Public Sector Spectrum Release (PSSR)

Award of the 2.3 GHz and 3.4 GHz bands

Consultation

Publication date: 7 November 2014

Closing Date for Responses: 23 January 2015

About this document

In this document we seek views on our proposals for conducting an auction of 190 MHz of radio spectrum being transferred from Ministry of Defence to civilian use.

We set out our proposals on auction design, technical and non-technical licence conditions and a competition assessment. We expect the auction to take place in late 2015 or early 2016.

We expect the spectrum, comprising frequencies in the 2.3 GHz and 3.4 GHz bands, will be of interest to mobile network operators and others.

We invite those interested in bidding to a workshop as part of our consultation. The deadline for responses to this consultation is 5pm on Friday 23 January, 2015.

Contents

Section 1

Executive Summary

Introduction

1.1 This consultation document sets out proposals for an auction of 190 MHz of radio spectrum being awarded by Ofcom for civilian use after being relinquished by the Ministry of Defence (MOD). It includes proposals on technical and non-technical licence conditions for the award, and an assessment of the competition issues that might arise if the spectrum were to be acquired by mobile network operators (MNOs).

Overview of the award spectrum

1.2 The frequencies being awarded 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).

1.3 We believe an award of the spectrum by auction is the best means of identifying the highest value user. We propose to auction the frequencies on a use-neutral basis and with no requirement for the spectrum to be used for either high or low power applications.

1.4 The spectrum to be awarded would 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 for Programme Making and Special Events (PMSE) as described below.

1.5 We expect the frequencies to be of interest to mobile networks operators (MNOs) and others with an interest in mobile broadband. The particular characteristics of the spectrum suggest it is likely to be suitable for providing additional capacity or for backhaul, rather than for wide area coverage.

1.6 Although we are auctioning 150 MHz of spectrum in the 3.4 GHz band, a further 40 MHz in the same band is currently held by UK Broadband Ltd (UK Broadband) at 3480-3500 MHz and at 3580-3600 MHz. If UK Broadband enters the auction, under our proposals the frequencies making up its current holding may change. This is to ensure that spectrum can be awarded in contiguous blocks for all successful bidders. We believe contiguity will benefit consumers by making spectrum use more efficient. The consultation therefore includes proposals on how this might be achieved through the auction process.

1.7 The consultation also includes proposals for synchronisation between all users of the 3.4 GHz spectrum band. This will also help to ensure the efficient use of the spectrum.

Auction design

1.8 We expect the auction to take place in late 2015 or early 2016. We set out a description of two possible auction designs, along with draft procedures for the running of the auction. We recommend for this specific auction a design based on a simultaneous multiple round ascending (SMRA) auction. We also considered the

benefits of using a combinatorial clock auction (CCA); we describe both auction formats and how they would work for this award, and we welcome views.

1.9 We propose that the spectrum will be sold in lots of 5 MHz and that bidders will be able to specify a minimum requirement of up to 20 MHz. We propose that there will be one category of 8 lots in the 2.3 GHz band and 30 lots in one category of the 3.4 GHz band. We set out several scenarios where this configuration of categories becomes less desirable, but we believe that, on balance, two categories will continue to be the most effective.

1.10 We propose reserve prices of a figure for the 2.3 GHz band in the range of £2.5 million to £5 million per 5 MHz lot and for the 3.4 GHz band £1 million per 5 MHz lot. The reserve prices are based on a benchmark of the prices paid for 2.6 GHz spectrum in the 2013 UK spectrum auction.

Competition assessment

1.11 Given the likely use of the frequencies for mobile broadband, we have undertaken a competition assessment to consider the potential for an asymmetric distribution of mobile spectrum to arise as a result of the auction. We considered whether acquirers of the frequencies could exercise undue influence on the market for network provision to the detriment of consumers.

1.12 On balance, our provisional conclusion is that some competition measures are justified in the 2.3/3.4 GHz auction because if we did not take any measure there would be a risk to competition. Whilst this is low in terms of likelihood, it could be significant for consumers if it were to materialise.

1.13 We propose that there should be an overall cap in the auction on the amount of mobile spectrum that may be held by one company of 310 MHz. This is a level proportionate to the level set ahead of the 800 MHz and 2.6 GHz award (approximately 37%). We believe it is appropriate in order to prevent a single operator from obtaining a very large share of spectrum. That is, it would impose some constraints on the amount of spectrum that EE and Vodafone could obtain in the auction, but still allow them considerable flexibility.

1.14 Our view is that more interventionist options are not justified, because the risk that they could prevent outcomes that might be beneficial for consumers outweighs our competition concerns. We believe the cap in the auction we have proposed provides a proportionate safeguard against future potential competition concerns that may arise from very asymmetric spectrum holdings.

1.15 We make proposals to amend the Mobile Trading Regulations to include spectrum in the 1.4 GHz, 2.3 GHz and 3.4 GHz bands.

Licence Conditions

1.16 Our proposed non-technical licence conditions set out the geographical coverage of the licences, including in relation to off-shore uses; trading provision; duration and fees. We propose that there will be no coverage obligations, and no ‘use it or lose it’ conditions.

1.17 Following a consultation on PMSE access to both award bands, we published on 28 October 2014 a statement setting out the details of our decision on this matter[1]. For both the 2.3 and 3.4 GHz bands there may be a requirement to source additional spectrum from licensees in a particular area on a coordinated ad hoc basis based on licensees' use in that area.

1.18 Reponses to our February 2014 technical coexistence consultation[2] raised four key issues in relation to potential synchronisation within the award bands:

- Risk of delays where the spectrum is not being used because of a lack of agreement over synchronised transmissions;
- Difficulties with the practicality of the restrictive mask and a desire to use global equipment;
- Optimising spectrum utilisation/efficiency;
- Desire for flexibility in setting downlink and uplink ratios.

1.19 We are now proposing synchronisation arrangements for the award bands which seek to mitigate those concerns through an Inter-operator Synchronisation Procedure. Our aim is to give operators some certainty by providing technical parameters, while at the same time allowing flexibility with joint agreement of operators.

