larger lots (e.g. multiples of 10 MHz) because of the disproportionate cost of deploying in smaller blocks.

Our assessment and decisions

- 4.18 Given the near unanimous support, we have decided to auction the award bands together, with one category of lots for the 2.3 GHz band and another category of lots for the 3.4 GHz band. The lots will be generic in the principal stage of the auction and there will be an assignment stage to determine the exact frequencies to be licensed to each successful bidder.
- 4.19 We note the concern that LTE requires large quantities of contiguous spectrum. For that reason we had proposed to protect bidders against the risk of acquiring unwanted smaller amounts of spectrum by allowing them to specify a minimum requirement of up to 20 MHz (i.e. four 5 MHz lots) in the SMRA auction format (the CCA does not subject bidders to this risk as each bid is for a package of lots, which is either accepted or rejected in its entirety).
- 4.20 We believe this is still the most appropriate approach for the 3.4 GHz spectrum because potential use cases are varied, and we want to provide the maximum flexibility.
- 4.21 However, after consideration of responses, we have decided to award the 2.3 GHz spectrum in 10 MHz lots.
- 4.22 Our decision to award 10 MHz lots is linked to a decision to impose mandated synchronisation in the 2.3 GHz band (described in section 8 of this document). Synchronisation means there is no requirement for operators to deploy a 5 MHz guard band to avoid interference between neighbouring spectrum users. 10 MHz lots therefore represent an efficient outcome in the 2.3 GHz band whilst ensuring no operator is left with just 5 MHz of spectrum. As we explain below (under auction design – principal stage), in light of the larger lot sizes in the 2.3 GHz we have also removed the possibility of specifying a minimum requirement in this band.

- 4.23 We believe the most likely use for the 2.3 GHz spectrum will be for 20 MHz TD-LTE carriers - although other arrangements involving 10 MHz holdings may be possible, and we would not wish to rule them out. The award of 10 MHz lots addresses both possibilities.

Auction design – principal stage

- 4.24 The November 2014 consultation said our choice of auction design should be consistent with our statutory objectives to further the interests of citizens in relation to communications matters, and to further the interests of consumers, where appropriate by promoting competition. It should also be consistent with our duty to secure the optimum use of the spectrum.
- 4.25 We said our statutory duties were more likely to be achieved through the following additional objectives:
- The design should be simple, where possible, without unduly compromising the efficient outcome of the auction;
 - The outcome of the auction should be perceived by all participants and stakeholders as fair and legitimate, and bidders should not feel that they would have bid differently when they see the final result.
- 4.26 We set out two options for the principal stage of the 2.3 and 3.4 GHz auction – a Simultaneous Multi-round Ascending auction (SMRA) and a Combinatorial Clock Auction (CCA).¹² We said both formats as designed were robust and would meet our statutory duties.
- 4.27 In the **SMRA** bids are placed for individual lots, and the auction proceeds in successive rounds with increasing prices until there are no new bids. In each round, the highest bid placed on each lot is called a standing high bid. When the auction ends, standing high bids become winning bids and the bidders pay the amounts they bid.
- 4.28 The **CCA** is a two-phased bidding process in which bids are submitted for packages of lots, not for individual lots. Bidders will either be awarded a combination (or package) of lots for which they bid in its entirety or nothing at all. In the CCA, final prices are usually based on opportunity costs. An opportunity cost price rule requires bidders to pay an amount for their winning package that is just sufficient to ensure that no other bidder or coalition of bidders was prepared to pay more for that package.
- 4.29 We noted that we had used a CCA auction format on several previous occasions – including the 2013 combined award of spectrum in the 800 MHz and 2.6 GHz bands - and that this approach can be the best under many circumstances. However, we said the SMRA format had important advantages given the specific circumstances of the 2.3 and 3.4 GHz award, not least its overall simplicity.
- 4.30 We noted that the 2013 auction had included spectrum best suited for the provision of broad coverage (800 MHz) alongside spectrum suited for delivering additional capacity (2.6 GHz). Amongst other reasons, the complementary nature of the two bands meant a combinatorial auction design was more appropriate. In contrast, the

¹² See section 6 of the November 2014 consultation (<http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz-auction-design/>)

2.3 and 3.4 GHz bands are not likely to be seen by bidders as complementary (i.e. they are both suited to providing network capacity rather than coverage). This was one reason why there was less need for a combinatorial approach.

- 4.31 Our November 2014 consultation therefore proposed an SMRA format for the 2.3 and 3.4 GHz award.

Auction rules

- 4.32 In the November 2014 consultation we proposed the following rules for conducting an SMRA auction:

- **Break ties:** Bidders placing bids in a given round would be ranked randomly and allocated lots until there were no lots available, with the effect that - at most - only one bidder could be standing high bidder on fewer lots than it bid for.
- **Information policy:** We proposed that the number and identity of qualified bidders should be disclosed before the auction begins, but information during the rounds would be limited to notification of prevailing round prices.
- **Withdrawals:** Bidders might withdraw standing high bids in any round (e.g. to transfer eligibility to another category) but would be liable to pay the total value of any standing high bids that are withdrawn, unless all lots in that category were assigned a standing high bid in that or any subsequent round.
- **Minimum requirement:** Bidders might specify a minimum requirement of up to a maximum of 20 MHz of spectrum in each category (i.e. 2.3 GHz and/or 3.4 GHz). A bidder who ended the auction as the standing high bidder on fewer lots than it had specified in its minimum requirement for a given category would not be assigned any lots (or have to make any payments) in relation to these bids.
- **Activity rule and eligibility:** Bidders would be eligible to bid on lots in any given round based on their activity level in the previous round. Bidders would be allowed up to three 'waivers' where they may abstain from bidding - or bid below their eligibility - without affecting their eligibility for the next round.

- 4.33 We set out alternative proposals on rules for a CCA auction in the event that consultation responses led us to change our view about adopting an SMRA format. These are explained in paragraphs 6.52 – 6.85 of the November 2014 consultation.

- 4.34 We noted some residual risks inherent in both auction formats, but said we did not believe any of the residual risks would present a serious threat to the award. We concluded that there was a trade-off between the possible inefficiencies of complexity and uncertainty in the CCA, against the possible inefficiencies or difficulties in the SMRA. Our assessment was that we had the right instruments in place to deal with the residual risks in the SMRA in a way that rendered the complexity and the uncertainty of the CCA unnecessary.

- 4.35 We posed the following questions in the November 2014 consultation:

Do you agree with our recommendation for an SMRA? If not, please explain why.

Do you agree with our proposals for the SMRA (including withdrawals, minimum requirements and waivers)? Do you have any other comments or views on this proposal?

Do you agree with our proposals for the CCA? Do you have any other comments or views on this proposal?

Consultation responses

- 4.36 A number of very detailed responses to our questions about the proposed auction format were submitted in confidence. In reaching our decisions, we have taken account of the points raised in those confidential responses alongside points submitted in non-confidential responses.
- 4.37 The paragraphs below represent a summary of the main general points and our overall assessment. A fuller assessment is set out in annex 4

Choice of format

- 4.38 There were mixed views on the choice of format. Some respondents favoured our recommendation for an SMRA. For example, BT said it was supportive of the simplicity and transparency of the SMRA process compared to a CCA format. UK Broadband said the proposed lot structure of the 2.3 GHz and 3.4 GHz auction was less complicated than Ofcom's 2013 4G auction. This made an SMRA a more appropriate form of auction. A confidential respondent said it strongly supported the proposed SMRA and that Ofcom had both under-estimated the risks associated with the CCA, and over-stated some of the risks associated with the SMRA.
- 4.39 However, some other respondents, like H3G and EE, were in favour of the alternative CCA format. Both said the instruments proposed for the SMRA – e.g. the withdrawal policy and the information policy – would not be effective in mitigating the residual risks we had identified, or might have unintended consequences.
- 4.40 H3G urged us to consider instead an alternative form of clock auction not based on combinations of lots. However, it said that if a preference was given to an SMRA anyway, it would be better to implement 'plain vanilla' SMRA rules, whereby every lot is treated as unique.

Ofcom assessment

- 4.41 The responses we received did not challenge our list of the relevant residual risks for this award. Instead, the discussion was centred on the particular *importance* of the residual risks identified by Ofcom - and the actual ability of each format to address them.
- 4.42 The respondents who favoured our recommended approach generally agreed the SMRA would be less complicated, more transparent and was likely to generate fewer difficulties for bidders in dealing with their internal governance. The respondents favouring a CCA believed it better addressed the risks we had identified. Overall, we do not think sufficient evidence has been provided to cause us to reject the assumptions on which we based our recommendation for the SMRA. In particular, we have not been provided compelling evidence that leads us to reject our assumptions about the nature of demand in the auction, such as the lack of significant value complementarities across bands or within each band, beyond 20 MHz. Nor have we

been offered compelling evidence that the severity of the SMRA's residual risks would outweigh those of the CCA.

- 4.43 Nevertheless, we commissioned independent analysis from Auctionomics, a US consultancy specialising in spectrum auctions, to review some of the claims made in a report by PowerAuctions which was submitted as an annex to H3G's consultation response. The Auctionomics analysis – published alongside this statement – broadly supports our conclusions, subject to us reviewing our proposed information policy (see below).
- 4.44 Therefore, we have decided to proceed with an SMRA auction and reject the CCA and other alternative auction formats (including H3G's alternative form of clock auction). The chief advantage of the clock auction, in our view, is that it concludes more quickly than the SMRA. However, speed is not a key concern in our particular award.
- 4.45 We have also considered H3G's alternative 'plain vanilla' SMRA. Our conclusion is that the SMRA proposed in the November 2014 consultation includes features which make it a better approach to our particular auction, particularly:
- Bidders do not bid for 'unique' lots¹³, but for a number of lots in each band. This simplifies the bidding in the auction;
 - The ranking rule we adopt ensures that at most one bidder is a standing high bidder on a partial bid in each lot category. This might not be the case if bidders could place bids for 'unique' lots in each lot category.
- 4.46 The decision to proceed with an SMRA is unaffected by the option of holding back some of the spectrum (see section 3). This SMRA auction design is sufficiently robust to cope with a smaller amount of spectrum being released. Further, the assumptions on which we based our recommendation for an SMRA, particularly the nature of demand in the auction, are not fundamentally changed by reducing the amount of spectrum available.
- 4.47 We also think the severity of the residual risks we identified for the SMRA is not affected significantly by a change in the amount of spectrum. The residual risks we identified were that there might be unsold spectrum, even though there is demand for it at reserve price; artificially low prices; and difficulty of bidding for the preferred spectrum.
- 4.48 We will therefore proceed with the SMRA. However, having taken note of some of the comments received by respondents, and the views of Auctionomics, we have revised several of the details we proposed in the November 2014 consultation. We believe that with these revisions in place, the residual risks identified for the SMRA are not likely to have a significant impact on the efficiency of the award. The arguments presented by respondents are set out more fully in annex 4. Our conclusions are as follows:

¹³ We understand that in H3G's proposal for the plain-vanilla SMRA, in the principal stage lots would be generic – in the sense that these lots do not correspond to specific frequencies – but there are individual lots which potentially have different prices.

Information Policy

- 4.49 A number of respondents expressed concerns about the proposed information policy and the consequences this might have for the auction, including respondents who were otherwise supportive of the SMRA format.
- 4.50 There are conflicting risks in the auction and the information policy plays an important role in addressing these. It needs to strike the right balance between a) allowing bidders sufficient knowledge to make appropriate decisions when bidding and b) not allowing so much information that it might encourage strategic bidding or 'gaming' to the detriment of other bidders and to efficiency. The nature of the risks is interrelated: the more difficult it is for bidders to engage in strategic bidding, the more difficult it may also be for them to devise their own bidding strategies.
- 4.51 We asked Auctionomics for advice on the information policy we had proposed in the consultation. Whilst acknowledging the potential to use information about the level of aggregate demand to bid strategically, Auctionomics believes bidders are likely to require more demand information than we proposed, in order to address effectively the risks they face, especially the aggregation risk. Having considered that advice, we have decided to make some additional information available as described below. We believe the potential for bidders to use this additional information strategically is limited. On balance, we believe the benefits in terms of assisting bidders to address their risks outweigh the potential downside.
- 4.52 We conclude that we should maintain a relatively limited information policy as we proposed in the November 2014 consultation. However, we have decided that we should disclose more information about the level of aggregate demand to bidders. In particular, we will let bidders know that excess demand in the preceding round was less than a multiple of 20 MHz (e.g. less than 20 MHz, less than 40 MHz, less than 60 MHz, etc.). This will allow bidders some information on excess demand without giving precise information which could be used more easily to support decisions about strategic demand reductions, to end the auction, for example.

Withdrawal rule

- 4.53 Some respondents expressed concern that the withdrawal rules could leave bidders facing difficulties when substituting across different categories.
- 4.54 A common theme among those respondents was that bidders who are provisional winning bidders may wish to withdraw or cancel their bids in order to move their demand to another band. However, if demand does not equal or exceed supply in that band in future rounds, bidders will pay the price for the spectrum in the other band, but not actually obtain it. This could discourage bidders from making legitimate use of withdrawals.
- 4.55 Having considered the consultation responses, including some particular 'scenarios' provided by a confidential respondent, we have decided to proceed with our proposed withdrawal rules, but with three modifications.
- We will limit the number of rounds where bidders may use withdrawals to five. This, albeit an unlikely scenario, is to prevent a bidder using withdrawals to extend the auction indefinitely.
 - We have decided that a bidder will not be allowed to withdraw from one band more than once if the price in that band has not increased since the round in

which the previous withdrawal was made. We can see no reason why a bidder would need to do this which is consistent with truthful bidding.

- When a bidder withdraws its standing high bids from one band and later bids again in the same band, then the bidder will not be liable for the withdrawn bids on lots for which it has bid again. It would be unfair to force a bidder to pay twice for the spectrum it won.

Minimum requirement

- 4.56 There was divided opinion on our proposals for allowing bidders to express a minimum spectrum requirement in the auction. Some, including BT, agreed both with the inclusion of the minimum requirement option and that the maximum amount of the minimum spectrum requirement should be 20 MHz. It said a figure less than this may not be sufficient to be viable, whilst a greater figure was not necessary and could be used strategically. UK Broadband also expressed support for Ofcom's reasoning. Others supported the principle of a minimum requirement but expressed a preference for a maximum level different from our proposed 20 MHz.
- 4.57 A confidential respondent said it was supportive of the intent in the proposal but said it disagreed with the approach because it could allow a bidder to drive prices higher on spectrum they had no intention of winning.
- 4.58 In considering these responses, we note the additional risk that price driving could result in an inefficient outcome for the award e.g. a bidder engaged in price driving, who is not the bidder with the highest value for the spectrum, could actually end up winning it if it miscalculates the point at which it needs to stop bidding.
- 4.59 The risk of an inefficient outcome is higher in the 2.3 GHz band because a minimum requirement of 20 MHz takes up half the available spectrum in the band. We have therefore decided to remove the ability of bidders to specify a minimum requirement in the 2.3 GHz band.
- 4.60 We note that this will expose bidders to the risk of winning less than 20 MHz, even though they may not wish to do so. Our decision to award the 2.3 GHz spectrum in 10 MHz lots mitigates this to some degree. It will protect bidders against the possibility of winning 5 MHz or 15 MHz when they do not want to, but will still expose bidders to the risk of winning 10 MHz when they want at least 20 MHz. We believe this risk can be managed by the bidders in the course of the auction, in particular given the changes we have made to the information policy.
- 4.61 We have decided against changing our proposals for allowing a minimum requirement of up to 20 MHz in the 3.4 GHz band. This is because there is significantly more spectrum in the 3.4 GHz band than in the 2.3 GHz band and, as a consequence, we believe the ability to use the minimum requirement to drive up prices in the 3.4 GHz band is limited.

Activity rule and eligibility points

- 4.62 We proposed a 1:1 eligibility ratio for bidders seeking to switch bids between the 2.3 and 3.4 GHz bands i.e. a bid for a lot in one band is equal to a bid for a lot in another. The rationale was that at certain price ranges bidders might be willing to substitute between the two bands on a MHz for MHz basis (e.g. substitute from 20 MHz in the 2.3 GHz band at a higher price to 20 MHz in the 3.4 GHz band at a lower price).

- 4.63 Some respondents thought this eligibility ratio might make switching difficult because spectrum is not worth the same across the two bands e.g. H3G said our proposal would establish an environment where bidders have a strong incentive to engage in 'parking'. BT said some bidders may use the equality of eligibility points to hide their demand for the more expensive spectrum (i.e. 2.3 GHz) by bidding for an equal amount of the less expensive spectrum in the early stages of the auction.
- 4.64 Other respondents suggested we used a relaxed activity rule in the SMRA so that when the price in one band decreases relative to the other band, bidders might be allowed to move their demand at a rate different to the eligibility ratio set by the auctioneer.
- 4.65 We have considered these points alongside our own further engagement with stakeholders, which suggests that different bidders may have different business cases for the different bands i.e. the 2.3 GHz band is very likely to be used for direct mobile access – but all or part of the 3.4 GHz band could be used for small-cells and for backhaul. The latter use may require a larger amount of contiguous spectrum, compared to the former. Therefore, bidders may not be willing to switch on a per MHz basis.
- 4.66 Our conclusion is that we should change the eligibility ratio from 1:1 to 2:1, as measured per MHz. This means each 10 MHz lot in the 2.3 GHz band will be assigned 4 eligibility points, and each 5 MHz lot in the 3.4 GHz band will be assigned 1 eligibility point.
- 4.67 We considered whether to introduce a relaxed activity rule. We have concluded that this would significantly increase the complexity of the auction for uncertain benefit and we have therefore decided against such a move.

Waivers

- 4.68 There was little comment overall on our proposals for waivers, and we have received no evidence that would lead us into changing the option for bidders to use three waivers each in the auction.
- 4.69 A confidential respondent said it supported our proposals and thought that an allowance of three waivers was "about the right number". EE noted that with only three waivers, bidders could effectively be restricted to no more than one swap between bands throughout the entire auction.
- 4.70 Only H3G said it would be best to avoid allowing bidding waivers, which introduce bidding complexity and offer no real benefit.
- 4.71 We understand waivers are useful to bidders in a number of different circumstances, which we list in annex 4, and we therefore disagree with H3G that they do not offer a real benefit. We also disagree with EE that three waivers restrict bidders to one swap between bands throughout the entire auction. We note the ability of bidders to move across bands is facilitated in the auction by a number of features other than waivers, including the ranking rule (whereby at most one bidder is a standing high bidder on less than its bid in the previous round); the ability of bidders to withdraw standing high bids; and the revised eligibility ratio.
- 4.72 While we are maintaining a limited information policy, we are now releasing more information than we proposed in the November consultation. We understand this poses a concern with regards to using waivers strategically. Therefore, we have

decided to restrict the use of waivers so that bidders cannot place new bids and/or make withdrawals, and waive at the same time.

Increments and pricing of bids

- 4.73 Two respondents commented on our proposals on bid pricing. BT questioned a rule whereby bidders wishing to bid for more lots in a category where they already hold standing high bids need to increase prices for all lots. It said modifying or abolishing this rule would reduce the linearity of prices and therefore strategic demand reduction.
- 4.74 A confidential respondent said a uniform price should apply to lots won by bidders in the same band. This should be based on the lowest winning bid amount.
- 4.75 We are unconvinced that allowing bidders to place bids at the round price while maintaining standing high bids at a previous round price would reduce the incentives for strategic demand reduction. On the contrary, we believe it might actually facilitate it, because bidders might be able to test demand and assess the benefits from reducing it strategically. In addition, we are of the view that price linearity in the SMRA is not changed by the measure proposed by BT.
- 4.76 We have also rejected the proposal put forward by the confidential respondent, because we believe this would change the nature of the SMRA. The SMRA is a pay-as-bid format, where bidders commit to pay their winning bids.

Deposits

- 4.77 In our November 2014 consultation we indicated that we would have power to require increases in deposits to reflect the level of bidding. Bidders will have to deposit sufficient funds to cover their allocation of eligibility points with Ofcom before the auction begins. Thereafter we may require deposit increases up to 100% of bids. Any bidder who drops out of the auction will have any sums owing to them returned as soon as possible after leaving the auction.

Ranking rule

- 4.78 Two respondents commented on our proposals for ranking bids in order to determine those which become standing high bids. H3G said the procedures created strategic opportunities for bidders. It said a bidder who expects to be tied with another bidder at a higher price level has strong incentives to time its bids strategically. A confidential respondent said priority should be given to bids submitted at higher prices and in earlier rounds.
- 4.79 The ranking rule we proposed allocates standing high bids randomly amongst the bids received in a given round. It was, however, not random in the way standing high bidders from previous rounds would have been displaced. We have therefore decided that in any round, standing high bids from previous rounds will be treated the same as new bids if they are at the same price. The only exception is that existing standing high bids on less than their full demand will be displaced first.
- 4.80 As with our consultation proposal, this rule ensures there is no more than one standing high bidder on less than their full demand. This reduces the scope for aggregation and substitution risks. An additional desirable feature of the new rule is that all bids at a given price have an equal chance no matter in which round they

were submitted. This should mitigate possible incentives to time bids with the aim of influencing the chance they may or may not be outbid in the following rounds.

4.81 An example of how this rule applies is set out in annex 5.

Proposals for the Combinatorial Clock Auction

4.82 In our November 2014 consultation we set out proposals for an alternative Combinatorial Clock Auction (CCA) if we were persuaded that an SMRA was not the most appropriate auction format.

4.83 Having considered the responses we received, we continue to believe that an SMRA is the best way to proceed. Accordingly, this document does not address the responses of stakeholders who expressed views on the detailed proposals for a CCA.

Auction design - assignment stage

4.84 Under either an SMRA or a CCA auction, the principal auction stage is followed by an assignment stage to determine the exact location of spectrum to be awarded to each successful bidder. We proposed a sealed-bid, single-round auction format with a second-price rule for the assignment stage.

4.85 We said for the 2.3 GHz band, we proposed to consider only assignment plans in which each bidder is assigned a contiguous frequency block that corresponds to the bandwidth they won in the principal stage. Any unsold spectrum would form a contiguous block. We said this rule is likely to lead to the most efficient use of the spectrum.

4.86 We noted that for the 3.4 GHz band, the outcome would depend on whether or not UK Broadband chose to participate in the auction. If so, we said we could consolidate the company's existing 3.4 GHz holding to form a single contiguous block. In those circumstances, we proposed a similar rule as for the 2.3 GHz band (see section 5 of this document for more discussion of UK Broadband).

4.87 If UK Broadband does not participate in the auction, we proposed that the 3.4 GHz band spectrum available for assignments to winners of the principal stage should be split into two sub-bands: a sub-band with 70 MHz (3410 MHz - 3480 MHz) and another sub-band with 80 MHz (3500 MHz – 3580 MHz). We said we would prioritise assignment plans in which each winner is assigned a single contiguous frequency block.

4.88 If a bidding process is needed for the assignment stage, we proposed a single round in which the relevant bidders may submit bids for their preferred frequency assignments. In such circumstances, we proposed that assignment stage prices, which are additional to base prices, should be calculated using a second-price rule. A final price for each bidder is calculated, combining the base price (from the principal stage of the auction) and any additional prices (arising from the assignment stage).

4.89 The November 2014 consultation asked the following questions:

Do you agree with our proposals for the assignment stage? Do you have any additional views or comments?

Do you have any other comments on auction design?

Consultation responses

- 4.90 There was almost unanimous support for our proposals in relation to the assignment stage. However, two respondents submitted confidential comments in relation to their own circumstances which we have considered.
- 4.91 Of the other responses, Huawei welcomed Ofcom's approach of only considering assignment plans in which each bidder is assigned a contiguous frequency block that corresponds to the bandwidth they won in the principal stage, and ensuring that any unsold spectrum will form a contiguous block. However, it continued to believe that a minimum bandwidth of 40 MHz was essential for exploiting the full long-term potential of the award bands.

Our assessment

- 4.92 We have decided to proceed as proposed in our consultation document.

Reserve Prices

- 4.93 The November 2014 consultation proposed reserve prices for the auction of £1 million per 5 MHz lot for the 3.4 GHz band and in the range of £2.5 million to £5 million per 5 MHz lot for the 2.3 GHz band. We said reserve prices set at this level would provide room for relevant price discovery, while still addressing concerns about gaming in the auction – although some specific additional factors were relevant for each band.
- 4.94 The reserve prices are based on a benchmark of the prices paid for 2.6 GHz spectrum in the 2013 UK spectrum auction. We noted that the bottom of the proposed range for the 2.3 GHz spectrum was near the lower end of our estimated benchmarks for 2.6 GHz unpaired spectrum (and only around 2/5 of the higher figure based on the analysis of market-clearing prices). The top of the range is still within the range of figures for 2.6 GHz unpaired. But, in our consultation, we also noted the potential for the 2.6 GHz paired spectrum as a relevant benchmark. This is because equipment availability in the 2.3 GHz band is more comparable to the 2.6 GHz paired band at the time of the auction. We note that the top end of the prices is still only a relatively low proportion of the 2.6 GHz paired benchmark (generally less than 20% of the benchmark figures). We noted that the prices we proposed roughly equated to the costs of the Ministry of Defence moving its usage to other spectrum bands.
- 4.95 We said that the 2.3 GHz band was likely to be valued more highly than the 3.4 GHz band for the following reasons:
- There is a wider availability of equipment in the 2.3 GHz band compared to the 3.4 GHz band;
 - The 2.3 GHz band is likely to be used to increase existing capacity whilst the 3.4 GHz band in the short term may be used for backhaul (at least by some operators); and
 - The 2.3 GHz has slightly more favourable propagation characteristics.
- 4.96 We said we would not consult on a single reserve price for the 2.3 GHz spectrum. We put the bottom of the range at £2.5m per 5 MHz lot and the top of the range at £5m per 5 MHz lot.

4.97 Given the relatively lower expected value of the 3.4 GHz spectrum and the risk of inadvertently setting a reserve price too high for this spectrum, we proposed a lower reserve price of £1 million per 5 MHz. With eight 5 MHz lots in the 2.3 GHz band and 30 lots in the 3.4 GHz band, the sum of reserve prices therefore ranged from £50 million to £70 million.

4.98 We asked the following consultation question:

Do you agree with our proposals for the reserve prices? If so, where in the range we propose should the reserve price for the 2.3 GHz band be? Do you have any other views or comments?

Consultation responses

4.99 In their consultation responses, a number of stakeholders indicated a preference for reserve prices to be set at the lower end of the proposed ranges – with some proposing even lower reserve prices. Only one confidential response, which was not from a mobile network operator, offered strong opposition to the reserve prices we had suggested to the extent that a potential bidder would refrain from bidding at those reserve prices.

4.100 Another confidential respondent disagreed with some of the principles used in setting the level of reserve prices. It said Ofcom was wrong to use prices for the 2.6 GHz auction as a reference point for setting reserve prices for the 2.3 GHz auction because:

- It risks a ratchet effect, where each subsequent auction is forced to achieve more than the previous one until spectrum is unsold; and
- It misses the point that (absent a growth in demand), releasing further supply of any commodity inherently decreases the demand/supply equilibrium point.

4.101 However, the respondent said, on the practicality of the values determined, it would not be discouraged from participating in the auction on this basis.

4.102 EE said it had no views on reserve prices due to value uncertainty but noted that if demand for one band significantly exceeds that of another band, Ofcom should respond by reflecting this in the size of the increments.

4.103 A confidential respondent saw no need to set reserve prices in line with the cost of MOD clearance from the band because the primary driver of the spectrum to be released was the scope for generating benefits to UK citizens from more efficient use of a hitherto underutilised spectrum resource. It noted there was no transparency regarding the estimate of the MOD's costs.

4.104 BT said reserve prices should be set more in line with a figure necessary to deter frivolous bids. It proposed a figure as low as £100,000 per lot for the 3.4 GHz band.

4.105 Other responses were broadly supportive of our approach.

Our assessment

4.106 We remain of the view that low reserve prices may provide incentives for bidders to engage in gaming. They could also incentivise individual bidders to bid for a lower number of lots than otherwise in the expectation that this will allow them to win less

spectrum, but at a lower price. These risks mean that we do not believe setting reserve prices purely to deter frivolous bidding would be appropriate in this case. While there was a query about the validity of using the 2.6 GHz spectrum awarded in the 2013 auction, no other benchmark was suggested and we continue to believe this is the best approach.

- 4.107 Since we published our November consultation, we have published¹⁴ on 16 February 2015, a provisional decision and further consultation on annual licence fees for 900 and 1800 MHz spectrum. This includes a more refined analysis of auction prices and opportunity costs in the 2013 auction for the unpaired (TDD-compatible) 2.6 GHz band (as a by-product of further analysis of the 800 MHz and paired - FDD-compatible - 2.6 GHz bands).
- 4.108 As set out below, this shows generally higher figures for prices and opportunity costs of unpaired 2.6 GHz spectrum than we reported in the November 2014 award consultation. This tends to strengthen the case for the reserve prices we proposed, including prices at the top end of the range for the 2.3 GHz band.
- 4.109 In the November 2014 consultation, we discussed the unpaired 2.6 GHz band when setting out benchmarks for commercial value:
- Auction price for Vodafone of £2.45 million per 5 MHz.
 - Auction price for Niche (BT) in a wide range between £1.2 million and £8.25 million per 5 MHz.
 - A discussion relating to the marginal bidder analysis with reference to H3G's losing bid for the entire band of £6.67 million per 5 MHz.
- 4.110 The results of our further, more refined analysis reported in the February 2015 document are shown in Table 1 below. This table includes both the auction prices and the opportunity costs in the auction. The difference between the two is that the latter are not affected by the reserve prices in the 2013 auction. In both cases there are alternative figures for the two winners of the unpaired 2.6 GHz spectrum, Niche and Vodafone, because the figures are based on decomposing multi-band packages amounts. There is no unique way to conduct this decomposition.
- 4.111 Table 1 shows the auction prices paid by Vodafone and Niche from the November 2014 consultation (listed above), but also the opportunity cost figures:
- For Vodafone, £2.45 million per 5 MHz is the lowest figure shown in Table 1. Other decompositions of package amounts are materially higher, including the highest figure at £6 million per 5 MHz.
 - For Niche, the top of the range in the November 2014 award consultation at £8.25 million per 5 MHz is also (nearly) the highest figure in Table 1. But the bottom of the range has been replaced by the substantially higher figure of £7 million per 5 MHz. So rather than a wide range for Niche, we now have the much narrower range of £7 million to £8 million per 5 MHz.
- 4.112 The marginal bidder analysis figure of £6.67 million per 5 MHz is not reported in the February 2015 document, but applying the approach in that document would yield the same figure.

¹⁴ <http://stakeholders.ofcom.org.uk/consultations/annual-licence-fees-further-consultation/>

Table 1: Auction prices and opportunity costs in the 4G auction for the TDD 2.6 GHz band

	Auction prices	Opportunity costs
	£m per 5 MHz	£m per 5 MHz
Vodafone (i)	£2.45m	£2.75m
Vodafone (ii)	£4.1m	£4.1m
Vodafone (iii)	£6m	£6m
Niche (1)	£7m	£7m
Niche (2)	£8.25m	£8.32m

Source: Tables A6.6 and A6.23 in the February 2015 document

Note: The table only shows the distinct values for TDD 2.6 GHz spectrum in the decompositions.

4.113 As in the November 2014 consultation, we also take into account the reference point of the FDD 2.6 GHz (paired) band, although we recognise that the 2.3 GHz band may only be a proportion of its value. As an example, a reserve price at the top end of our proposed range (£5m per 5 MHz) for the 2.3 GHz band would generally represent 20% or less of the benchmarks for the FDD 2.6 GHz band¹⁵.

4.114 We believe we should set the final reserve prices as close to the actual auction as possible. This will allow us to take account of the latest market information and any changes in market conditions. However, at this stage, we see no reason to vary the proposals set out in the November 2014 consultation.

Summary of decisions on auction process and design

4.115 In summary, the decisions included in this section of the statement are as follows:

- We will award the 2.3 and 3.4 GHz spectrum bands through a single Simultaneous Multi-round Ascending auction (SMRA) with two categories of generic lots, one for each spectrum band¹⁶.
- In the 2.3 GHz band there will be four 10 MHz lots and in the 3.4 GHz band there will be thirty 5 MHz lots¹⁷.
- We will maintain a relatively limited information policy. We will publish the names of qualifying bidders in advance of the auction. During the auction we will release to bidders the price level in each round, and that excess demand in the preceding round was less than a multiple of 20 MHz (i.e. it was less than 40 MHz, less than 60 MHz, etc.).
- In each round bidders will bid for a number of lots at the given round prices. The ranking rule to assign standing high bidders will be random in the way it

¹⁵ Our favoured estimate in the ALF February 2015 document for FDD 2.6 GHz spectrum remains equivalent to £27.5m per 5 MHz (which is the same figure as reported in paragraph 6.175 of the November 2014 consultation). A reserve price of £5m per 5 MHz would constitute 18% of this figure. We have slightly refined the figures for the auction prices and opportunity costs in the auction since the November 2014 consultation. The auction prices for FDD 2.6 GHz spectrum range between £19m and £28.5m per 5 MHz (see Table A6.6 in the February 2015 document, where the figures are expressed in £m per MHz). The opportunity costs in the auction of FDD 2.6 GHz spectrum range between £25.5m and £28.5m per 5 MHz (see Table A6.23 in the February 2015 document).

¹⁶ We note that we are consulting on holding back some spectrum, as described in section 3, in which case we would award the spectrum held back at a later date.

¹⁷ This assumes that Ofcom will not hold spectrum back, as described in section 3.

displaces standing high bidders from previous rounds, subject to there being at most one partial bidder in every round in each lot category.

- We will allow bidders the opportunity to withdraw standing high bids, but a bidder doing so risks being required to pay the full amount in the event that it is not possible to establish a standing high bid on all lots in that category later in the auction. However, when a bidder withdraws its standing high bids from one band, and later bids again in the same band, then the bidder will not be liable for the withdrawn bids on lots for which it has bid again. Bidders will be allowed to withdraw from a maximum of five rounds during the auction and will not be allowed to withdraw from one band more than once if the round price in that band has not changed since the round in which the previous withdrawal was made.
- In the 3.4 GHz band we will allow bidders to set a minimum requirement of 20 MHz. A bidder who ends the auction as the standing high bidder on fewer lots than it has specified in its minimum requirement for the 3.4 GHz band will not be assigned any lots (or have to make any payments) in relation to these bids.
- Bidders will be eligible to bid on lots based on their activity in the previous round. We will set a 2:1 per MHz eligibility ratio for bidders seeking to switch bids between the 2.3 and 3.4 GHz categories. That is to say, a bid for a 10 MHz lot in the 2.3 GHz band has the same number of eligibility points as four 5 MHz lots in the 3.4 GHz band.
- Bidders will be allowed to use up to three waivers. A bidder could exercise a waiver when abstaining from bidding or when the number of eligibility points in their standing high bids fall below their eligibility. Bidders will not be allowed to submit bids and/or withdrawals and waive simultaneously in any given round.

4.116 We will proceed to draft regulations on the basis of these decisions. However, we recognise that some aspects may change in the process of drafting the regulations. We will consult on the draft regulations and we will note any significant alterations from the policy stated here.

Section 5

UK Broadband and contiguity

- 5.1 This section of the statement sets out our decisions on how to address the issues raised by UK Broadband's spectrum holding in the 3.4 GHz band. UK Broadband holds 40 MHz of spectrum in two non-contiguous 20 MHz blocks at 3480-3500 MHz and 3580-3600 MHz.
- 5.2 In October 2013¹⁸ we consulted on a proposal to consolidate the UK Broadband holding into a single contiguous 40 MHz block at 3560-3600 MHz before the award of the 3.4 GHz band. We said there were potential spectrum inefficiencies arising from a non-contiguous spectrum holding sitting within the 3.4 GHz award band.
- 5.3 However, we decided against proceeding with the proposal to consolidate UK Broadband's spectrum holding at that stage in the light of consultation responses. That decision was set out within a further consultation (published in June 2014¹⁹) on an application by UK Broadband for its existing licence (for the split assignment) to be extended indefinitely beyond its expiry date in 2018.
- 5.4 On 9 October 2014, following consideration of consultation responses, we published a statement²⁰ setting out our decision to grant the UK Broadband application. However, the statement noted: *"Although we believe our decision to extend UK Broadband's licence provides the best overall outcome - when considered against the alternative of not extending the licence – we note there may still be potential for spectrum inefficiency costs to arise as a result of the non-contiguous nature of the frequencies"*.
- 5.5 We noted there may be opportunities to address the spectrum inefficiency costs if UK Broadband and other operators were able to reach synchronisation agreements²¹. However, we also said that consolidation of UK Broadband's spectrum into a single holding could mitigate spectrum inefficiency costs by a) reducing the number of inter-operator frequency boundaries and b) by making it easier to accommodate different demands within the spectrum to be awarded.

Our proposals

- 5.6 In our November 2014 consultation on auction design, we set out proposals providing an opportunity for UK Broadband to achieve contiguous spectrum – if it chose to participate in the auction. We said UK Broadband participation would mean that other winning bidders in the award could also be guaranteed a contiguous spectrum assignment.
- 5.7 In setting out our proposals, we said that while only 150 MHz of 3.4 GHz band spectrum would be available in the auction's principal stage, UK Broadband's current

¹⁸ <http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/summary/2.3-3.4-ghz.pdf>

¹⁹ <http://stakeholders.ofcom.org.uk/consultations/uk-broadband-licence/summary>

²⁰ http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

²¹ The November 2014 consultation included proposals requiring synchronisation between 3.4 GHz spectrum users. Please see section 8 of this document for discussion of consultation responses and our decisions on this issue.

40 MHz holding would then be added to the frequencies allocated in the assignment stage.

- 5.8 If UK Broadband wished to obtain spectrum in addition to its existing 40 MHz holding it would enter the auction at the principal stage. If it was not seeking to obtain additional spectrum, it could move straight to the assignment stage. However, UK Broadband would need to qualify for participation in the auction even if it only wanted to participate in the assignment stage.
- 5.9 We proposed that UK Broadband would effectively give up its current holding of 40 MHz if it participated – but would then be guaranteed to obtain an equivalent, but contiguous, amount of spectrum in the auction. The precise location within the 3.4 GHz band would be determined by bidding against other bidders in the assignment stage, if necessary.
- 5.10 We proposed that if UK Broadband participated in the auction and was assigned different frequencies from its current holding, it would be allowed 6 months to move to the new frequencies. If another licensee won spectrum currently held by UK Broadband, both UK Broadband and the new licensee(s) would be required to co-operate in order to protect UK Broadband's existing services during that period.
- 5.11 We asked the following consultation question:

Do you agree with our proposals for achieving contiguity, and if not please provide further explanation.

Consultation responses

- 5.12 There was unanimous agreement among consultation respondents with our proposals for achieving contiguity. One confidential submission addressed issues of direct relevance to that company and these have been considered by Ofcom.
- 5.13 In its own submission, UK Broadband noted that its 40 MHz of spectrum in the 3.4 GHz band would be added to the frequencies allocated at the assignment stage, if the company participated in the auction. The company acknowledged that it would be guaranteed contiguous spectrum at this stage – but that its precise location in the band would depend on bids made in the assignment stage. The company agreed with this proposal.

Our decision

- 5.14 In light of the unanimous agreement to our proposal – and the lack of any further evidence suggesting any alternative approach – we intend to proceed with our proposed approach to ensuring contiguity of spectrum.

Section 6

Technical coexistence issues

- 6.1 This section of the document sets out our decisions on coexistence between new services in the 2.3 and 3.4 GHz bands and existing current users of neighbouring frequencies.
- 6.2 We first consulted on these matters in February 2014²², and identified coexistence between Wi-Fi operating in the 2.4 GHz licence exempt band (2400- 2483.5 MHz) and LTE in the 2.3 GHz award band as the most significant potential issue to be addressed. The consultation also addressed coexistence issues for other licence exempt uses of the 2.4 GHz band, including Bluetooth, ZigBee, medical equipment and assistive listening devices (ALDs). We proposed that no intervention in the market was justified.
- 6.3 Additionally, the February 2014 consultation assessed coexistence issues for radar and satellite services operating close to the award bands.
- 6.4 In the light of responses to the consultation, and our own further consideration of the issues involved, we carried out a significant amount of further technical analysis of the issues for Wi-Fi and other licence exempt devices (including ALDs). This further analysis was published in December 2014²³ in the form of an update to the February 2014 consultation.
- 6.5 The December 2014 document did not include any revised proposals for addressing coexistence issues for Wi-Fi and other licence exempt uses of the spectrum, because we believed the new technical analysis provided strong additional evidence in support of the position we set out in the earlier consultation. Accordingly, we presented a detailed further reassessment of all the issues involved, including our reasons for continuing to believe that no intervention in the market was justified to protect uses of the 2.4 GHz licence exempt band. This reasoning is summarised below, but is not repeated in full.
- 6.6 The December 2014 document also set out our further consideration of coexistence issues for radar and satellite. As for Wi-Fi and other licence exempt uses, we said there was no reason for us to revise the original proposals set out in the February 2014 consultation.
- 6.7 Following on from the update document, we now set out our final conclusions on coexistence issues as follows:
- Coexistence between 2.3 GHz LTE and Wi-Fi;
 - Coexistence between 2.3 GHz LTE and medical devices;
 - Coexistence between 2.3 GHz LTE and ALDs;
 - Coexistence between 2.3 GHz LTE and other licence exempt devices;
 - Coexistence issues for satellite services;

²² <http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf>

²³ <http://stakeholders.ofcom.org.uk/consultations/pssr-2014/updated-analysis/>

- Coexistence issues for maritime and aeronautical radar.

Coexistence between 2.3 GHz LTE and Wi-Fi

- 6.8 Both our February 2014 consultation and the December 2014 update document identified a potential risk of interference to Wi-Fi in the 2.4 GHz band from new 2.3 GHz LTE services. The risk stems mainly from Wi-Fi equipment (routers, laptops, tablets etc.) picking up signals from outside the designated Wi-Fi operating band, leading to signal blocking. It is not typically caused by LTE emissions outside its own band interfering with Wi-Fi frequencies.
- 6.9 The February 2014 consultation document said the likelihood of interference occurring in practice was very low. We proposed restrictions on emissions from base stations above 2403 MHz in line with the ECC Decision(14)0224 to ensure that this remains the case. We said the risks were not significant enough to justify further regulatory intervention.
- 6.10 Some consultation respondents questioned our interpretation of the data we had gathered. Others suggested we should carry out further testing of potential interference from particular sources, especially from small cell LTE deployments (such as femto cells) and from user equipment such as mobile phones. Some suggested we should conduct 'real life' tests in the field. Finally, some respondents suggested the mitigations we proposed for the rare circumstances where interference occurred in practice were not practical.
- 6.11 After considering these responses, we carried out further testing and analysis as suggested by industry stakeholders - particularly in respect to assessing interference from small cells and from LTE mobile equipment. This was in addition to a re-examination of our own earlier work. We also reconsidered the theoretical circumstances in which interference to Wi-Fi could occur and the likelihood of this actually happening in practice. Additionally, we engaged with industry, standards bodies and international stakeholders to understand their assessment of the potential impact and how they plan to mitigate it.
- 6.12 We presented our further findings in the December 2014 update. In summary, the additional technical assessment confirmed our original assessment of the level and scale of risk. It confirmed that the impact of 2.3 GHz LTE is far more likely to result in some degradation of Wi-Fi services than in a complete loss of service. We noted that degradation will not even be noticed by consumers in many cases. In only a tiny number of instances there was a risk of Wi-Fi becoming unusable. Overall, the further analysis suggested there may be even less chance of Wi-Fi actually failing than we originally believed. We noted that there is ongoing effort within industry to improve the filtering and coexistence capabilities of future equipment.
- 6.13 In setting out our further assessment of the evidence, we noted that Wi-Fi already operates in a congested environment and that degradation of service is unlikely to be any worse than if a number of people in a particular area are all using Wi-Fi at the same time. In line with the original proposals set out in the February 2014 consultation, we said internet service providers were best placed to address issues for both domestic consumers and for public Wi-Fi.

²⁴ ECC Decision(14)02, Harmonised technical and regulatory conditions for the use of the band 2300-2400 MHz for Mobile/Fixed Communications Networks (MFCN), <http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCDEC1402.PDF>

- 6.14 The December 2014 update said the precise number of people who could be affected after the 2.3 GHz award was difficult to determine since it depended on a number of variables, including the extent of LTE roll-out; the timing of LTE roll-out; and the type of Wi-Fi equipment being used.
- 6.15 We noted that degradation was only a possibility in areas where 2.3 GHz LTE is actually deployed. We believe a UK wide roll-out is highly unlikely in the short term because we expect the spectrum to be used initially for the provision of additional capacity only in areas of particular congestion. This means it is likely to be deployed in dense urban areas where usage is high - and not necessarily areas that are predominantly residential (such as suburbs).
- 6.16 Noting the very low likelihood of noticeable interference occurring in the first place, we nevertheless reconsidered the effectiveness of available mitigations for the small number of Wi-Fi users affected. We noted that in almost all cases it will be impossible to determine if degradation of 2.4 GHz Wi-Fi services is due to the proximity of 2.3 GHz LTE base stations or user equipment, or if it is due to other factors.
- 6.17 The most important and effective mitigation is for the Wi-Fi router/device to use the alternative 5 GHz Wi-Fi band. Almost all new Wi-Fi equipment has this capability. If the equipment is able to switch automatically then consumers will not even notice this has occurred. However, some older equipment which is able to operate at 5 GHz may need to be switched manually.
- 6.18 Our December 2014 update noted that remaining issues were mainly limited to legacy equipment that can operate only at 2.4 GHz and which has insufficient filtering (noting that a small volume of newer equipment may also be 2.4 GHz only). Where a router or device is not able to use the 5 GHz band, then simply relocating the equipment within a building may well resolve any issues. Our technical analysis suggested that moving a device by around 1 metre should make a significant improvement.
- 6.19 Alternatively, we said it could be appropriate to hard-wire certain devices instead - particularly large non-mobile equipment such as smart TVs and games consoles. We noted that some instruction manuals also make this suggestion, as an alternative to Wi-Fi use, in order to ensure the best connection.
- 6.20 However, we acknowledged that this mitigation – whilst probably effective – was not always practical because it relied on some degree of technical awareness and a willingness to forego use of a preferred technology. We said that equipment may need to be replaced in some very limited circumstances. However, we considered it was not practical or proportionate to intervene in the market to address these rare circumstances.

Further representations

- 6.21 We received further representations from Arqiva and from Sky in respect to the coexistence of 2.3 GHz LTE and Wi-Fi operating in the 2.4 GHz band.

- 6.22 Arqiva's submission included a report based on a technical study the company had conducted into the power levels used by 2.3 GHz LTE and the interference (blocking) effect on Wi-Fi devices²⁵. The study included:
- Measurements of LTE user device interference into Wi-Fi devices based on a range of LTE traffic profiles and TD-LTE duty cycles;
 - An assessment of LTE user equipment power levels in a number of operational environments using a range of traffic profiles;
 - An evaluation of the separation distances necessary to limit interference, based on the measured levels and LTE terminal powers.
- 6.23 The Arqiva report said measured interference levels for LTE user devices were found to be less damaging than LTE base station signals, because of their lower duty cycle. However, output powers from LTE user devices varied significantly depending on the user application. A heavy upload of data resulted in significantly higher powers than was assumed in Ofcom's own studies.
- 6.24 As a result of this varying power, a range of separation distances from less than 1 metre to 3.7 metres was seen to cause a reduction in Wi-Fi throughput, depending on the Wi-Fi device and the type of traffic the LTE user equipment was handling. There was therefore a greater risk of degradation to Wi-Fi than identified by Ofcom.
- 6.25 Arqiva said Ofcom should consider whether changes to our proposals were appropriate e.g. through changes to the licence conditions or through other mitigations which could be put in place by Ofcom or by Government.
- 6.26 Sky noted that our technical analysis had suggested there was a "very low" risk of interference to Wi-Fi actually occurring in practice, and acknowledged that subsequent field tests had confirmed low levels of degradation. However, Sky noted that some degradation was found to have occurred in certain situations - and said the impact on consumers may not be immaterial, given the large volume of Wi-Fi users.
- 6.27 In considering the primary mitigation we proposed in the February 2014 consultation and December 2015 update (i.e. use of the alternative 5 GHz Wi-Fi band) Sky said this would be effective in the short-term. However, the consequences of increased traffic in the 5 GHz band meant it should be a priority for Ofcom to offset this with additional Wi-Fi spectrum. Sky noted that Ofcom had acknowledged the need for additional 5 GHz spectrum (in its mobile data strategy²⁶) and that discussions with international groups were ongoing. Sky also noted our proposals for low out-of-band emissions requirements on LTE in the 2.3 GHz, in line with latest proposals from CEPT, and said it considered this was appropriate.
- 6.28 Finally, Sky said the "more rudimentary" mitigations proposed for legacy equipment unable to access the 5 GHz band – such as moving affected equipment away from the source of interference, changing its orientation, or wiring a device directly to a router – were likely to reduce or eliminate interference, but may not find favour with consumers.

²⁵ http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/responses/Arqiva_Annex_Report.pdf

²⁶ <http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/statement/>

Our response

- 6.29 We note the findings of the Arqiva technical study suggesting greater separation distances may be required between 2.3 GHz LTE user equipment and 2.4 GHz Wi-Fi. However, we note that the power levels identified in the Arqiva study - and the consequent separation distances needed to avoid degradation - are broadly in line with our own analysis. Only in the case of heavy upload, which leads to high power in user equipment, does the Arqiva study suggest greater separation distances may be needed.
- 6.30 In our December 2014 update, we addressed earlier consultation responses suggesting our analysis had been based on transmit powers that were too low. We conducted a series of walk tests in urban and suburban areas recording the transmit power of a mobile device on different existing mobile networks. We used the 50th percentile results from each test, as we believed these were the most relevant for a mobile system, while noting that higher powers are possible in extreme cases.
- 6.31 We continue to believe that higher transmit powers will occur only in relatively rare cases and, where they do, for only short periods – such as uploading a video. In a congested environment, it is unlikely that an individual user would have high power access to large parts of a cell, and so the impact will be less than is possible in theory.
- 6.32 We note Sky's comments about the need for additional Wi-Fi spectrum. However, this is not the subject of this statement.

Our decisions

- 6.33 For the reasons set out in both the February 2014 consultation and the December 2014 update document – and summarised again above - we have concluded there is no justification for further intervention in the market to protect Wi-Fi in the 2.4 GHz band from interference issues caused by coexistence with 2.3 GHz LTE.
- 6.34 However, if it proves necessary, we will assist ISPs in gathering information about LTE roll-out, subject to respecting commercial confidentiality (see section 7 on information provision within non-technical licence conditions). We will continue to ensure Wi-Fi equipment manufacturers (in addition to ISPs) understand that their devices should be able to coexist alongside LTE in the 2.3 GHz band. This might require improved filter capability, which we note industry is already working to achieve.
- 6.35 We will work with industry to ensure precautions are taken to limit the possibility of interference occurring in the first place. We will provide guidance to manufacturers/retailers recommending that suitable information should be provided in installation guides and on packaging. As a specific example, we will encourage manufacturers to place stickers on 2.3 GHz femto cell equipment to advise about suitable separation distances from Wi-Fi routers.

Coexistence between 2.3 GHz LTE and medical devices

- 6.36 A small volume of medical equipment is currently deployed in the 2.4 GHz licence exempt band, mainly based on Wi-Fi or related technologies. The devices are used mainly for routine monitoring within hospitals - e.g. for heart rate, blood pressure etc.

- but equipment may also be deployed to transmit information from patients being monitored from home²⁷.

- 6.37 Licence exempt bands are not suitable for the deployment of safety critical devices because the frequencies can offer no protection from interference caused by other users²⁸. Ofcom's guidance identifies specific alternative bands for such uses²⁹. Medical equipment using the 2.4 GHz band is therefore designed mainly to provide assistance for medical staff in delivering care, and not for safety-of-life applications.
- 6.38 Our February 2014 consultation noted that the impact of 2.3 GHz LTE on medical devices was likely to be broadly similar to that for other types of Wi-Fi devices. We said there was a theoretical risk from both base stations and from mobile devices.
- 6.39 In respect to interference from mobile phones, we noted it was already standard practice for many hospitals to require mobile devices to be switched off in areas where licence exempt medical equipment was being used. We noted that there remained a small theoretical risk of interference from LTE base stations. However, the consultation presented technical analysis suggesting a very low likelihood of interference occurring in practice. We therefore considered that regulatory-led intervention in the market would be disproportionate – although we recommended that hospitals work with relevant LTE licensees to satisfy themselves that 2.3 GHz base station deployments on hospital premises did not cause unacceptable interference to systems.
- 6.40 Our analysis was not challenged in the consultation responses. However, we decided to reassess the potential issues for medical equipment in our December 2014 update document, in light of our further testing of general Wi-Fi devices. We did this mainly through engagement with manufacturers of medical devices and with other stakeholders.
- 6.41 It was apparent that manufacturers themselves were relatively unconcerned about the potential impact of LTE. In general, the information transmitted is of low data rate, meaning the device is likely to operate even in a significantly degraded Wi-Fi environment. In most cases, the information being transmitted is not latency critical and can, in many circumstances, be retransmitted if interference occurs. Monitors and central displays both have visual and audible alarm mechanisms in the event of a lost connection.
- 6.42 The December 2014 update also presented further technical analysis of the potential for interference from mobile devices. This showed that with a minimum separation distance of 1 metre there would be no risk of impact based on the onset of degradation. As noted above, medical applications do not require the high data rates assumed in this analysis, and therefore separation distances can be expected to be even lower in practice.
- 6.43 Finally, we noted the importance of considering existing practice in relation to mobile phones within hospitals. In particular, we noted the guidance issued by the Department of Health on restricting the use of mobile phones in key medical areas. This includes critical or intensive care wards and units; special care baby units and

²⁷ Home monitor devices typically transmit to an in-home receiver which then sends data to the hospital via broadband

²⁸ <http://stakeholders.ofcom.org.uk/spectrum/information/licence-exempt-radio-use/>

²⁹ <http://stakeholders.ofcom.org.uk/spectrum/information/licence-exempt-radio-use/licence-exempt-devices/short-range-devices-information>

neonatal wards; and any area where specialist medical equipment is being used to treat a patient.

- 6.44 In respect to home deployments of medical monitoring, the risk of interference from base stations is extremely low, in line with that for general Wi-Fi. There may be some risk of interference from LTE handsets if they are used in extremely close proximity to medical monitoring equipment, although lower throughput requirements are likely to mean that any interference is not noticeable in a domestic scenario. Any interference is easily mitigated by moving the LTE mobile device away from the medical equipment, as outlined earlier in this document in respect to 2.4 GHz Wi-Fi in general.

Our decisions

- 6.45 In line with the analysis set out in both the February 2014 consultation and the December 2014 update – and summarised above – we have decided that intervention in the market to protect medical devices is not justified.
- 6.46 However, we continue to recommend that hospitals work with any mobile network licensee seeking to site a 2.3 GHz base station on hospital premises to ensure it does not risk interference to hospital systems operating in the 2.4 GHz licence exempt band. This could take the form of a simple RF test under controlled conditions prior to deployment for example.
- 6.47 In addition, we will write to hospital trusts to alert them of the need to ensure there are no interference issues for medical equipment, and to advise on how best to address any problems that arise.

Assistive listening devices (ALDs)

- 6.48 The February 2014 consultation noted the slight risk of interference from LTE mobile devices to ALDs. An ALD might typically work in conjunction with a person's hearing aid in order to deliver enhanced sound from a particular 'wanted' source (such as a microphone used by a classroom teacher). The 2.4 GHz signal is picked up by a receiver worn by the user and then relayed to the person's hearing aid. In an increasing number of cases, an ALD receiver may form part of the hearing aid itself.
- 6.49 In response to the February 2014 consultation, a large number of stakeholders submitted comments expressing concern about the potential impact of 2.3 GHz LTE on ALDs used by people with hearing loss.
- 6.50 Our consultation had also included an invitation to ALD equipment manufacturers to make use of our technical facility at Baldock in Hertfordshire to test their devices in the presence of simulated LTE signals. More than 12 ALD systems from six different manufacturers were subsequently tested in two phases.
- 6.51 The results confirmed there was a potential risk to some systems if operated in close proximity to an interfering base station or a mobile device operating at high power. As with other licence exempt devices, any issues stemmed from ALDs 'listening in' to signals outside their own frequency band, and not from LTE emissions into the licence exempt band. We believe that ALDs with effective filtering are not affected. Our December 2014 update noted:

- LTE base stations could cause a slight reduction in the maximum operating range of ALDs if there was no wall between a close-by base station and the ALD receiver.
- LTE devices operating at median LTE terminal power levels have no issues with separation distances of between a few 10s of centimetres (up to a maximum of 1 metre) in almost all circumstances. Only a mobile device in the same room operating at maximum power (23 dBm) and uploading a heavy data stream, such as a video or a music file, could lead to interference within 1 to 4 metres of an ALD unit (depending on equipment). Newer ALD systems based on Bluetooth LE technology seemed to be more susceptible than older classic Bluetooth technology.

6.52 We also noted that less than 1% of the 6 million hearing aid users in the UK have associated ALDs that may be susceptible to interference - although we acknowledged the market is growing. Interference would only occur in an area where 2.3 GHz LTE had deployed and if the 2.3 GHz frequencies were actually in use at the time. Even in those circumstances, we said there was a low likelihood of interference actually occurring in practice:

- There was little risk of interference from base stations because most ALD use is indoors, such as in a school classroom. Base stations are not typically located very near to schools;
- There was a low risk of interference from mobile devices because the likelihood of persistent transmission at maximum power in the same room as an ALD system was low. If interference occurred, it could be mitigated by switching off or moving the device (as long as the user had the knowledge to link cause and effect of the interference). We noted that a classroom, for example, is a controlled environment.

6.53 Overall, the December 2014 update document assessed the potential impact of 2.3 GHz LTE on ALDs as very low. As a result, we said there were no reasons to change our proposal that no intervention in the market was necessary to protect ALDs.

Further representations

6.54 We received two further submissions from stakeholders about ALDs, from Mr Brian Copsey of Copsey Communications and from Professor Wendy McCracken, representing The UK Children's FM Working Group – a body focussed on the ability of deaf children to learn. The group's submission was supported by a range of other organisations (National Deaf Children's Society; The British Association of Teachers of the Deaf; Action on Hearing Loss; The Ewing Foundation; Cued Speech Association; Burwood Park Foundation; Deaf Education through Listening and Talking (DELTA) and 16 individuals.

6.55 The submission said Ofcom had failed to understand the implications of deafness in children. It did not challenge our testing or our conclusions in respect to the low impact on people with some level of hearing impairment. However, it said we had failed to understand the implications of actual deafness in children and their ability to learn. It said children do not gain adult-like hearing abilities until their late teens and even a low level of interference is significant and could have lifelong implications. Any additional effort required to listen to speech reduces their cognitive effort in other areas and places severe limits on their education.

- 6.56 The use of current hearing aid technology offers more opportunities than at any other time in history to counter this. ALDs offer access to wider society and to the workplace – but interference with such devices reduces the opportunities this brings and is likely to result in poor hearing aid compliance.
- 6.57 Mr Copsey’s submission said Ofcom had not properly fulfilled its obligation to assess the *“impact on one group of stakeholders”* as set out in its own guidance on the completion of an Equality Impact Assessment. He said there should be a requirement under non-technical licence conditions for mobile operators and those selling mobile phones to inform purchasers - ideally, prior to purchase - that mobile phones *“will interfere or totally block their ALD system and equipment...”* At the very least there should be a requirement for clear labelling on all mobile phones and equipment using the 2.3 GHz band, he said.

Further stakeholder engagement

- 6.58 Although we believe the likelihood of interference to ALDs actually occurring in practice to be very low, we were concerned to understand in more depth the impact on deaf children if it did occur. Accordingly, we met with members of the UK Children’s FM Working Group and Mr Copsey to discuss in detail the points made by the group and to explain our test findings.
- 6.59 The group members told us ALDs are not an addition to hearing aids, but an essential in a classroom environment and were now available on the NHS. They added that all hearing aids will have ALD capability in the future, and will generally be using the 2.4 GHz band because of the ability to link to other technology, such as mobile phones. A hearing aid alone only picks up signals within 1-2 metres and does not filter out background noise. The ALD enables the pupil to listen at a distance from the teacher, and helps considerably with the acoustics in the classroom. In a noisy environment this is crucial to children’s learning. Any loss of quality will cause difficulties.
- 6.60 The group also questioned the ease of controlling interference in schools. They said recommendations from the Stewart Report³⁰ that base stations should not be located on school premises were sometimes ignored, and it was in any case difficult to control the use of mobile phones by school pupils. Other devices, such as iPads, were growing in use within classrooms.
- 6.61 Mr Copsey discussed technological mitigations. He suggested that fitting filters to ALD equipment was impossible due to the size involved and the impact on power consumption and battery life.
- 6.62 We have also met with the European Hearing Instruments Manufacturers Association (EHIMA) to discuss the findings of the previous testing and its implications.

Our assessment for ALDs

- 6.63 We continue to believe there is only a very low risk of interference to ALDs, given the number of factors that all need to occur simultaneously for them to be affected i.e. high power data upload from a mobile device actually using the 2.3 GHz band – and not one of the many other ‘preferred’ bands – in close proximity to an unfiltered ALD.

³⁰ <http://webarchive.nationalarchives.gov.uk/20101011032547/http://www.iegmp.org.uk/report/text.htm>

The actual impact when a mobile device was using the 2.3 GHz band could be a reduction in the range of ALDs and/or some distortion of sound for a short time.

- 6.64 We recognise that there may be some use cases where an individual ALD user is also using their mobile handset in close proximity to the ALD receiver. However we recognise that these scenarios are not unique to our release of spectrum and there is unlikely to be any practicable constraints that we can apply through the award.
- 6.65 We note that the UK Children's FM Working Group did not challenge our conclusions in respect to most users of ALDs i.e. those who do not need to 'learn' how to hear (i.e. people who may always have had partial hearing or who have suffered some hearing loss). Given the low likelihood of interference occurring at all - and the low impact if interference does occur - we do not consider it is necessary or justified to intervene in the market to protect ALDs for this group.
- 6.66 However, in view of our increased understanding of issues affecting deaf children who need to learn how to hear from scratch, we have given further consideration to the impact on this sub-set of users. We acknowledge that even a low level of interference to ALDs could be a significant problem for deaf children – particularly in respect to their education.
- 6.67 We are therefore committed to working with manufacturers of ALD equipment and with those involved in the education of deaf children to ensure any negative impacts can be avoided, if possible. We are planning to work with manufacturers to enable them to conduct 'real life' testing on actual ALDs.
- 6.68 We note there is a similar likelihood of interference stemming from LTE handsets using the 2.6 GHz band, which is already in use with LTE services deployed in many countries around the world. We are not aware of any reported issues for ALDs and believe that if significant interference had occurred elsewhere it would have been reported.
- 6.69 Both the 2.3 and 2.6 GHz band are harmonised for mobile use across Europe and elsewhere, and so manufacturers of devices designed to use the 2.4 GHz licence exempt frequencies will need to find solutions if they have concerns. If there is an issue, it is not one only for the UK.
- 6.70 We are concerned to note from our testing that that newer Bluetooth LE based ALD systems seemed to be more susceptible than older classic Bluetooth technology. This seems contrary to the spirit and intentions of the European Radio Equipment Directive (RED), due to come into force in June 2016. The aim of the Directive is to ensure that all kinds of radio equipment are made to standards that ensure they can coexist without interference. Manufacturers, importers and distributors will have to respect a set of clear obligations to ensure the compliance of any radio equipment placed in the EU market.
- 6.71 We intend to work with EHIMA to make sure manufacturers are aware of the implications of the Directive. They will need to ensure that ALD equipment is robust. We will also encourage equipment makers to make further use of our facilities and contacts to test their systems in 'real life' scenarios, rather than the simulated and recorded environments used in the previous tests. This is likely to involve testing coexistence of ALDs alongside mobile equipment using the 2.6 GHz band.

Our decision on the coexistence of 2.3 GHz LTE and ALDs

- 6.72 Having considered carefully the further evidence presented by the UK Children's FM Working Group following publication of our December 2014 update, we continue to believe that intervention in the market to protect ALDs is not justified. However, as outlined above, we will continue to engage constructively with manufacturers and groups representing the deaf and those with hearing impairments to ensure ALD equipment is robust.
- 6.73 There are no practical means available to us for adjusting handset powers in an LTE network that is subject to global standards and harmonisation. We will work with manufacturers and standards bodies as part of our normal activities to encourage improvements, wherever possible.

Coexistence between 2.3 GHz LTE and other licence exempt devices

- 6.74 Our February 2014 consultation considered the potential for interference to a range of licence exempt applications:
- Bluetooth devices (including both regular Bluetooth and Bluetooth Low Energy or Bluetooth 'Smart'): used especially for hands-free cordless headsets for mobile phones;
 - ZigBee devices: low power systems used to provide low data rate communications e.g. for smart meters, traffic and street light control;
 - Video Devices: including in-home video senders, door entry monitors and baby monitors;
 - Audio Devices: such as radio microphones;
 - Short Range Devices (SRDs): a generic title covering a range of equipment, including assistive listening devices (considered separately above). These may use Wi-Fi, Bluetooth or similar proprietary technologies.
- 6.75 For each technology we considered the likelihood and impact of interference from new services using LTE technology in the adjacent 2.3 GHz award band in typical scenarios. Our assessment showed that interference is possible in certain circumstances. However, in setting out our proposals, we said in the February 2014 consultation that applications and protocols were robust to interference in almost all circumstances. We therefore proposed that mitigations in the very few cases where interference remained a possibility were more appropriately left to natural market developments.
- 6.76 In our December 2014 update document we considered consultation responses from the Bluetooth Special Interest Group in respect of interference to Bluetooth devices, and from Energy UK in respect to smart meters. There were no comments of note in respect to other device technologies.
- 6.77 On Bluetooth, we noted that the close proximity of new LTE systems in the 2.3 GHz band may increase the risk of interference to Bluetooth. However, as for Wi-Fi, we said it was important to note that our measurements showed that the dominant interference was a wideband blocking effect caused by Bluetooth devices 'listening'

outside the 2.4 GHz band – rather than LTE out-of-band emissions. Manufacturers told us that receiver filtering would be an effective solution. Alternatively, the use of short ‘packets’ can allow Bluetooth signals to operate in the gaps between TD-LTE transmissions.

- 6.78 On smart meters (ZigBee) we noted that 2.3 GHz LTE signals might cause degradation to the smart meter home networks in only a very small proportion of households, reducing coverage by 0.25%. This was within the margin of error already associated with coverage assumptions.

Further representations on coexistence of 2.3 GHz LTE and Bluetooth

- 6.79 We received further representations from the Bluetooth Special Interest Group (Bluetooth SIG) in response to the December 2015 technical update.
- 6.80 In its submission, the group said we had presented insufficient technical analysis of the impact to Bluetooth LE technology. The award of the 2.3 GHz spectrum represented a risk of interference to existing Bluetooth LE sensor devices in various markets, and several forthcoming devices in the hearing aid, audio, medical, Internet of Things, and health and fitness markets.
- 6.81 The group suggested that Ofcom had failed to take account of comments made in earlier stakeholder engagement that filtering was not an appropriate solution. Additionally, it said Ofcom had ignored “technical clarifications” on expected interference in the lower end of the 2.4 GHz band and, in particular, on Bluetooth LE Channel 37 at 2402 MHz.
- 6.82 The group also said Ofcom had failed to acknowledge that Bluetooth LE standards were adopted as early as 2010 and that we had erroneously considered it to be a new technology with *“functionality not expected to be standardised until 2016”*. According to the submission, the technology was in fact in *“a boom of innovation, resulting in a range of products in a wide variety of usages”*. It was predicted that a total of 4.7 billion Bluetooth LE single mode and Classic & LE Dual mode devices will be shipped by 2018 worldwide.
- 6.83 Finally, the Bluetooth SIG challenged our assertion in the December 2014 update that it should actively encourage manufacturers to improve coexistence capabilities in new equipment using Bluetooth LE. It said Bluetooth LE was designed to *“coexist as a good neighbour with other short-range unlicensed wireless devices. It was not, however, developed to cope with licensed, higher-power equipment working in an adjacent band which is allowed to pollute the 2.4 GHz band with its spurious radiation”*.
- 6.84 The group called for further analysis and testing of the impact on Bluetooth LE devices.

Our response

- 6.85 We note the comments made by Bluetooth SIG and the concerns expressed about the potential impact on Bluetooth LE devices.
- 6.86 It is important to note that our comments in the December 2014 technical update about functionality not being standardised until 2016 related solely to the use of Bluetooth LE in ALDs (see above) - and not to Bluetooth technology in general. We accept that broader Bluetooth LE standards were developed somewhat earlier.

- 6.87 Our technical analysis took measurements from two Bluetooth LE development boards and we used these to guide our overall assessment. We acknowledged in both the February 2014 consultation and in the December 2014 update that Bluetooth LE may be more vulnerable to interference than classic Bluetooth. However, we believe actual interference is likely to occur in only rare circumstances and that it would be disproportionate to intervene in the market to protect Bluetooth LE.
- 6.88 We note that the 2.3 GHz band has already been allocated for LTE use globally. In the UK – unlike other countries – there is a 10 MHz guard band at the top of the 2.3 GHz spectrum we are awarding i.e. in the frequencies closest to the 2.4 GHz licence exempt band. Accordingly, our analysis suggests that any potential degradation to Bluetooth will not be due to interference from 2.3 GHz LTE - as asserted in the Bluetooth SIG response - but from Bluetooth LE picking up signals from outside its designated band.
- 6.89 Although filtering is not possible for existing Bluetooth LE devices, our evidence suggests it may be appropriate for new applications – especially having regard to other countries where there is no guard band. We acknowledge that this may involve some additional cost and could make devices more bulky. This conclusion is supported by studies conducted by Cambridge Silicon Radio Ltd in relation to classic Bluetooth applications³¹.
- 6.90 We note the evidence presented by the Bluetooth SIG that the market for Bluetooth LE products is predicted to grow exponentially over the coming years. However, we have not seen any significant evidence of widespread *current* deployments. In reaching our conclusions on coexistence, we believe we should take account mainly of the current market, rather than basing our decisions on predictions about the potential take up of products which have not yet been adopted.
- 6.91 In light of the low levels of current deployment, we continue to believe the impact of 2.3 GHz LTE to be very low. Manufacturers of devices being designed to operate in licence exempt spectrum bands need to take account of the licensed use of neighbouring bands. We believe that this is a requirement of the Radio Equipment Directive³² that will come into force in Europe in June 2016.

Our decisions in respect to coexistence with licence exempt equipment

- 6.92 In line with the analysis set out in the December 2014 update – and summarised above – we have decided that intervention in the market to protect licence exempt devices in the 2.4 GHz band, including ALDs, is not justified.
- 6.93 As proposed earlier, we believe the Bluetooth SIG should encourage manufacturers to improve coexistence capabilities in new equipment, particularly those being developed using Bluetooth LE. This should be taken into account in the upcoming standardisation of audio profiles.

³¹ Bluetooth Performance with 2.3 GHz LTE: Interference Report published alongside this document

³² Directive 2014/53/EU, April 2014: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOL_2014_153_R_0002&from=EN%20

Coexistence issues for radar

- 6.94 Radar systems operate in spectrum bands adjacent to the 3.4 GHz award band. We addressed the potential impact on radar from 3.4 GHz LTE in both the February 2014 consultation and the December 2014 update.

Royal Navy systems

- 6.95 We said in our February 2014 consultation and December 2014 update that the MOD was likely to require us to put in place some coordination procedures around a small number of coastal locations. We have not yet concluded discussions, but we can confirm that these procedures will be necessary. The locations include Portsmouth Naval Base, Cowes, Portsmouth Technology Park and Devonport Naval Base.

Civilian maritime radar

- 6.96 S-band maritime radars are mandatory on ships with a gross tonnage greater than 3,000 tonnes. Our technical analysis for the February 2014 consultation showed low ranges of potential interference from 3.4 GHz LTE in 'real-life' testing.
- 6.97 In view of the results of these tests, we agreed with the Maritime and Coastguard Agency that it was not necessary to propose any additional mitigations (such as coordination) to address interference from 3.4 GHz LTE. However, we recommended that radar manufacturers should consider these and future systems when developing the receivers for new radar systems.
- 6.98 In our December 2014 update document we discussed the four responses we received to the consultation. All of the respondents agreed with our proposed position. As a result we said we had not carried out any additional testing for maritime radar and did not see any reason to consider further the potential impact of 3.4 GHz LTE.
- 6.99 In the absence of any further evidence, we now confirm as a decision the proposals set out in the February 2014 consultation and summarised above.