Next Steps

1.20 As part of this consultation, we will hold a workshop in December 2014 to discuss our proposals. Room will be limited, but anyone interested in attending should contact Ofcom as soon as possible using this response address: Spectrum.award.event@ofcom.org.uk

1.21 Once we have considered all the consultation responses, we will publish, in draft, proposed Regulations that detail the arrangements and processes for the auction. We expect at the same time to publish a statement and information memorandum.

1.22 We will also publish shortly a technical update relating to the award. This will focus on responses to our February 2014 consultation on coexistence with usage in adjacent spectrum bands, in particular relating to Wi-Fi and other licence–exempt uses and will provide details of further work we have done since. We will also provide an update on satellite and radar and coexistence. PMSE is dealt with in the statement referred to above and technical licence conditions are dealt with in this document.

[1] http://stakeholders.ofcom.org.uk/consultations/pssr-2014/?a=0
[2] http://stakeholders.ofcom.org.uk/consultations/pssr-2014/?showResponses=true

Section 2

Introduction

2.1 This consultation document sets out our proposals for an award of:

i) 40 MHz of spectrum within the 2.3 GHz band (2350-2390 MHz) and

ii) 150 MHz of spectrum within the 3.4 GHz band (3410-3480 MHz and 3500-3580 MHz).

2.2 The award spectrum is currently designated as Crown spectrum in the UK Frequency Allocation Table[3] and is used by the Ministry of Defence (MOD). MOD intends to clear the bands of existing military/Government use, except in a very few localised areas described later in this document.

2.3 The spectrum will be awarded by Ofcom for civilian use. Ofcom will award this spectrum in line with its duties.

2.4 In developing our proposals we have taken into account the recommendations of the National Audit Office in its review of Ofcom's 2013 auction of spectrum in the 800 MHz and 2.6 GHz bands.[4]

2.5 We published a 'Call for Inputs' in October 2013[5] in which we sought the views of stakeholders on a number of issues around this award. In February 2014 we issued a consultation on technical issues including coexistence with users in adjacent spectrum bands[6]. On 7 April 2014 we issued a statement on amateur use in the award and adjacent bands[7] which followed a consultation the previous year. In this document we make proposals for technical licence conditions which take on board some of the responses to the February consultation. We intend to issue a further consultation on technical issues later.

2.6 We make proposals in this document as to how, in our proposed auction, awards could be made in such a way that all licensees (including UK Broadband with its current holding at 3480-3500 MHz and 3580-3600 MHz) are awarded contiguous spectrum.

2.7 We expect to make an award of the 2.3 GHz and 3.4 GHz spectrum in late 2015 or early 2016.

2.8 In this document we propose an award by auction and provide auction design proposals, with illustrative auction procedures, and proposals on packaging and reserve prices. We also set out a competition assessment relating to the award spectrum. We go on to propose technical and non-technical licence conditions. In due course we will publish for comment a notice containing a draft of Regulations which will contain the detailed arrangements for the auction.

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[3] http://stakeholders.ofcom.org.uk/spectrum/information/uk-fat/

[4] "4G radio spectrum auction: lessons learned" Report by the Comptroller and Auditor General HC 968 SESSION 2013-14 12 MARCH 2014 http://www.nao.org.uk/report/4g-radio-spectrum-auction-lessons-learned-2/

[5] http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/

[6] http://stakeholders.ofcom.org.uk/consultations/pssr-2014/

[7] http://stakeholders.ofcom.org.uk/binaries/consultations/public-sector-spectrum-release/statement/PSSR_amateur_statement.pdf

Structure of this document

2.9 Following this introduction, the remainder of this document is set out as follows:

- Section 3 sets out the legal framework under which we must make our decisions. This includes outlining our statutory duties in managing the spectrum and identifying our obligations to consider the impact of our decisions on other spectrum users.

- Section 4 is an overview of the award and the key issues we need to address. It begins by describing the nature of the spectrum that is being released and its likely future use. It goes on to set out the broad policy frameworks we have used in developing our proposals. It includes consideration of EU/international harmonisation measures which apply to the frequencies we plan to award. It goes on to explain why we believe an auction is the most appropriate method to make an award and the packaging proposals we make for the auction based on the nature of the spectrum we describe in the section.

- Section 5 discusses the position of 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 describes our proposed auction design, for which illustrative auction procedures are set out in Annex 6. The section also makes proposals for reserve prices. We make proposals as to how the 40 MHz spectrum in the 3.4 GHz band currently held by UK Broadband might be brought into the auction so that all licensees (including UK Broadband) hold contiguous spectrum.

- Section 7 contains our competition assessment relating to the award bands and the 1.4 GHz band.

- Section 8 sets out our proposals for non-technical licence conditions relating to the award.

- Section 9 discusses responses received to the technical licence conditions part of the February Consultation and sets out some further proposals to enable deployments immediately following the award, such as use of synchronisation. This section comments on some other technical issues following the February consultation.

- Section 10 describes next steps.

2.10 The annexes set out how to respond to this consultation, and also include, as well as the illustrative auction procedures, further technical analysis and a draft licence.

Section 3

Legal Framework

3.1 In this section we describe the general legal and policy framework in the UK within which we are considering the issues surrounding the award of the 2.3 and 3.4 GHz spectrum bands. The legal framework derives from our duties under both European and domestic legislation, specifically from:

- the European Common Regulatory Framework[8] for electronic communications networks and services, in particular, the Framework Directive and the Authorisation Directive and
- the Communications Act 2003 (the "Communications Act") and the Wireless Telegraphy Act 2006 (the "WTA") which transpose the provisions of those directives into national law.

3.2 We also discuss Commission Decision 2008/411/EC on the harmonisation of the 3400-3800 MHz frequency band, as amended by Commission Decision 2014/276/EU of 14 May 2014, and the regulations implementing that decision, as well as European Electronic Communications Committee (ECC) Decision 14(04) on harmonised technical and regulatory conditions for the use of the 2300-2400 MHz frequency band.

European Regulatory Framework

3.3 Article 8 of the Framework Directive sets out the objectives that national regulatory authorities (NRAs) must take all reasonable steps to achieve. These include:

- the promotion of competition in the provision of electronic communications networks and services by, among other things, ensuring that there is no distortion or restriction in competition in the electronic communications sector, and encouraging efficient use of radio frequencies; and
- contributing to the development of the internal market by, among other things, removing obstacles to the provision of electronic communications networks and services at a European level, and encouraging the interoperability of pan-European services.

3.4 In pursuit of these policy objectives, Article 8 requires NRAs to apply objective, transparent, non-discriminatory and proportionate regulatory principles by (amongst other things) ensuring that, in similar circumstances, there is no discrimination in the treatment of undertakings providing electronic communications networks and services; safeguarding competition to the benefit of consumers; and promoting efficient investment and innovation in new and enhanced infrastructures.

[8]The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC).

3.5 Article 8 also requires EU member states to ensure that in carrying out their regulatory tasks, NRAs take the utmost account of the desirability of making regulations technologically neutral.

3.6 Article 9 of the Framework Directive requires member states to ensure the effective management of radio frequencies in accordance with (amongst other things) Article 8 and to ensure that the allocation and assignment of radio frequencies is based on objective, transparent, non-discriminatory and proportionate criteria. Article 9 also requires Member States to promote the harmonisation of use of radio frequencies across the Community, consistent with the need to ensure effective and efficient use of frequencies.

3.7 Article 5 of the Authorisation Directive provides that where it is necessary to grant individual rights of use of radio frequencies, member states must grant such rights through open, objective, transparent and non-discriminatory and proportionate procedures and in accordance with the provisions of Article 9 of the Framework Directive. When granting those rights, member states are required to specify whether they can be transferred by the holder, and if so, under which conditions.

3.8 Article 7 of the Authorisation Directive provides that where member states decide to limit the number of rights of use to be granted for radio frequencies, they must (amongst other things) give due weight to the need to maximise benefits for users and to facilitate the development of competition.

3.9 The legal duties imposed on the UK by the Framework and Authorisation Directives are transposed into UK law and given effect by the Communications Act and the WTA.

Duties under the Communications Act 2003

3.10 Section 3 of the Communications Act 2003 provides that our principal duty is:

- 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.

3.11 In carrying out our functions, section 3(2) provides that we are required, amongst other things, to secure the optimal use for wireless telegraphy of the electromagnetic spectrum; and the availability throughout the UK of a wide range of electronic communication services.

3.12 Section 3(3) provides that, in performing our duties, we must in all cases have regard to the principles of transparency, accountability, proportionality and consistency, as well as ensure that our actions are targeted only at cases in which action is needed.

3.13 Section 3(4) requires us, in carrying out our functions, to have regard to certain factors as appear relevant in the circumstances, including the desirability of encouraging investment and innovation in relevant markets; and desirability of encouraging the availability and use of high speed data transfer services throughout the UK.

3.14 In performing our duty under Section 3 of furthering the interests of consumers, we must have regard, in particular, to the interests of those consumers in respect of choice, price, quality of service and value for money.

3.15 Section 4 requires Ofcom to act in accordance with the six Community requirements, which give effect to the requirements of Article 8 of the Framework Directive.

Duties under the Wireless Telegraphy Act 2006

3.16 Section 3 of the Wireless Telegraphy Act (WTA) imposes a number of further duties relating to spectrum management. Amongst other things, in carrying out our spectrum functions, we are required to have regard to the extent to which the spectrum is available for use and to the demand, both current and future, for the use of the spectrum.

3.17 In carrying out those duties, Section 3(2) requires us to have regard to (amongst other things) the desirability of promoting the efficient management and use of the spectrum; the economic and other benefits that may arise from the use of wireless telegraphy; and the development of innovative services and competition in the provision of electronic communications services.

Wireless telegraphy licences

3.18 The WTA sets out our legal power to grant wireless telegraphy licences. Section 8(1) makes it an offence for any person to establish or use any station for wireless telegraphy or to install or use any apparatus for wireless telegraphy except under and in accordance with a licence granted by us under that Section (a wireless telegraphy licence).

3.19 Section 9(1) of the WTA gives us the power to grant wireless telegraphy licences subject to such terms as we think fit. This broad discretion is, however, subject to the rule that we must impose only those terms that we are satisfied are objectively justifiable in relation to the networks and services to which they relate, not unduly discriminatory, and proportionate and transparent as to what they are intended to achieve (see Section 9(7)).

3.20 In addition, our discretion under Section 9 must be interpreted in a way that is consistent with the licence conditions permitted under the Authorisation Directive.

Granting licences

3.21 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.

3.22 Ofcom has made general regulations in relation to licensing procedures (the Wireless Telegraphy (Licensing Procedures) Regulations 2010[9]. Where Ofcom decides to award licences by auction, it makes specific regulations for those purposes, in accordance with section 14 of the WTA.

Charging fees for wireless telegraphy licences

3.23 Section 12 of the WTA permits Ofcom to charge fees for wireless telegraphy licences, subject to certain specified exemptions relating to licences granted in accordance with auction regulations made under Section 14 of the WTA.

[9] Made under section 10 and Schedule 1 of the Wireless Telegraphy Act 2006.

3.24 Under Article 13 of the Authorisation Directive, any fees imposed for rights of use of radio frequencies must reflect the need to ensure the optimal use of the resources. Such fees must be objectively justifiable, transparent, non-discriminatory and proportionate in relation to their intended purpose and take into account the objectives set out in Article 8 of the Framework Directive.

Our approach to applying our duties

3.25 The duties set out above require us to balance a range of considerations. In doing so, we have a variety of regulatory tools and market mechanisms at our disposal in order to carry out our functions.

A market-led approach

3.26 We stated in our Spectrum Management Statement published on 30 April 2014[10] that our key objective when managing spectrum is to deliver its optimal use, meaning the use that delivers the greatest value to UK citizens and consumers. To do this, we will continue to rely on market mechanisms where possible and effective, but also take regulatory action where necessary. Market mechanisms are generally considered to be the most effective method of allocating scarce resources to ensure they are used efficiently once the conditions required for them to be effective are in place. They enable the transfer of rights to scarce resources based on the value that users, and potential users, place on these resources. In the absence of market failures, those that value the resource the highest are most likely to deliver the greatest value from the use of spectrum.