Aeronautical radar

- 6.100 In the frequency band 2700-3100 MHz there are both air traffic control (ATC) and air traffic management (ATM) radars, both civilian and military, used for aviation radio navigation purposes.
- 6.101 In our February 2014 consultation, we noted that the use of the 2.6 GHz band for 4G communications services had raised concerns associated with radar performance vulnerability. We said the potential for similar issues to arise if the 3.4 GHz spectrum band was used for high power applications, such as LTE, had been identified at the time. As a result, the relevant radars were upgraded to cope with LTE transmissions within the 2.6 GHz and 3.4 GHz bands.
- 6.102 We proposed that a coordination procedure should be implemented alongside existing radar remediation filtering, as agreed with the Civil Aviation Authority. We said in the 3.4 GHz band this was justified to retain the integrity of the ATC/ATM radio navigation services. We said the coordination procedure should specify power flux density (pfd) limits for both signal and noise that must not be exceeded at the defined radar locations.

- 6.103 In the December 2014 update we considered the six consultation responses we received. All respondents agreed with our overall approach in aligning coordination procedures with those applying to the 2.6 GHz award, although some said different pfd limits should apply to different parts of the 3.4 GHz band.
- 6.104 We said we had no evidence to determine by how much the requirement may be exceeded in different parts of the band. We therefore remained of the opinion that we should apply a constant value for pfd across the whole band.
- 6.105 In the absence of any further evidence, we now to confirm as a decision the proposals set out in the February 2014 consultation.

Coexistence issues for Government systems

- 6.106 There are a number of public sector systems that will operate on a co-channel or adjacent channel basis following the award of the spectrum. These include a number of terrestrial and airborne telemetry and data transfer systems operating below 2350 MHz. There are also ongoing discussions with the Home Office regarding use of spectrum below 2350 MHz for an air to ground communications system.
- 6.107 Airborne, maritime and land based telemetry, data transfer and radar systems will also remain in spectrum adjacent to the 3.4 GHz band. There are satellite based systems operating close to both bands.
- 6.108 The MOD has undertaken studies in order to assess the risk of interference between future uses of the award spectrum and the public sector systems operating within or adjacent to those likely new uses. Where public sector systems require additional protections in order to avoid harmful interference, coordination procedures will be put in place as described in section 7 of this document.
- 6.109 Government departments have endeavoured wherever possible to minimise the risk of interference from any public sector systems to new systems operating in the spectrum to be awarded. However where any residual risk of interference may remain, details of the systems and/or the likely impact will be described in the Information Memorandum to be published prior to the award.

Section 7

Non-technical licence conditions

- 7.1 This section of the statement sets out our decisions on the non-technical licence conditions we will include in the licences issued after the award of the 2.3 GHz and 3.4 GHz spectrum bands (see annexes 6 and 7).
- 7.2 In our November 2014 consultation, we said the licences would contain the minimum necessary restrictions on permitted use of the spectrum bands in order to avoid harmful interference to others, and to ensure compliance with our statutory duties and international obligations. The consultation included specimen draft licences for both the 2.3 and the 3.4 GHz band.
- 7.3 In setting out our final decisions on non-technical conditions below, we summarise the proposals set out in the November 2014 consultation and our subsequent consideration of consultation responses.

Licence commencement and duration

- 7.4 We proposed that the licences should:
- Be issued for an indefinite duration;
 - Be issued for an initial period of 20 years, after which they would be subject to a provision that would enable Ofcom to impose an on-going additional annual fee (the licence fee for the initial period would be determined through the award process);
 - Be revocable before the expiry of the initial period only on certain limited grounds (i.e. at the request or with the consent of the licensee; for non-payment or late payment of the relevant licence fee; for breach of any of licence terms; for breach of auction regulations; for breach of trading regulations; for national security or to comply with international agreements; or under direction of the Secretary of State);
 - Be revocable from any point after the expiry of the initial period on the grounds set out above and, additionally, for spectrum management reasons, subject to five years notice.
- 7.5 We said the mechanism and level of annual fees after the initial licence term would depend on our general approach to the use of this spectrum at the time, and how that general approach related to these licences and to our statutory duties. Prior to any imposition of fees, we would expect to consult as appropriate and to give notice of our specific proposals, before any fees are introduced.
- 7.6 However, this would not apply to the 40 MHz of spectrum held by UK Broadband. Instead, if UK Broadband were to participate in the auction and a new licence was issued for frequencies it was allocated, we proposed that an annual licence would apply from 2018, in line with its current licence terms.
- 7.7 We asked the following consultation question:

Do you have any comments on the proposals relating to the duration of the initial licence period, our rights to revoke the licence during this period, the charging of licence fees after the end of the initial period and our additional revocation powers following the initial period?

Consultation responses

- 7.8 Nine stakeholders submitted responses on aspects of the proposed non-technical licence conditions. Three of the responses were submitted confidentially.
- 7.9 None of the respondents questioned our proposals relating to the initial licence period or our proposals on our rights to revoke licences. BT and UK Broadband both noted that the proposals were standard for this kind of licensing and were broadly accepted.
- 7.10 EE argued there was no reason to apply licence fees after the expiry of the initial licence term. Such fees were unnecessary to incentivise efficient use of the spectrum and could have negative consequences in a market based spectrum management framework. No other respondent commented on the future implementation of fees.

Our decision

- 7.11 For the reasons set out in the consultation and following consideration of stakeholder responses, we have decided to proceed with our proposals on licence commencement and duration. In respect to annual licence fees after the initial licence term, we note that no fees will be introduced until after further consultation. We therefore see no reason to change our proposals at this stage.

Territorial extent of licences

- 7.12 The November 2014 consultation noted that the territorial extent of the licences for the 2.3 and 3.4 GHz bands would differ due to on-going use in some areas by the MOD.
- 7.13 We said the MOD had some concerns regarding deployments at sea, as these may interfere with systems in use at its test ranges (around Aberporth and St Kilda) and with systems deployed on Navy vessels. The MOD indicated that it wished for any off-shore deployments to be coordinated with the Ministry prior to deployment. This will include some areas of internal waters as well as territorial seas³³.
- 7.14 The consultation also noted the increasing number of requests for localised wireless networks in support of installations such as wind farms and oil rigs located off of the coast of the UK, especially in the 3.4 GHz band³⁴. Given the restrictions referred to above, we proposed that territorial seas or areas of internal waters³⁵ adjacent to territorial seas - and more than 2km wide - should not be included in the licences.³⁶ We said that if anyone requested use in such areas (i.e. holders of 2.3 or 3.4 GHz

³³ Internal waters are indicated in:

<http://www.ukho.gov.uk/ProductsandServices/Services/Documents/UK%20Territorial%20Sea%20Limits.pdf> and in the Water Resources Act 1991 Section 221(1) <http://www.legislation.gov.uk/ukpga/1991/57/section/221>

³⁴ There is one licence already granted for the London Array which is just outside the 12 nm limit

³⁵ Within the Water Resources Act 1991 Section 221(1) internal waters means rivers, streams and watercourses as well as lakes, ponds, reservoirs, docks channels, creeks, bays, estuaries and arms of sea.

³⁶ The 2km definition aims to ensure there are no restrictions in narrow areas of internal waters such as rivers, lakes or ponds.

licensees or others) we would consider authorising localised individual licences off-shore on a first come first served basis, subject to MOD coordination. Licences would be issued on the basis that licensees cannot claim protection from nor cause interference to MOD systems or other UK licensees³⁷.

- 7.15 As noted in section 2, we proposed that the **2.3 GHz licences** would cover Great Britain, but not Northern Ireland (due to continued MOD use of the band). The licences would not extend to the Channel Islands and Isle of Man. We proposed an exclusion covering the Outer Hebrides, the Isle of Skye and the Small Isles due to on-going MOD requirements.
- 7.16 In addition, we proposed that licensees would need to coordinate with the MOD around St Kilda, Aberporth, Oakhanger, Colerne and Menwith Hill. Finally, we said our ongoing discussions with MOD regarding other military systems in the 2.3 GHz band suggested that the MOD was likely to require us to put in place some coordination of a similar nature around one or two additional sites, such as Boscombe Down.
- 7.17 We proposed that the **3.4 GHz licences** should cover the whole of the United Kingdom. The licences would not extend to the Channel Islands and the Isle of Man. As with the 2.3 GHz licences, territorial seas or any areas of internal waters adjacent to territorial seas and more than 2 km wide would also be excluded.
- 7.18 We noted that we had previously proposed that licensees would need to coordinate with the MOD around Bude, and with aeronautical radar. Whilst we did not propose any formal coordination arrangements with the adjacent satellite services above 3.6 GHz, we said we had not yet concluded on this issue.
- 7.19 In addition, we said our ongoing discussions with MOD regarding Navy systems suggested the MOD was likely to require us to put in place some coordination around a small number of coastal locations, including but not limited to Portsmouth. We said the exact number of sites and the extent of any coordination was still being evaluated and that we would provide an update prior to the award of the spectrum.
- 7.20 We asked the following consultation question:

Do you have any comments on our proposals relating to the territorial extent in the award licences?

Consultation responses

- 7.21 Most respondents offered no comments on the proposed territorial extent of the licences. However, H3G said it would like to deploy any spectrum acquired in the 2.3 and 3.4 GHz bands on a nationwide basis. The company said the spectrum could be aggregated with 2100 and 1800 MHz spectrum in high traffic urban areas.
- 7.22 Some respondents, including UK Broadband and stakeholders who submitted responses in confidence, urged Ofcom to consider licensing spectrum in territorial seas and/or adjacent internal waters. EE said the exclusion of territorial waters would result in a material reduction in the value of the licences.

³⁷ We proposed that any localised licence would require compliance with European recommendations covering signal thresholds for international coordination.

- 7.23 UK Broadband noted that the MOD was likely to put in place some coordination requirements around some locations. The company acknowledged that this was still under discussion, but said it was important that full details were made available as soon as possible. A confidential respondent also said confirmation of coordination requirements should be made available to potential bidders before the auction.

Our decisions

- 7.24 The territorial extent of the licences we will issue has been determined primarily by the terms of its release by the MOD. As a result of continuing MOD needs, the 2.3 GHz spectrum cannot be made available in Northern Ireland. Similarly, the MOD is clear that licences in either band cannot be made generally available for territorial waters and adjacent waterways. However, as indicated, licensees and others may request localised individual licences off-shore on a first come first served basis, subject to MOD coordination.
- 7.25 We have not been persuaded to seek further negotiation with the MOD over extending the territorial extent of the licences. We understand the nature of the MOD's concerns and do not think it likely that the position will change. Further discussion could result in delay to the award for little additional advantage, given our ability to consider requests for additional licences on an ad hoc basis.
- 7.26 We have not yet concluded our discussions with the MOD regarding all the sites that require protection. However, we can confirm that a 10 km coordination zone around Boscombe Down and Warton airfields will be required in the 2.3 GHz licence to protect MOD uses. The MOD analysis suggests that these requirements are unlikely to cause any significant restrictions on deployments in practice. Within the coordination zone, this is likely to mean that local site engineering should be sufficient to ensure that sites can be deployed. These restrictions are in addition to the requirements to coordinate with the MOD around St Kilda, Aberporth, Oakhanger, Colerne and Menwith Hill.
- 7.27 In addition, the MOD has also asked us to protect its continuing 2.3 GHz uses in Northern Ireland. We will therefore apply a coordination requirement with threshold values consistent with those required to protect uses in the Republic of Ireland. However the coordination procedure and methodology will be aligned with those for other MOD sites.
- 7.28 In the 3.4 GHz band, in addition to coordination requirements around Bude and aeronautical radar sites, the MOD also requires protection around a small number of coastal locations where Navy systems are in use. We have not yet finalised all the details with the MOD. However, these locations will include, but may not be limited to, Portsmouth Naval Base, Cowes, Portsmouth Technology Park and Devonport Naval Base.
- 7.29 Additionally, we are working to ensure that prior to the award we have in place international coordination requirements where necessary. Those with the Republic of Ireland and France have been agreed³⁸ and we are working with the Communications Commission to determine the most appropriate approach for avoiding interference with the Isle of Man.

³⁸ International Memoranda of Understanding are published at:
<http://licensing.ofcom.org.uk/radiocommunication-licences/mobile-wireless-broadband/cellular-wireless-broadband/policy-and-background/licensee-freq-tech-information/international-coordination/>

- 7.30 Accordingly, with the additional protected sites above, we have decided to proceed with the proposals covering the territorial extent of the licences, as set out in our November 2014 consultation. We will finalise the details of the outstanding protections required and the associated coordination procedures prior to the award.

Provision of information to facilitate optimal spectrum use

- 7.31 In line with our duty to manage the spectrum efficiently, the November 2014 consultation proposed to include a condition in the licences requiring licensees to provide, on request, general information regarding their equipment and use of frequencies, or the roll-out of their network. We said we may publish information received on the number of base stations and frequency use in areas throughout the UK.
- 7.32 We said the provision of this information could help interested parties who do not have access to this spectrum to identify areas where they might provide additional services. It would be open to them to gain access to spectrum in those areas by trading with licensees. This would help secure optimal use of the spectrum.
- 7.33 The information would also be used to assist with work being undertaken to conduct a spectrum inventory across the European Union, as required by Commission Decision 2013/195/EU³⁹. This work forms part of the Radio Spectrum Policy Programme⁴⁰ that sets out the strategic policy objectives for spectrum by the EU.
- 7.34 We asked the following consultation question:

Do you have any views on the proposed approach to information provision; in particular concerning the type of information that may be helpful and any impacts that publication of information might have both on licence holders and the wider spectrum market?

Consultation responses

- 7.35 Some respondents had concerns about the provision of information; about the form of any publication of that information; and about the use to which the information might be put.
- 7.36 For example, BT said it did not have any concerns in principle about the record keeping requirements that Ofcom proposed for the licences. However, it had concerns about the required frequency of updating this information and the burden this may place on licensees. BT also said it had concerns about the potential publication of commercially sensitive information. It said precise height and detailed grid reference details may not be readily available and are not necessary for Ofcom's purposes anyway.
- 7.37 BT also had concerns about the requirements to provide information about femto cells, and suggested Ofcom review the 20dBm power threshold below which less onerous record keeping requirements applied. It said a figure of 24dBm would be

³⁹ Commission Implementing Decision of 23 April 2013 defining the practical arrangements, uniform formats and a methodology in relation to the radio spectrum inventory established by Decision No 243/2012/EU of the European Parliament and of the Council establishing a multiannual radio spectrum policy programme. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:113:0018:0021:EN:PDF>

⁴⁰ <http://ec.europa.eu/digital-agenda/rspp-roadmap-wireless-europe>

more appropriate to cover in-building cells. The higher power level threshold for record keeping would also be consistent with the 24dBm power limit proposed by Ofcom in the context of unsynchronised indoor small cells. Access and inspection rights that go beyond the basic requirements of the Wireless Telegraphy Act may not be necessary for inclusion in licences, or could be waived for indoor femto cells. These are in many respects similar to Wi-Fi, for which the licence-exemption regulations do not include access and inspection provisions.

- 7.38 EE also raised the question of commercial sensitivity. Additionally, it said the proposal to force the licensee to provide information as part of a condition within the licence was disproportionate. It said Ofcom already has powers under both the Communications Act 2003 and the Wireless Telegraphy Act (WTA) to request information from spectrum licence holders.
- 7.39 EE also said the provision of information could become overly burdensome and therefore disproportionate. The information Ofcom required in relation to base stations was not regularly gathered and had not been required before. Ofcom has not explained how it intends to use this information, nor has it justified why it is required.
- 7.40 H3G and UK Broadband both said they had no objection to the provision of information, but did have concerns about any Ofcom plans to publish site information. The companies said it would like further details on how the information was likely to be shared in the public domain or how the information would be beneficial to the public in general.
- 7.41 Arqiva said it was happy with the information provision. It said it would expect that when there was a specific interference issue a licensed or unlicensed user could request access to this data.

Our decisions

- 7.42 We note that our proposed provisions are consistent with other licences e.g. the 800 MHz licences. We do not believe they place a significant burden on licensees.
- 7.43 We agree with EE that we have powers under both the Communications Act (Section 135 to 146) and the Wireless Telegraphy Act (Sections 32 to 34) to require the provision of information. However, we consider that there remains a benefit in requiring licensees to compile and maintain basic details relating to the radio equipment they are using so that it is readily available in the event that it is needed. We will not require licensees to submit this information routinely, but on request. We will handle any information we receive in accordance with the obligations and restrictions placed on us under the Acts. The information is not routinely published.
- 7.44 In respect to the power threshold for information provision on femto cells, we note the comments of BT and agree with the points made.
- 7.45 In summary, therefore, we have decided to confirm our proposals on information provision as set out in the consultation. However, we will raise the threshold for femto cells to 24 dBm.

Additional non-technical conditions

- 7.46 The November 2014 consultation set out proposals on other aspects of the non-technical licence conditions, and sought responses from stakeholders through a single general consultation question:

Do you have any comments on other proposed non-technical licence conditions and the draft licences at annexes 8 and 9 [of the November 2014 consultation]?

- 7.47 The proposals relating to these additional matters are summarised in turn below. We received very few comments addressing additional matters. Where comments were submitted we note them below, together with our consideration of any issues that they raise.

Spectrum trading

- 7.48 We proposed to award licences that would be made tradable by amending the Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011 (the 'Mobile Trading Regulations')⁴¹ to include the new frequency bands of the 2.3 GHz and 3.4 GHz bands. In line with Ofcom's current policy, a licence variation to enable leasing is not available in respect of licences that are covered by the Mobile Trading Regulations. We have decided to confirm this proposal as a **decision**.

Non-technical restrictions on use

- 7.49 We did not propose to impose any non-technical restrictions in the licences on the use to which the spectrum could be put (such as specifying the type of service that should be offered, the technology that should be deployed or the equipment that should be used). We now confirm this proposal as a **decision**.

Access and inspection

- 7.50 In accordance with our standard spectrum licence conditions, we proposed that licensees should be required to permit any person authorised by Ofcom to have access to and to inspect the radio equipment specified in the licence at all reasonable times. We now confirm this proposal as a **decision**.

Modification, restriction and closedown

- 7.51 In line with standard provisions, we proposed a licence provision permitting Ofcom to require that the Radio Equipment (or any part of it) be modified, restricted in use or temporarily or permanently closed down if a licensee breached the terms of its licence; the use of radio equipment is or may be causing or contributing interference to the operation of other authorised radio equipment; or it appeared necessary or expedient in the event of a national or local state of emergency. We now confirm this proposal as a **decision**.

Coverage

- 7.52 We proposed that no coverage obligations should be included in the licence conditions. We said the 2.3 and 3.4 GHz bands were likely to be used for the

⁴¹ We have consulted separately on the timing of when the 2.3 and 3.4 GHz spectrum (along with spectrum in the 1452-1492 MHz range) should be brought under the MTR (<http://stakeholders.ofcom.org.uk/consultations/mobile-trading-regs-apr-15/>). We will be making a statement on this subject shortly.

provision of additional capacity for mobile networks, or to support backhaul connectivity for small cells operating in other frequencies. We did not consider the spectrum was best suited for providing wide area coverage. We therefore considered that coverage obligations were not appropriate.

- 7.53 One consultation respondent – a private individual – questioned why Ofcom was not seeking coverage obligations to ensure that areas without existing mobile coverage were served in future.
- 7.54 In response, we note the reasoning put forward in the consultation (as summarised above). We believe this assessment remains correct. As a result, we now confirm our proposal on coverage as a **decision**.

'Use-it-or-lose it' clause

- 7.55 We proposed that licensees should not forfeit any spectrum acquired through the award in the event that they did not subsequently use the frequencies. As above, we said the spectrum was likely to be used to ease capacity issues for mobile network operators rather than for expanded coverage. As such, it may be used initially only in high density areas where capacity is an issue, with the spectrum left unused in other areas. We noted that licences issued by Ofcom are not exclusive, and that we have discretion to authorise use of these or any other frequencies, for any purpose, in line with our statutory duties, whether through licensing or licence exemption.
- 7.56 A confidential respondent said it supported our proposal that a use-it-or-lose-it clause should not be applied to the 2.3 and 3.4 GHz award. It said it was generally not sensible for regulators to become engaged in how operators manage the deployment of their spectrum portfolios.
- 7.57 However, the respondent said its support was qualified on the basis that Ofcom takes appropriate action when designing primary awards (or scrutinising mergers and secondary trades) to ensure that spectrum holdings do not become overly concentrated in the hands of one or two operators. A situation where an operator hoards spectrum for anti-competitive purposes should not arise in a competitive and well regulated market.
- 7.58 In response, we note that the 2.3 and 3.4 GHz spectrum will be subject to Mobile Trading Regulations (along with spectrum in the 800 MHz, 900 MHz, 1.4 GHz, 1.8 GHz, 2.1 GHz and 2.6 GHz bands). Under those regulations, a competition assessment is undertaken in the event of any proposed trade. We also note that no licence issued by Ofcom is exclusive, and that we have discretion to authorise use of these or any other frequencies, for any purpose, in line with our statutory duties.
- 7.59 Consequently, we now confirm the proposal that there should be no use-it-or lose-it clause as a **decision**.

Sharing

- 7.60 The November 2014 consultation noted the emerging concept of dynamic spectrum sharing. This is the ability of users to share spectrum in a dynamic way by making use of unused frequencies through a variety of means, such as geolocation databases, Licensed Shared Access (LSA) or cognitive devices. We said allowing such sharing could, in future, provide extra data capacity or greater download speeds to end users.

- 7.61 However, we said dynamic spectrum sharing was still evolving as a concept. We did not feel it was necessary, therefore, to include any specific conditions about spectrum sharing in the 2.3 and 3.4 GHz licences. We said we may consider consulting on the possibility of varying licences in future, if the regulatory environment changed.
- 7.62 Only one respondent – UK Broadband – commented on this matter. It said regulatory certainty was a vital prerequisite for the auction. It was important that all issues were concluded in advance, and any decisions or proposed licence conditions published in time for the auction. A requirement to share the spectrum might well affect its value.
- 7.63 In response, we note that our thinking on spectrum sharing remains an issue for the long term, as identified in the November 2014 consultation. As such, it would be premature to publish any consultation on the issue at this stage. However, we think it is important to note that no licences issued by Ofcom are exclusive, and we have discretion to authorise use of any spectrum frequencies, for any purpose, in line with our statutory duties. The November 2014 consultation merely noted this point and assured potential licensees that no changes would be made to facilitate sharing without further consultation.

PMSE access

- 7.64 We proposed licence conditions to ensure the provision of information to enable PMSE access to spectrum to support peak demand events (such as major sports events or national occasions). We said we would request information on base stations within 10 km of the event, both already deployed and planned to be transmitting during the event period (including temporary deployments). This information will be used to assess whether the spectrum is usable by PMSE and whether that use is likely to cause harmful interference to licensees' networks.
- 7.65 We said any request for information should be made not later than six weeks before the event. We further said that a response would be needed not later than four weeks before the event in order to allow time to assess whether the spectrum can be used and to factor this into the channel plan.
- 7.66 We received one response on this issue. A confidential respondent said it did not agree with the timescales proposed by Ofcom for requesting and providing information. The respondent said six weeks was an unreasonably short time before an event for licensees to collect and provide information. It said a peak demand event would normally be planned many months in advance and the date and likely requirements known at an early stage. Any request for information should be made as far in advance of the event as possible - and not later than 12 weeks before the event. This would give licensees eight weeks to collate and provide the information to Ofcom.
- 7.67 In response, we agree with the respondent that most peak time events are planned well in excess of six weeks ahead. For that reason, we would expect notice to be given much earlier in practice. The six weeks' notice period should therefore be regarded as a minimum. However, we do not believe it would be difficult for licensees to provide the information at short notice if required. We note that they provide similar information very promptly in response to applications for test and development licence requests.
- 7.68 As a result, we now confirm our proposals on PMSE access as a **decision**.

Section 8

Technical licence conditions

- 8.1 This section of the statement sets out our final decisions on the technical licence conditions which will be applied to the 2.3 and 3.4 GHz award (see annexes 6 and 7).
- 8.2 We first set out proposals on technical licence conditions in our February 2014 consultation. In light of responses to that consultation we were able to confirm our position on a number of issues related to power limits, including maximum in band power limits for base stations and for user terminals in both bands. We included preliminary conclusions on these matters alongside a number of further proposals on technical licence conditions in the November 2014 consultation. In summary we:
- Sought stakeholder views on two possible options for inter-operator synchronisation;
 - Proposed that indoor small cells should be exempt from synchronisation;
 - Provided clarification on our position on power control for femto cells;
 - Proposed out-of-band power limits above 2403 MHz in line with ECC Decision (14)02;
 - Set out a proposed position on out of block levels applicable to UK Broadband's spectrum holding at 3605–3689 MHz.

Our Decisions

- 8.3 Our decisions on block edge mask requirements for inclusion in the 2.3 and 3.4 GHz licences are summarised in Figure 8.1 for base stations and Figure 8.2 for user terminals. Our reasoning in reaching these conclusions is set out in the paragraphs below.

Block edge masks and synchronisation

- 8.4 In the February 2014 consultation, we proposed to permit two block edge masks – a permissive mask and a restrictive mask - to be used under different conditions of network synchronisation. We noted that the restrictive mask would in practice require some internal guard bands in order for control of emissions levels to be achieved. We proposed that all spectrum should be assigned to licensees at maximum permitted power with no built-in guard bands or lower power restricted blocks. We noted that licensees were free to negotiate alternative out of block emissions requirements if they wished to.
- 8.5 We considered carefully the responses we received to the February 2014 consultation in then setting out the further proposals included in the November 2014 document. In particular:
- We said it was our priority that licensees could start using the spectrum shortly after the auction without undue delay, so the benefits of new services are realised for consumers in a timely manner;

Figure 8.1: Block edge mask requirements for base stations

	2.3 GHz		3.4 GHz	
Band plan	TDD		TDD	
In block power limit EIRP	61 dBm / 5 MHz *		65 dBm / 5 MHz *	
	Femto cells up to and including 24dBm must use power control		Femto cells up to and including 24dBm must use power control	
Out of block baseline power limit (BS)	Permissive mask (synchronised) Min(PMax ⁴² – 43, 13) dBm / 5 MHz EIRP per antenna	Restrictive mask (unsynchronised) - 36 dBm /5 MHz EIRP* Not initially required	Permissive mask (synchronised) Min(PMax – 43, 13) dBm /5 MHz EIRP per antenna	Restrictive mask (unsynchronised) -34 dBm /5 MHz EIRP*
	Applies only within the spectrum to be made available in this award i.e. 2350 – 2390 MHz.		Applies within 3400 – 3800 MHz where there is a licensed wireless broadband operator i.e. a winner of the upcoming spectrum award or an existing licensee such as UK Broadband.	
Transitional levels The transitional levels are applicable between 0 – 10 MHz from the block edge with the permissive mask, After 10 MHz, the permissive baseline power levels apply.	-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna The transition region extends into 2340 – 2350 MHz and 2390 – 2400 MHz.	-10 to -5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna	-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna The transition region extends into 3400 – 3410 MHz and 3600 – 3605 MHz	-10 to -5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna
Other levels:	Below 2340 MHz: PMax > 35 dBm, -36 dBm / 5 MHz EIRP* PMax ≤ 35 dBm, -20 dBm/5 MHz EIRP* 2400 – 2403 MHz : Min(PMax – 43, 13) dBm /5 MHz EIRP per antenna Above 2403 MHz: PMax > 42 dBm, 1 dBm /5 MHz EIRP* 24 dBm < PMax ≤ 42 dBm, (PMax -41) dBm / 5 MHz EIRP* PMax ≤ 24 dBm, -17 dBm/5 MHz EIRP*		3390 -3400 MHz : Min(PMax – 43, 13) dBm / 5 MHz EIRP per antenna Below 3390 MHz: -50dBm / MHz EIRP* ⁴³ Above 3605 MHz : -34dBm / 5 MHz EIRP* ⁴⁴	
Synchronisation requirements	Licensees must comply with the requirements of an Inter-Operator Synchronisation Procedure This requires identical frame structures. There are exemptions from some parameters for some small cells, see paragraphs 8.61 to 8.66. All licensees can therefore use the permissive mask.		Licensees must comply with the requirements of an Inter-Operator Synchronisation Procedure This requires alignment of the start of the frame and the first three sub-frames only. For further information, see sub-section below. There are exemptions from some parameters for some small cells, see paragraphs 8.61 to 8.66 Licensees are permitted to use the permissive mask if they are using the preferred TD-LTE configuration (or equivalent frame structure) otherwise they must use the restrictive mask.	

* The maximum mean power relates to the EIRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

⁴² Where PMax is the maximum mean power for the base station in question, measured as EIRP per carrier and is used in the baseline and transitional region levels.

⁴³ We note that this level is defined in the Commission Decision 2014/276/EU as per MHz rather than per 5 MHz.

⁴⁴ This limit shall not apply if the licensee of the Spectrum Access 3.6 GHz licence (above 3605 MHz), uses a TDD frame structure compatible with that which is set out in the Inter-Operator Synchronisation Procedure

Figure 8.2: : For user terminals

In block power limit	2.3 GHz		3.4 GHz	
	Mobile or nomadic Radio Equipment	Fixed or installed Radio Equipment	Mobile or nomadic Radio Equipment	Fixed or installed Radio Equipment
	25 dBm TRP* ⁴⁵	25 dBm EIRP*	25 dBm TRP *	35dBm/5 MHz EIRP *
	(Licence exempt)	(Licence exempt)	(Licence exempt)	(Not licence exempt)

* The maximum mean power relates to the EIRP or TRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

- We acknowledged that base station equipment that must have operator specific filters (to meet the restrictive mask) may result in some inefficiencies in spectrum use or additional costs that may be passed on to consumers;
- We wished to avoid inefficient use of spectrum which may cause additional costs that may be passed on to consumers; and
- We wished to ensure that licensees have some flexibility to change the mix of downlink and uplink traffic in their frame structures.

8.6 We also said it was important to give some certainty on deployment timescales and parameters at the time of the award. This would allow bidders to assess how their plans fit with a proposed synchronisation profile, and allow them to make more informed bidding choices.

8.7 We proposed two possible options that would enable licensees to deploy with the permissive masks and make use of global equipment ecosystems without needing to come to agreements with neighbouring licensees. Both options assume some level of synchronisation:

- Option 1: We mandate traffic frame alignment but not identical frame structure. We permit licensees to use the permissive mask if they are using the specified TD-LTE configuration (or equivalent frame structure) and are compliant with the other parameters in the Inter-Operator Synchronisation Procedure. If they are not using the specified frame structure they must use the restrictive mask. This means that it is possible to have two adjacent licensees operating on different frame structures, one with the permissive mask and one with the restrictive mask.
- Option 2: We mandate identical frame structures. Licensees must use the mandated configuration (or equivalent frame structure) and be compliant with the other parameters in the Inter-Operator Synchronisation Procedure. All licensees can therefore use the permissive mask. This means there is certainty of the frame structure of an adjacent licensee.

8.8 We said that with both options, the details of the required parameters would be determined by Ofcom in an Inter-Operator Synchronisation Procedure through the licence. Under either option, we said there would be some additional flexibility if licensees agreed between themselves and proposed amendments to the procedure.

8.9 In setting out our proposals on synchronisation, we said we needed to determine a particular frame structure that was not a significant compromise for any licensee

⁴⁵ Total Radiated Power (TRP). TRP is a measure of how much power the antenna actually radiates. The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere. EIRP should be used for fixed or installed terminal stations and the TRP should be used for the mobile or nomadic terminal stations.

within the band. We said that whilst licences would be issued on a technology neutral basis, both harmonisation for the bands and discussions with stakeholders suggested TD-LTE was the technology most likely to be deployed. We therefore proposed parameters based on TD-LTE. More specifically, we proposed that TD-LTE configuration 2 (a 3:1 downlink to uplink profile) was the most appropriate arrangement for the anticipated use of the bands, noting that certain frame structures for 802.16e technology should also be compatible.

8.10 We asked the following consultation questions:

Of our two possible options to encourage or mandate synchronisation do you prefer Option 1 or Option 2? Please explain your preference for the option and let us know if you have other comments or suggestions.

Do you agree with our proposed frame structure of LTE configuration 2 or equivalent?

Consultation responses

8.11 We received eight responses to our questions about synchronisation. Of these, two responses were submitted confidentially. Three stakeholders submitted both confidential and non-confidential responses.

Choice between Options 1 and 2

8.12 There was some disagreement between respondents on which option should be adopted. A majority of respondents favoured greater flexibility and this led some of those to favour Option 1. However, some respondents argued strongly in favour of Option 2. A confidential respondent argued for a separate approach to be adopted for the 2.3 and 3.4 GHz spectrum bands.

8.13 BT said it was important that Ofcom supported technological neutrality as required by the EU regulatory framework. In particular, the conditions should include possible supplementary downlink (SDL) mode and future 5G technologies. For that reason it urged Ofcom to review its proposals on mandatory frame synchronisation. Whilst neither of the two options offered by Ofcom was satisfactory to BT, the first option was preferable to the second as it at least gave flexibility to use different frame structures, albeit with the requirement to synchronise the start of each frame.

8.14 A confidential respondent expressed a strong preference for Option 1 i.e. the ability of individual licensees to use a restricted or permissive mask according to compliance with an agreed Inter-Operator Synchronisation Procedure. It said Option 2 was inappropriate because:

- Different licensees will be using the spectrum for different applications. Some may be using the spectrum on a standalone basis, whereas others will be using the spectrum in a carrier aggregation mode with other spectrum holdings. Within that scenario the existing spectrum holdings will be different, according to the licensee. This means that the required uplink/downlink ratio will vary between operators, and use of a common structure – even one agreed as a compromise – could be suboptimal.
- Even within a licensee's own network, different frame structures could be required. For example, the licensee could be using the spectrum purely for

microcells (in which case the spectrum would be used on a standalone basis) or for macrocells too (in which case carrier aggregation would apply).

- Locking down to a fixed frame structure means that future developments such as the use of iMTA⁴⁶ could be precluded.
- The spectrum is likely to be used for both access and backhaul purposes – the required frame structure could vary between these.

8.15 EE said its views were most closely aligned to Option 1 as it supported frame alignment to mitigate inter time slot interference, but not a mandated uplink/downlink ratio. However, it could not support a mixture of restrictive and permissive mask implementation, except in the context of specific neighbour operator agreement. Instead, restrictive mask operation with minimum 5 MHz guard bands should be mandated in the auction as the default implementation standard to prevent excessive interference between neighbouring systems.

8.16 UK Broadband said its strong preference was for Ofcom to avoid mandatory synchronisation between operators. This was because a mandatory regime could restrict operators' ability to adapt to changes in user behaviour, or to innovate with new products or business models. Operators may wish to modify their uplink/downlink ratios as their products and services develop. UK Broadband said operators will inevitably choose to synchronise with their neighbours, where possible, in order to maximise the efficiency of their own spectrum allocations.

8.17 Orange said it had "significant issues" with both options 1 and 2. It recognised that Ofcom had determined that only a TDD band-plan was acceptable for the 3.4GHz band. However, Orange said that an FDD arrangement would overcome all the interference issues that had been highlighted - without the need for synchronisation or the need of guard-bands - and would be more suited for wide-area deployments of LTE-A.

8.18 Huawei took a different view. It said synchronisation among TDD operators was essential for efficient use of the radio spectrum. It therefore concluded that Option 1 could not work in practice. Huawei said the use of a restrictive emission mask by an unsynchronised operator would not mitigate harmful base-to-base interference. On the other hand, Option 2 achieved the right balance of providing immediate certainty and future flexibility when combined with Ofcom's proposed Inter-Operator Synchronisation Procedure.

8.19 H3G agreed that full synchronisation offered higher spectral efficiency and more consistent services. It said interference caused by the adjacent band can be significant unless the frame structure is synchronised. In an un-synchronised network, H3G had concerns regarding the uplink interference from devices in the adjacent band. It expressed agreement with Ofcom's analysis and summary which it said outlined the issues associated with different deployment scenarios.