Commission Decision 2008/411/EC on the harmonisation of the 3400-3800 MHz frequency band, as amended by Commission Decision 2014/276/EU

3.27 On 21 May 2008, the European Commission adopted a decision 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[11]. In relation to the 3400-3600 MHz band, the decision provides that member states should designate, by 21 November 2008, the band, on a non-exclusive basis, for terrestrial electronic communications networks in compliance with the parameters set out in the Annex to the decision.

3.28 On 2 May 2014, the European Commission adopted Decision 2014/276/EU[12], which amended Commission Decision 2008/411/EC, primarily in relation to the technical conditions set out in the annex. It stated that the preferred duplex mode of operation in the 3.4-3.6 GHz sub-band shall be Time Division Duplex (TDD).

3.29 Any award of the 3.4 GHz band has to be compliant with the Commission Decision.

[10] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf
[11] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:144:0077:0081:EN:PDF
[12] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0276&qid=1414427840029&from=EN

ECC Decision (14)02 on the harmonised technical and regulatory conditions for the use of the band 2300-2400 MHz for Mobile/Fixed Communications Networks (MFCN)

3.30 The ECC Decision[13] sets out harmonised technical and regulatory conditions for the band. The decision is not mandatory. However, the European Commission has issued a mandate to CEPT to carry out work that, in all likelihood, will result in a commission decision for the 2.3 GHz band, which will be mandatory. Current indications are that CEPT's final report to the Radio Spectrum Committee of the EU will be submitted in March 2015, with a Commission Decision possible that autumn.

3.31 The proposals set out in this consultation are consistent with the ECC Decision and further work undertaken for the commission mandate for the potential commission decision.

Impact Assessment

3.32 This consultation as a whole, including its annexes, comprises an impact assessment as defined in Section 7 of the Communications Act.

3.33 Impact assessments provide a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practise policy-making. This is reflected in Section 7 of the Act, which means that generally we have to carry out impact assessments where our proposals would be likely to have a significant impact on businesses or the general public, or when there is a major change in Ofcom's activities.

3.34 The following sections and annexes contain analysis of the policy options relating to an award of spectrum in the 2.3 and 3.4 GHz bands that we have considered, and the potential impact of our proposals. In particular, we have considered the citizen and consumer interests in relation to our policy objectives.

3.35 Ofcom is an evidence based organisation and welcomes responses to this consultation. Any comments about our assessment of the impact of our proposals should be sent to us by the closing date for this consultation. We will consider all comments before deciding whether to implement our proposals. For further information about our approach to impact assessments, see the guidelines, *Better policy-making: Ofcom's approach to impact assessment*, which are on our website: http://www.ofcom.org.uk/consult/policy_making/guidelines.pdf

Equality Impact Assessment

3.36 Ofcom is separately required by statute to assess the potential impact of all our functions, policies, projects and practices on race, disability and gender equality. Equality Impact Assessments (EIAs) also assist us in making sure that we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity.

3.37 We do not consider that our proposals to award the 2.3 and 3.4 GHz spectrum are likely to have a particular impact on one group of stakeholders as opposed to another.

[13] http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCDEC1402.PDF

3.38 Nevertheless, we considered whether some existing users of adjacent spectrum may be disproportionately affected. In that context, we considered especially the impact of potential interference on users of licence exempt devices which may be perceived as having health or safety implications. This includes users of medical monitoring equipment and assistive listening devices. These issues were discussed in detail in the technical consultation published in February 2014. We have subsequently undertaken additional tests and trials with manufacturers; we are analysing the results which we will publish in due course.

3.39 The award of the 2.3 GHz spectrum relates to licences which will apply to Great Britain (i.e. to England, Scotland and Wales but not to Northern Ireland). For that reason there is no need for us to carry out separate equality impact assessment in relation to Northern Ireland for this band.

3.40 The award of the 3.4 GHz spectrum band relates to all of the United Kingdom. We do not believe any aspect of the award raises issues requiring separate EIAs in relation to race or gender equality or equality schemes under the Northern Ireland and Disability Equality Schemes.

Section 4

Overview of the Spectrum

4.1 In this section, we set out an overview of the 2.3 and 3.4 GHz spectrum bands. We begin by describing the nature and characteristics of the spectrum to be awarded, identify its likely future use and then set out our proposed method of the award bearing in mind the characteristics we have identified. The next section provides details of the auction formats on which we are consulting.

The spectrum to be awarded

4.2 MOD's decision to relinquish use of 190 MHz of spectrum is part of a Government commitment to release 500 MHz of public sector spectrum by 2020 for new civilian uses. This commitment aims, in part, to address the increasing UK demand for spectrum fuelled by the adoption of devices such as smartphones and tablets. This demand has been identified, amongst other places, in our May 2014 Mobile Data Strategy statement[14].

4.3 If UK Broadband Limited (UK Broadband) enters the auction, we are proposing a mechanism whereby it could contribute its current 40 MHz holding in the 3.4 GHz band and participate in the auction to acquire a different block. More detail is in sections 5 and 6 of this document.

4.4 The 2.3 GHz spectrum under our proposals would be made available for new uses throughout Great Britain (i.e. in England, Scotland and Wales, but not in Northern Ireland). The 3.4 GHz spectrum would be made available throughout the whole of the United Kingdom with some exceptions as set out in full in section 8 of this document. We expect the award bands to be cleared of all existing uses except in a few localised areas where MOD use will continue and which may require co-ordination zones to protect that ongoing MOD usage. As described in our February 2014 coexistence consultation document, for the 2.3 GHz band there would be an exclusion zone around St Kilda making up the Outer Hebrides, Isle of Skye and the Small Isles.

4.5 Following our consultation on PMSE (Section 8 of our February 2014 technical coexistence consultation) 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. Details of this decision were published on 28 October 2014 in our statement setting out the conclusions on our strategy for video PMSE.

4.6 More details are contained in section 8 of this document.

The 2.3 GHz band

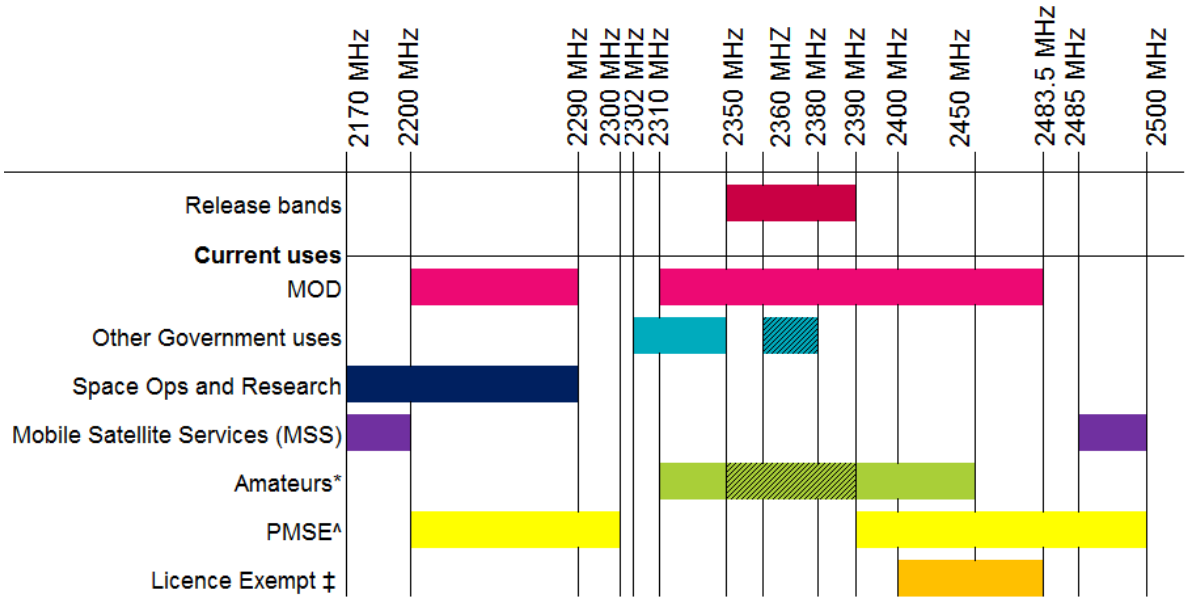
4.7 The 2.3 GHz award band (2350-2390 MHz) is illustrated in Figure 1. In addition to MOD and other Government uses, the spectrum is currently used for amateur radio and, occasionally, for PMSE (to support television coverage of major sporting events). We consulted on a proposal to end amateur radio access to the 2.3 GHz

[14] http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/statement/statement.pdf

award band in 2013[15] and published a statement on 7 April 2014[16]. Amateur licences will be removed from April 2015.

4.8 Adjacent deployments include significant use of frequencies between 2400 and 2483.5 MHz, sometimes referred to as the 2.4 GHz licence exempt band. These include domestic and commercial Wi-Fi; Bluetooth; and ZigBee devices, such as smart meters and monitoring equipment and also by licence exempt industrial, scientific and medical applications.

Figure 1. Use of spectrum in the 2.3 GHz and neighbouring spectrum bands



* 2400 to 2450 MHz may also be used by the amateur satellite service
‡ 2400 to 2500 MHz is designated for Industrial, Scientific and Medical applications
^ The bands 2200-2300 and 2390-2500 MHz are allocated to PMSE (on a shared basis). Access to the 2300-2390 MHz band is sometimes allowed on a coordinated basis with existing users as a 'spectrum loan' to facilitate high demand events
Band currently in use but will have remediated out in full by auction
BT has a small number of fixed links in 2200-2290. We do not percieve there to be any interference issues with the release band

4.9 We consulted on the potential interference impact of the proposed new services in the 2.3 and 3.4 GHz bands to existing users in adjacent bands in a document published in February[17]. We are considering the responses. We will publish a technical update at a later date.

4.10 As we stated in our October, 2013 Call for Inputs, we have decided to award the 2.3 GHz band in a way that is consistent with an unpaired, TDD-compatible, band plan only.

The 3.4 GHz band

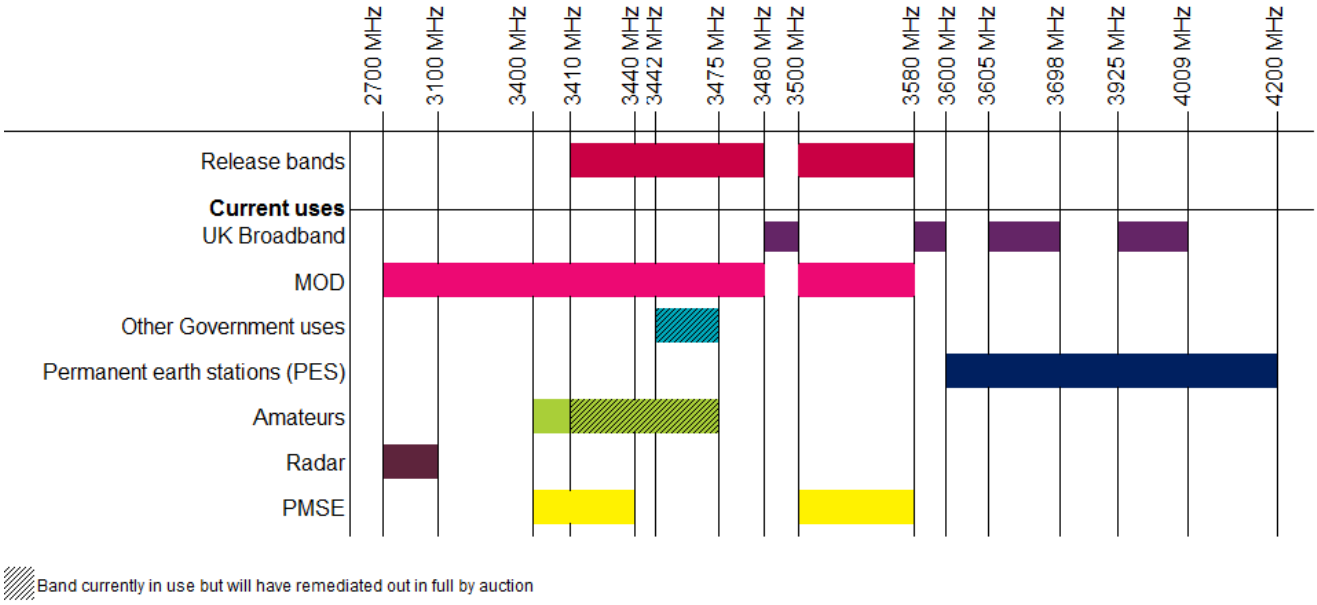
4.11 The 3.4 GHz award band is illustrated in Figure 2. The band occupies the frequencies between 3410 MHz and 3600 MHz. As with the 2.3 GHz band, part of the 3.4 GHz release spectrum is currently used by amateur radio (3410-3475 MHz) and by PMSE (3410-3440 MHz and 3500-3580 MHz). Amateur licences will be removed from April 2015. Details relating to PMSE are in the PMSE statement we