8.20 However, it encouraged Ofcom to also consider the 2.3 GHz and 3.4 GHz bands as SDL because both bands could be used with the 1.8 GHz and/or 2.1 GHz bands. H3G said it should be possible to have one licensee operating with the preferred TDD configuration and the permissive mask, whilst the neighbour licensee is using the restrictive mask with a different configuration i.e. SDL.

⁴⁶ A protocol which allows for flexible traffic profiles for small cells that differ from those on the macro cell layer.

- 8.21 Another confidential respondent said it may be appropriate to apply different technical licence conditions to the two bands. It said for the 2.3 GHz band, option 2 was best because there was only 40 MHz of spectrum available. Using a 5 MHz guard band under the 'restrictive mask' as required under Option 1 would waste a large proportion of an operator's spectrum. The benefit of removing interference risk under Option 2 outweighed the disadvantage of reduced flexibility. For the 3.4 GHz band, the respondent said Option 1 may be more appropriate, where operators may choose an alternative frame structure under the restrictive mask. In this case, owing to the large quantity of spectrum available in the band, it would be reasonable for an operator to set aside 5 MHz or 10 MHz for guard bands, in order to have free choice of frame structure. For example, an operator might acquire 70 MHz to allow three 20 MHz channels at any frame structure plus a 10 MHz guard band.

Frame structure

- 8.22 There was also some disagreement on the proposed frame structure with some respondents saying a 3:1 frame structure was a suitable default option and others suggesting alternatives.
- 8.23 Of those who did not agree, EE said a mandated frame structure configuration was unduly restrictive and likely to introduce both short term and long term inefficiencies. It did not believe it was possible to set a frame ratio in advance of network implementation - or that changes to any ratio were sufficiently predictable to allow the efficient management of an industry wide Inter-Operator Synchronisation Procedure. It noted traffic ratios⁴⁷ of between 5:1 and 8:1 in some countries.
- 8.24 H3G also said it would prefer a higher downlink to uplink ratio than the 3:1 set out in the consultation document. It said the ratio in its own UK network is 7:1. It urged Ofcom to facilitate open technical discussions on the frame configuration with the spectrum licence holders. BT said it may be best to indicate a range of envisaged uplink/downlink ratios and leave the final decision to be taken by Ofcom after the licensees have been identified and had the possibility to discuss the issue between them.
- 8.25 However, other respondents supported the proposed 3:1 frame structure. A confidential respondent said it recognised that determining a frame structure inevitably meant a compromise. The appropriate compromise was to select a frame structure whereby - in the majority of cases - it was more efficient than having to create guard bands. However, the opt-out of using the restrictive mask should be available, if required. It therefore considered Ofcom's proposed 3:1 ratio was suitable – although it said this should be kept under review, particularly in the light of any future eIMTA deployment⁴⁸. Huawei and a confidential respondent said the configuration was well supported by network vendors, and has been proven in several existing mobile deployments. There were very few operators using other configurations.
- 8.26 UK Broadband said mandating identical frame structures would allow the fastest deployment of networks and time to market and provide the best compromise in downlink/uplink performance. It said the 3:1 frame ratio proposed by Ofcom would best suit the needs of the market. However, it said there could be a third option which

⁴⁷ Traffic ratios relate to throughput on the uplink and downlink and do not directly relate to the frame structure ratios as downlink sub-frames are able to support higher throughputs than an equivalent uplink one.

⁴⁸ An enhanced form of IMTA.

allowed operators to agree a synchronised frame structure. In the event that agreement could not be reached, Ofcom would then impose LTE Configuration 2 (3:1) as the default position.

Our decisions

- 8.27 We have considered carefully the consultation responses submitted by stakeholders in reaching our decisions. We have noted in particular the desire of a number of operators for greater flexibility. The reasons given by stakeholders include the ability to use eIMTA; to select a higher downlink profile or to use the spectrum for SDL; or because they have not yet decided what they might do with the spectrum.
- 8.28 We believe it is often best left to the market to determine the most efficient use of spectrum. We therefore generally support the idea of giving the greatest possible flexibility to operators, subject to international harmonisation and the need to avoid harmful interference between users.
- 8.29 However, we have sought to balance the general principle of flexibility in spectrum allocation alongside our other stated priorities, such as the aim of making the 2.3 and 3.4 GHz bands available for use in as timely a manner as possible. We recognise that TD-LTE is the technology most likely to be deployed in the 2.3 and 3.4 GHz bands – although we note there are other options – and that it is important to give some certainty for those wishing to deploy services relatively quickly. Our proposals were aimed at enabling potential bidders to assess how their plans might fit with synchronisation and a proposed frame structure, allowing them to make more informed bidding choices in the auction.
- 8.30 We have also considered further the two options set out in our consultation. Our proposed Option 1 offers the benefits of greater flexibility over Option 2 but at an increased risk of interference. Both options assume some level of synchronisation. With Option 1, it is possible to have one licensee operating with the preferred 3:1 configuration and the permissive mask, whilst the neighbour licensee is using the restrictive mask with a different configuration. In this situation the first licensee would still be considered as ‘synchronised’.
- 8.31 With both options, the details of the required parameters will be provided by Ofcom under the licence by specifying an Inter-Operator Synchronisation Procedure that will be sufficient to enable licensees to deploy immediately after the award should they wish. There is future flexibility if licensees propose and agree amendments to this procedure. In certain circumstances there can be temporary bilateral/multilateral agreements between the licensees in the band.
- 8.32 We have considered further the alternative uses of the spectrum – most notably small cell deployments and SDL. SDL is not currently a TD-LTE frame structure. However, we note that there is an ongoing 3GPP study item “*Study on possible additional configuration for LTE TDD*”⁴⁹. This study will evaluate coexistence issues, benefits and drawbacks, related to the potential introduction of SDL as an additional configuration for LTE TDD⁵⁰: This study item will be completed in September 2015 and at best, SDL could be incorporated in 3GPP Release 13 in March 2016, although this is still uncertain.

⁴⁹ <http://www.3gpp.org/dynareport/36825.htm>

⁵⁰ 10:0:0 and 9:1:0 (DL:Sp:UL)

- 8.33 We note that an SDL only configuration, as a preferred synchronisation profile, could prevent smaller players or new entrants from bidding in the auction. We have therefore decided to exclude use of SDL at this stage. Post award, if standards exist and all licensees within a band agree, then SDL could be permitted via an update to the Inter-Operator Synchronisation Procedure.
- 8.34 Should we decide to withhold some spectrum from the award for the reasons contemplated in section 3, we recognise that this may add a further consideration to the Inter-Operator Synchronisation Procedure. We will need to ensure that any proposed changes by licensees within the first phase of the spectrum award are unlikely to cause significant limitations for possible future licensees in the second phase. We will provide further details on how this will be managed when we reach a decision on withholding spectrum.

2.3 GHz spectrum band

- 8.35 On balance, we have concluded that Option 2 is the most appropriate approach for the award of the 2.3 GHz spectrum. Although this decision allows for less flexibility, we believe mandatory synchronisation and frame structure represents the most efficient arrangement for what we believe is the likely outcome of the auction in terms of spectrum use. It is therefore both practical and pragmatic. It allows the maximum use of the available spectrum with the minimum risk of interference.
- 8.36 In reaching our conclusions, we have noted the distinctive characteristics of the 2.3 GHz band compared to the 3.4 GHz band. In particular, we note there is only 40 MHz of spectrum available in the 2.3 GHz band. We also note the greater volume of equipment already available for use in the 2.3 GHz band compared to the 3.4 GHz band.
- 8.37 Our engagement with stakeholders continues to suggest the 2.3 GHz band is very likely to be used for radio access networks using LTE, and that spectrum blocks of at least 20 MHz will be sought by potential bidders (or, at least, multiples of 10 MHz). This makes it likely that the spectrum will be acquired by one or two bidders. The early availability of equipment means it is likely the 2.3 GHz band will be of greater immediate value for increasing LTE mobile broadband capacity than the 3.4 GHz band. New services could be rolled out quickly if there was certainty that neighbouring users would be operating similar services, appropriately synchronised and with compatible frame structures.
- 8.38 If one of a small number of operators in the band wished to use the 2.3 GHz spectrum in a different way, Option 2 offers an equal starting point for negotiations – but the default position will remain if there is no agreement to change it.
- 8.39 For the reasons set out above, we have decided to adopt Option 2 for the 2.3 GHz spectrum.

Frame structure option for 2.3 GHz band

- 8.40 We note the general agreement that a 3:1 frame structure was the most appropriate for this award – even among those respondents who argued for the greater flexibility of Option 1 (or for no synchronisation requirement at all). However, EE and H3G argued that different frame structures were likely to prevail – and some respondents favoured use of the spectrum for SDL.

8.41 For the reasons set out in our November 2014 consultation and above, we have decided to proceed with our proposal to adopt the frame structure consistent with LTE configuration 2 (a 3:1 downlink to uplink ratio). We consider that with full licensee agreement that this ratio could be changed in the future and would only necessitate a software configuration change on the deployed networks.

3.4 GHz spectrum band

8.42 On balance, we have concluded that a different approach is more appropriate for the 3.4 GHz band, and that we should adopt Option 1 for this band.

8.43 As noted above, there is considerably more spectrum available in the 3.4 GHz band and less equipment on the market for immediate use. Although UK Broadband is already delivering a commercial service as a fixed broadband substitute in the 3.4 GHz band today, the band is not yet widely supported by handsets. This means alternative uses of the band – or newer technologies – may become more valuable uses for the frequencies over time. For these reasons, we have concluded that whilst we consider that this band should be synchronised, there is more desire to allow greater flexibility and more scope to avoid the same risk of interference to LTE services – whilst still recognising that expanding TD-LTE capacity remains a very likely use of the spectrum.

8.44 In reaching this decision, we have taken account of the views of those stakeholders who objected in principle to the idea of mandatory outcomes. As stated above, our general preference is for the market to decide the most efficient use of spectrum and for us to allow the greatest flexibility possible. Where we limit flexibility – such as in the 2.3 GHz spectrum – there are clear, practical reasons.

8.45 Our engagement with stakeholders suggests the band could be used for a mixture of radio access including small cells, backhaul, SDL, and possibly for future 5G technologies. We note that a licensee may get capacity improvements by changing the traffic configuration (frame structure) on small cells, whereas macro cells may typically be synchronised within an operator's network to avoid self-interference.

8.46 We noted the interference risk for adjacent licensees using different masks (annex 10 of the November 2014 consultation)⁵¹. We believe that the most significant form of this interference is base station to base station interference⁵² as a result of the uplink signal at one licensee's base station being interfered with by the downlink signal from a base station in adjacent spectrum (although this can be possible for more than just the immediately adjacent licensee).

8.47 When licensees are using the permissive mask, there is potential for interference from the high power transmissions in neighbouring spectrum to occur over several kilometres. However, this risk varies significantly depending on a number of assumptions, including the performance of the base station receivers and the number of differences in the traffic frames used by the licensees.

8.48 We noted Huawei's strong views against Option 1 suggesting that synchronised use was a key enabler and that unsynchronised use might lead to higher costs imposed on some operators. We believe that Option 1 partially mitigates this risk by requiring

⁵¹ http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/summary/2_3_and_3_4_GHz_award.pdf

⁵² Mobile to mobile and mobile to base station interference are also possible in certain scenarios although we believe these mechanism are less likely.

frame alignment. Frame alignment results in at least one of each Downlink, Uplink and Special sub-frame (D, U and S slots) within a frame always aligning, which we believe should reduce the risk of interference as there are always some timeslots that will align. This also means that the initial use of SDL is excluded, even if using the restrictive mask as it may still reduce the capacity on the uplink and downlink of an adjacent licensee who does not have the ability to use SDL, such as a player with access to limited spectrum bands or a new entrant. A licensee using the restrictive mask of Option 1 will in practice have to move its in-block carrier away from the edge of its assigned spectrum to ensure emissions are below the restrictive baseline level. If a neighbouring licensee prefers a greater level of protection then they are also free to use some of their spectrum for additional internal guard bands and/or use the restrictive mask under all circumstances, irrespective of their frame structure.

- 8.49 Although there may be some uncertainty over the interference environment that may pertain under Option 1, with 150 MHz of spectrum available there are options for a bidder to acquire additional spectrum to use if it chooses to minimise the risk further.
- 8.50 For the reasons set out above, we have decided to adopt Option 1 for the 3.4 GHz spectrum.

Frame structure options for 3.4 GHz band

- 8.51 Due to the general support for frame structure with a 3:1 ratio, as proposed in the November 2014 consultation, we are also specifying that this is the 'preferred frame structure' that will permit use of the permissive mask.
- 8.52 Due to the low latency requirements being discussed for future services, we believe that 5G may have smaller sub-frames. However, at the moment 5G is not defined. We also note that evolutions of technologies may need to be compatible with LTE. Therefore we expect future technologies may also be compatible with the sub-frame structure available today for TD-LTE and therefore may not be precluded by our frame alignment approach. With appropriate agreement, changes could be made to the Inter-Operator Synchronisation Procedure in the future to accommodate technology developments wherever possible.

Synchronisation for indoor small cells

- 8.53 The November 2014 consultation assessed the risk of interference between spectrum users in a range of circumstances. This included small cell to small cell interference in a domestic environment, and small cell to macro cell in other environments.
- 8.54 In light of our analysis, we proposed that small cells using an EIRP of less than or equal to 24 dBm per carrier would not need to be synchronised. We posed the following consultation question:

Do you agree with our proposal that indoor small cells, with power levels up to 24 dBm EIRP, do not need to synchronise?

Consultation responses

- 8.55 There was wide general agreement with the principle that it was not necessary to synchronise indoor small cells, although there was some uncertainty about how 'indoor' should be defined.

- 8.56 Only Huawei expressed disagreement with the principle behind our proposals. It said it could foresee scenarios where multiple operators will deploy small TDD cells within the same building, and this will result in high levels of mutual base-to-base and terminal-to-terminal harmful interference due to a lack of synchronisation. Furthermore, a protection distance of 100-300 metres between an indoor femto base station and an outdoor macro base station for the mitigation of base-to-base interference was large - and would be even greater when aggregation of harmful interference from multiple femto cells is taken into account. Huawei therefore believed that synchronisation should be mandated for all cells, irrespective of their dimension.
- 8.57 In contrast, BT said it agreed with the proposal and said Ofcom should look into whether it could be extended to also apply to outdoor small cells. It said this would be logical because the unsynchronised indoor cells could have outdoor mobiles, and these would have a similar potential to interfere with adjacent TDD systems as an unsynchronised outdoor base station of the same maximum power as a mobile.
- 8.58 A confidential respondent said it agreed with the principle of the proposal but further clarification was required. There was a need to consider whether 'indoor' should be considered analogous to domestic usage, or whether a more liberal interpretation that incorporated shopping centres, sports stadiums and stations should be employed. The respondent agreed there was little scope for interference in a domestic environment, but was less comfortable about the prospect for interference with macro-cells in a quasi-indoor scenario. It would be prudent to adopt a conservative definition for now with a view to adopting a subsequent liberalisation if appropriate.
- 8.59 Another confidential respondent supported the idea that indoor small cells should be exempt from synchronisation requirements, in the case of a single-operator deployment. There was a limited risk of interference with macro networks, combined with the technical challenge of supplying phase synchronisation to an indoor small cell, it said. However, there was a significant risk of interference between co-located small cell deployments from different operators using the same band. The respondent therefore suggested that a coordination procedure for small cell deployments may be appropriate, that would support operators' efforts to coordinate and avoid interference. This procedure could include a 'fall-back' frame structure (and associated conditions) that should be used if co-located operators are unable to come to an alternative coordination agreement.
- 8.60 EE, H3G and UK Broadband agreed that indoor small cells with power levels up to 24dBm do not require inter operator synchronisation. EE also suggested that the permissive mask should be permitted for such systems.

Our decisions

- 8.61 We have concluded that small cells of up to and including 24 dBm per 20 MHz carrier may use the permissive mask and will not be required to synchronise provided that these small cells are in domestic indoor locations, or other indoor locations where harmful interference is not caused to another licensee.
- 8.62 To date, base stations are typically synchronised using the clock signal from GPS satellite reception. For indoor deployments achieving a timing reference is more challenging. Although there are some techniques for distributing timing signals over the backhaul network, these are not currently sufficient for all types of domestic broadband connections.

8.63 We recognise there were mixed views from respondents on whether flexibility should also be extended to outdoor small cells and indoor multi-operator environments e.g. shopping centres, sport stadiums and train stations. Unsynchronised, there remains some risk of desensitising macro cells if they are located particularly close to an indoor or outdoor small cell (e.g. within approximately 100 – 325m):

- **Outdoor small cells** will typically have no difficulty in receiving GPS satellite reception. We believe that the requirement for outdoor small cells to comply with the required frame alignment and frames structure should not be a barrier for early deployments. Therefore for these two reasons we have decided that we should maintain the requirement for outdoor small cells to comply with the parameters in the Inter-Operator Synchronisation Procedure.
- With **indoor small cells** in non-domestic environments, we want to minimise barriers to early deployments wherever possible. We recognise that there is both limited risk of interference and potentially some additional challenges to synchronise indoors (depending on the backhaul technology used), although these may not be as significant as for domestic cases. We will therefore permit those cells to operate without synchronisation initially. However, if other licensees deploy within the same indoor environment and demonstrate they are suffering harmful interference we would expect licensees to co-operate with one another. Ultimately they must comply with the parameters in the Inter-Operator Synchronisation Procedure (including synchronisation where appropriate) within a reasonable timeframe if other solutions cannot be found by the licensees.

8.64 We believe that this approach provides licensees with the greatest flexibility to synchronise on deployment; to coordinate with other licensees in non-domestic indoor environments; or to synchronise later should that be necessary.

8.65 Our position is summarised in Figure 8.3

Figure 8.3: Synchronisation exemptions for small cells, a base station using an EIRP up to 24dBm⁵³ with the use of power control; also referred to as a femto cell

Environment	Decision
Indoor domestic	Small cell base stations will be exempted from the agreed requirements to align the frame and use any specified or preferred frame structure. In all cases the small cell may use the permissive mask.
Other indoor locations	Initially, small cell base stations in any indoor location will be exempted from the agreed requirements to align the frame and use any specified or preferred frame structure. In all cases the small cell may use the permissive mask. However, if another licensee within the same non-domestic environment demonstrates that they are suffering harmful interference as a result then the indoor small cells must comply with the requirements in the Inter-Operator Synchronisation Procedure within a reasonable timeframe if other solutions cannot be found by the licensees.
Outdoor	All outdoor small cells irrespective of power level will be required to comply with the frame alignment and frame structure requirements for the use of either the permissive or restrictive mask, as set out in the Inter-Operator Synchronisation Procedure

⁵³ This is a very similar power as proposed UE's, 25 dBm, and is a lower power than fixed UE's we are proposing for the 3.4 GHz band.

- 8.66 We note that our approach may initially constrain developments such as eIMTA, within Release 12 of the 3GPP standard for LTE which enables small cells (at least pico or femto cells) to change UL/DL configuration to adapt to the current traffic needs in the network without the need to change block edge masks..
- 8.67 Our intention is not to exclude technology developments such as eIMTA for small cells in the longer term. However we expect that licensees are best placed to determine the exact details of the required coordination and we believe that our approach does not constrain the early deployment of small cells. Any agreed coordination processes can be accommodated within an update to the Inter-Operator Synchronisation Procedure.

Inter-Operator Synchronisation Procedure

- 8.68 In the November 2014 consultation, we proposed to impose an Inter-Operator Synchronisation Procedure for licensees. This would specify when a licensee may use the permissive mask. We said that ECC Report 216⁵⁴ had stated that agreement needed to be reached between neighbouring operators on the following issues in order to deploy synchronised TDD mobile networks in a multi-operator context (without guard bands):
- A common phase clock reference (e.g. UTC⁵⁵) and accuracy/performance constraints;
 - A compatible frame structure (including TDD UL/DL ratio) in order to avoid uplink/downlink transmissions overlapping;
 - A commitment not to interfere with each other, for example, defining a timescale for the reliability of the reference clock to be realigned and/or defining a procedure to regain alignment with the reference clock.
 - The terms and conditions where cross-operator synchronisation must apply and/or may not be required (e.g. geographical areas, isolated base stations/deployments etc.);
 - How to update those parameters.
- 8.69 We proposed that the 2.3 and 3.4 GHz licences should require compliance with an Inter-Operator Synchronisation Procedure and that they should specify the conditions for frame alignment under which the permissive mask may be used. In order to provide certainty to bidders at the time of the award, we proposed that an initial version of this procedure would form part of an Information Memorandum to be published subsequently, and would thereafter be issued with the licences.
- 8.70 We proposed a separate procedure should be issued for each band, as the licensees will likely be different, and those procedures can therefore be developed separately

⁵⁴ ECC Report 216, "Practical guidance for TDD synchronisation.", <http://www.erodocdb.dk/doks/doccategoryecc.aspx?doccatid=4>

⁵⁵ Co-ordinated Universal Time

over time as necessary. We also proposed the details of the key criteria that needed to be within the Inter-Operator Synchronisation Procedure⁵⁶.

8.71 We asked the following consultation questions:

Do you agree with our approach in the Inter-Operator Synchronisation Procedure?

Do the parameters to be provided in the Inter-Operator Synchronisation Procedure give you sufficient certainty at the time of the award for your future deployments? If not can you provide further information on what extra detail information would need to be covered?

Would any of the potential changes to the procedure that we have considered made within the first 12 months following the award have a significant impact to a network that has been deployed in the interim? If so please explain any concerns.

Consultation responses

8.72 Almost all consultation responses expressed broad agreement with our proposals to use Inter-Operator Synchronisation Procedures to set out when the permissive mask can - and when the restrictive mask should - be used, and to describe the detailed technical parameters, with many offering no detailed comments on those parameters.

8.73 However, Orange said the procedure should be seen as a guideline for mutual agreement, not as a mandated licence condition. EE restated its opposition to any mandated synchronisation (see above). A confidential respondent said the synchronisation procedure was not required where a restrictive mask was used.

8.74 Some stakeholders said it may be important for them to reach separate bi-lateral agreements with adjacent licensees in certain circumstances. These could raise issues of commercial confidentiality and should not be openly disclosed. A confidential respondent said changes in consumer behaviour, technology or market structure may mean the conditions appropriate today may be inappropriate in the future. It strongly supported the need to allow bi-lateral or multi-lateral agreements that allow operators to use a different frame structure.

Our decision

8.75 We note that virtually all consultation respondents agreed with our proposal. Having considered all views, we have decided to proceed with mandating the procedure, one for each band.

8.76 In order to allow use of the spectrum in a timely manner and give certainty to bidders, we believe that we should mandate the Inter-Operator Synchronisation Procedure rather than use it, as Orange suggested, as a guideline only.

8.77 We note the confidential request for private bi-lateral agreements. However we do not favour these as it creates uncertainty around the technical conditions used in the market, and the consequences for the risk of interference to other operators. We are happy to update the Inter-Operator Synchronisation Procedure to capture revisions,

⁵⁶ Page 108, Figure 13, http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/summary/2_3_and_3_4_GHz_award.pdf

including adding details that relate to specific neighbours at their spectrum boundary, allowing individual arrangements to be captured⁵⁷. However, we do not believe that sufficient evidence of the harm of these arrangements being in the public domain has been provided for us to change our proposed approach to using the Inter-Operator Synchronisation Procedure.

- 8.78 We recognise that for specific short term events up to a maximum of three months, it might not be appropriate to revise the Inter-Operator Synchronisation Procedure every time, and it may not be necessary for Ofcom to be aware of these. However, longer term agreements must be captured in the Inter-Operator Synchronisation Procedure. Licensees must not cause harmful interference to other licensees (or neighbouring spectrum users) that are not part of any temporary agreement. In the case of a dispute, Ofcom may request copies of any temporary agreements that are in force between licensees. However we reserve the right to consider the current version of the Inter-Operator Synchronisation Procedure will take precedence.

Technical parameters

- 8.79 Huawei and a confidential respondent queried the clock accuracy requirement of +/- 3 μ s. Huawei said TD-LTE allows for a worst case timing error of 3 μ s between two adjacent channel base stations. For this reason, the synchronization requirement should specify a timing accuracy of ± 1.5 μ s with respect to a common clock reference, thereby dividing the burden of timing equally between two licensees. The confidential respondent said the requirement was not in alignment with the 3GPP specifications for macro cells which states +/- 10 μ s. Although many cells will have a radius of less than 3 km - hence falling into the definition of the tighter specification - it is prescriptive to place this requirement on all cells.

Our decision

- 8.80 With the exception of the comments above about clock accuracy, we received few comments on the other technical parameters. We have therefore decided to proceed with those proposals as broadly set out in the December 2014 consultation. We note however that while we believe that such parameters are appropriate, we believe it is not necessary to specify this detail in the Inter-Operator Synchronisation Procedure. This is because: a) we consider that these parameters may be vendor specific in some circumstances and b) we do not believe that the absence of these parameters from the Inter-Operator Synchronisation Procedure will constrain the ability of a licensee to deploy systems.
- 8.81 In respect to the clock accuracy we have contacted two equipment manufacturers who have clarified that equipment is readily available to achieve a timing accuracy of ± 1.5 micro seconds and is the normal level used in deployments. It has been highlighted to us that equipment will most likely still work with a 10 micro seconds accuracy – however, potentially, with a reduced throughput and reduced cell size. ECC Report 216 also provides the values ± 1.5 micro seconds in their example. Therefore we believe that it is an appropriate value to use. However, as indicated above, this is not captured in the Inter-Operator Synchronisation Procedure.

Changes to the procedure

- 8.82 BT said flexibility to update the synchronisation procedure in light of developments

⁵⁷ We note that if so, we will consider whether to bring the Inter-Operator Synchronisation Procedure, which is currently Schedule 2 of the licence, outside the licence.

was an important element. However, it was not clear to BT which elements of the procedure Ofcom considers are the ones subject to potential change and which are not.

- 8.83 Huawei said administrative mechanisms needed to be put into place by Ofcom to allow various details of the procedure to be modified in an efficient and timely manner following the award, where those modifications are agreed by the licensees. It said the impacts of any modifications are likely to be more severe in the context of femto cell base stations because they were in the possession of consumers and are also more cost-sensitive. If low power base stations are not required to synchronise, and subsequently it is found that synchronisation is an essential requirement, the retrofitting of large numbers of femto cells with synchronisation technologies would be costly and/or prohibitive.
- 8.84 Huawei also noted that it could be possible that consensus on changes is not achieved and that it might be beneficial for Ofcom to have the ability to intervene as a last resort and mandate a change in order to prevent a licensee frivolously blocking a change desired by all other parties.
- 8.85 EE noted Ofcom's proposals in relation to periodic review of frame ratio, but believed such arrangements will inherently default towards medium or lowest common denominator frame ratios, and thus prove continuously inefficient and stifling of service innovation. EE said our proposals would potentially have a dampening effect on operator rollout plans. In the presence of potential changes to procedure, operators would likely proceed only as far as initial investment in trial or experimental networks and await the outcome of any review. Major investment in network infrastructure requires certainty (including in relation to preferred service offering and its associated symmetry) and a stable regulatory environment.
- 8.86 The IET proposed that there ought to be a 3.4 GHz Special Interest Group set-up to also manage future changes by mutual consent between 3.4 GHz licensees. The IET recommends that a framework be created to consider future cooperation so making it more straightforward for the spectrum holders to evaluate opportunities for cooperation and then rapidly implement them.

Our decisions

- 8.87 As set out above, compliance with the Inter-Operator Synchronisation Procedure is a condition of the licence, and the procedure itself is part of the licence as schedule 2. As such, the provisions of the WTA relating to licence variations apply.
- 8.88 However, as set out above, we recognise that the Inter-Operator Synchronisation Procedure may need to change and evolve over time and that licensees have an important role to play. Licensees are therefore free to discuss and agree alternative arrangements (via special interest group or otherwise). Where licensees agree alternative arrangements, they should bring the agreement to Ofcom for consideration. If Ofcom agrees to the changes, we would vary all the licences. We would currently expect to agree to a variation if all operators agreed and if there were not interference effects for third parties (and if it complied with any applicable EU or international rules).
- 8.89 If agreement cannot be reached, Ofcom may consider any proposals brought to us and take a decision on whether the Inter-Operator Synchronisation Procedure should be changed, where appropriate after further consultation. Ofcom may also review the procedure of its own initiative, for spectrum management purposes.

8.90 We recognise that if any changes require alterations to the configuration - or in the unlikely event hardware - of deployed networks, a reasonable time should be allowed for a licensee to make the changes. We therefore do not envisage that changes to the procedure will adversely affect deployments already made and are more likely to become more permissive or change parameters that are software configurable.

8.91 The key parameters for synchronisation are provided in Figure 8.4

Figure 8.4: Key criteria for synchronisation procedure

Criteria	Our Decision
A common phase clock reference	An agreed common clock reference for the start of the frame to be aligned with UTC (Co-ordinated Universal Time).
A compatible frame structure for use of the permissive mask	TD-LTE configuration 2 (also referred as 3:1) or an equivalent ⁵⁸ frame structure if a different technology is used.
A compatible guard period	Special sub-frame configuration 6 (also referred as 9:3:2) or an equivalent guard period if a different technology is used.
Frame alignment for the restrictive mask	Transmissions must comply with the defined frame structure for the first three sub-frames. Where the transmission in a timeslot is not defined then the licensee may choose whether transmissions are in the Downlink or Uplink direction.
Accuracy/performance constraints	There should be alignment to the reference clock with an accuracy of +/- 1.5 μ s.
A commitment not to interfere with each other e.g. timescales for the realignment of the reference clock.	Unless agreed otherwise, timing misalignments by more than 1.5 μ s from that reference clock must be rectified within 24 hours of an issue being identified.
The terms & conditions where cross-operator synchronisation may not apply/be required	The Inter-Operator Synchronisation Procedure is required for all types of deployments. There are exceptions for certain parameters for indoor small cells using an EIRP less than or equal to 24 dBm per carrier. (See paragraphs 8.61 to 8.66 for further information.)
How to update the Inter-Operator Synchronisation Procedure	Licensees to request any proposed changes to Ofcom. Ofcom to update Inter-Operator Synchronisation Procedure once agreement is reached and to send updates to all relevant licensees. .

Power limits

8.92 The power limits to be included in the licences were originally proposed in our earlier February 2014 consultation. In setting out the additional proposals within the November 2014 consultation, we considered in detail the submissions we received from stakeholders in response to the February 2014 document. As a result, we were able to confirm our position on maximum in band power limits for base stations and

⁵⁸ An equivalent frame structure is when downlink and uplink sub-frames are aligned and transmitted at the same time. The specified frame structure and guard period requirements should entail that there are no overlaps if either TD-LTE or WiMAX technologies are used.

for user terminals in both bands. However, in light of responses, we said we were working with the MOD to see if more relaxed out of block power limits could be used in practice below 2340 MHz, and below 3400 MHz, whilst still ensuring there is adequate protection of MOD systems.

- 8.93 The proposals set out in the November 2014 consultation also set out our views on a number of additional issues, as described below.

Femto cells

- 8.94 The November 2014 consultation noted a European Commission Decision for the 3.4 GHz band that requires femto cells to use power control. The decision was also provided for in the ECC Decision for the 2.3 GHz band. We therefore proposed that this should be incorporated within our licence for both bands.

Power limits above 2403 MHz

- 8.95 The November 2014 consultation noted that ECC Decision (14)02 had been finalised with new out-of-band limits to protect systems above 2400 MHz. We therefore proposed to apply this limit to our licenses within the 2.3 GHz band in line with the ECC Decision.

Out of block levels above 3605 MHz

- 8.96 The November 2014 consultation noted that the licence conditions in place for UK Broadband spectrum above 3605 MHz are not the same as those we proposed for the 3.4 GHz band award (including UK Broadband's spectrum at 3480-3500 and 3580–3600 MHz). We proposed that the restrictive baseline level should apply to the spectrum above 3605 MHz. However, should UK Broadband agree to use the frame structure set out in the Inter-Operator Synchronisation Procedure in its 3605–3689 MHz spectrum, then the permissive baseline may apply.

- 8.97 We asked the following consultation questions:

Do you agree with our approach for power control for femto cells?

Do you agree with our position to adopt the new power limits above 2403 MHz?

Do you agree with our position with regard to the out of block levels applicable in UK Broadband's spectrum holding of 3605 – 3689 MHz?

Do you have any other comments on the proposed technical licence conditions and the draft licences attached at annexes 8 and 9 [of the November 2014 consultation]?

Consultation responses

- 8.98 Our proposals on power limits were broadly accepted by most stakeholders who responded to the consultation. Many offered no particular comments on the proposals. We do not identify where respondents agreed with our proposals or made no comment. The paragraphs below identify only where specific additional comment was made.

Femto cells

- 8.99 BT said it did not consider that downlink power control was important in femto cell deployments in the 2.3 GHz and 3.4 GHz bands in order to limit interference between cell coverage areas, or to limit interference levels to other systems operating in adjacent channels. However, it noted that the ECC Decision for the 2300-2400 MHz band requires femto cells to use power control - and that the EC Decision for the 3400-3800 MHz band mentions a minimum ATPC (i.e. power control) requirement. BT said we should not specify the algorithms involved.
- 8.100 Orange said it agreed that power control for femto cells could be helpful in reducing interference from equipment that may be deployed by consumers, and so not coordinated with surrounding networks. However, Orange did not agree that this condition should be part of the licence conditions as it is out of the mobile operator's control. It instead should be included in the harmonised standard.
- 8.101 Three agreed that a power control policy should be implemented in femto cells but said that any algorithm(s) mandated should be backed up by evidence which demonstrates its ability to improve the customer experience.

Our decision

- 8.102 We note the consultation responses outlined above – and that most respondents either expressed support for our proposals or offered no comments. Having taken account of all the views, we have decided to proceed with our proposal requiring femto cells to operate under power control.
- 8.103 We wish to clarify that we are not specifying the algorithms used for the power control of femto cells.

Power limits above 2403 MHz

- 8.104 BT said it considered that protection of Wi-Fi was an important consideration and it supported any necessary power limits above 2403 MHz that were intended to address the issue of out-of-band interference from LTE base stations in to Wi-Fi. BT was concerned about the potential impact on some consumers (please see section 6).
- 8.105 Orange said it understood that the new power limits above 2403 MHz were being proposed to protect the ISM band above 2400 MHz, but this requirement may only be needed for femto cells. Only the home base station out-of-band emissions level defined in the harmonised standard can meet this new power limit requirement, and it is not certain that the wide area base station and local area base station limit defined in the harmonised standard can meet the limits.

Our decision

- 8.106 We have decided that we should adopt new power limits above 2403 MHz in line with the ECC decision and that we should impose restrictions above 3605 MHz in order to protect UK Broadband, as set out in our proposals.
- 8.107 All the required power levels are summarised in Figure 8.1

Additional matters

- 8.108 H3G suggested that Ofcom should consider varying the maximum permissible transmit power of the 2.3 GHz band to be at least 65 dBm/5 MHz to facilitate SDL deployment of the 2.3 GHz (and/or 3.4 GHz band) with 1800 MHz and/or 2100 MHz. This would also be consistent with the maximum permissible transmit power for the 3.4 GHz band, which is currently proposed in the draft 3.4 GHz licence.
- 8.109 For the 2.3 GHz band, we do not believe that a higher level would sufficiently mitigate the risk of interference to MOD, other Government uses and licence exempt systems (in particular outdoor Wi-Fi) in adjacent spectrum. Therefore we remain of the view that the in-block powers that we consulted on should not be increased.
- 8.110 Huawei identified a number of technical clauses in the draft licence which it said should be clarified. These related to clarifying if power levels were per cell or per antenna. We have considered all the points raised by Huawei. These related to the in block powers and elements of the block edge and band edge masks set out in Section 9 and the annexes to our November 2014 consultation.
- 8.111 As highlighted in our November 2014 consultation, discussions with the MOD on amendments to the block edge masks to protect their systems were ongoing. We are pleased to clarify that we have been able to increase the level for emissions below 2340 MHz for cells with in block power up to and including 35dBm. We have also increased the emission levels permissible below 3400 MHz for all cell types.
- 8.112 These changes are detailed in Figure 8.1 at the start of this section and in the relevant technical conditions in the licence (annexes 6 and 7) where we believe this is necessary.