[15] http://stakeholders.ofcom.org.uk/binaries/consultations/public-sector-spectrum-release/summary/condoc.pdf
[16] http://stakeholders.ofcom.org.uk/consultations/public-sector-spectrum-release/statement
[17] http://stakeholders.ofcom.org.uk/consultations/pssr-2014/

made on 28 October and in section 8 of this document. Amateur radio and PMSE also have access to 3400-3410 MHz.

4.12 The illustration also shows other current uses of the adjacent bands. These include radar (2700-3100 MHz) and permanent satellite Earth stations (3600-4200 MHz).

Figure 2. Use of spectrum in the 3.4 GHz and neighbouring spectrum bands



4.13 In our February 2014 technical consultation[18] we announced our decision to proceed to award the 3.4 GHz band in a way that is consistent with an unpaired, TDD-compatible, band plan only.

Adjacent bands

4.14 We consider that potential bidders are better placed to determine any impacts from neighbouring bands into the 2.3 and 3.4 GHz bands being awarded in relation to their own particular business models and deployment plans.

4.15 However, due to the nature of some of the MOD systems in adjacent bands, it is not appropriate for us to provide full information to potential bidders and consequently they will be unable to make their own assessments of the risk from these systems. The MOD has therefore undertaken a series of analyses between its systems and example TD-LTE uses in the release bands. Where we believe there may be some material risk of interference to new uses then we plan to make details of this risk available to bidders. Studies to assess the possibility of interference between the systems are ongoing and this information will therefore be provided as part of the Information Memorandum associated with this award prior to the auction. MOD has also indicated that it is prepared to provide more detailed information to winning bidders with appropriately security cleared personnel to enable those winning bidders to deploy their networks as efficiently as possible. Any analysis, or system changes, to enable more efficient deployment of networks will need to be resourced by the operators concerned.

[18] http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf

Potential future use of the award bands

4.16 Over the past few years, the volumes of data carried over mobile networks have materially increased. The 2013 update of our Infrastructure Report[19] showed that data traffic carried by UK mobile networks went up by 50% between June 2012 and June 2013. Our Mobile Data Strategy published on 28 May 2014[20] recognised that while UK citizens and consumers already benefit considerably from use of mobile devices, the data traffic consumed by those devices is expected to grow significantly in the future. Our 2014 Communications Market Report[21] identified household take up of tablet computers rising to 44%, with 57% of people accessing the internet on their mobile phones.

4.17 The particular characteristics of the spectrum to be awarded, in terms of propagation and the penetration of signals, make it especially suitable for use by mobile broadband applications such as Long Term Evolution (LTE). For example, the 2.3 GHz spectrum has propagation characteristics very similar to the 2.6 GHz band already used for 4G mobile. Such uses are also likely to be the most valuable in commercial terms, particularly as the bands are internationally harmonised and are likely to be incorporated as standard in devices. Equipment designed to operate in the bands is already being developed. According to figures published by the GSA[22], the Global mobile Suppliers Association, on 14 October 2014, 427 LTE commercial devices supporting use in the 2.3 GHz band (sometimes known as band 40) are now available on the market.

4.18 The 3.4 GHz band may be valuable in providing additional options for network operators facing capacity pressures in other frequencies. We note that LTE equipment and devices are also available for this band, although in lower quantity than for 2.3 GHz band. The October 2014 GSA figures indicated 26 devices in the 3400-3800 MHz bands (also known as bands 42 and 43). We expect more devices to become available in the future.

4.19 All of these developments suggest the 2.3 and 3.4 GHz award is likely to attract interest from mobile network operators for either high power or low power LTE uses. However, we do not propose that alternative uses should be precluded if winning bidders for the spectrum have other plans (subject to compliance with technical parameters and licence conditions).

4.20 The regulatory environment for future use of each band is discussed separately below.

European and International use of the 2.3 GHz band

4.21 Around 60 countries worldwide have either assigned the 2.3 GHz band to mobile operators to deliver wireless broadband services or have announced their intention to do so within the next two years. TD-LTE has already rolled out, for example in India, Saudi Arabia, Australia, Russia, Oman, China and Sri Lanka. A number of other countries have indicated future use for mobile broadband.

[19] Infrastructure Report: 2013 update, October 2013, http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2013/
[20] http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/statement/statement.pdf
[21] http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr14/2014_UK_CMR.pdf
[22] http://www.gsacom.com/

4.22 It is likely that a mandatory Commission Decision on the 2.3 GHz award band will be made. This follows the ECC[23] Decision described below.

4.23 An ECC project team (CEPT WG FM52) developed a draft ECC Decision aimed at harmonising implementation measures for mobile/fixed communications networks in the 2.3 GHz frequency band[24]. The team considered frequencies between 2300 and 2400 MHz (including the award band 2350-2390 MHz). The scope of work included the development of:

- least restrictive technical conditions, taking into account the existing standardisation framework, activities at the worldwide level, and an appropriate frequency arrangement;

- regulatory provisions based on Licence Shared Access,[25] to ensure the continuing long-term incumbent use of the band in the territory of administrations wishing to maintain such use (although in the UK we are proposing an award as set out in this consultation).

4.24 The resultant ECC Decision (14)02 setting out harmonised technical and regulatory conditions for the band is not mandatory. However, the European Commission has issued a mandate to CEPT to carry out work that, in all likelihood, will result in a Commission Decision for the 2.3 GHz band which will be mandatory. Current indications are that CEPT's final report to the Radio Spectrum Committee of the EU will be submitted in March 2015, with a Commission Decision possible that Autumn.