Annex 1

Responding to this consultation

How to respond

- A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on Friday 26 June 2015**.
- A1.2 Ofcom strongly prefers to receive responses using the online web form at <http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz-auction-design/statement-further-consultation/>, as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.
- A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email Pssr.award@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.
- A1.4 Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

John Glover
Floor 3
Spectrum Policy Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

- A1.5 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at the end of section 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

- A1.6 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact John Glover on 020 7981 3878 or Keith Gibbins on 020 7981 3742.

Confidentiality

- A1.7 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether

all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

- A1.8 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.
- A1.9 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at <http://www.ofcom.org.uk/terms-of-use/>
- A1.10 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: <http://www.ofcom.org.uk/email-updates/>

Ofcom's consultation processes

- A1.11 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in annex 2.
- A1.12 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.
- A1.13 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email: Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

- A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.
- A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.
- A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.
- A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at <http://stakeholders.ofcom.org.uk/consultations/consultation-response-coversheet/>.
- A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing	<input type="checkbox"/>	Name/contact details/job title	<input type="checkbox"/>
Whole response	<input type="checkbox"/>	Organisation	<input type="checkbox"/>
Part of the response	<input type="checkbox"/>	If there is no separate annex, which parts?	

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here.

Name

Signed (if hard copy)

Annex 4

Auction design

- A4.1 The responses we received to our proposals on auction design are summarised in section 4 of this document, together with our final decisions. This annex sets out more fully the content of those responses, and our detailed consideration of the points raised by particular stakeholders. It concentrates on the submissions about the principal stage of our proposed SMRA auction format.
- A4.2 Some paragraphs from section 4 are repeated or summarised in this annex in order to provide context.

Spectrum packaging and stages of the auction

- A4.3 Our November 2014 consultation set out proposals for a single auction of both the 2.3 and 3.4 GHz bands. We said that whilst lots in the 2.3 and 3.4 GHz bands are not likely to be seen by bidders as perfect substitutes, they were to some extent substitutable at some prices. Holding a combined auction therefore made sense from a bidder's point of view. It would also be administratively convenient and cost-effective to have an auction of both bands at the same time.
- A4.4 We proposed that frequencies in the 2.3 GHz and 3.4 GHz spectrum bands should be auctioned in lot sizes of 5 MHz. We said the different characteristics of the 2.3 and the 3.4 GHz band warranted a different category in the auction. We therefore proposed there should be one category of 2.3 GHz lots and one category of 3.4 GHz lots. While there may also be some value differences *within* the bands, we said these could be addressed through the assignment stage of the auction.
- A4.5 We proposed an overall auction process as follows:
- Interested persons would be required to **apply** for the grant of a licence;
 - Applicants would need to **qualify** to participate in the award process. An applicant may be disqualified where Ofcom determines that it is not fit to hold a licence. Applicants may also be disqualified in connection with bidder groups;
 - The first stage of the auction is the **principal stage**, consisting of a number of rounds. The principal stage results in the determination of the winning principal stage bids and the **base price** for each winning principal stage bid. At this stage, lots within each category are considered to be generic and so bidders do not bid for specific frequencies;
 - The second stage of the auction is the **assignment stage**, whereby actual frequencies are assigned to the winning bidders from the principal stage. The assignment stage allows bidders to express a preference for a particular part of the band. For the 2.3 GHz band we will only consider assignments in contiguous blocks. We will also consider only assignments of contiguous blocks in the 3.4 GHz band if UK Broadband participates in the auction (see section 5). If UK Broadband does *not* participate in the auction, in most circumstances bidders will be able to express a preference for a contiguous assignment. The assignment stage results in the determination of the

winning assignment stage bids and the **additional price** for each winning assignment stage bid;

- The final stage is the **grant stage**, whereby Ofcom grants the licence to the winning bidder(s). The initial licence fee payable by a winning bidder is equal to the total of the base price and the additional price for each winning assignment stage bid.

A4.6 We asked two questions on these points in the 2014 consultation:

*Do you agree with our proposals for categories and lot sizes in the auction?
If you disagree please provide evidence for your position.*

Do you have any other comments or views relating to the overview of the spectrum?

Consultation responses

- A4.7 Only one respondent suggested a different approach to our overall award process. The Institution of Engineering and Technology (IET) urged us to treat the 2.3 and 3.4 GHz awards differently. It said the planning assumptions around the 2.3 GHz band were firm already, and the release of the band for LTE was timely. However, determining the best use of the 3.4 GHz band was not so certain. The IET therefore proposed the establishment of a 3.4 GHz Spectrum Interest Group to manage future potential changes of use in the 3.4 GHz spectrum through mutual consent.
- A4.8 No other respondent challenged our proposal for a combined award of the 2.3 and 3.4 GHz bands. Nor was there any challenge to our proposal that there should be two categories - one for each band – or that lots within the two bands should be generic in the principal stage. All of those respondents who commented on the overall award process, apart from the IET, supported our proposals.
- A4.9 H3G (Three) agreed with our proposals for 5 GHz lot sizes for the 2.3 GHz band, but said that 10 MHz lots should be considered for the 3.4 GHz spectrum because there was much more spectrum available in that band. It was likely that an operator would only be interested in acquiring larger lots (e.g. multiples of 10 MHz) because of the disproportionate cost of deploying in smaller blocks.
- A4.10 BT and Angie suggested that 10 MHz blocks were more appropriate for both bands. BT said the use of 10 MHz blocks would simplify the award process by reducing the opportunity for strategic bidding on combinations unlikely to be required. This could be a particular issue for the 2.3 GHz spectrum.
- A4.11 A confidential respondent agreed in principle with our proposals for categories and lot sizes, but believed 10 MHz might be preferable.
- A4.12 Orange also supported the idea of larger lot sizes. In its consultation response, the company said 5 MHz allocations could lead to inefficient use of the spectrum if operators do not wish to use the defined timeslot/frame configuration. In those circumstances, there was a risk that a significant portion of the available spectrum would need to be used for guard bands. This represented inefficient use of the spectrum.
- A4.13 Huawei went further, and suggested that lots of 40 MHz were much more useful for IMT deployments than smaller lots. Huawei said there were no deployments

anywhere in the world based on 5 MHz bandwidths, and 10 MHz bands were only deployed where there had been migration from other technologies. The most efficient use of the spectrum – in terms of extracting value from the spectrum set against the cost of network deployment – involved larger lots.

- A4.14 Our proposals for 5 MHz lots in both bands were supported by UK Broadband, EE and a confidential respondent. The confidential respondent noted that all bidders were likely to require spectrum in quantities greater than 5 MHz, but outcomes where bidders target 15 or 25 MHz were plausible. This would be precluded if a larger lot size were adopted.

Our assessment and decisions

- A4.15 Given the near unanimous support, we have decided to auction the award bands together. Although the IET was concerned about making available the 3.4 GHz band on the proposed timescale, as we said previously, we consider that, on balance, the 2015-16 timescale is right. It is consistent with our duties to ensure the most efficient use of spectrum to allow consumers to benefit from use of the spectrum as soon as is feasible.
- A4.16 There will be one category of lots for the 2.3 GHz band and another category of lots for the 3.4 GHz band. The lots will be generic in the principal stage of the auction and there will be an assignment stage to determine the exact frequencies to be licensed to each successful bidder.
- A4.17 We understand from the consultation that there is a general concern that LTE requires large quantities of contiguous spectrum. In the SMRA auction format, we had proposed to protect bidders against the risk of acquiring smaller amounts of spectrum by allowing them to specify a minimum requirement of up to 20 MHz. At the same time, as noted above, we had proposed to make all of the spectrum available in 5 MHz lots, in order to maximise flexibility.
- A4.18 We believe this is still the most appropriate approach for the 3.4 GHz spectrum. The potential use cases are varied, and we want to keep the maximum flexibility to enable them. However, we now believe the 2.3 GHz spectrum should be awarded in 10 MHz lots.
- A4.19 Our decision to award 10 MHz lots is linked to a decision to impose mandated synchronisation in the 2.3 GHz band (described in section 8 of this document). Synchronisation means there is no requirement for operators to deploy a 5 MHz guard band to avoid interference between neighbouring spectrum users. 10 MHz lots therefore represent an efficient outcome whilst ensuring no operator risks being left with 5 MHz of unusable spectrum.
- A4.20 We believe the most likely use for 2.3 GHz spectrum will be for 20 MHz TD-LTE carriers - although other arrangements involving 10 MHz holdings may be possible, and we would not wish to rule them out. The award of 10 MHz lots addresses both opportunities.
- A4.21 As we explain below (under auction design – principal stage), larger lot sizes in the 2.3 GHz will also allow us to do away with the minimum requirement in this band. We think this is desirable, given the responses we received. This is relevant only because we have decided to hold a Simultaneous Multi-round Ascending (SMRA) auction, described below.

A4.22 The decision to proceed with 5 MHz lots in the 3.4 GHz band is also linked to our conclusions on synchronisation. With 150 MHz of new spectrum available, we see no reason to mandate full synchronisation for the 3.4 GHz frequencies. As a consequence, operators, if they choose to use the restrictive mask, will require an internal guard band to enable them to use the spectrum innovatively . We have also decided to retain the 20 MHz minimum requirement option for bidders in the 3.4 GHz band to protect them against the risk of winning less spectrum than they require. Again, this is discussed in more detail below.

Auction design – principal stage

A4.23 The November 2014 consultation said our choice of auction design should be consistent with our statutory objectives to further the interests of citizens in relation to communications matters, and to further the interests of consumers, where appropriate by promoting competition. It should also be consistent with our duty to secure the optimum use of the spectrum.

A4.24 We said our statutory duties were more likely to be achieved through the following additional objectives :

- The design should be simple, where possible, without unduly compromising the efficient outcome of the auction;
- The outcome of the auction should be perceived by all participants and stakeholders as fair and legitimate, and bidders should not feel that they would have bid differently when they see the final result.

A4.25 We set out two options for the principal stage of the 2.3 and 3.4 GHz auction – a Simultaneous Multi-round Ascending auction (SMRA) and a Combinatorial Clock Auction (CCA).⁵⁹ We said both formats as designed were robust and would meet our statutory duties.

A4.26 In the **SMRA** bids are placed for individual lots, and the auction proceeds in successive rounds with increasing prices until there are no new bids. In each round, the highest bid placed on each lot is called a standing high bid. When the auction ends standing high bids become winning bids and the bidders pay the amounts they bid.

A4.27 The **CCA** is a two-phased bidding process in which bids are submitted for packages of lots, not for individual lots. Bidders will either be awarded a combination (or package) of lots for which they bid in its entirety or nothing at all. In the CCA, final prices are usually based on opportunity costs. An opportunity cost price rule requires bidders to pay an amount for their winning package that is just sufficient to ensure that no other bidder or coalition of bidders was prepared to pay more for that package.

A4.28 We noted that we had used a CCA auction format on several previous occasions – including the 2013 combined award of spectrum in the 800 MHz and 2.6 GHz bands - and that this approach can be the best under many circumstances. However, we said the SMRA format had important advantages given the specific circumstances of the 2.3 and 3.4 GHz award, not least its overall simplicity. We therefore proposed an SMRA auction process, based on some key assumptions.

⁵⁹ See section 6 of the November 2014 consultation (<http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz-auction-design/>)

- A4.29 In particular, we assumed a much simpler demand structure than for the 2013 auction. We noted that the earlier auction had included both spectrum best suited for the provision of broad coverage and spectrum suited for delivering additional capacity. The complementary nature of the two bands meant a combinatorial auction design was more appropriate in that case.
- A4.30 We considered that the spectrum available in the 2.3 and 3.4 GHz bands is unlikely to be seen by potential bidders as complementary – at least to the extent of the 2013 auction. There was therefore less need for a combinatorial approach. However, we said we would re-assess our proposal for an SMRA auction in the light of stakeholder responses to the November 2014 consultation.

Auction rules

A4.31 We proposed the following rules for conducting an SMRA auction:

- **Break ties:** Bidders placing bids in a given round would be ranked randomly and allocated lots until there would be no lots available with the effect that at most one bidder could be standing high bidder on fewer lots than it bid for.
- **Information policy:** We proposed that the number and identity of qualified bidders should be disclosed before the auction begins, but information during the rounds would be limited to notification of prevailing round prices.
- **Withdrawals:** Bidders might withdraw standing high bids in any round (e.g. to transfer eligibility to another category) but would be liable to forfeit the total value of standing high bids withdrawn from their deposit unless all lots in that category are assigned a standing high bid in that or any subsequent round.
- **Minimum requirement:** Bidders might specify a minimum requirement of up to a maximum of 20 MHz of spectrum in each category (i.e. 2.3 GHz and/or 3.4 GHz). A bidder who ended the auction as the standing high bidder on fewer lots than it had specified in its minimum requirement for a given category would not be assigned any lots (or have to make any payments) in relation to these bids.
- **Activity rule and eligibility:** Bidders would be eligible to bid on lots in any given round based on their activity level in the previous round. Bidders would be allowed up to three 'waivers' where they may abstain from bidding - or bid below their eligibility - without affecting their eligibility for the next round.

A4.32 We set out alternative proposals on rules for a CCA auction in the event that consultation responses led us to change our view about adopting an SMRA format. These are explained in paragraphs 6.52 – 6.85 of the November 2014 consultation.

A4.33 In our November consultation, we put forward what we considered to be the best versions of both award processes for this particular auction. We also identified six residual risks. The first three were more of a concern in the SMRA, and the other three in the CCA. The residual risks were:

- There may be some unsold spectrum, even though there is demand for that spectrum at the reserve price;
- The auction generates artificially low prices due to strategic bidding;

- Bidders may be prevented, or find it more difficult, to always bid for their most preferred spectrum;
- Bidders may face difficulties developing and gaining approval for their bidding strategy within their organisation;
- Bidders may not be aware of the price they will have to pay until the end of the auction;
- The auction may generate a result which might surprise bidders and may therefore be perceived as unfair.

A4.34 We noted that we did not believe any of the residual risks would present a serious threat to the award. We concluded that there was a trade-off between the possible inefficiencies of complexity and uncertainty in the CCA, against the possible inefficiencies or difficulties in the SMRA resulting from:

- Potential strategic demand reduction (that is the incentive for bidders to reduce demand in an attempt to keep prices low, believing that doing so will allow them to acquire less spectrum, but at a lower price. The concern here is not about the level of revenue in itself, but that it could lead to an inefficient outcome);
- How bidders manage substitution risks (generated by restrictions that prevent bidders from easily moving their demand from one band to another); and
- Aggregation risks (when a bidder is forced to bid for individual lots, yet the amount they are prepared to pay for each individual lot could have changed depending on the type and quantity of spectrum they will secure at the end of the auction).

A4.35 Our preliminary assessment was that, for this particular award, we had the right instruments in place to deal with the residual risks in the SMRA in a way that rendered the complexity and the uncertainty of the CCA unnecessary. This assessment was based on a number of assumptions about the structure of demand and supply in this auction. In particular, we assumed:

- Value complementarity: This is where the value placed on a certain amount of spectrum is higher than the total of the values placed on each individual lot in that amount. We assumed the most important source of value complementarity occurred in the first 20 MHz in each band. Where there were other complementarities between bands, or within each band beyond 20 MHz, the resulting aggregation and substitution risks could be managed by bidders in the course of the auction.
- Spectrum packaging: We would make the spectrum in the 2.3 GHz band available in a single lot category, and the spectrum in the 3.4 GHz available in another single lot category. We believed this would greatly simplify the auction process and reduce the need for bidders to switch across categories of similar lots, which could create substitution risks
- Policy instruments: We would be able to reduce the level of information provided to bidders during the auction and set reserve prices that took into

consideration the incentives of bidders to reduce demand for strategic purposes.

A4.36 We posed the following questions in the November 2014 consultation:

Do you agree with our recommendation for an SMRA? If not, please explain why.

Do you agree with our proposals for the SMRA (including withdrawals, minimum requirements and waivers)? Do you have any other comments or views on this proposal?

Do you agree with our proposals for the CCA? Do you have any other comments or views on this proposal?

Consultation responses

A4.37 A number of very detailed responses to our questions about the proposed auction format were submitted in confidence. In reaching our decisions, we have taken account of the points raised in such confidential responses alongside those points submitted in non-confidential responses.

A4.38 The paragraphs below represent a summary of the main general points and our overall assessment.

Choice of format

A4.39 There were mixed views on the choice of the format. Some respondents favoured our recommendation for an SMRA. For example, BT said it was supportive of the simplicity and transparency of the SMRA process compared to a CCA format. UK Broadband said the proposed lot structure of the 2.3 GHz and 3.4 GHz auction was less complicated than Ofcom's 2013 4G auction. This made an SMRA a more appropriate form of auction. In contrast, UK Broadband said the alternative CCA rules and structure could make it very difficult for a bidding organisation, citing three reasons:

- A bidder would need a much more robust valuation of the spectrum outside an SMRA, which was difficult over a "long horizon period";
- There is no certainty of outcome during the CCA rounds, which would make it difficult to convey the status of bidding to senior managers within a company;
- CCAs can encourage 'gaming' across bands.

A4.40 A confidential respondent said it strongly supported the proposed SMRA and that Ofcom had both under-estimated the risks associated with the CCA, and over-stated some of the risks associated with the SMRA. Another confidential respondent agreed with the conclusion that an SMRA represented a suitable overall approach and that the complexity of a CCA cannot be justified for this auction.

A4.41 However, some other respondents argued in favour of the alternative CCA format. EE proposed a CCA similar to the process used in our 2013 combined 4G award. It said Ofcom had over-reacted to perceived lessons from the earlier award. It said the proposed SMRA format was untested and introduced unnecessary complexity

by trying to “patch over the shortcomings” of the former process. In particular, it pointed to aggregation and substitution risks. EE also say that Ofcom does not provide any indication of how it weighs the various residual risks or any clear justification for placing more weight on some risks than others. In addition, EE claimed that Ofcom may be placing more weight on residual risks which are unlikely to impact on the outcome of the auction, and less weight on risks which are likely to increase the risk of an inefficient auction outcome.

- A4.42 Both EE and H3G claimed that the instruments Ofcom proposed in the SMRA – for instance the withdrawal policy and the information policy – would not be effective in mitigating the risks involved, or might have unintended consequences.
- A4.43 EE claim that aggregation risks remain a concern under Ofcom’s proposed SMRA, as, amongst other reasons, the last bidder provisionally allocated lots may still be a standing high bidder on fewer lots than the number of lots they bid for.
- A4.44 EE also claim that the ability of bidders to withdraw or waive, as proposed by Ofcom, is unlikely to mitigate substitution risks in the auction and may even increase the level of risk.
- A4.45 H3G argued that the proposed SMRA had a number of flaws and was therefore “not fit for purpose”. It was particularly opposed to what it described as “half way measures” between an SMRA and a CCA. It listed criticisms including of the proposed information policy; the withdrawal rules and the pricing rules (see relevant sub-sections below). Instead, it proposed first, in order of preference, the CCA and, second, a clock auction similar to the auction rules proposed in December 2014 for the forward auction of the USA’s Federal Communications Commission (FCC) Incentive Auction programme.
- A4.46 However, H3G said that if a preference was given to an SMRA anyway, it would be better to implement ‘plain vanilla’ SMRA rules. It said that, besides the disclosure of demand information, the key difference between a ‘plain-vanilla’ SMRA and Ofcom’s proposed SMRA was that the ‘plain-vanilla’ version treats every lot as unique, rather than generic. As such, bidding for one lot never requires placing a bid on another lot, so bidders are never required to raise their own standing high bids.
- A4.47 Orange did not express an opinion on whether a CCA or SMRA would be preferred, but objected to specific proposals for both formats - particularly where modifications had been suggested to standard approaches. Orange said Ofcom should consider a more standardised approach even when factoring in the particular context that exists in the UK.

Ofcom assessment

- A4.48 The responses we received did not challenge our list of the relevant residual risks for this award. Instead, the discussion was centred on the particular *importance* of the residual risks identified by Ofcom - and the actual ability of each format to address them.
- A4.49 The respondents that favoured our recommended approach generally agreed the SMRA would be less complicated, more transparent and was likely to generate fewer difficulties for bidders in dealing with their internal governance. The respondents favouring a CCA believed it better addressed the risks we identified, in particular aggregation and substitution risks.

- A4.50 We do not think sufficient evidence has been provided to cause us to reject the assumptions on which we based our recommendation for the SMRA. In particular:
- **Value complementarity.** We considered that for this particular spectrum value complementarity, other than for the first 20 MHz in each band, could be managed by bidders in the course of the auction. Our view is that respondents did not give enough evidence to contradict this assumption.
 - **Spectrum packaging.** Respondents did not challenge the two lot categories we proposed. In an annex to its response, H3G noted that if Ofcom believes bidding in the 3.4 GHz band will be undermined due to a possibility of a non-contiguous award, it should consider options that allow bidders to specify where a non-contiguous award is acceptable, including having two lot categories in the band. However, as we noted in the consultation, we do not think bidding in the 3.4 GHz band will be undermined in this way.
 - **Policy instruments:** We remain of the view that we have the right instruments in place to deal effectively with the risks in the SMRA. With regards to the information policy, we still believe the effects of strategic bidding resulting from a transparent information policy outweigh the possible benefits. However, as we explain in more detail below, we now agree that some limited information about the level of aggregate demand may be beneficial to bidders, particularly when they face aggregation risks. The information policy will remain relatively limited, at a level which we believe still deters strategic bidding. As we set out in section 4, we are minded to set reserve prices which take into consideration the incentives of bidders to reduce demand for strategic purposes.
- A4.51 As acknowledged in our November 2014 consultation, the instruments and policies we proposed for the SMRA mitigate, but do not completely remove the aggregation and substitution risks we identified.
- A4.52 With regards to EE's claims, we believe we have provided an indication of how we weigh the various residual risks. We have identified six residual risks, three that were more important for the SMRA, and three that were more important for the CCA. We have concluded that, under our proposals, the three residual risks of the CCA outweigh the three residual risks in the SMRA.
- A4.53 In addition, we do not think that the risks which we have identified for the SMRA are more likely to lead to an inefficient outcome, compared to the risks identified for the CCA.
- A4.54 Nevertheless, we asked Auctionomics, a US consultancy specialising in spectrum auctions, to review some of the claims made by PowerAuctions in the report which was included as an annex to H3G's response to the consultation. These included the choice of the format. Auctionomics agrees with Ofcom that there are important advantages and disadvantages to both the CCA and the SMRA, and that the advantages for the CCA are most important when either the auction context presents a severe aggregation risk or demand reduction threatens to depress prices and harm efficiency. The analysis concludes that, subject to reviewing the information policy, the PSSR auction poses no severe aggregation risk and that there is no conclusive risk that demand reduction will be damaging to efficiency. The Auctionomics note is published alongside this statement.

- A4.55 We continue to believe that, given our assumptions for this specific award, and in particular those on the nature of demand, the CCA poses unnecessary challenges. Namely, difficulties in agreeing bidding strategies in an organisation; not knowing the price to pay; and a perception of surprise or unfair outcome. This may be particularly harmful to smaller, less experienced (and/or budget constrained) bidders. These factors may cause them either to not to enter the auction or to bid in a conservative way.
- A4.56 In light of the above, we have decided to proceed with an SMRA auction, and to reject the CCA. We have also considered H3G's alternative form of clock auction, which resembles the format which is being proposed for a US incentive auction being run by the FCC. We note that it shares many similarities with the SMRA we proposed. We understand the more relevant differences to be the following:
- In the clock auction described by H3G, bidders are only allowed to contract demand if this does not generate excess supply. In our SMRA, bidders have the choice to contract demand, even if that causes excess supply, by withdrawing their standing high bids (subject to paying the full price of the withdrawn bid in the circumstances described in the sub-section on the withdrawal rule below). We believe this is a desirable feature in this particular award, as it facilitates switching between two bands which we believe are to some extent substitutable at some prices, as confirmed by some respondents. As Auctionomics points out in the note prepared for Ofcom, substitutability is more important in the PSSR auction than in the FCC's incentive auction.
 - The clock auction allows bidders to specify that they wish either to contract demand in blocks, or not contract demand at all. This is not possible in the SMRA. When bidders contract a given amount of their demand, they may end up as standing high bidders on a part of this amount. We believe we have addressed aggregation risks using a number of different instruments, which include the ranking rule and the minimum requirement in the 3.4 GHz band.
 - The risk of price overshooting is treated differently in the two formats. The clock auction allows for inter-round bidding, which allows a speedier auction. The SMRA we proposed addresses price overshooting by setting appropriate price increments and mitigates the risk by allowing bidders to maintain their standing high bids rather than deciding whether to accept a new price level in each round. We believe this is a desirable feature, as it allows more time for bidders to consider their bidding strategies.
- A4.57 The chief advantage of the clock auction in our view is that it is speedier than the SMRA. However, speed is not a key concern in our particular award. We have therefore decided to proceed with an SMRA auction.
- A4.58 In selecting the SMRA over the CCA, we have considered H3G's suggestion of a 'plain vanilla' version. We think the SMRA proposed in the November 2014 consultation includes features which make it a better approach to our particular auction. We believe the following are the most important points:

- Bidders do not bid for 'unique' lots⁶⁰, but for a number of lots in each band. This simplifies the bidding in the auction, eliminates substitution risks in the band and reduces the scope for signalling and strategic bidding.
- The ranking rule we adopt ensures that at most one bidder is a standing high bidder on a partial bid in each lot category. This might not be the case if bidders could place bids in 'unique' lots in each lot category.

A4.59 However, having taken on board some of the comments received by respondents, and the views of Auctionomics, we have revised several of the details we proposed in the November 2014 consultation. We believe that with these revisions in place, the residual risks identified for the SMRA are not likely to have an impact on the efficiency of the award.

A4.60 We address further the specific detail of the SMRA we propose in subsequent subsections and the concerns expressed by some respondents, including H3G. Our overall assessment is that we have adopted the necessary changes to the auction design which confirm our understanding that the SMRA we chose is better for this particular award than a CCA, a simple clock auction or a 'plain-vanilla' SMRA.

Information Policy

A4.61 A number of respondents expressed concerns about the proposed information policy and the consequences this might have for the auction, including respondents who were otherwise supportive of the SMRA format.

A4.62 A confidential respondent noted Ofcom's proposed approach was based on preventing strategic bidding. However, it said bidders will be able to observe the bidding patterns of others in any case: the process gave sufficient clues for activity to be deduced as the auction progresses. This respondent suggested that it would be preferable for Ofcom to simply publish aggregate demand - or even allow full disclosure of bidders and total lots secured after each round - to allow bidders to concentrate more simply on bidding.

A4.63 H3G accused Ofcom of going backwards by replacing successful dynamic auction methods with an approach more suited to a sealed bid auction process. This poses a risk to efficiency and transparency. H3G said the most critical flaw in the rules proposed by Ofcom was the withholding of demand information from bidders, even in aggregate between bidding rounds. The current proposals would have bidders participate in a lengthy, but almost entirely opaque multi-round procedure, eliminating the standard benefits of dynamic auctions.

A4.64 Other respondents – including BT and a confidential respondent - expressed support for the proposed information policy. However, BT noted that their support was conditional upon Ofcom solving their concern about liability for unsold lots – that is the potential liability of bidders who withdraw to pay for spectrum which effectively goes unsold. The confidential respondent said it would normally expect aggregate demand to be disclosed in every round, as the combination of price and demand revelation facilitates price discovery and builds confidence in the auction process. However, it recognised that in exceptional circumstances, where there were significant asymmetries between bidders and concerns about anti-competitive

⁶⁰ We understand that in H3G's proposal for the plain-vanilla SMRA, in the principal stage lots would be generic – in the sense that these lots do not correspond to specific frequencies – but there are individual lots which potentially have different prices.

bidding behaviour, there may be a case for further restrictions on information release. This award was one of these exceptional cases. The respondent said the biggest risk in the auction was collusion and anti-competitive gaming strategies.

A4.65 EE said that a strict information policy risked an inefficient outcome due to the likelihood of common value uncertainty. It said the risk of tacit collusion was actually low and, even if it did occur, was unlikely to be particularly harmful to spectrum efficiency. It too said full information about bidders' demand should be made available. EE also said Ofcom's proposed information policy was likely to discourage bidders from withdrawing a bid. This is because the bidder is unable to determine the level of excess demand at the end of each round, which will make it difficult for the bidder to assess the likelihood that there will be unsold lots if it withdraws (i.e. the bidder cannot assess the likelihood of facing a penalty).

Ofcom assessment

A4.66 We understand there are conflicting risks in the auction and the information policy plays an important role in addressing these.

A4.67 A strict information policy may pose challenges to how bidders go about devising their bidding strategies:

- On one hand, bidders might require information about demand from other bidders during the auction to update their individual estimates of the value of the spectrum – as noted by EE, this might be relevant in the context of common value uncertainty, where the value of spectrum is common to the bidders but unknown to them.
- On the other hand, information during the auction might be important to manage aggregation and substitution risks. It may help aggregation risks because bidders might need information to assess the risk of ending up winning less spectrum than they require. It may help substitution risks because bidders might need information to assess the risk of moving their demand from one band to the other as relative prices change (and being stuck as a standing high bidder on lots in the band from which they are moving).

A4.68 A limited information policy may, however, reduce the likelihood of strategic bidding in the auction, by increasing the risks such bidding poses to bidders. As explained in the consultation document, a strict information policy will increase the risks faced by bidders who engage in price driving and vexatious bidding and will reduce the incentives to engage in gaming, such as strategic demand reduction. Precise information about the level of aggregate demand, for instance, might allow individual bidders to be able to bring the auction to an earlier end by contracting demand.

A4.69 We understand the spectrum which Ofcom is auctioning is likely to add to existing players' spectrum portfolios. These portfolios are diverse and as a consequence the marginal value bidders place on this spectrum is likely to be in the greater part particular to each one of them. This means that private values are likely to be more important than common values. In addition, we believe that the part of the value of the spectrum that is common to all bidders is likely to be relatively known. This seems to be particularly the case in the 2.3 GHz band, which has a developed ecosystem. This means that information about the level of aggregate demand may not be especially relevant to address common value uncertainty.

- A4.70 However, we acknowledge that some information about the level of aggregate demand may be useful to address risks in the auction, particularly the aggregation risk. Under the proposals we put forward in the November consultation, in addition to setting a minimum requirement in each band, a bidder could address aggregation risks by using a combination of waivers and withdrawals. For instance, a standing high bidder who wished to contract its demand in a band, but wished to avoid the risk of being stranded as a standing high bidder on a partial bid, could use a waiver to see if it is outbid in all its standing high bids before committing to a withdrawal.
- A4.71 Given the concerns expressed by respondents, we understand the ability to use waivers and withdrawals does not remove all the underlying bidding risks in the SMRA. We asked Auctionomics to advise us on the level of the information policy we proposed in the consultation.
- A4.72 Whilst acknowledging the potential to use information about the level of aggregate demand to bid strategically, Auctionomics believes bidders are likely to require more information to be able to address effectively the risks they face, especially the aggregation risk. A way to compromise, in its view, would be to indicate to bidders whether in each band excess demand in the preceding round was less than a multiple of 20 MHz. For instance, if the aggregate demand in 2.3 GHz in a given round was 130 MHz, and if there are 40 MHz available in the band, bidders would be informed that the level of excess demand was lower than 100 MHz.
- A4.73 We understand there is an increased risk in this approach in terms of strategic gaming in the auction. However, we believe the potential for bidders to use this information strategically is limited.
- A4.74 A limited amount of information about the level of aggregate demand in each band, as opposed to information about the exact amount, creates a risk to bidders who wish to bid strategically. A bidder who wishes to contract demand to bring an auction to an earlier end would be unsure by how much they would need to contract that demand. Also, bidders could not be certain as to how much other bidders are bidding. Finally, bidders who wish to bid in a band for the purpose of increasing the price other bidders pay is also risky, as bidders do not have enough information to assess the risk of being stuck as a standing high bidder on part or the whole of their demand.
- A4.75 The advantage of releasing a limited amount of information about excess demand is that bidders may use this information to better estimate how prices are likely to evolve during the auction. A better estimate of final prices will allow them to make better decisions during the auction, such as how they deal with value complementarities. When a bidder's value for a package of lots exceeds the sum of the value they place on each individual lot in that package, they will wish to avoid winning part of the package at a price that exceeds the value they place on each individual lot. A better understanding of how prices are likely to evolve will allow bidders to limit such risks. This will also allow bidders to better deal with the risk of being stuck as a partial standing high bidder when moving from one band to the other.
- A4.76 On balance, we believe the benefits in terms of assisting bidders to address aggregation and substitution risks outweigh the potential downside.
- A4.77 Finally, we note that some potential bidders have commercial arrangements with other potential bidders, and disclosure of more information could assist them. However, a fully open information policy would expose the auction to severe risks in

terms of gaming, while not solving the problem it aims to solve. In particular, full information about what bidders are bidding on would not provide certainty to individual bidders as to what other bidders might be able to acquire at the end of the auction. The other bidder's strategy might change, or they might be outbid.

- A4.78 We conclude that we should maintain a relatively limited information policy as we proposed in the November 2014 consultation. However, we also conclude that we will disclose some information about the level of aggregate demand to bidders. In particular, we will let bidders know for each lot category, after the first round, that excess demand in the preceding round was less than a multiple of 20 MHz. (e.g. less than 20 MHz, less than 40 MHz, less than 60 MHz, etc.).
- A4.79 We define the active bids in a category in a given round as all standing high bids in that category at the beginning of the round that have not been withdrawn or raised by the bidder during the round, plus any new bids for lots in that category submitted in the round. We define excess demand for lots in a lot category as the total bandwidth of active bids in that category minus the total bandwidth corresponding to all the lots available in that category.
- A4.80 If the level of excess demand is less than 0, we will let bidders know the level of excess demand is below 20 MHz. For instance, if demand is 10 MHz less than the available supply in any lot category, that is if the level of excess demand is minus 10 MHz, bidders will only be informed the level of excess demand is smaller than 20 MHz. We continue to believe that detailed information about the level of excess supply would provide incentives for bidders to engage in strategic demand reduction and price driving.

Withdrawal rule

- A4.81 There was concern expressed by some respondents that the withdrawal rules could leave bidders facing difficulties when substituting across different categories. A common theme among those respondents was that bidders who are provisional winning bidders may need to withdraw or cancel their bids to be able to move their demand to another band. If demand does not equal or exceed supply in that band, bidders will pay a withdrawal penalty (i.e. they would pay the price for the spectrum, but would not obtain it).
- A4.82 EE recognised that Ofcom had proposed this financial penalty in order to mitigate other risks - such as incentives for strategic bidding. However, EE said the high financial penalties meant bidders were likely to be highly discouraged, or even entirely constrained, from switching between lot categories.
- A4.83 A confidential respondent said it shared Ofcom's concern that withdrawals could be abused by bidders for gaming purposes, such as price driving in the 2.3 GHz band. However, it also recognised that withdrawals could provide useful flexibility to bidders facing substitution risk – even though the penalty rules meant that withdrawals were not risk-free.
- A4.84 It proposed that the circumstances under which bidders can exercise withdrawals should be limited. Specifically, bidders should only be allowed to exercise withdrawals from a band in situations where they did not become the standing high bidder on all the lots on which they were currently bidding in that band. Withdrawing from bids where the bidder became the standing high bidder on all lots on which they were bidding in that band was likely to be linked to gaming. The proposed rule change would increase certainty over auction outcomes as (at most) only one

bidder in any round would be eligible to withdraw demand. It would also further decrease the risk of unsold lots.

- A4.85 UK Broadband supported Ofcom's proposed withdrawal mechanism because it allowed bidders to move demand across categories and so reduce aggregation risk. By withdrawing their standing high bids, bidders free up eligibility which they can then use to bid on another category. However, UK Broadband also recognised that withdrawal could have the unintended consequence of enabling gaming and pushing up prices.
- A4.86 H3G cautioned that withdrawals permit total relaxation of eligibility, which could be used to exclude others from the spectrum, and create unnecessary strategic complexity.
- A4.87 Like others, BT said it was concerned that the potential penalty may discourage bidders from making legitimate use of withdrawals. It proposed either that the information policy should be changed to give a better idea of the risk of withdrawal or that there should be a single additional sealed-bid round for unsold lots – perhaps prohibiting any bidder liable for a penalty. More generally, Ofcom should either ensure that no bidder is required to hold standing high bids on fewer lots than its minimum requirement, or allow a penalty-free withdrawal if the number of lots provisionally held is less than the minimum requirement.
- A4.88 A confidential respondent argued that when combined with the minimum requirement, withdrawal rules could leave bidders 'stranded' on 2.3 GHz spectrum when 3.4 GHz was more attractive (and vice versa); or leave them locked into a 'useless bid' with no way to escape. This respondent also presented Ofcom with a number of 'scenarios' where the consequence of withdrawals was not clear.