4.25 The work undertaken for the Commission Mandate for the potential Commission Decision includes a report on technical licence conditions. These technical licence conditions are consistent with the ECC Decision (14)02.

4.26 It is our intention to issue the award spectrum with licence conditions aligned with any Commission Decision. If no such Decision exists at the time of the auction, our licence conditions will be aligned with the ECC Decision or any more recent report if appropriate. If a subsequent Commission Decision mandated different conditions, we would consider our obligations arising from that Decision.

4.27 Relevant licence conditions for the 2.3 GHz band set out in this document are aligned with the ECC Decision.

European and international use of the 3.4 GHz band

4.28 The 3.4 GHz band is already used for wireless broadband in a number of countries. In Europe there have been authorisations in Estonia, Germany, Ireland, Italy, Latvia, Macedonia, Norway, Portugal, Spain, Sweden, Switzerland, and the UK (by UK Broadband). By July 2014 six TDD networks had been launched commercially in the 3.4 GHz band in Bahrain, Belgium, Canada, the Philippines, Spain and the UK.

4.29 The USA is discussing allowing shared access to the 3550-3650 MHz frequencies via a managed database system. This would be based on small cell use of the spectrum, to protect incumbent users.

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[23] One of three business committees of the European Conference of Postal and Telecommunications Administrations (CEPT)

[24] http://www.cept.org/ecc/groups/ecc/wg-fm/fm-52/client/introduction/terms-of-reference

[25] https://circabc.europa.eu/d/d/workspace/SpacesStore/3958ecef-c25e-4e4f-8e3b-469d1db6bc07/RSPG13-538_RSPG-Opinion-on-LSA%20.pdf

4.30 A CEPT ECC[26] meeting of 5-8 November 2013 identified: "a single TDD option as the preferred channelling arrangement at 3.4-3.6 GHz, with FDD as an alternative for those administrations which would prefer to use it".[27] It also updated the technical conditions. These recommendations were reviewed by the European Commission's Radio Spectrum Committee and led to Commission Implementing Decision of 2 May 2014 (2014/276/EU) amending Decision 2008/411/EC[28]. The 2 May Decision is binding on Member States and confirms the preferred unpaired, TDD-compatible, option which we will adopt. Our band plan is consistent with the May 2014 Commission Decision.

High power/low power

4.31 We set out in our technical co-existence consultation in February 2014 the reasons for our proposals about usage. High power use requires licensing in order to avoid interference between users. In its consultation response, BT supported the idea of a licensed use of the spectrum, but suggested it might be for licensed *low* power assignment. We note the interest in low power uses, but also note that almost all other potential users supported the idea of high power use. We further note that the possibility of low-powered shared access was offered in the 2.6 GHz award. However, there was only limited demand from bidders, and this was insufficient to outweigh the demand for high power use. Our proposed technical licence conditions would support both high and low power use, neither precluding either use nor reserving spectrum for it.

Timing of the award

4.32 In our October 2013 Call for Inputs and in our February 2014 consultation on co-existence issues, we indicated that the earliest we were pragmatically likely to be able to make the award would be in the financial year 2015-16. In the Call for Inputs we sought views on the optimum timing for the award and when successful bidders would be likely to start using the spectrum. There were a range of views expressed, mostly in confidential responses, which ranged from a preference for an award in 2014 to one in 2017-18. Indications were that usage might start from immediately after licences were issued to 2020 or later. In light of these responses 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. We currently expect to make the award in the second half of the financial year 2015-16 following publication of a statement and an information memorandum and a consultation on draft regulations.

Method of award

4.33 As described in the Legal Framework section of this document, Ofcom has a duty to secure the optimal use of radio spectrum. This will usually be the most valuable use. We therefore have a preference for allowing market based mechanisms to determine the outcome of an award, such as an auction process, as set out in our Spectrum Management Statement.

[26] The European Conference of Postal and Telecommunications Administrations (CEPT) Electronic Communications Committee (ECC)
[27] http://www.cept.org/Documents/ecc/14301/ECC(13)090-Annex09_Draft-amended-ECCDEC(11)06-for-PC-(with-rev-marks)
[28] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.139.01.0018.01.ENG

Combined auction

4.34 We are proposing a single auction for both the 2.3 and 3.4 GHz. While we do not think lots in 2.3 GHz and 3.4 GHz bands are likely to be seen by bidders as perfect substitutes, we believe they may to some extent be substitutable at some prices and therefore holding a combined auction makes sense from a bidder's point of view. It is also administratively convenient and cost-effective to have an auction at the same time. We do not expect that holding a combined auction will delay the award of either band; we plan to award both bands as soon as we are practicably able to do so.

The auction process

4.35 Our illustrative auction procedures are set out in Annex 6, and the two options for auction format we are considering are set out in section 6. In summary, the auction process would be as follows:

- Interested persons are required to **apply** for the grant of a licence;
- Applicants need to **qualify** to participate in the award process. Applicants 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;
- The second stage of the auction is the **assignment stage**, whereby frequencies are assigned to winning bidders that submitted one of the winning principal stage bids. 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. 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.

Generic lots

4.36 The first stage of the auction, the principal stage, would involve generic lots, that is bids would not relate to specific frequencies within each band, but simply to lots of unspecified frequencies within the award band. Specific frequencies could be bid for in the second stage of the auction, the assignment stage, if bidders have a preference. There are several reasons for taking this approach, which is usual in a spectrum auction.

4.37 Generic lots minimise the risk of fragmentation of the spectrum; that is they aid contiguity. Using a generic lot stage allows simplicity of bidding, allows a speedier auction and is more flexible than a single stage frequency-specific auction. A generic stage also reduces the opportunity for strategic bidding aimed at splitting a competitor's spectrum holding. The consequence of having generic lots in the principal stage is a need for an assignment stage. That will be the only place in the auction bidders have to express a preference for a particular part of the band, or, a

preference for a contiguous assignment (if UK Broadband does not participate in the auction).

Lot categories in the auction (types of lot)

4.38 If there are significant differences in value between lots, they should be split into different lot categories. A lot category is a range of frequencies that comprise a certain number of generic lots.

4.39 When there are differences in value, but they are not clear, the decision of how many lot categories to define should strike an appropriate balance between two opposing effects. A high number of lot categories may create difficulties when bidders want to shift their demand across different categories as relative prices change[29]. A low number of categories results in bidders having to wait until the assignment stage to know whether they have won lots in their preferred part of the spectrum.