Ofcom assessment

- A4.89 We set out in the illustrative auction procedures that *"A bidder who withdraws their standing high bids in a lot category may be required to pay the full amount of all standing high bids the bidder withdraws. This will apply only in the event that it is not possible to establish a standing high bid on all lots in that lot category at any later point in the auction."*
- A4.90 Having considered the consultation responses, including the 'scenarios' provided by a confidential respondent, we have decided to proceed with our proposed withdrawal rules, but with three modifications.
- A4.91 Firstly, we have decided to limit the number of bid withdrawals a bidder may use in the course of the auction. This is aimed at precluding the theoretical possibility that a bidder might be able to prevent the auction from coming to an end. Although the likelihood of such strategy is low, it was theoretically possible under our initial proposals. To prevent it from happening, we will limit the number of rounds in which a bidder may withdraw to five.
- A4.92 Secondly, we have decided that a bidder will not be allowed to withdraw from one band more than once if the price in that band has not increased since the round in which the previous withdrawal was made. We can see no reason why a bidder would need to do this consistent with truthful bidding. The relative price in the band from which the bidder wishes to withdraw the second time must either have remained the same, or gone down. There might, however, be legitimate reasons for a bidder who withdrew from a band once to go back to bidding on that band. We are

therefore allowing the bidder to bid again on the band from where it withdrew, even if the price has not changed.

- A4.93 Thirdly, when a bidder withdraws its standing high bids from one band and later bids again in that same band then the bidder would not be liable for the withdrawn bids on lots for which it has bid again. It would be unfair to force a bidder to pay twice for the spectrum it won.
- A4.94 We also clarify that a bidder who is a standing high bidder on less than its minimum requirement in the 3.4GHz band⁶¹ will be able to bid for lots in the 2.3GHz band without being forced to withdraw its standing high bids on 3.4GHz lots or place a new bid for at least the amount of spectrum specified as a minimum requirement in the 3.4GHz band. However, if the bidder specified a minimum requirement in the 3.4 GHz band, its new bids for that band will need to be for at least as much spectrum as specified in the minimum requirement.
- A4.95 We address in turn below the other concerns regarding the withdrawal rules we proposed:
- the interplay between the minimum requirement and the withdrawals;
 - the circumstances where bidders are allowed to withdraw.

1) Interplay between minimum requirement and withdrawals

- A4.96 As explained in the next section, we have now revised our proposal allowing bidders to specify a minimum requirement in the 2.3 GHz band. As a consequence, any concerns no longer apply in this band.
- A4.97 In the 3.4 GHz band, bidders will still be able to specify a minimum requirement up to 20 MHz. This means bidders who are standing high bidders on less than their minimum requirement might still face a choice between a) withdrawing their standing high bids to free up eligibility, which might expose them to the risk of paying for the spectrum without acquiring it; or b) waiting to be outbid in order to avoid paying for the spectrum while not receiving it, and so risk being unable to move demand to another band.
- A4.98 We have looked into the following ways of addressing this trade-off by:
- allowing bidders to withdraw at no cost if they are standing high bidders on less than their minimum requirement;
 - not assigning standing high bids below a minimum requirement;
 - doing away with the minimum requirement in the 3.4 GHz band.
- A4.99 With regards to the first two 'solutions', we believe that the initial standpoint in the SMRA should be that bids are as committing as possible. Other formats, like the CCA, facilitate truthful bidding by making all bids potentially committing. We recognise there are circumstances where bid commitment in the SMRA might be lowered, for instance to assist with aggregation and substitution risks. .

⁶¹ As we note in the following section, bidders will not be allowed to specify a minimum requirement in the 2.3 GHz band.

- A4.100 As a result, we proposed in the November 2014 consultation a minimum requirement to apply in both bands. While this reduces the bid commitment, it does so to address a risk which was weighed as being more important, namely the risk of winning less than a minimum usable amount of spectrum.
- A4.101 Allowing bidders to withdraw without any potential cost - or not assigning standing high bids below a minimum requirement – could facilitate strategic bidding. A bidder might be able to bid with no interest in acquiring the spectrum, but only to raise the prices paid by competitors. The bidder could then leave the band altogether and possibly move its freed up eligibility to bid in the other band, at no potential cost - provided they cannot be deemed standing high bidders on less than their minimum requirement. By assigning standing high bids below a minimum requirement a standing high bidder will not be able to move its demand to the other band unless it withdraws, in which case it may face a cost.
- A4.102 We considered whether this risk of strategic bidding could be of a lower order than the underlying substitution risk. We note, however, that the risk of strategic bidding might impact all other bidders via the price paid - whilst substitution difficulties will only apply to a bidder who is a standing high bidder on less than their minimum requirement (and who wishes to move its demand to 2.3 GHz and is not outbid in the following round).
- A4.103 Given the nature of the ranking and the activity rules, only one bidder in any round will find themselves in such circumstances.
- A4.104 Doing away with a minimum requirement in the 3.4 GHz band could make the auction simpler. However, with 5 MHz lots, the potential for an outcome where a bidder is left with a quantity of spectrum which it cannot use is higher. We believe this is undesirable.

b. Circumstances where a bidder is allowed to withdraw

- A4.105 One respondent suggested we should only allow bidders to withdraw bids if they are left as standing high bidders on less than their full bid in the previous round. However, we recognise there may be legitimate reasons for a bidder to withdraw bids, even if it is a standing high bidder on its full bid from the previous round.
- A4.106 On a broader note, we believe that under the withdrawal rule we proposed, there are very limited incentives to use withdrawals strategically. For that reason, we do not think that there are sound reasons to restrict the ability of bidders to withdraw, except in the circumstances explained in the beginning of the current sub-section.

Minimum requirement

- A4.107 There was divided opinion on our proposals for allowing bidders to express a minimum spectrum requirement in the auction. Some supported the principle but expressed a preference for a maximum level different from our proposed 20 MHz.
- A4.108 BT agreed both with the inclusion of the minimum requirement option and that the maximum amount of the minimum spectrum requirement should be 20 MHz. It said a figure less than this may not be sufficient to be viable, whilst a greater figure was not necessary and could be used strategically. UK Broadband also expressed support for Ofcom's reasoning and said bidders should be able to express a minimum requirement of up to 20 MHz in multiples of 5 MHz lots.

- A4.109 A confidential respondent said it was supportive of the intent in the proposal but said it disagreed with the approach. As noted in the sub-section on withdrawals, this respondent claimed that that when combined with the withdrawal rules it might have unintended consequences. The respondent also noted that the minimum requirement could allow a bidder to drive prices higher on spectrum they had no intention of winning.
- A4.110 Another confidential respondent recognised there was a potential rationale for allowing bidders to express a minimum spectrum requirement in each band. Such a rule could prevent outcomes where a bidder fails to win what it views as a critical mass of spectrum. A minimum requirement might also make interference coordination easier. However, the rule could be abused for ‘gaming’ purposes and may lead to lots going unsold – especially in the 2.3 GHz band, given there are only eight lots available.
- A4.111 It proposed there should be no minimum requirement option for mobile network operators at 2.3 GHz. However, there could be a case for minimum requirements for other bidders – although it should be limited to 10 MHz. The balance of issues at 3.4 GHz was “rather different”, and the respondent supported our proposal for a minimum requirement option of up to 20 MHz option for all bidders.
- A4.112 H3G argued that the minimum spectrum requirement option could allow bidders to impose externalities on others without paying the cost - or even to exclude smaller rivals from the 2.3 GHz band. It said the minimum requirement should be no more than 10 MHz to avoid strategic bidding. H3G also said that if Ofcom insisted on running an SMRA with a minimum requirement, there should be a way for bidders to express substitution across the two bands directly. There should also be a tie-breaking rule so that if a bidder is below its minimum requirement, another bidder should be allowed to ‘win’ the spectrum instead.
- A4.113 Orange said the whole notion of a minimum requirement was untried and untested and suggested instead that Ofcom increased the lot sizes instead.

Ofcom assessment

- A4.114 Our proposal to allow bidders to specify a minimum requirement was made to protect them from aggregation risk. We believed the most relevant source of value complementarity, and therefore the most relevant source of aggregation risk, occurred in the initial 20 MHz in each band. We also understood the main advantage of a minimum requirement – protection against aggregation risk – might come at the expense of generating or increasing other risks to the auction. In particular, we noted in the consultation that bidders might be able to exploit this feature to increase the prices paid by competitors.
- A4.115 We understand price driving might have a material impact on the efficiency of the auction. We also accept that efficiency might be harmed in two ways if bidders engage in price driving:
- First, we may fail to assign the spectrum in a band to those bidders who value it the most if a bidder who engages in price driving and who is not the bidder with the highest value for the spectrum actually ends up acquiring it. This would be the case if the bidder who is price driving miscalculates the point at which it needs to stop bidding;

- Second, price driving in one band might also impact the outcome in another band. For example, a budget constrained bidder wishing to obtain spectrum in both bands might need to limit bidding in one of them to retain enough resources to bid in the other.

A4.116 We believe that in our auction the potential to generate an inefficient outcome is higher in the 2.3 GHz band. This is because a minimum requirement of 20 MHz takes up half of the available spectrum in the band (if we reduce the amount of spectrum available in the band, the proportion would be even higher). Respondents seemed to agree with this presumption. We are therefore removing the ability of bidders to specify a minimum requirement in the 2.3 GHz band.

A4.117 We note that this will expose bidders to the risk of winning less than 20 MHz, even though they may not wish to do so. Our decision to award the 2.3 GHz spectrum in 10 MHz lots mitigates this to some degree. It will protect bidders against the possibility of winning 5 MHz or 15 MHz when they do not want to – but will still expose bidders to the risk of winning 10 MHz when they want at least 20 MHz.

A4.118 We think the risk of this outcome is relatively low. The nature of the ranking rule in the SMRA means that at most one bidder will win less than its full demand at the final round price. A bidder will only win 10 MHz when it wanted at least 20 MHz if it is the standing high bidder with the lowest marginal value for an extra 10 MHz. Given that there are 40 MHz in total in the 2.3 GHz band, this means that the bidder's incremental value for 10 MHz is lower than either:

- the incremental value of 10 MHz in addition to 20 MHz from another bidder; or
- the value for 10 MHz from another bidder who only wishes to acquire 10 MHz at the final round price.

A4.119 We do not think this is likely to occur in the circumstance where there are significant complementarities for that bidder which, by definition, means the value for an extra 10 MHz in addition to an initial 10 MHz is high. In any case, a bidder left with an unwanted 10 MHz lot can trade the spectrum. We therefore believe that on balance the additional benefits in the auction outweigh the risks.

A4.120 In addition, we believe an outcome where a bidder wins only 10 MHz in the 2.3 GHz band might be desirable under certain circumstances and we do not wish to preclude that by adopting 20 MHz lots.

A4.121 We have not changed our proposals for allowing a minimum requirement of up to 20 MHz in the 3.4 GHz band. This is because there is significantly more spectrum in the 3.4 GHz band than in the 2.3 GHz band and, as a consequence, 20 MHz takes up relatively less spectrum in the 3.4 GHz band. Therefore, we believe the ability to use the minimum requirement to drive up prices in the 3.4 GHz band is more limited. Even if we reduce the amount of spectrum available in the band, there would still be a significant amount of it left and a minimum requirement of 20 MHz would take up proportionally less spectrum in the 3.4 GHz band than in the 2.3 GHz band. The benefits of the minimum requirement on the other hand are important, as they prevent circumstances where bidders acquire quantities of spectrum for which they have no efficient use.

Activity rule and eligibility points

- A4.122 We proposed 1:1 eligibility ratio for bidders seeking to switch bids between the 2.3 and 3.4 GHz bands i.e. a bid for a lot in one band has the same eligibility points as a lot in another. The rationale was that at certain price ranges bidders might be willing to substitute between the two bands on a MHz for MHz basis (e.g. substitute from 20 MHz in the 2.3 GHz band at a higher price to 20 MHz in the 3.4 GHz band at a lower price). Some bidders thought this eligibility ratio might make switching difficult because spectrum is not worth the same across the two bands. Some bidders put forward alternative proposals.
- A4.123 H3G said our proposal to attach equal eligibility points for the two spectrum bands would establish an environment where bidders have a strong incentive to engage in 'parking'. It suggested this would increase the strategic complexity of the auction, further decrease transparency, and likely diminish the efficiency of the auction outcome. It proposed a ratio "somewhere between" a 2:1 and 4:1 eligibility ratio between the 2.3 GHz and 3.4 GHz bands respectively.
- A4.124 BT expressed similar concerns. It said the price per MHz of spectrum in the two bands will not be equal, or even approximately equal. This raised two concerns:
- Some bidders may use the equality of eligibility points to hide their demand for the more expensive spectrum by bidding for an equal amount of the less expensive spectrum in the early stages of the auction;
 - Bidders who see 2.3 and 3.4 GHz spectrum as being partial substitutes, but not of equal value, may have to bid for more spectrum than they really need at certain price points, in order to maintain sufficient eligibility to switch their demand into the less valuable spectrum.
- A4.125 However, another confidential respondent said it supported our proposal precisely because the spectrum bands were substitutable.
- A4.126 Other respondents suggested we used a relaxed activity rule in the SMRA. Under a relaxed activity rule, when the price in one band decreases relative to the other band, bidders might be allowed to move their demand at a rate different to the eligibility ratio set by the auctioneer.

Ofcom assessment

- A4.127 For the sake of simplicity, we refer in this sub-section to eligibility ratio as the eligibility ratio per MHz, abstracting from the actual size of the lots in each band. A 1:1 eligibility ratio means 1 MHz in the 2.3 GHz band can be switched to 1 MHz in the 3.4 GHz band without loss of eligibility. A 2:1 eligibility ratio means 1 MHz in the 2.3 GHz band can be switched to 2 MHz in the 3.4 GHz band.
- A4.128 We note that some of the responses we received point to a degree of substitution between the 2.3 and 3.4 GHz bands. However, substitution may be made difficult if individual bidders would like to substitute across bands at a rate which differs from the eligibility ratio set by the auctioneer.
- A4.129 This is a concern in all auction formats which use a point-based eligibility rules, including the CCA which Ofcom used in its 2013 auction. However, in the CCA, the point-based eligibility rule applies only in the clock stage. In a subsequent stage, the

supplementary bids round, bidders are allowed to submit bids which reflect their relative preferences for the bands.

- A4.130 The SMRA does not include this further round. In this format, minimising impediments to switching requires an understanding of the structure of demand, that is, an understanding of how bidders are likely to wish to substitute across bands.
- A4.131 The eligibility points ratio should reflect the ratio of substitution rather than an expected value difference. The ratio of substitution should depend on whether the bidder might require different bandwidth when substituting across bands. To see why, let us consider two different scenarios:
1. Bidders may have the same business plan for both bands, but believe one band is more valuable than the other (e.g. due to the propagation characteristics and the ensuing potential to save costs in network deployment). Bidders will choose to bid in the higher value spectrum until the price plus the cost of deployment outweighs the equivalent combined cost in the alternative cheaper band. The difference in value between the bands determines whether the bidder wishes to move demand from one band to the other, but does not determine how they wish to do that.
 2. The other scenario is that bidders have two alternative business plans, one for each band, which require different amounts of spectrum. Let us assume that the bidder requires 40 MHz in the 3.4 GHz band or 20 MHz in the 2.3 GHz band. The bidder will wish to switch on a 2:1 ratio whenever the price difference between these packages is greater than the difference in the value of the corresponding business plans. Again, the difference in value between the bands does not determine how the bidders wish to switch between bands, but only whether they wish to switch.
- A4.132 In the first scenario, the right eligibility ratio is 1:1. In the second scenario, the right ratio is larger than 1:1. In the example provided, it would be 2:1.
- A4.133 Setting the right ratio therefore requires Ofcom to make a judgement on what is the most likely scenario, that is, whether bidders are likely to have the same or different business cases for the bands.
- A4.134 If Ofcom sets the ratio too low, then bidders will not be able to expand demand as much as they may wish when moving from 2.3 GHz to 3.4 GHz spectrum. Bidders may accept this and not move their demand. Or they may instead adopt a strategy to protect against the difficulty in substituting. This might be to bid for more spectrum than they would otherwise require in the 3.4 GHz band to allow for later substitution. Therefore, too low a ratio may lead to either overstating or understating demand for 3.4 GHz spectrum.
- A4.135 Some respondents suggested another consequence of too low a ratio, namely the possibility that bidders 'parked' their eligibility in the least valuable band, instead of revealing it from the beginning. We do not think this is likely. Bidders who choose to 'park' demand in the 3.4 GHz band carry a risk of being designated standing high bidders in that band. If they are not outbid during the course of the auction, those bidders would end up either winning spectrum which they do not value, or withdrawing and so risk paying for the spectrum without acquiring it. We think this is a high risk, compared to the limited advantage of not revealing the true demand from the beginning.

- A4.136 If the ratio is set too high, bidders may be prevented from switching from 3.4 GHz to 2.3 GHz. Again, bidders may accept this and not switch. This would lead to an understatement of demand for the 2.3 GHz band. Alternatively, bidders may overstate demand in the 3.4 GHz band to maintain enough eligibility to switch back to 2.3 GHz.
- A4.137 We understand bidders may have different business cases for the bands. We have in particular been told in the October 2013 Call for Inputs that operators may use 2.3 GHz predominantly to provide mobile access and 3.4 GHz for small-cells and for backhaul. The latter use may require a larger amount of contiguous spectrum, compared to the former. This therefore means we should consider moving away from an eligibility ratio of 1:1 to a higher ratio.
- A4.138 Whilst we do not have precise information on how much spectrum bidders are likely to require in either band, we should be cautious of setting too high a ratio for the reasons presented above.
- A4.139 We note a 3:1 ratio would mean a bidder bidding on 50 MHz in the 3.4 GHz band (which would be a third of the available spectrum in that band if we auction 150 MHz, or more than a third if we reduce the amount of spectrum available in the band) would only be able to move to at most 10 MHz to 2.3 GHz⁶². We think this would unduly limit the ability to move from the first to the latter. As noted, bidders might anticipate this risk and bid for more spectrum than they would otherwise require in the 3.4 GHz band.
- A4.140 However, given the relatively high probability of becoming standing high bidders on those bids in the 3.4 GHz band, bidders might instead adopt a different strategy. In particular, they might instead start the auction bidding on the 2.3 GHz band and only move to the 3.4 GHz band once the price in the 2.3 GHz reaches the expected final price. This would lead to a two-stage auction: an initial stage where bidders bid for 2.3 GHz until the price reaches the expected final price and a second stage where bidders bid for the 3.4 GHz. Bidders in such an auction might fail to benefit from some of the advantages of a simultaneous auction. In addition, the outcome of such an auction might be inefficient, particularly if bidders make a wrong estimate as to the likely final price in the 2.3 GHz band.
- A4.141 A 2:1 ratio carries a lower risk. On one hand, it does not preclude substitution back to the 2.3 GHz band. A bidder who is bidding on 50 MHz in the 3.4 GHz band would be able to move to 20 MHz in the 2.3 GHz band. On the other hand, it allows bidders to expand demand in the 3.4 GHz band when moving away from the 2.3 GHz band.
- A4.142 For the reasons set out above, we have decided to change the eligibility ratio from 1:1 to 2:1, as measured per MHz. This means each 10 MHz lot in the 2.3 GHz band will be assigned 4 eligibility points, and each 5 MHz lot in the 3.4 GHz band will be assigned 1 eligibility point.
- A4.143 With regards to the proposals for a relaxed activity rule in the SMRA, we note we had proposed such a rule for the CCA in our consultation. However, the relaxed

⁶² Each 10MHz lot of 2.3GHz would have 6 eligibility points, while each 5MHz lot of 3.4GHz would have 1 eligibility point. Therefore, a bid for ten 5MHz lots of 3.4GHz would require 10 eligibility points, which would allow the bidder to switch to a bid for one 10MHz lot of 2.3GHz (which requires 6 points), but not to a bid for two 10MHz lots of 2.3GHz (which would require 12 points).

activity rule would also have included provisions that guaranteed that bidders' preferences were consistent throughout the auction, namely the chain bids.

A4.144 Without provisions to ensure that bids must be consistent with preferences revealed in earlier rounds a relaxed activity rule would increase the scope for untruthful bidding. In particular, it might materially increase the scope for price driving strategies and for withholding demand. On the other hand, introducing such provisions in the SMRA would require bidders to submit alternative bids when this might be required to maintain consistency with preferences revealed by earlier bids, and using a combinatorial approach to determining standing high bids. This would completely change the nature and the structure of the auction and significantly reduce its simplicity. We have therefore decided not to introduce a relaxed activity rule in the SMRA.

Waivers

A4.145 There was less comment overall on our proposals for waivers. A confidential respondent said it supported the idea, including default waivers, and thought that an allowance of three waivers was "about the right number". It suggested discretion for Ofcom to grant additional waivers to bidders who can demonstrate that their use of a waiver was due to technical issues outside their reasonable control, and not for strategic purposes.

A4.146 However, H3G said it would be best to avoid allowing bidding waivers, which introduce bidding complexity and offer no real benefit. It would be better to use round extensions instead, as in past UK auctions. H3G said waivers may invite market division by allowing a bidder to hold a credible threat of retaliation.

A4.147 EE noted that a bidder who is the standing high bidder on a portion of lots, but who wishes to switch demand, could use a waiver in one round and then hope it is outbid. This would enable it to switch demand in the subsequent round. However, this was not certain. With only three waivers, bidders could effectively be restricted to no more than one swap between bands throughout the entire auction. The outcome was that substitution between the two lot categories was obstructed under the rules. EE said this was a further argument for a CCA auction process.

Ofcom assessment

A4.148 We understand waivers may be useful to bidders in a number of different circumstances.

- Waivers are useful when bidders experience difficulties, technical or otherwise, which prevent them from submitting a bid. In the circumstances where the failure to submit a bid would result in a loss of eligibility, a default waiver will be used on behalf of the bidder.
- Waivers may also be useful when bidders would want to use information (for example, a change in relative prices) from the auction before they commit to a decision on how to bid.
- Finally, waivers may assist bidders when they are faced with some of the residual risks which we have identified for the SMRA in our consultation. In particular, waivers may be useful to address substitution risks when standing high bidders in one band wish to assess their chances of being outbid in all their standing high bids before moving to another band. Given the inherent

difficulty of setting the appropriate eligibility ratio, as described above, we believe waivers may play an important role in addressing this type of risk.

- A4.149 Extension rights might replace waivers when bidders face difficulties that prevent them from submitting a bid, but would not assist bidders in the two other circumstances.
- A4.150 Whilst we acknowledge that waivers may be used strategically, in the ways described by H3G, we also understand this would be made difficult by the limited information policy we proposed in the auction. This limited information policy was aimed precisely at mitigating the risk of strategic demand reduction and market division.
- A4.151 While we are maintaining a limited information policy, we are now releasing more information than we proposed in the November consultation. We understand this poses a concern with regards to using waivers strategically. Therefore, we decided to restrict the use of waivers so that bidders cannot place new bids and waive at the same time. Bidders will still be able to use waivers but will not be able to place new bids simultaneously.
- A4.152 We note that if bidders could place waivers and bids simultaneously, they might be able to test whether they could succeed at reducing demand for strategic purposes. This could be done by submitting a waiver while simultaneously bidding for a certain amount of spectrum which they would be content to acquire if they successfully managed to bring the auction to an earlier end. If this failed to bring the auction to an end, the bidder would still maintain eligibility for the following round.
- A4.153 In addition, bidders might place waivers and bids simultaneously to send signals to other bidders. In particular, because some information about the level of aggregate demand is disclosed, other bidders could observe the change in the aggregate demand that result from a bidder submitting a waiver while reducing its demand.
- A4.154 We disagree with EE that 3 waivers restrict bidders to one swap between bands throughout the entire auction. We note the ability of bidders to move across bands is facilitated in the auction by a number of features other than waivers. These include the ranking rule that guarantees that at most one bidder is a standing high bidder on less than its bid in the previous round. This minimises the chances of being stuck while moving demand from one band to the other. In addition, bidders are allowed to withdraw standing high bids. Finally, the eligibility ratio was revised to facilitate switching.

Increments and pricing of bids

Maintaining standing high bids at previous round prices

- A4.155 BT questioned the rule that bidders who wish to bid for more lots in the same category as they hold standing high bids need to increase prices for all lots. BT said that modifying or abolishing the rule would reduce the linearity of prices and therefore strategic demand reduction.

Ofcom assessment

- A4.156 Allowing bidders to place bids at the round price while maintaining standing high bids at a previous round price, as proposed by BT, facilitates strategic demand

reduction. Bidders might be able to test demand in order to assess the benefits of reducing demand strategically.

A4.157 Price linearity in the SMRA is not changed by the measure proposed by BT. Non-linear prices may increase efficiency in some circumstances, and reduce the incentives for strategic demand reduction, because they allow the auctioneer to set prices for packages rather than standalone lots. This allows bidders to specify their willingness to bid for extra spectrum, if such bidding does not raise the cost of their bid for a lower amount of spectrum. It is, in that respect, a conditional bid. A bidder in the SMRA, who would be allowed to submit a bid at a higher price for more spectrum, while maintaining standing high bids at a lower price, would not in fact be placing a conditional bid. Its bid for more spectrum might, for instance, cause an increase in price for the whole band and displace its own standing high bids at a lower price.

Uniform prices within a band for winning bids

A4.158 A confidential respondent said a uniform price should apply to lots won by bidders in the same band. This should be based on the lowest winning bid amount.

Ofcom assessment

A4.159 We believe this would change the nature of the SMRA. The SMRA is a pay-as-bid format, where bidders commit to pay their winning bids. Changing the nature of the SMRA could have detrimental consequences, including:

- Standing high bids established in previous rounds (at a lower price) might not confer an advantage to the bidders who placed them. They would end up paying the same price as other bidders who were not deemed standing high bidders at that price. The result may be perceived as unfair.
- There might be unhappy losers. Bidders who placed bids at the lower price, but were not selected as standing high bidders, would be willing to acquire spectrum at the final price but might have failed to do so because they did not want to place a bid at a higher price. Under the rule proposed by the confidential respondent, if standing high bidders are outbid and the auction closes without them bidding back, the winning bidder would only be required to pay the price at which the losing bidder held the standing high bids that had been outbid. However, in this case, it would be difficult to justify not awarding the lots to the losing bidder, given that they would be sold at the price of its previous standing high bids. This might be even more of a concern when a bidder is outbid on only some of its standing high bids, so that it wins some of its bids but it loses others at the same price.
- The change in the price rule might increase bidding complexity. In particular, bidders who reached either their valuation or their budget in a certain band at a certain price, but were not deemed standing high bidders (or were deemed standing high bidders in a partial bid), might still be tempted to place a bid at a higher price because they might not pay this price, but a lower one. This may risk efficiency in the auction.

A4.160 The upside from adopting such a rule is unclear. At best, it would not change the outcome of the auction – only the prices paid. At worst, it would change the outcome of the auction by making it less efficient for the reasons noted above. We have therefore rejected the proposal made by the confidential respondent. In any

case, any difference in final prices paid in the same band may be reduced by setting appropriate increments.

Deposits

A4.161 In our November 2014 consultation we indicated that we would have power to require increases in deposits to reflect the level of bidding. We have decided that bidders will have to deposit with Ofcom before the auction begins sufficient funds to cover their allocation of eligibility points. Thereafter we may require deposit increases up to 100% of bids. Any bidder who drops out of the auction will have any sums owing to them returned as soon as possible after leaving the auction.

Ranking rule

A4.162 Two respondents commented on our proposals for ranking bids randomly in order to determine those which become standing high bids.

A4.163 H3G said the rule was not random in reality, and the procedures created strategic opportunities for bidders. It said a bidder who expects to be tied with another bidder at a higher price level has strong incentives to time its bids strategically. A sophisticated bidder might be able to use this strategically to win spectrum at a lower increment, or take advantage of losing a tie break to preserve eligibility and raise other bidder's prices.

A4.164 A confidential respondent said priority should be given to bids submitted at higher prices and in earlier rounds. They also claimed the minimum requirement should apply when determining standing high bids.

Ofcom assessment

A4.165 The ranking rule we proposed allocates standing high bids randomly. It was, however, not random in the way standing high bidders from previous rounds are displaced. More recent standing high bidders would be displaced first. This rule aimed to ensure that no more than one bidder is standing high bidder on less than their full demand. This is a desirable feature of the ranking rule, as it reduces the scope for aggregation and substitution risks.

A4.166 We can still maintain this desirable property, while making the rule that determines how standing high bidders are displaced more random. Specifically, any bidder who is standing high bidder on fewer lots than it bid for when it submitted its standing high bids should be outbid first, but otherwise bidders with bids at the same price level should be ordered randomly and independently of the round in which they submitted their bids. A consequence of this is that when the price in a lot category does not change from one round to another, new bids at the same price may displace standing high bids submitted in an earlier round. The advantage of this approach is that all bids at a given price level (other than standing high bids held by a bidder whose demand has not been satisfied) are considered with equal chance independently of the round in which they were submitted. This should mitigate possible incentives to time bids with the aim of influencing the chances that they may or not be outbid in the following rounds. An example of how the rule works is provided in the next annex (annex 5).

Annex 5

Illustrative auction procedures

- A5.1 This annex sets out revised illustrative procedures that we intend to adopt for the auction. This is not an attempt to draft Regulations for the award. The procedures may change as a result of amendments to the auction design, as we prepare the draft regulations. We shall consult again on draft regulations. We are publishing these revised illustrative procedures to help consideration of the practical implementation of the auction design.
- A5.2 These illustrative auction procedures do not consider the option of withholding some spectrum as described in section 3. If we decide to do this, some detail set out here would need to change although there would not be a fundamental difference in the auction design.
- A5.3 The determination of frequency assignments will consist of two stages. In the first stage (the 'principal stage'), Ofcom will determine the bandwidth to be assigned to each bidder in each band on the basis of a Simultaneous Multi-round Ascending (SMRA) bidding process. In the second stage (the 'assignment stage'), Ofcom will determine the specific frequencies to be assigned to each bidder.

Lot structure

Use of frequency generic lots

- A5.4 The award mechanism will consist of two distinct stages. In the first stage (the principal stage), the spectrum available will be offered as 'frequency-generic' lots grouped into two 'lot categories', one for each frequency band. Each frequency-generic lot will correspond to a frequency block of a pre-specified bandwidth in the corresponding frequency band, but will not be linked to specific frequencies in that band. During this stage, bids will relate to a number of lots in each category, but not to specific frequencies within the category's frequency range. This first stage will allow Ofcom to determine the number of lots (i.e. the total bandwidth) to be assigned to each bidder in each band.
- A5.5 The specific frequencies assigned to each winner of frequency-generic lots will then be determined in a follow-up assignment stage (the assignment stage). In the assignment stage, Ofcom will determine, for each frequency band, the potential assignment band plans that minimise fragmentation of assignments. Further details on the selection of potential assignment band plans are provided in the subsection on the assignment stage below.
- A5.6 In the event there are alternative assignment band plans in which some bidders would be assigned different frequencies, such bidders will be invited to bid for their preferred option.

Spectrum packaging

- A5.7 The spectrum in the 2.3 GHz band will be assigned in 10 MHz lots. The spectrum in the 3.4 GHz band will be assigned in 5 MHz lots.

Lot categories

- A5.8 The spectrum available will be offered in two generic lot categories
- 2.3 GHz: This category will contain four frequency-generic 10 MHz lots in the frequency range 2350-2390 MHz; and
 - 3.4 GHz: This category will contain thirty frequency-generic 5 MHz lots within the frequency range 3410-3600 MHz.

Eligibility points

- A5.9 Each lot in the 2.3 GHz lot category will be assigned four eligibility points, while each lot in the 3.4 GHz lot category will be assigned one eligibility point.
- A5.10 The activity of a bidder in a round is equal to the sum of the eligibility points of all the lots for which the bidder submits or maintains a bid in the round. As lots in the 2.3 GHz category have double the eligibility points of lots in the 3.4 GHz category on a per MHz basis, bidders may increase their demand in MHz when switching from 2.3 GHz lots to 3.4 GHz lots; if they do not increase their demand in MHz when switching from 2.3 GHz to 3.4 GHz, then they may lose eligibility. Conversely, bidders switching from 3.4 GHz to 2.3 GHz will have to reduce their overall demand in MHz.

Demand on application, initial deposit and qualification

- A5.11 If Ofcom imposes spectrum caps, applicants will be required to specify their current spectrum holdings in their application, as this information may be required for the implementation of spectrum caps. Along with their application, applicants will be required to submit an initial monetary deposit, which might be forfeited in whole or in part if the applicant subsequently breaches the award regulations. Any interest on deposits will be retained by Ofcom.
- A5.12 After the deadline for application, Ofcom will publish the list of applicants (but not their initial eligibility levels or deposits). Applicants will then need to ensure they meet bidder association rules, which will not allow for two or more associated applicants to participate in the auction and may require some applicants to withdraw their application. Other qualification criteria to ensure that applicants are suitable to hold a licence will also apply. The provisions for qualification of bidders can be expected to be similar to those used in recent awards by Ofcom, and will be specified in the Regulations once these are published.
- A5.13 After the deadline to notify Ofcom of changes to application groups, Ofcom will determine which applicants qualify to participate in the auction. Ofcom may require additional information from specific applicants, which would need to be provided before a deadline specified by Ofcom. Ofcom will announce the list of qualified applicants, and return the initial deposit to any applicants who fail to qualify. Following the last day of withdrawals from the award, Ofcom will determine the bidders.
- A5.14 Before the first round of the auction takes place, bidders will need to provide an additional deposit to Ofcom, which will determine the bidder's initial eligibility level. The initial eligibility will correspond to the maximum activity that the bidder could achieve under the constraint that the sum of reserve prices for all the lots for which they bid may not exceed the total deposit provided by the bidder. The initial

eligibility level of a bidder determines the bids that the bidder may submit in the first round of the auction, as the bidder's activity in a round cannot exceed their eligibility level for that round. Ofcom will provide guidance on the deposit requirements for all possible initial eligibility levels.

- A5.15 In the event that the price that the bidder has to pay at the end of the auction is lower than their deposit, the bidder will receive any difference between the price to be paid and their deposit. Details about how and when to pay the initial guarantee deposit will be provided at a later stage.

The auction

- A5.16 Only qualified bidders will be allowed to participate in the auction. The auction is expected to be run over the Internet using an Electronic Auction System (EAS). No specialist hardware or software will be required on bidder's terminals, as the EAS interface will run on a standard web browser. However, bidders will need to install authentication credentials, provided by Ofcom only to qualified bidders, on any computer they wish to use to access the system. As in previous auctions, Ofcom expects to allow bidders to submit bids by fax in the event that they experience technical difficulties with the EAS, subject to Ofcom granting permission to the bidder to do so and provided that fax bids are authenticated in accordance with the regulations for the auction.

The principal stage

- A5.17 The bids received during the principal stage determine the bandwidth to be assigned to each bidder in each band, and the 'base price' that each winner of spectrum will be required to pay for the lots they have won.
- A5.18 Bidding in the principal stage will proceed in rounds, which consist of time windows scheduled by the auctioneer during which bidders are invited to submit bids at the lot prices announced by the auctioneer. Bids are only accepted while a round is in progress, and are only processed once the round has finished. At the end of each round, bidders will be notified whether the auction will proceed to the next stage or a further bidding round is needed, and given certain information about the results of the completed round (as detailed below).

Overview of the bidding process

- A5.19 Bidders may submit bids for the lots available at prices announced by the auctioneer. At the end of each round, the auctioneer determines provisional winning bids for each lot (the 'standing high bids'), which will become the winning bids unless they are replaced in subsequent rounds or withdrawn by the bidder. The process ends when there is no bidding activity (which includes submitting new bids, withdrawing standing high bids or using waivers) in a round. Standing high bids become the winning bids (except where a bidder's number of standing high bids in the 3.4 GHz band does not meet the minimum requirement specified by the bidder for that band, explained below). Winners will be required to pay the amount of their winning bids for the lots they have won.

Bids

- A5.20 The bid submission process requires bidders to select the number of lots they wish to bid for at the prices specified by the auctioneer. However, this is not a package

bid. Formally, where a bidder opts to bid for a number of lots this will be treated as separate bids for individual lots from that bidder. However, the auction is structured so that new bids will be subject to a common round price applying to all lots in a category; this facilitates the making of bids through the EAS, as bidders will simply need to specify the number of lots sought in each category.

A5.21 Each bid must specify:

- the lot category to which the bid applies; and
- the price that the bidder would pay for the lot if the bid is selected as a winning bid (determined by the lot prices set by the auctioneer for the round in which the bid was submitted).

A5.22 Submitting a bid establishes a commitment to acquire, in the event that the bid is selected as a winning bid, a lot in the specified lot category at a price equal to the bid amount.

A5.23 Bidders may bid for multiple lots simultaneously. However, it is possible that only some of these bids may be selected as winning bids, subject to the provisions for minimum spectrum requirements in the 3.4 GHz band set out below. Notwithstanding this, the process for selecting standing high bids has been designed with the intention of minimising the number of potential bidders who win some, but not all, of the bids they made simultaneously for lots in a lot category.

A5.24 A bid is only valid if it is submitted during a round in accordance with the auction rules set out below.

A5.25 Bidders may withdraw their standing high bids under specific circumstances and subject to potential penalties, as set out below.

Minimum spectrum requirements

A5.26 In their application, bidders may specify a minimum requirement ('MR') of up to four lots in the 3.4 GHz band. A bidder who specifies an MR will not be assigned any spectrum in the 3.4 GHz band if the number of lots they provisionally win at the end of the bidding process in the 3.4 GHz band is smaller than the MR they have specified.

A5.27 Specifying an MR will also establish a constraint on the bids that the bidder may submit for 3.4 GHz lots. Specifically, the bidder will not be able to submit bids for fewer lots in this category than the minimum required for them to meet their MR.

A5.28 The specification of an MR is irreversible and cannot be modified after application or at any point during the auction. Therefore, a bidder who specifies an MR for 3.4 GHz lots in their application will not, under any circumstances, be able to submit bids for, or win, less 3.4 GHz spectrum than their MR.

The bidding process

A5.29 The bidding process will require one or more rounds, each round consisting of a fixed time window during which bidders may submit bids in accordance with prices announced by the auctioneer and the auction procedures:

- when scheduling a round, Ofcom will announce the price per lot for each lot category for that round (the 'round prices');
- while the round is in progress, bidders may specify the number of lots in each lot category for which they wish to submit a bid at the round prices.

A5.30 Bidders may not specify a bid amount that differs from round prices.

Scheduling of rounds

A5.31 Ofcom will specify in advance of the auction the minimum notice period that will be provided before the start of a round and a minimum round duration.

A5.32 When a round is scheduled, the following information will be made available to each bidder:

- the schedule of the round;
- the round prices for each lot category for that round;
- the bidder's own eligibility level;
- the number of waivers the bidder has left (explained below);
- the standing high bids the bidder holds;
- the number of rounds in which the bidder may still withdraw their standing high bids (explained below); and
- any applicable sums for which the bidder is currently liable as a result of withdrawing their standing high bids (in accordance with the procedures set out below).

Bid submission during a round

A5.33 In each round, bidders can make a single submission of bids using the EAS. Therefore, bidders should submit all of the bids they wish to submit in a given round simultaneously, and specify any withdrawals or waivers (subject to the constraint set out in section "waivers", below) in the same submission. When a round is in progress, each bidder's EAS interface will provide a bid form.

A5.34 To make a submission, a bidder will need to:

- specify, using the bid form provided by the EAS,
 - a) the number of lots in each category for which they wish to submit a bid at the round prices (subject to the constraints on valid bids set out below);
 - b) if they wish to withdraw their standing high bids in a lot category (only possible when the bidder holds standing high bids);
 - c) if they wish to submit a waiver in the round (only possible if the bidder has waivers left, if the bidder's bidding activity is less than the bidder's eligibility in the round and if the bidder is not submitting any bids and/or withdrawals, as explained in section "waivers", below).

- send the completed bid form to the auction server, so that the bid can be checked for validity against the auction rules;
- provided that the submission is valid according to the auction rules, confirm the submission using the confirmation form provided in the bidder interface of the EAS.

A5.35 The submission process is only completed when the bidder confirms their submission. Submissions sent to the server to check validity but not confirmed will be discarded by the EAS.

A5.36 Upon receipt of a valid submission, the EAS interface will provide a confirmation page. Conversely, if the submission process fails, the EAS interface will revert to the bid form. It is the responsibility of the bidder to check (through its bidder interface) that its submission has been successfully received by the auction server, and to alert Ofcom if it suspects any problems have occurred.

A5.37 Once the auction server has received a confirmation of a valid submission in a round, the bidder will not be able to revise or withdraw this submission, or submit any further bids, withdrawals or waivers in the round.

A5.38 In the first round, each bidder must submit a bid for at least one lot. Any bidders who do not submit a bid in the first round will be excluded from the auction and may not have the full amount of their deposit returned.

A5.39 Bidders may not submit a waiver in the first round.

A5.40 A bidder may submit a decision not to place any bids in any round after the first round.

Valid bid combinations

A5.41 A bidder may only submit a combination of bids and withdrawals such that:

- any bid submitted for 3.4 GHz lots corresponds to at least the bidder's MR; and
- if Ofcom imposes spectrum caps, the bidder would not breach any such spectrum caps.

Bidding for lots when the bidder holds standing high bids

A5.42 Bidders may not submit any bids for lots in a lot category from which they are withdrawing existing standing high bids.

A5.43 After the first round, a bidder holding standing high bids in a lot category may submit bids in that lot category according to the following:

- If the price for lots in the lot category has increased relative to the price at which they submitted the bids that are currently standing high bids. In this case, the bidder may submit bids at the new round price, subject to the requirement that the bidder must bid for at least as many lots as they hold standing high bids on. If a bidder submits bids at the new price level, then the bidder's standing high bids at the earlier price level will be discarded, when superseded by bids submitted at the new round price (regardless of

whether the new bids become standing high bids, and independently of the bids submitted by other bidders); or

- Conversely, if the price for lots in the lot category has not increased relative to the price at which they submitted the bids that are currently standing high bids. In this case, the bidder may submit bids at the round price for at least as many lots as they held standing high bids on. If a bidder submits new bids for that lot category, any standing high bids held by the bidder will be cancelled. Therefore:
 - i) the bidder must specify the total number of lots they wish to bid for at the prevailing round price; and
 - ii) as previous standing high bids are cancelled, there is no guarantee that the bidder will hold any standing high bids after bids for the round have been processed.

Determination of standing high bids

A5.44 At the end of each round, the EAS will determine the standing high bids for each lot category. Standing high bids are determined for each lot category independently.

A5.45 For each lot category:

- i) The EAS will consider:
 - 1. the standing high bids in the category at the beginning of the round that have not been cancelled during the round (as a result of a withdrawal, or the standing high bidder submitting new bids in that category); and
 - 2. the new bids in that category submitted during the round.
- ii) The EAS will order the bidders who have maintained standing high bids for lots in that category or submitted new bids in the most recent round for lots in that category as follows:
 - 1. first, take in random order those bidders whose bids are at the current round price (regardless of whether they maintained previous standing high bids or submitted new bids in the current round);
 - 2. next, take in random order those bidders who (i) maintained standing high bids with a bid amount lower than the current round price and (ii) are standing high bidder on the number of lots they bid for in that lot category when they submitted these bids;
 - 3. finally, if there is a bidder who (i) maintained its standing high bids with a bid amount lower than the current price and (ii) is standing high bidder on strictly fewer lots than they bid for in the round in which they submitted their standing high bids this bidder is ordered last. (There is at most one bidder in this situation in each category as a consequence of the rules.)

- iii) The EAS will then select the standing high bids by taking the bids submitted by each of these bidders in the order established in the previous step, until there are no more lots available.

A5.46 This approach ensures that:

- i) at most one standing high bidder in each lot category may hold standing high bids on fewer lots than they bid for in that category in the round in which they submitted these standing high bids; and
- ii) bids at the same price level are treated equally (regardless of whether they have been submitted in an earlier or later round), except for standing high bids from a bidder whose demand at the price of their standing high bids is not satisfied, which are outbid first.

Box 1: Example of the determination of standing high bids

Consider the 2.3 GHz lot category, with four lots available and four bidders (A, B, C and D). Suppose that the auction progresses as shown by the table below. The bids and prices shown are purely illustrative.

Round	Price	Round bids				Order	Standing high bids at the end of the round [price]			
		A	B	C	D		A	B	C	D
1	10	3	3	2	1	BDAC	-	3 [10]	-	1 [10]
2	11	2	-	2	1	ADCB	2 [11]	-	1 [11]	1 [11]
3	12	-	2	W	-	BDAC	1 [11]	2 [12]	-	1 [11]
4	12	-	-	2	1	DBCA	-	2 [12]	1 [12]	1 [12]

At the end of round 1, there are four bidders who have bid at the current round price. The EAS generates a random order for this group of bidders (BDAC). There are no other bidders to consider. The EAS will select standing high bids by taking the bids submitted by each of these bidders in order. Bidder B bid for 3 lots and becomes standing high bidder on 3 lots. The next-ranked bidder, D, bid for 1 lot and becomes standing high bidder on 1 lot. There are no residual lots available, so A and C do not become standing high bidders.

In round 2, the price increases. Bidders A, C and D submit new bids (although bidder D would not need to submit a new bid at the new round price, as they are a standing high bidder at the previous round price, they may do so if they want).

The EAS will first consider the bids at the current round price and generates a random order for the corresponding group of bidders (ADC).

Bidder B has maintained standing high bids with a bid amount lower than the current round price and will only be considered afterwards.

Therefore, the overall order of bidders is ADCB. Bidder A bid for 2 lots and becomes

standing high bidder on 2 lots. The next-ranked bidder, D, bid for 1 lot and becomes standing high bidder on 1 lot. The next-ranked bidder, C, bid for 2 lots but there is only one residual lot available, so C becomes standing high bidder on 1 lot. Bidder B is not standing high bidder on any lots.

In round 3, the price again increases. Bidder B bids at the new price, bidder C submits a waiver and the other bidders simply maintain their standing high bids.

Bidder B is the only bidder to have bid at the current round price, so B will be considered first by the EAS.

Then, the EAS will consider bidders who maintained standing high bids with a bid amount lower than the current round price and who are standing high bidders on the number of lots they bid for when they submitted those bids – this applies to A and D. The EAS generates a random order for this group of bidders (DA).

Finally, any bidder who maintained standing high bids but was standing high bidder on strictly fewer lots than it bid for in the round in which it submitted its standing high bids is ordered last by the EAS – this applies to C.

Therefore, the overall order of bidders is BDAC. Bidder B bids for 2 lots and becomes standing high bidder on 2 lots. The next-ranked bidder, D, was standing high bidder on 1 lot and retains this standing high bid. The next-ranked bidder, A, was standing high bidder on 2 lots but there is only 1 residual lot available, so A remains standing high bidder on only 1 lot. Bidder C is not standing high bidder on any lots.

In round 4, the price is unchanged. Bidders C and D submit new bids.

Bidders B, C and D now have bids at the current round price. The EAS generates a random order for this group of bidders (BDC).

Bidder A maintained a standing high bidder with a bid amount lower than the current round price, and was standing high bidder on strictly fewer lots than it bid for in the round in which it submitted its standing high bids, so A is ordered last.

Therefore, the overall order of bidders is BDCA. Bidder B was standing high bidder on 2 lots and retains these standing high bids. The next-ranked bidder, D bid for 1 lot and becomes standing high bidder on 1 lot. The next-ranked bidder, C, bid for 2 lots but there is only 1 residual lot available, so C becomes standing high bidder on 1 lot. Bidder A is not standing high bidder on any lots.

Round prices

A5.47 For each round, Ofcom will specify the round price per lot for each lot category.

A5.48 In the first round, the round price for each lot category will be the reserve price for each lot in that category.

A5.49 In subsequent rounds:

the round price for a lot category will increase if the number of standing high bids in that category with a price that is equal to the round price in the most recent round is equal to the total number of lots available in the category; and

otherwise, the round price for the lot category will remain unchanged.

A5.50 Therefore, round prices may not decrease over the course of the rounds.

A5.51 The increase in round prices, when applicable, will be determined at Ofcom's discretion and may vary across lot categories and across rounds. Ofcom currently expects setting price increments of no less than 2% and no more than 20% from one round to the next.

A5.52 Round prices will be specified in whole thousands of pounds.

Withdrawal of standing high bids

A5.53 A bidder who holds standing high bids may withdraw all of their standing high bids in a given lot category in the course of a round.

A5.54 A bidder may withdraw all their standing high bids in a lot category while maintaining any other standing high bids in a different lot category. However, a bidder may not withdraw only some of their standing high bids in a given lot category.

A5.55 A bidder may submit their withdrawals along with bids for a different lot category, but may not withdraw standing high and bid at the same time for lots in the same lot category.

A5.56 A bidder may only withdraw standing high bids in at most five rounds during the auction.

A5.57 A bidder cannot withdraw more than once from a lot category if the round price for lots in that category has not increased since the round in which the previous withdrawal was made.

A5.58 Bidders who withdraw standing high bids from a lot category may be liable to pay up to the total bid amount corresponding to the standing high bids withdrawn. In the event that several bidders withdraw their standing high bids, all of these bidders may be liable to pay. However:

- if a bidder who has withdrawn standing high bids from a lot category bids again for lots in that category, then the sum payable with respect to that withdrawal will not exceed the bid amount corresponding to the number of lots from which the bidder has withdrawn but not bid back. Therefore, if a bidder withdraws their standing high bids from four lots and then bids back on two lots, then the bidder would only be liable to pay (with respect to this withdrawal) up to the total bid amount corresponding to the withdrawn standing high bids on two lots; and
- if a standing high bid is selected for all the lots in the category after processing the bids from the round in which a withdrawal is made, or in any subsequent round, then there will be no payment required corresponding to this withdrawal.

Box 2: Example of payments related to withdrawals

This example demonstrates how standing high bids would be determined in the 2.3 GHz lot category, with four lots available, four bidders (A, B, C and D) and the auction progressing as shown. The bids and prices are purely illustrative.

Round	2.3 GHz lot category				3.4 GHz lot category				Maximum withdrawal liability
	Price	Decision	Outcome	Do all lots have SHBs?	Price	Decision	Outcome	Do all lots have SHBs?	
1	10	No bid	No SHB	Yes	3	Bid, 16 lots	SHB, 6 lots	Yes	-
2	11	Bid, 4 lots	SHB, 4 lots	Yes	4	Withdraw	No SHB	No	18
3	12	No bid	No SHB	Yes	4	No Bid	No SHB	No	18
4	13	Bid, 4 lots	SHB, 3 lots	Yes	4	No Bid	No SHB	No	18
5	14	No bid	SHB, 3 lots	No	4	Bid, 4 lots	SHB, 4 lots	No	6
6	14	No bid	SHB, 3 lots	No	4	No bid	No SHB	Yes	-

In round 1, the bidder bids for 16 lots in the 3.4 GHz category and becomes standing high bidder on 6 lots in that category.

In round 2, the bidder opts to withdraw their standing high bids in the 3.4 GHz category and submit new bids in the 2.3 GHz category, becoming standing high bidder on four lots in that category. It has not been possible to select standing high bids for all lots in the 3.4 GHz category. Therefore, at this point the bidder's maximum withdrawal liability is the total bid amount corresponding to the standing high bids withdrawn (6 lots priced at 3 each, which gives a total bid amount of 18).

In round 3, the bidder loses their standing high bids in the 2.3 GHz category.

In round 4, the bidder bids again for 4 lots in the 2.3 GHz lot category and becomes standing high bidder on 3 lots. During these rounds it has still not been possible to select standing high bids for all lots in the 3.4 GHz category and therefore the bidder remains liable for a maximum penalty of 18 in relation to its withdrawal in round 2.

In round 5, the bidder does not submit new bids in the 2.3 GHz category, but returns to the 3.4 GHz category with the eligibility they do not have committed to their standing high bids on 2.3 GHz lots, bidding for 4 3.4 GHz lots. The bidder becomes standing high bidder on 4 lots in the 3.4 GHz category. The bidder had earlier withdrawn 6 standing high bids in this category, but has now bid back for 4 lots. Therefore, their liability for their earlier withdrawal relating to 4 of the 6 lots from which they have withdrawn is cancelled, but they remain liable in relation to the 2 lots from which they have withdrawn, equal to the full amount of the standing high bid they have withdrawn. Therefore, their current maximum liability in relation to their withdrawal in round 2 is 6.

In round 6, other bidders submit bids for 3.4 GHz lots and it is possible to select standing high bids for all lots in the 3.4 GHz category. As a result, the bidder is no longer liable for payments in relation to their withdrawal in round 2.

Activity rules

A5.59 The activity of a bidder in a round is calculated as:

- i) the sum of eligibility points assigned to all lots for which the bidder holds a standing high bid in lot categories where the bidder does not submit any bids and which are not withdrawn by the bidder in the round; plus
- ii) the sum of eligibility points assigned to all lots for which the bidder submits bids in the round.

A5.60 Each bidder will start each round with a given eligibility level. Bidders will start the first round with eligibility equal to their initial eligibility level. In subsequent rounds, the bidder's eligibility will be equal to the bidder's activity in the most recent completed round in which the bidder did not submit a waiver (explained below).

A5.61 The activity of a bidder in a round cannot exceed the bidder's eligibility for that round.

Waivers

A5.62 Each bidder may submit up to three waivers during the auction. A bidder may submit a waiver in any round in which their activity from standing high bids is lower than their eligibility, except the first round. A bidder who submits a waiver in a given round cannot submit any new bids or withdraw any standing high bids in the same round. The effect of the waiver will be to preserve the eligibility of the bidder for the following round; eligibility reductions are only made in relation to the bidder's activity in a round in which they do not submit a waiver.

Default submissions

A5.63 The EAS will submit a default waiver for any bidder who does not submit a decision within a round if:

- the bidder's activity from standing high bids is less than their eligibility for the round; and
- the bidder has waivers left.

A5.64 The EAS will not make any other default submissions.

A5.65 To prevent the submission of a default waiver, bidders may submit a decision not to place any bids in the round, in which case they may lose eligibility in the following round.

End of the bidding process

A5.66 The bidding process ends after the first round in which no bids, withdrawals or waivers (including default waivers) are submitted.

Determination of winning bids

A5.67 At the end of the bidding process, standing high bids will become winning bids, except for standing high bids for 3.4 GHz lots which are fewer than the bidder's MR.

Determination of base prices

A5.68 The base price for each winning bid will be equal to the round price at which the bid was submitted.

Information released at the end of each round of the bidding phase

A5.69 At the end of each round the EAS will process the submissions in the round and determine whether a further round is needed. In the event that a further round is needed, the EAS will determine which categories require a price increase. Information about a completed round will be made available to bidders only after the auctioneer approves the results for the round.

A5.70 The 'active bids' in each category in a given round are defined to be:

- the standing high bids in that category at the beginning of the round that have not been cancelled (as a result of a withdrawal, or the standing high bidder submitting new bids in that category); and
- the new bids for lots in that category submitted in the round.

A5.71 We define 'excess demand' for lots in a lot category in a given round as the total bandwidth corresponding to all active bids in that category minus the total bandwidth corresponding to all the lots available in that category.

A5.72 If a further round is needed, the following information will be made available to each bidder on the EAS interface:

- the bids submitted by the bidder in the most recent round;
- the standing high bids currently held by the bidder;
- whether the bidder withdrew their standing high bids in a lot category in the most recent round;
- any applicable financial liabilities resulting from withdrawals, given the bids received up to the most recent round;
- the round prices for each lot category in the most recent round;
- for each lot category, after the first round, the smallest positive multiple of 20 MHz that is strictly greater than excess demand in that category in the most recent round (i.e. whether excess demand for that category in the round was less than 20 MHz, 40 MHz, 60 MHz, 80 MHz, etc);
- which lot categories will require a price increment;
- the bidder's own eligibility level;
- the number of waivers that the bidder has available for further rounds; and
- the number of rounds in which the bidder may still withdraw standing high bids.

- A5.73 At this stage, no further information will be released about the bids submitted by other bidders.
- A5.74 If the bidding process has ended, the following information will be made available to each bidder on the EAS interface:
- a message informing the bidder that the bidding process has ended;
 - the standing high bids held by the bidder at the end of the round;
 - any applicable financial liabilities resulting from withdrawals;
 - the round prices for each lot category in the final round; and
 - the winning bids of the principal stage for all bidders.
- A5.75 The EAS will provide the functionality to view and download the information provided after each completed round, once approved by the auctioneer.

The assignment stage

- A5.76 The specific frequencies assigned to bidders who have won any lots in the principal stage will be determined in the assignment stage.
- A5.77 The assignment of specific frequencies will be determined independently for each band.

Possible assignment plans

- A5.78 For the 2.3 GHz band, Ofcom will only consider assignment plans in which each bidder is assigned a contiguous frequency block that corresponds to the bandwidth they won in the principal stage, and in which any unallocated spectrum forms a contiguous frequency block.
- A5.79 For the 3.4 GHz band, it may not be possible to assign to each winner as a contiguous range all of the frequencies they have won in the principal stage if UK Broadband does not participate in the auction. However, Ofcom will prioritise assignment plans in which unnecessary fragmentation of assignments is avoided. Accordingly, Ofcom will only consider those assignment plans in which the unassigned frequencies in each sub-band (i.e. above or below UK Broadband's lower block) form a contiguous frequency block. In addition, the range of assignment plans may be narrowed in accordance with the following procedures:
- if there are assignment plans in which each bidder is assigned a single contiguous frequency range, then only these assignment plans will be considered;
 - if it is not possible to assign a single contiguous frequency range to each bidder, but there are assignment plans in which each bidder who receives non-contiguous frequencies obtains their frequencies in two contiguous frequency blocks of at least 20 MHz each, then only these assignment plans will be considered;

- of the remaining assignment plans, only those in which the number of winners receiving non-contiguous frequencies is minimised will be considered.

A5.80 If there is only one assignment that meets these requirements, then bidders will be assigned the frequencies corresponding to the spectrum they won in the relevant lot category in accordance with this assignment. If there are multiple assignments that meet these requirements, then bidders who are assigned alternative frequencies in different assignments will be invited to submit bids for these alternative options.

A5.81 If a bidding process for the assignment stage is needed, Ofcom will schedule a single round of bidding (the 'assignment round') in which the relevant bidders may submit bids (the 'assignment bids') for their preferred frequency assignments. Ofcom would determine the assignment that would allow us to maximise the value of accepted bids. Bidders may then be required to pay a price (the 'additional price'), on top of their base price, for the frequencies they are assigned (if they submitted a bid for this option and other bidders had expressed a preference for an option that is not compatible with this). Bidders do not have to submit assignment bids to be assigned spectrum they won in the principal stage. Participation in the bidding process of the assignment stage is optional.

Assignment bids

A5.82 The 'assignment options' for each bidder are determined by Ofcom in accordance with our determination of possible assignment plans.

A5.83 If there are multiple possible assignment plans for a band, then at least two bidders will have multiple assignment options in that band. Any such bidders will have the opportunity to express their preferences over those options in the form of assignment bids.

A5.84 An assignment bid consists of:

- an assignment option; and
- a bid amount, specified in pounds, and which must be in whole thousands of pounds and at least zero.

A5.85 Submitting a bid establishes a commitment to pay an additional price that would not exceed the bid amount in the event that the bidder is assigned the frequencies specified in the corresponding option.

Scheduling of the assignment round

A5.86 Ofcom will specify in advance of the auction the minimum notice period that will be provided before the start of the assignment round and a minimum round duration.

A5.87 When the assignment round is scheduled, the following information will be made available to each bidder:

- the schedule of the round;
- the alternative assignment options that the bidder may bid for.

Bid submission

- A5.88 When the assignment round is in progress, participating bidders may submit a single list of assignment bids using the EAS.
- A5.89 The interface of the EAS will provide a bid form that lists all assignment options available to the bidder.
- A5.90 To submit its list of assignment bids, a bidder will need to:
- enter the bid amount for each one of the assignment options they wish to bid for in their bid form (the bid amount for any options left blank will be set to zero);
 - send the bid form to the auction server, so that it can be checked for validity against the auction procedures;
 - provided that all bids in the list are valid according to the auction procedures, confirm submission of their assignment bids using the confirmation form provided by the bidder interface of the EAS.
- A5.91 The submission process will be blocked if any of the assignment bids in the list are invalid. In such a case, none of the assignment bids will be accepted, unless the bidder amends their list and completes the submission process of a valid list of assignment bids.
- A5.92 The process of submitting a list of assignment bids is only completed when the bidder confirms the submission. A list sent to the server to check for validity but not confirmed will be discarded by the EAS.
- A5.93 Upon receipt of a valid submission of a list of assignment bids, the EAS interface will provide a confirmation page, listing the assignment bids received by the EAS. Conversely, if the assignment bids submission process fails, the EAS interface will revert to the bid form. It is the responsibility of the bidder to check (through its bidder interface) that their list of assignment bids has been successfully received by the auction server, and to alert Ofcom if they suspect any problems have occurred.
- A5.94 Once the auction server has received a confirmation of a valid submission of a list of assignment bids in the assignment round, the bidder will not be able to revise or withdraw this submission, or submit any further assignment bids.
- A5.95 Any bidder who fails to submit a list of assignment bids before the end of the assignment round will lose the opportunity to submit assignment bids. In this case, the bid for all their assignment options will be set to zero by default.

Determination of winning assignments

- A5.96 The determination of winning assignments will be calculated independently for each band.
- A5.97 For each band, the EAS will sum the bid amounts of the bids that can be accepted in each alternative possible assignment plan. The winning assignment plan will be the one that yields the greatest value of accepted bids. If there are multiple assignment plans that yield the greatest value, one of these will be selected as the winning assignment plan at random.

Determination of additional prices

- A5.98 The determination of additional prices is calculated independently for each band. The total additional price to be paid by each bidder will be equal to the sum of additional prices they have to pay.
- A5.99 Additional prices to be paid by winning bidders for the specific frequencies awarded to them in the assignment stage are based on the concept of opportunity cost.
- A5.100 For each band, the opportunity cost of assigning a subset of bidders their frequencies in the winning assignment plan is calculated as the difference between:
- the highest value of bids that could be achieved across all alternative assignment plans if all the bids from the bidders in the subset were set to zero; and
 - the sum of bid amounts of bids that are accepted from bidders that are not included in the subset in the winning assignment plan.
- A5.101 The standalone opportunity cost of a bidder is the opportunity cost of the subset of bidder that includes only this bidder.
- A5.102 For a given frequency range, the additional prices must satisfy the following conditions:
- the additional price for each bidder cannot be negative;
 - the additional price for each bidder cannot exceed the bid amount specified by the bidder for the assignment option they are assigned in the winning assignment plan;
 - the sum of additional prices for each subset of bidders (including subsets containing a single bidder, and the subset containing all bidders) must be at least the joint opportunity cost for that subset of bidders;
 - the total sum of additional prices must be the smallest across all possible sets of prices that meet the three conditions above.
- A5.103 If there are multiple combinations of prices (one for each winning bidder) that satisfy the conditions above, then the additional prices will be the unique combination of prices that minimises the sum of squares of the differences between each bidder's additional price and their standalone opportunity cost across all sets of prices that satisfy all four the conditions above.

Deposit calls

- A5.104 At any point during the auction, Ofcom may require bidders to increase their deposit up to an amount equal to the highest financial exposure of the bidder, including any withdrawal payments for which the bidder is liable.
- A5.105 In the event of a deposit call, Ofcom would specify a deadline for bidders to make any additional deposits, and provide details of how to make the additional deposit.
- A5.106 Failure to make a sufficient additional deposit before the specified deadline may result in:

- the bidder being prevented from submitting any further bids;
- some or all bids submitted by the bidder in earlier rounds being cancelled; and/or
- the bidder being excluded from the auction.

Extraordinary events

A5.107 Ofcom retains powers to address extraordinary events that might otherwise compromise the auction, including:

- rescheduling a round that has been scheduled and has not yet started;
- rescheduling the end of a round in progress;
- cancelling a round in progress;
- cancelling one or more completed rounds;
- suspending the auction;
- cancelling the auction;
- cancelling some or all bids submitted by one or more bidders in earlier rounds and
- excluding one or more bidders from the auction.

A5.108 Bidders who breach the auction procedures may forfeit part or all of their deposit.

Information released at the end of the auction

A5.109 The auction ends with the completion of the assignment stage. At this point, the following information will be released to all bidders:

- the frequencies assigned to each bidder that has been awarded spectrum; and
- the price to be paid by each bidder that has been awarded spectrum, including a breakdown of the base price and any additional prices.

A5.110 The current expectation is that Ofcom would also release all of the bid data from the auction.

Annex 6

Example 2.3 GHz licence



[Header (to all pages)]

[Company] – Spectrum Access 2.3 GHz Licence
Company registration number: XXXXX
First issued: xx/xx/xx – Licence Number: xxxxxxxx – xx/xx/xx

Office of Communications (Ofcom) Wireless Telegraphy Act 2006

SPECTRUM ACCESS 2.3GHz LICENCE

Licence no: **XXXX**

Date of issue: **XXXX**

Fee payment date **XXXX (annually)**
[(from **XXXX 2035/36**)]

1. The Office of Communications (Ofcom) grants this wireless telegraphy licence ("the Licence") to

[Company]
(Company registration number **XXXX**)
("the Licensee")
Add 1
Add 2
Add 3
Postcode

to establish, install and use wireless telegraphy stations and/or wireless telegraphy apparatus as described in the Schedules to this Licence (together "the Radio Equipment") subject to the terms set out below.

Licence Term

2. This Licence shall continue in force until revoked by Ofcom or surrendered by the Licensee.

Licence Variation and Revocation

3. Pursuant to Schedule 1 paragraph 8 of the Wireless Telegraphy Act 2006 ("the Act"), Ofcom may not revoke this Licence under schedule 1 paragraph 6 of the Act except:
 - (a) at the request, or with the consent, of the Licensee;

- (b) if there has been a breach of any of the terms of this Licence;
 - (c) in accordance with schedule 1 paragraph 8(5) of the Act;
 - (d) if it appears to Ofcom to be necessary or expedient to revoke the Licence for the purpose of complying with a direction by the Secretary of State given to Ofcom under section 5 of the Act or section 5 of the Communications Act 2003;
 - (e) if, in connection with the transfer or proposed transfer of rights and obligations arising by virtue of the Licence, there has been a breach of any provision of regulations made by Ofcom under the powers conferred by section 30(1) and 30(3) of the Act⁶³;
 - (f) for reasons related to the management of the radio spectrum, provided that in such a case the power to revoke may only be exercised after at least five years' notice is given in writing (such notice not to be given before [XXXX 2030/31]; or
 - (g) if the Licensee has been found to the reasonable satisfaction of Ofcom to have been involved in any act, or omission of any act, constituting a breach of the [Wireless Telegraphy (Licence Award) Regulations 20xx ("the Regulations")].
4. Ofcom may only revoke or vary this Licence by notification in writing to the Licensee and in accordance with schedule 1 paragraphs 6, 6A and 7 of the Act.

Transfer

5. This Licence may not be transferred. The transfer of rights and obligations arising by virtue of this Licence may however be authorised in accordance with regulations made by Ofcom under powers conferred by section 30 of the Act⁶⁴.

Changes to Licensee details

6. The Licensee shall give prior notice to Ofcom in writing of any changes to the Licensee's name and/or address as recorded in paragraph 1 of this Licence.

Fees

7. In accordance with the Regulations, the fee in consideration of which this licence is granted is [XXXX].
8. From [Date XXXX], the Licensee shall each year pay to Ofcom the relevant fee(s) as provided in section 12 of the Act and the regulations made thereunder on or before the fee payment date shown above, or on or before such dates as are notified in writing to the Licensee.
9. The Licensee shall also pay interest to Ofcom on any amount which is due to Ofcom under the terms of this Licence or provided for in any regulations made by Ofcom

⁶³ These are regulations on spectrum trading.

⁶⁴ See Ofcom's website for the latest position on spectrum trading and the types of trade which are permitted.

under sections 12 and 13(2) of the Act from the date such amount falls due until the date of payment, at the then applicable Bank of England base rate. In accordance with section 15 of the Act any such amount and any such interest is recoverable by Ofcom.

10. If the Licence is surrendered, revoked or varied, no refund, whether in whole or in part, of any amount which is due under the terms of this Licence, payable in accordance with the Regulations, or provided for in any regulations made by Ofcom under sections 12 and 13(2) of the Act will be made, except at the absolute discretion of Ofcom.

Radio Equipment Use

11. The Licensee shall ensure that the Radio Equipment is established, installed and used only in accordance with the provisions specified in the Schedules to this Licence. Any proposal to amend any detail specified in any of the Schedules to this Licence must be agreed with Ofcom in advance and implemented only after this Licence has been varied or reissued accordingly.
12. The Licensee shall ensure that the Radio Equipment is operated in compliance with the terms of this Licence and is used only by persons who have been authorised in writing by the Licensee to do so and that such persons are made aware of, and of the requirement to comply with, the terms of this Licence.

Access and Inspection

13. The Licensee shall permit any person authorised by Ofcom:
 - (a) to have access to the Radio Equipment; and
 - (b) to inspect this Licence and to inspect, examine and test the Radio Equipment,at any and all reasonable times or, when in the opinion of that person an urgent situation exists, at any time, to ensure the Radio Equipment is being used in accordance with the terms of this Licence.

Modification, Restriction and Closedown

14. Any person authorised by Ofcom may require the Radio Equipment or any part thereof, to be modified or restricted in use, or temporarily or permanently closed down immediately if in the opinion of the person authorised by Ofcom:
 - (a) a breach of this Licence has occurred; and/or
 - (b) the use of the Radio Equipment is, or may be, causing or contributing to undue interference to the use of other authorised radio equipment.
15. Ofcom may require any of the Radio Equipment to be modified or restricted in use, or temporarily closed down either immediately or on the expiry of such period as may be specified in the event of a national or local state of emergency being declared. Ofcom may only exercise this power after a written notice has been served on the Licensee or a general notice applicable to holders of a named class of licence has been published.

Geographical Boundaries

16. Subject to the requirements of any coordination and synchronisation procedures notified to the Licensee pursuant Schedule 1 to this Licence, and excluding the areas set out in condition 17, the Licensee is authorised to establish, install and use the Radio Equipment in Great Britain. For the avoidance of doubt, Great Britain excludes Northern Ireland, the Channel Islands and the Isle of Man.
17. The areas excluded from this licence are:
 - (a) the Outer Hebrides, the Isle of Skye and the Small Isles;
 - (b) the territorial sea and any internal waters adjacent to the territorial sea, but in the case of streams, rivers or other watercourses which form part of such internal waters only where such stream, river or watercourse is more than 2km wide.

Interpretation

18. In this Licence:
 - (a) the establishment, installation and use of the Radio Equipment shall be interpreted as establishment and use of wireless telegraphy stations and installation and use of wireless telegraphy apparatus for wireless telegraphy as specified in section 8(1) of the Act;
 - (b) the expression “interference” shall have the meaning given by section 115 of the Act;
 - (c) the expressions “wireless telegraphy station” and “wireless telegraphy apparatus” shall have the meanings given by section 117 of the Act;
 - (d) the expression “territorial seas” shall be determined in accordance with the Territorial Sea Act 1987;
 - (e) the expression “internal waters” shall have the meaning given by section 221(1) of the Water Resources Act 1991;
19. The Schedule(s) form part of this Licence together with any subsequent Schedule(s) which Ofcom may issue as a variation to this Licence.
20. The Interpretation Act 1978 shall apply to the Licence as it applies to an Act of Parliament.

Issued by Ofcom
Office of Communications

SCHEDULE 1 TO LICENCE NUMBER: XXXX

Schedule Date: XXXX 20XX

Licence category: Spectrum Access 2.3 GHz

Description of Radio Equipment

1. References in this Schedule to the Radio Equipment are references to any wireless telegraphy station or wireless telegraphy apparatus that is established, installed and/or used under this Schedule.

Interface Requirements for the Radio Equipment

2. Use of the Radio Equipment shall be in accordance with the following Interface Requirement:

[IR 20 XXXX: Terrestrial systems capable of providing electronic communications services in the band XXXX]

Special conditions relating to the Radio Equipment

3.
 - a) Subject to paragraph 3(b) of this Schedule, during the period that this Licence remains in force, unless consent has otherwise been given by Ofcom, the Licensee shall compile and maintain accurate written records of the following details relating to the Radio Equipment:
 - i) postal address (including post code);
 - ii) National Grid Reference, to at least 10 metre resolution;
 - iii) antenna height (above ground level), type, and boresight bearing east of true north (if applicable);
 - iv) radio frequencies which the Radio Equipment uses; and
 - v) Transmitted power expressed in dBm / 5 MHz EIRP per cell.

and the Licensee must produce these records if requested by any person authorised by Ofcom.

b) The conditions relating to the keeping of records contained in sub-paragraphs 3(a)(ii) and (iii) of this Schedule shall not apply in respect of femto cell equipment and smart/intelligent low power repeater equipment.

c) The conditions relating to the keeping of records contained in paragraph 3(a) of this Schedule shall not apply in respect of licence exempt radio equipment.

d) The Licensee shall submit to Ofcom copies of the records detailed in sub-paragraph 3(a) above at such intervals as Ofcom may notify to the Licensee.

e) The Licensee shall submit to Ofcom in such manner and within such period as specified by Ofcom, such other information in relation to the Radio Equipment, or any wireless telegraphy station or wireless telegraphy apparatus which the Licensee is planning to use, as Ofcom may from time to time request. Such information may include, but is not limited, to information in relation to the radio frequency, transmitted power and date of first use for wireless telegraphy stations or wireless telegraphy apparatus to be established, installed or used within such timeframe and in such areas as Ofcom may reasonably request.

Co-ordination at frequency and geographical boundaries

4. The Licensee shall ensure that the Radio Equipment is operated in compliance with such co-ordination procedures as may be notified to the Licensee by Ofcom from time to time.

Synchronisation of networks

5. The Licensee shall ensure that the Radio Equipment is operated in compliance with the Inter-Operator Synchronisation Procedure in Schedule 2.

International cross-border coordination

6. The Licensee shall ensure that the Radio Equipment is operated in compliance with such cross-border co-ordination and sharing procedures as may be notified to the Licensee by Ofcom from time to time.

Permitted Frequency Blocks

7. Subject to the emissions permitted under paragraph 8 of this Schedule, the Radio Equipment may only transmit within the following frequency bands (the "Permitted Frequency Blocks"):

XXXX - XXXX MHz

Maximum power within the Permitted Frequency Blocks

8. The power transmitted in the Permitted Frequency Blocks shall not exceed:

Radio Equipment	Maximum mean power
Base station (see Note 1)	61 dBm / 5 MHz EIRP*
Mobile or nomadic UE Radio Equipment	25 dBm TRP*
Fixed or installed UE Radio Equipment	25 dBm EIRP*

* The maximum mean power relates to the EIRP or TRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

Note 1: For femtocell base stations, power control must be applied to minimise interference to adjacent channels.

Maximum power of base stations outside the Permitted Frequency Blocks

9.

- a) Except as set out in paragraph 9(c) below, where the Inter-Operator Synchronisation Procedure in Schedule 2 determines that the Restrictive Mask applies, for transmissions on the downlink frequencies, the EIRP emanating from the Radio Equipment transmissions at any frequency outside the Permitted Frequency Blocks shall not exceed the following baseline:

Out of block baseline power limit (BS)	- 36 dBm / 5 MHz EIRP*
--	------------------------

- b) Except as set out in paragraph 9(c) below, where the Inter-Operator Synchronisation Procedure in Schedule 2 determines that the Permissive Mask applies, for transmissions on the downlink frequencies, the EIRP emanating from the Radio Equipment transmissions at any frequency outside the Permitted Frequency Blocks shall not exceed the following transitional and baseline requirements :

-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna
-10 to -5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna
Out of block baseline power limit (BS) < -10 MHz offset from lower block edge > 10 MHz offset from upper block edge	Min(PMax – 43, 13) dBm / 5 MHz EIRP per antenna

- c) The EIRP emanating from the Radio Equipment transmissions at any frequency outside the Permitted Frequency Blocks shall not exceed the following band edge requirements:

2345 MHz – 2350 MHz 2390 MHz – 2395 MHz	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna	
2340 MHz – 2345 MHz 2395 MHz – 2400 MHz	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna	
Below 2340 MHz	PMax > 35 dBm	-36 dBm / 5 MHz EIRP*
	PMax ≤ 35 dBm	-20 dBm / 5 MHz EIRP*
2400 MHz – 2403 MHz	Min(PMax – 43, 13) dBm / 5 MHz EIRP per antenna	
Above 2403 MHz	PMax > 42 dBm	1 dBm / 5 MHz EIRP*
	24 dBm < PMax ≤ 42 dBm	(PMax -41) dBm / 5 MHz EIRP*
	PMax ≤ 24 dBm	-17 dBm / 5 MHz EIRP*

* The maximum mean power relates to the EIRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

Interpretation of terms in this Schedule

10. In this Schedule:

- a) "dBm" means the power level in decibels (logarithmic scale) referenced against 1 milliwatt (i.e. a value of 0 dBm is 1 milliwatt);
- b) "EIRP" means the equivalent isotropically radiated power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain), measured during the "on" part of the transmission;
- c) "femtocell" means Radio Equipment transmitting on the downlink frequencies, which operates at a power not exceeding 24 dBm EIRP per carrier, and which is or will be used only by and under the control of the Licensee, following the establishment of a telecommunications link between the femtocell and a network of the Licensee;
- d) "Fixed or installed" means used or installed at specific fixed points;
- e) "IR" means a United Kingdom Radio Interface Requirement notified by Ofcom in accordance with Article 4.1 of Directive 1995/5/EC of the European Parliament and of the Council on radio equipment and telecommunications terminal equipment (RTTE) and the mutual recognition of their conformity;
- f) "lower block edge" means, in relation to each Permitted Frequency Block, the lowest frequency in that Permitted Frequency Block;
- g) "mobile or nomadic" means intended to be used while in motion or during halts at unspecified points;
- h) "Permitted Frequency Blocks" has the meaning given to it in paragraph 6 of this Schedule;
- i) "PMax" is the maximum mean power for the base station in question, measured as EIRP per carrier and determined irrespective of the number of transmit antennas;
- j) "smart/intelligent low power repeater" means a repeater which operates with power not exceeding 24 dBm EIRP per carrier, which may be established by customers of the Licensee who have written agreements with the Licensee and:
 - The Licensee has ultimate control of the repeater, i.e. each individual repeater can be disabled remotely by the Licensee;
 - The repeater operates only on the Licensee's frequencies and with their valid Public Land Mobile Network Identifier;
 - Must not cause undue interference to other spectrum users; and
 - The repeater only transmits on the uplink frequencies when actively carrying a call (voice, video or data) or signalling from serviced handsets.

- k) "TRP" means the total radiated power. This is the integral of the power transmitted in different directions over the entire radiation sphere, measured during the on part of the transmission; and
- l) "upper block edge" means, in relation to each Permitted Frequency Block, the highest frequency in that Permitted Frequency Block.

Ofcom

SCHEDULE 2 TO LICENCE NUMBER: XXXX
Inter-Operator Synchronisation Procedure⁶⁵

Schedule Date: XXXX 20XX

Licence category: **Spectrum Access 2.3 GHz**

Introduction

1. The holders of licences in the 2350 MHz – 2390 MHz band (such licences further referred to as the “Licences”, and the holders of the Licences together further referred to as, “the Licensees”) must co-operate in such a way that harmful interference is not caused by one network deployment to that of another Licensee within the band.
2. This procedure sets out the circumstances in which the Licensees can use the Restrictive Mask and the Permissive Mask, each as specified in Schedule 1 paragraph 9, so as to minimise the risk of harmful interference to other Licensees.

Conditions

Frame structure

3. Except as set out in paragraph 6 below, the emissions from the Licensee’s base stations must comply with the following frame structure:
 - a) The Frame Structure. Where the Licensee’s base station complies with this Frame Structure, the Permissive Mask as set out in Schedule 1 paragraph 9 (b) of this Licence applies:
 - i) Transmissions from the Licensee’s base stations must have a frame structure as shown in Figure 1. Indicated timeslots (or subframes) must not be allocated to anything other than Downlink (D) and Uplink (U) transmissions. S denotes a special subframe (See paragraph 4)
 - ii) Timeslots must have a duration of 1 millisecond
 - iii) TD-LTE frame configuration 2 (3:1) is compatible with this frame structure. Other technologies are permitted provided that the requirements of 3(a)(i) and (ii) are met.

Figure 3: Frame structure

DL/UL ratio	Subframe number									
	0	1	2	3	4	5	6	7	8	9
3:1	D	S	U	D	D	D	S	U	D	D

⁶⁵ Ofcom has made a statement as to the circumstances in which this procedure may be amended. See section 8 paragraphs 8.87 to 8.91

A compatible special subframe.

4. Except as set out in paragraph 6 below, the Licensee must ensure that the special subframes (S) in timeslot 1 and 6 have a structure that is compatible with TD-LTE special subframe configuration 6, also known as 9:3:2 (DwPTS: GP: UpPTS). For the avoidance of doubt, a special subframe structure is compatible where there are no uplink transmissions within the downlink pilot timeslot (DwPTS) or guard period (GP) and no downlink transmissions within the uplink pilot timeslot (UpPTS) or guard period (GP)

Timing and Alignment

5. Except as set out in paragraph 6, the Licensee shall ensure that frames start at a common reference time so that all licensees' frames are aligned and transmissions synchronised.

Small Cells

6. The Licensee is not required to comply with the requirements set out in paragraphs 3, 4 and 5 above, and the Permissive Mask as set out in Schedule 1 paragraph 9 (b) of this Licence applies, for:
 - (a) Indoor Domestic Small Cells; or
 - (b) Indoor Non-domestic Small Cells, except where another licensee demonstrates that they are suffering harmful interference as a result.

For the avoidance of doubt, if another licensee demonstrates that they are suffering harmful interference as a result of an Indoor Non-domestic Small Cell, the Indoor Non-domestic Small Cell must comply with the requirements set out in paragraphs 3, 4, 5 and 6 above

Definitions

7. In this Schedule:
 - a) "Downlink" means transmissions from a base station to a terminal station (handset)
 - b) "Indoor" means a location inside a building or place in which the shielding will typically provide the necessary attenuation to protect wireless telegraphy against harmful interference
 - c) "Indoor Domestic Small Cell" means a base station with an EIRP of less than or equal to 24dBm per carrier that is located within a residential property
 - d) "Indoor Non-domestic Small Cell" means a base station with an EIRP of less than or equal to 24dBm per carrier that is located indoors but not within a residential property
 - e) "TDD" means the application of time-division multiplexing to separate outward and return signals.
 - f) "TD-LTE" means the TDD variant of LTE (Long Term Evolution or 4G technology)

g) "Uplink" means transmissions from a terminal station (handset) to a base station

Annex 7

Example 3.4 GHz licence



[Header (to all pages)]

<p>[Company] – Spectrum Access 3.4 GHz Licence Company registration number: xxxx First issued: xx/xx/xx – Licence Number: xxxxxxxx – xx/xx/xx</p>

Office of Communications (Ofcom)
Wireless Telegraphy Act 2006

SPECTRUM ACCESS 3.4 GHz LICENCE

Licence no: **XXXX**

Date of issue: **XXXX**

Fee payment date **XXXX (annually)**
[(from **XXXX 2035/36**)]

1. The Office of Communications (Ofcom) grants this wireless telegraphy licence ("the Licence") to

[Company]
(Company registration number **XXXX**)
("the Licensee")
Add 1
Add 2
Add 3
Postcode

to establish, install and use wireless telegraphy stations and/or wireless telegraphy apparatus as described in the Schedules to this Licence (together "the Radio Equipment") subject to the terms set out below.

Licence Term

2. This Licence shall continue in force until revoked by Ofcom or surrendered by the Licensee.

Licence Variation and Revocation

3. Pursuant to Schedule 1 paragraph 8 of the Wireless Telegraphy Act 2006 ("the Act"), Ofcom may not revoke this Licence under schedule 1 paragraph 6 of the Act except:

- (a) at the request, or with the consent, of the Licensee;
 - (b) if there has been a breach of any of the terms of this Licence;
 - (c) in accordance with schedule 1 paragraph 8(5) of the Act;
 - (d) if it appears to Ofcom to be necessary or expedient to revoke the Licence for the purpose of complying with a direction by the Secretary of State given to Ofcom under section 5 of the Act or section 5 of the Communications Act 2003;
 - (e) if, in connection with the transfer or proposed transfer of rights and obligations arising by virtue of the Licence, there has been a breach of any provision of regulations made by Ofcom under the powers conferred by section 30(1) and 30(3) of the Act⁶⁶;
 - (f) for reasons related to the management of the radio spectrum, provided that in such a case the power to revoke may only be exercised after at least five years' notice is given in writing (such notice not to be given before **XXXX** 2030/31)]; or
 - (g) if the Licensee has been found to the reasonable satisfaction of Ofcom to have been involved in any act, or omission of any act, constituting a breach of the [Wireless Telegraphy (Licence Award) Regulations 20xx ("the Regulations")].
4. Ofcom may only revoke or vary this Licence by notification in writing to the Licensee and in accordance with schedule 1 paragraphs 6, 6A and 7 of the Act.

Transfer

5. This Licence may not be transferred. The transfer of rights and obligations arising by virtue of this Licence may however be authorised in accordance with regulations made by Ofcom under powers conferred by section 30 of the Act⁶⁷.

Changes to Licensee details

6. The Licensee shall give prior notice to Ofcom in writing of any changes to the Licensee's name and/or address as recorded in paragraph 1 of this Licence.

Fees

7. In accordance with the Regulations, the fee in consideration of which this licence is granted is [£XXXX].
8. From [Date **XXXX**], the Licensee shall each year pay to Ofcom the relevant fee(s) as provided in section 12 of the Act and the regulations made thereunder on or before the fee payment date shown above, or on or before such dates as are notified in writing to the Licensee.

⁶⁶ These are regulations on spectrum trading.

⁶⁷ See Ofcom's website for the latest position on spectrum trading and the types of trade which are permitted.

9. The Licensee shall also pay interest to Ofcom on any amount which is due to Ofcom under the terms of this Licence or provided for in any regulations made by Ofcom under sections 12 and 13(2) of the Act from the date such amount falls due until the date of payment, at the then applicable Bank of England base rate. In accordance with section 15 of the Act any such amount and any such interest is recoverable by Ofcom.
10. If the Licence is surrendered, revoked or varied, no refund, whether in whole or in part, of any amount which is due under the terms of this Licence, payable in accordance with the Regulations, or provided for in any regulations made by Ofcom under sections 12 and 13(2) of the Act will be made, except at the absolute discretion of Ofcom.

Radio Equipment Use

11. The Licensee shall ensure that the Radio Equipment is established, installed and used only in accordance with the provisions specified in the Schedules to this Licence. Any proposal to amend any detail specified in any of the Schedules to this Licence must be agreed with Ofcom in advance and implemented only after this Licence has been varied or reissued accordingly.
12. The Licensee shall ensure that the Radio Equipment is operated in compliance with the terms of this Licence and is used only by persons who have been authorised in writing by the Licensee to do so and that such persons are made aware of, and of the requirement to comply with, the terms of this Licence.

Access and Inspection

13. The Licensee shall permit any person authorised by Ofcom:
 - (a) to have access to the Radio Equipment; and
 - (a) to inspect this Licence and to inspect, examine and test the Radio Equipment,at any and all reasonable times or, when in the opinion of that person an urgent situation exists, at any time, to ensure the Radio Equipment is being used in accordance with the terms of this Licence.

Modification, Restriction and Closedown

14. Any person authorised by Ofcom may require the Radio Equipment or any part thereof, to be modified or restricted in use, or temporarily or permanently closed down immediately if in the opinion of the person authorised by Ofcom:
 - (b) a breach of this Licence has occurred; and/or
 - (c) the use of the Radio Equipment is, or may be, causing or contributing to undue interference to the use of other authorised radio equipment.
15. Ofcom may require any of the Radio Equipment to be modified or restricted in use, or temporarily closed down either immediately or on the expiry of such period as may be specified in the event of a national or local state of emergency being declared. Ofcom may only exercise this power after a written notice has been served on the Licensee or a general notice applicable to holders of a named class of licence has been published.

Geographical Boundaries

16. Subject to the requirements of any coordination and synchronisation procedures notified to the Licensee pursuant Schedule 1 to this Licence, and excluding the areas set out in condition 17, the Licensee is authorised to establish, install and use the Radio Equipment in the United Kingdom. For the avoidance of doubt, the United Kingdom excludes the Channel Islands and the Isle of Man.
17. The areas excluded from this licence are:
 - (a) the territorial sea and any internal waters adjacent to the territorial sea, but in the case of streams, rivers or other watercourses which form part of such internal waters only where such stream, river or watercourse is more than 2km wide.

Interpretation

18. In this Licence:
 - (b) the establishment, installation and use of the Radio Equipment shall be interpreted as establishment and use of wireless telegraphy stations and installation and use of wireless telegraphy apparatus for wireless telegraphy as specified in section 8(1) of the Act;
 - (c) the expression “interference” shall have the meaning given by section 115 of the Act;
 - (d) the expressions “wireless telegraphy station” and “wireless telegraphy apparatus” shall have the meanings given by section 117 of the Act;
 - (e) the expression “territorial seas” shall be determined in accordance with the Territorial Sea Act 1987;
 - (f) the expression “internal waters” shall have the meaning given by section 221(1) of the Water Resources Act 1991;
19. The Schedule(s) form part of this Licence together with any subsequent Schedule(s) which Ofcom may issue as a variation to this Licence.
20. The Interpretation Act 1978 shall apply to the Licence as it applies to an Act of Parliament.

**Issued by Ofcom
Office of Communications**

SCHEDULE 1 TO LICENCE NUMBER: XXXX

Schedule Date: XXXX 20XX

Licence category: Spectrum Access 3.4 GHz

Description of Radio Equipment

1. References in this Schedule to the Radio Equipment are references to any wireless telegraphy station or wireless telegraphy apparatus that is established, installed and/or used under this Schedule.

Interface Requirements for the Radio Equipment

2. Use of the Radio Equipment shall be in accordance with the following Interface Requirement:

[IR 20xx: Terrestrial systems capable of providing electronic communications services in the band XXXX]

Special conditions relating to the Radio Equipment

3.
 - a) Subject to paragraph 3(b) of this Schedule, during the period that this Licence remains in force, unless consent has otherwise been given by Ofcom, the Licensee shall compile and maintain accurate written records of the following details relating to the Radio Equipment:
 - i) postal address (including post code);
 - ii) National Grid Reference, to at least 10 metre resolution;
 - iii) antenna height (above ground level), type, and boresight bearing east of true north (if applicable);
 - iv) radio frequencies which the Radio Equipment uses; and
 - v) Transmitted power expressed in dBm / 5 MHz EIRP per cell.and the Licensee must produce these records if requested by any person authorised by Ofcom.
 - b) The conditions relating to the keeping of records contained in sub-paragraphs 3(a)(ii) and (iii) of this Schedule shall not apply in respect of femtocell equipment and smart/intelligent low power repeater equipment.
 - c) The conditions relating to the keeping of records contained in paragraph 3(a) of this Schedule shall not apply in respect of licence exempt radio equipment.
 - d) The Licensee shall submit to Ofcom copies of the records detailed in sub-paragraph 3(a) above at such intervals as Ofcom may notify to the Licensee.
 - e) The Licensee shall submit to Ofcom in such manner and within such period as specified by Ofcom, such other information in relation to the Radio Equipment, or

any wireless telegraphy station or wireless telegraphy apparatus which the Licensee is planning to use, as Ofcom may from time to time request. Such information may include, but is not limited, to information in relation to the radio frequency, transmitted power and date of first use for wireless telegraphy stations or wireless telegraphy apparatus to be established, installed or used within such timeframe and in such areas as Ofcom may reasonably request.

Co-ordination at frequency and geographical boundaries

4. The Licensee shall ensure that the Radio Equipment is operated in compliance with such co-ordination procedures as may be notified to the Licensee by Ofcom from time to time.

Synchronisation of networks

5. The Licensee shall ensure that the Radio Equipment is operated in compliance with the Inter-Operator Synchronisation Procedure in Schedule 2.

International cross-border coordination

6. The Licensee shall ensure that the Radio Equipment is operated in compliance with such cross-border co-ordination and sharing procedures as may be notified to the Licensee by Ofcom from time to time.

Permitted Frequency Blocks

7. Subject to the emissions permitted under paragraph 8 of this Schedule, the Radio Equipment may only transmit within the following frequency bands (the "Permitted Frequency Blocks"):

XXXX - XXXX MHz

Maximum power within the Permitted Frequency Blocks

8. The power transmitted in the Permitted Frequency Blocks shall not exceed:

Radio Equipment	Maximum mean power
Base station (see Note 1)	65 dBm / 5 MHz EIRP*
Mobile or nomadic UE Radio Equipment	25 dBm TRP*
Fixed or installed UE Radio Equipment	35 dBm / 5 MHz EIRP*

* The maximum mean power relates to the EIRP or TRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

Note 1: For femtocell base stations, power control must be applied to minimise interference to adjacent channels.

Maximum power of base stations outside the Permitted Frequency Blocks

9.

- a) Except as set out in paragraph 9(c) below, where the Inter-Operator Synchronisation Procedure in Schedule 2 determines that the Restrictive Mask applies, for transmissions on the downlink frequencies, the EIRP emanating from the Radio Equipment transmissions at any frequency outside the Permitted Frequency Blocks shall not exceed the following baseline:

Out of block baseline power limit (BS)	- 34 dBm / 5 MHz EIRP*
--	------------------------

- b) Except as set out in paragraph 9(c) below, where the Inter-Operator Synchronisation Procedure in Schedule 2 determines that the Permissive Mask applies, for transmissions on the downlink frequencies, the EIRP emanating from the Radio Equipment transmissions at any frequency outside the Permitted Frequency Blocks shall not exceed the following transitional and baseline requirements :

-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna
-10 to -5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna
Out of block baseline power limit (BS) < -10 MHz offset from lower block edge > 10 MHz offset from upper block edge	Min(PMax – 43, 13) dBm / 5 MHz EIRP per antenna

- c) The EIRP emanating from the Radio Equipment transmissions at any frequency outside the Permitted Frequency Blocks shall not exceed the following band edge requirements:

3405 MHz – 3410 MHz 3600 MHz – 3610 MHz	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna
3400 MHz – 3405 MHz	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna
3390 MHz – 3400 MHz	Min(PMax – 43, 13) dBm / 5 MHz EIRP per antenna
Below 3390 MHz	- 50 dBm / MHz ⁶⁸ EIRP*
Above 3605 MHz (see Note 2)	- 34 dBm / 5 MHz EIRP*

* The maximum mean power relates to the EIRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

Note 2: This limit shall not apply if the licensee of the Spectrum Access 3.6 GHz licence (above 3605 MHz), uses a TDD frame structure compatible with that which is set out in the Inter-Operator Synchronisation Procedure

⁶⁸ We note that this level is defined in the Commission Decision 2014/276/EU as per MHz rather than per 5 MHz.

Interpretation of terms in this Schedule

10. In this Schedule:

- a) “dBm” means the power level in decibels (logarithmic scale) referenced against 1 milliwatt (i.e. a value of 0 dBm is 1 milliwatt);
- b) “EIRP” means the equivalent isotropically radiated power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain), measured during the “on” part of the transmission;
- c) “femtocell” means Radio Equipment transmitting on the downlink frequencies, which operates at a power not exceeding 24 dBm EIRP per carrier, and which is or will be used only by and under the control of the Licensee, following the establishment of a telecommunications link between the femtocell and a network of the Licensee;
- d) “Fixed or installed” means used or installed at specific fixed points;
- e) “IR” means a United Kingdom Radio Interface Requirement notified by Ofcom in accordance with Article 4.1 of Directive 1995/5/EC of the European Parliament and of the Council on radio equipment and telecommunications terminal equipment (RTTE) and the mutual recognition of their conformity;
- f) “lower block edge” means, in relation to each Permitted Frequency Block, the lowest frequency in that Permitted Frequency Block;
- g) “mobile or nomadic” means intended to be used while in motion or during halts at unspecified points;
- h) “Permitted Frequency Blocks” has the meaning given to it in paragraph 6 of this Schedule;
- i) “PMax” is the maximum mean power for the base station in question, measured as EIRP per carrier and determined irrespective of the number of antennas;
- j) “smart/intelligent low power repeater” means a repeater which operates with power not exceeding 24 dBm EIRP per carrier, which may be established by customers of the Licensee who have written agreements with the Licensee and:
 - The Licensee has ultimate control of the repeater, i.e. each individual repeater can be disabled remotely by the Licensee;
 - The repeater operates only on the Licensee’s frequencies and with their valid Public Land Mobile Network Identifier;
 - Must not cause undue interference to other spectrum users; and
 - The repeater only transmits on the uplink frequencies when actively carrying a call (voice, video or data) or signalling from serviced handsets.

- k) "TRP" means the total radiated power. This is the integral of the power transmitted in different directions over the entire radiation sphere, measured during the on part of the transmission; and
- l) "upper block edge" means, in relation to each Permitted Frequency Block, the highest frequency in that Permitted Frequency Block.

Ofcom

SCHEDULE 2 TO LICENCE NUMBER: XXXX
Inter-Operator Synchronisation Procedure⁶⁹

Schedule Date: XXXX 20XX

Licence category: **Spectrum Access 3.4 GHz**

Introduction

1. The holders of licences in the 3410 MHz – 3600 MHz band (such licences further referred to as the “Licences”, and the holders of the Licences together further referred to as, “the Licensees”) must co-operate in such a way that harmful interference is not caused by one network deployment to that of another Licensee within the band.
2. This procedure sets out the circumstances in which the Licensees can use the Restrictive Mask and the Permissive Mask, each as specified in Schedule 1 paragraph 9, so as to minimise the risk of harmful interference to other Licensees.

Conditions

Frame structure

3. Except as set out in paragraph 6 below, the emissions from the Licensee’s base stations must comply with one of the following frame structures:
 - a) The Preferred Frame Structure. Where the Licensee’s base station complies with this Preferred Frame Structure, the Permissive Mask as set out in Schedule 1 paragraph 9 (b) of this Licence applies:
 - i) Transmissions from the Licensee’s base stations must have a frame structure as shown in Figure 1. Indicated timeslots (or subframes) must not be allocated to anything other than Downlink (D) and Uplink (U) transmissions. S denotes a special subframe (See paragraph 4)
 - ii) Timeslots must have a duration of 1 millisecond
 - iii) TD-LTE frame configuration 2 (3:1) is compatible with this frame structure. Other technologies are permitted provided that the requirements of 3(a)(i) and (ii).
 - b) The Compatible Frame Structure. Where the Licensee’s base station complies with this Compatible Frame Structure, the Restrictive Mask as set out in Schedule 1 paragraph 9 (a) of this Licence applies:
 - i) Transmissions from the Licensee’s base stations must have a frame structure as shown in Figure 2. Indicated timeslots (or subframes) must not be allocated to anything other than Downlink (D) and Uplink (U) transmissions. S denotes a special subframe (See paragraph 4)
 - ii) Timeslots must have a duration of 1 millisecond

⁶⁹ Ofcom has made a statement as to the circumstances in which this procedure may be amended. See section 8 paragraphs 8.87 to 8.91

- iii) All current TD-LTE frame configurations are compatible with this frame structure. Other technologies are permitted provided that the requirements of 3(b)(i) and (ii) are met;
- iv) Timeslots with no transmission indicated may be determined as a Downlink, Uplink or Special subframe as necessary in order to ensure compliance with paragraph 3(b)(i) [and (ii)];
- v) Licensees must cooperate to minimise harmful sub-frame overlaps if different technologies are used. On rare occasions this may require the frame alignment or guard period to be slightly offset;
- vi) For the avoidance of doubt all-downlink frame structures such as Supplementary Downlink (SDL) are not permitted.

Figure 4: Preferred frame structure

DL/UL ratio	Subframe number									
	0	1	2	3	4	5	6	7	8	9
3:1	D	S	U	D	D	D	S	U	D	D

Figure 5: Compatible frame structure

DL/UL ratio	Subframe number									
	0	1	2	3	4	5	6	7	8	9
Any	D	S	U							

A compatible special subframe.

- 4. Except as set out in paragraph 6, the Licensee must ensure that the special subframe (S) in timeslot 1 has a structure that is compatible with TD-LTE special subframe configuration 6, also known as 9:3:2 (DwPTS: GP: UpPTS). For the avoidance of doubt, a special subframe structure is compatible where there are no uplink transmissions within the downlink pilot timeslot (DwPTS) or guard period (GP) and no downlink transmissions within the uplink pilot timeslot (UpPTS) or guard period (GP).

Timing and Alignment

- 5. Except as set out in paragraph 6, the Licensee shall ensure that frames start at a common reference time so that all licensees’ frames are aligned and transmissions synchronised.

Small Cells

- 6. The Licensee is not required to comply with the requirements set out in paragraphs 3, 4, and 5 above, and the Permissive Mask as set out in Schedule 1 paragraph 9 (b) of this Licence applies, for:
 - (a) Indoor Domestic Small Cells; or

- (b) Indoor Non-domestic Small Cells, except where another licensee demonstrates that they are suffering harmful interference as a result.

For the avoidance of doubt, if another licensee demonstrates that they are suffering harmful interference as a result of an Indoor Non-domestic Small Cell, the Indoor Non-domestic Small Cell must comply with the requirements set out in paragraphs 3, 4, 5 and 6 above.

Definitions

7. In this Schedule:

- a) "Downlink" means transmissions from a base station to a terminal station (handset)
- b) "Indoor" means a location inside a building or place in which the shielding will typically provide the necessary attenuation to protect wireless telegraphy against harmful interference
- b) "Indoor Domestic Small Cell" means a base station with an EIRP of less than or equal to 24dBm per 20 MHz carrier that is located within a residential property
- c) "Indoor Non-domestic Small Cell" means a base station with an EIRP of less than or equal to 24dBm per 20 MHz carrier that is located indoors but not within a residential property
- d) "TDD" means the application of time-division multiplexing to separate outward and return signals.
- e) "TD-LTE" means the TDD variant of LTE (Long Term Evolution or 4G technology)
- f) "Uplink" means transmissions from a terminal station (handset) to a base station

Annex 8

Glossary of terms

3GPP	The 3rd Generation Partnership Project - Collaboration between groups of telecommunications associations, to make a globally applicable third-generation (3G) mobile phone system specification within the scope of the International Mobile Telecommunications-2000 project of the International Telecommunication Union (ITU).
4G	Fourth generation mobile phone standards and technology
5G	Fifth generation mobile phone standards and technology (not yet developed)
ACIR	The Adjacent Channel Interference Ratio is a useful method for determining the interference between two systems in adjacent bands. It takes into account both the out-of-band leakage (ACLR) of the transmitter (interferer) and the receive filtering (ACS) of the receiver (victim).
ACLR	The Adjacent Channel leakage ratio (ACLR) of a radio transmitter is the ratio of in band transmitted power to out-of-band power in the adjacent channel (or for a specified frequency offset).
ACS	Adjacent channel selectivity. A measure of how susceptible a receiver is to unwanted signals in adjacent spectrum.
AIP	Administrative Incentive Pricing
ALD	Assistive Listening Device
ALF	Annual Licence Fees
ATC/ATM	Air Traffic Control/ Air Traffic Management
BEM	Block Edge Masks
Bluetooth	Wireless standard for short-range radio communications between a variety of devices such as PCs, headsets, printers, mobile phones, and PDAs.
Bluetooth LE	Bluetooth Low Energy – a newer version of Bluetooth, generally smaller and designed to have a long battery life.
BS	Base Station
CCA	Combinatorial Clock Auction
CEPT	The European Conference of Postal and Telecommunications Administrations

CFI	Call for Inputs
Communications Act	The Communications Act 2003
CPI	The Consumer Price Index (CPI) is a measure of inflation. It measures the changes in the price level of consumer goods and services purchased by households. The most significant item excluded in the CPI, but included in the RPI, is mortgage interest rate payments.
dB / dBm	Decibel. A notation for dealing with ratios that vary over several orders of magnitude by using logarithms / The power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW).
DotEcon	DotEcon Ltd is a consulting firm.
DTT	Digital Terrestrial Television – Broadcasting delivered by digital means. In the UK and Europe, DTT transmissions use the DVB-T and DVB-T2 technical standards
EAS	Electronic Auction System
EC	European Commission
ECC	Electronic Communications Committee – One of the three business committees of the European conference of Postal and Telecommunications.
EE	Everything Everywhere Ltd – An MNO.
EHIMA	European Hearing Instruments Manufacturers Association
EIA	Equality Impact Assessment
EIRP	Equivalent Isotropically Radiated Power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).
EU	European Union
E-UTRA	Evolved Universal Terrestrial Radio Access
FCC	Federal Communication Commission – US regulatory authority for communications
FDD	Frequency Division Duplex – a technology that deals with traffic asymmetry between uplink and downlink where separate frequency bands are used for send and receive operations

Frame structure	The combination of downlink and uplink sub-frame transmissions that make a frame. A frame is 10ms long with TD-LTE.
GHz	Gigahertz. 1,000,000,000 (or 10^9) oscillations per second.
GPS	Global Positioning System
GSA	Global Suppliers Association
H3G	Hutchinson 3G UK Ltd – trading as Three - An MNO.
IEEE	Institute of Electrical and Electronics Engineers (standards body)
iMTA/ eiMTA	(Enhanced) Interference Mitigation & Traffic Adaptation – the frame structure is changed dynamically in order to meet traffic requirements or to minimise interference to neighbouring base stations.
ITU	International Telecommunications Union - Part of the United Nations with a membership of 193 countries and over 700 private-sector entities and academic institutions. ITU's headquarters are in Geneva, Switzerland.
ISP	Internet Service Provider
LSA	Licence shared access of radio spectrum
LTE	Long Term Evolution. Part of the development of 4G mobile systems that started with 2G and 3G networks. Aims to achieve an upgraded version of 3G services having up to 100 Mbps downlink speeds and 50 Mbps uplink speeds.
MHz	Megahertz. A unit of frequency of one million cycles per second.
MNO	Mobile network operator
MOD	The Ministry of Defence
MVNO	Mobile virtual network operator
NAO	National Audit Office
NGR	National Grid Reference
NRA	National Regulatory Authority. The relevant communications regulatory body for each country in the EU. Ofcom is the NRA for the United Kingdom.
Ofcom	The Office of Communications
P2P	Point to Point

PMSE	Programme-making and special events. A class of radio application that support a wide range of activities in entertainment, broadcasting, news gathering and community events.
PSSR	Public Sector Spectrum Release
MR	Minimum Requirements
Mobile Trading Regulations	Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011
RAN	Radio Access Network
RED	Radio Equipment Directive – a new EU Directive with requirements for radio transmitters and receivers
RF	Radio Frequency
SDL	Supplementary Down Link – where unpaired spectrum is used for downlink transmission only
SMRA	Simultaneous multiple-round ascending auction.
TDD	Time Division Duplex – a technology that deals with traffic asymmetry where the uplink is separated from the downlink by the allocation of different time slots in the same frequency band.
TD-LTE	Time Division Long Term Evolution. Sometimes referred to as Long Term Evolution Time-Division Duplex.
TRP	Total Radiated Power. The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere.
UE	User Equipment
UL/DL	Uplink/Downlink
UTC	Co-ordinated Universal Time
Wi-Fi	Commonly used to refer to wireless local area network (WLAN) technology, specifically that conforming to the IEEE 802.11 family of standards. Such systems typically use one or more access points connected to wired Ethernet networks which communicate with wireless network adapters in end devices such as PCs. It was originally developed to allow wireless extension of private LANs but is now also used as a general public access technology via access points known as "hotspots".
WiMAX	Worldwide Interoperability for Microwave Access is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates.
WTA	Wireless Telegraphy Act 2006

WTR

Wireless Telegraphy Regulations

ZigBee

brand name for part of IEEE 802.15 Personal Area network Standards