4.40 We have described earlier in this section of the consultation document the characteristics of the 2.3 GHz band and of the 3.4 GHz band. We believe these different characteristics warrant a different category in the auction for each band. We are proposing that there should be one category of 2.3 GHz lots and one category of 3.4 GHz lots. While there may be some differences within the bands, they can be addressed in the assignment stage, as described below. In considering whether there are differences in value within each band, we took into account our technical analysis of uses of the bands and coexistence with users in adjacent bands, outlined above. We found no evidence to suggest there were sufficient differences to warrant separate categories of lots in each band. We welcome views on this issue.

4.41 While all respondents to the Call for Inputs agreed that contiguous spectrum is desirable, most respondents at this stage did not regard any part of either the 2.3 GHz or 3.4 GHz award band as any more desirable than any other part of the same award band. BT however, suggested[30] that the upper part of the 3.4 GHz band could be considered more valuable. They pointed out that the US Federal Communication Commission (FCC) had proposed to make 3550-3650 MHz available for small cells and so the top part of the 3.5 GHz band may have low cost equipment available and hence is of particular interest to BT and possibly to other companies. We do not have a view as to whether this part of the 3.4 GHz spectrum band has a different value to the remainder of the band, as the FCC has yet to release it, but we note that it could be. We suggest that any difference in value across the band is difficult to quantify and can be resolved in the assignment stage.

4.42 We have undertaken some work to satisfy ourselves that the risk of any interference into new uses is not likely to affect significantly the valuation that bidders may place on different lots within each band – that is, we believe the use of generic lots and an assignment stage remains an appropriate award format. One confidential response to the Technical Consultation suggested that we look into the effects of Wi-Fi into LTE in the 2.3 GHz band. Our assessment, including conversations with stakeholders, suggests that whilst there may be some trade-offs between 2.3 GHz LTE and 2.4 GHz Wi-Fi performance when both technologies are within the same device, interference from Wi-Fi *into* LTE is not likely to have a significantly greater effect at the higher end than the lower end of the 2350 – 2390 MHz band.

[29] This is particularly relevant for the SMRA format described in the next chapter.
[30] http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/responses/BT.pdf

4.43 We believe that a single lot category in the 3.4 GHz band is appropriate even if UK Broadband do not come to the auction[31]. This will facilitate switching across lots within the 3.4 GHz band, thereby reducing substitution risks that might exist if there were two categories, as described above. A consequence, if UK Broadband does not come to the auction, is that winning bidders could have a split assignment. While contiguity of spectrum holding is desirable, there are mitigations, including technological developments and our proposals for synchornisation. Furthermore, a split assignment is relatively unlikely even if UK Broadband do not come to the auction. A note from DotEcon on "Fragmented Assignments in the 3.4 GHz band" is attached as annex 7 to this document. This sets out the results of mathematical calculations (making assumptions of awards of 20-80 MHz and that any unsold spectrum is retained in contiguous blocks above and/or below the current UK Broadband holding). The results apply to either of the auction formats we detail. It shows that the scenario in which a split assignment is the most likely to occur is where there are three successful winning bidders, but even then, out of a total 240 possible permutations of allocation, only 33[32] would require a split assignment. All assignments over 80 MHz would require a split.

Lot size

4.44 We proposed using lot sizes of 5 MHz in both the 2.3 and 3.4 GHz band in our October 2013 Call for Inputs and sought views on whether a 10 MHz lot size would be more suitable for the 3.4 GHz band. Most responses, mostly confidential, agreed with the thrust of our proposal. We therefore in this document set out proposals for lots of 5 MHz.

4.45 A number of respondents suggested that in addition a minimum holding would be required. Some confidential respondents indicated this would be 10 MHz, others 20 MHz, one suggested 30 MHz.

4.46 Based on the information available from the Call for Inputs responses about potential demand and its structure, there is a risk that lots greater than 5 MHz could create asymmetries between bidders and technology. While bidders may require a minimum usable block of 20 MHz, there is no consensus on a larger lot size. Bidders may have different views on the potential need for additional spectrum, for example to be used as guard blocks or for additional capacity. Using larger lots would require pre-judging efficient lot sizes and number of lots of each size, both of which have implications on the structure of downstream markets; misjudging this might preclude an efficient allocation of spectrum, and could also facilitate market division by incumbent bidders and denial of entry.

4.47 In our SMRA design, we set out our proposal for bidders to express a minimum requirement of up to 20 MHz. In the CCA design, bidders can choose the amounts they require as they bid for packages. Our proposals on how bidding will work, including minimum requirements, are set out in the next section of this document.

Call for Inputs

4.48 In response to our October 2013 Call for Inputs, a number of confidential responses indicated a preference for an auction. Respondents also indicated that they would be interested in acquiring spectrum though an auction.

[31] The impact of UK Broadband's holding in the 3.4 GHz band is discussed later in the next section.
[32] This should not be taken as a probability, as not all outcomes are equally likely.

4.49 BT considered that, rather than an auction, means of facilitating shared use of the spectrum should be examined. BT's preferred scenario was an award of part of the available spectrum in a large block suitable for a neutral host network operator and including wholesale access obligations. If Ofcom were to follow this scenario, BT believed a beauty contest might be more appropriate than an auction because this would reduce the cost of spectrum and enable the most attractive shared network to be provided at lower cost.

4.50 If Ofcom did not choose the neutral host operator option, BT agreed that an auction process would be suitable.

4.51 Espirito Ltd[33] also suggested more spectrum efficiency could be gained through service sharing and supported a beauty contest.

4.52 Ofcom has chosen not to propose regulated wholesale access attached to a large spectrum block, allocated through a beauty contest. Ofcom prefers to adopt a market-led approach. We believe an auction is a fairer, more open and more transparent procedure and is likely to lead to a more efficient outcome, especially in the context of technological and service neutrality. This is in line with Ofcom and European practice and we have found no evidence that another approach would be likely to lead to a better outcome in this case. We do not believe an allocation of spectrum achieved through auction prevents the outcome that BT would like to see. That is to say, a bidder could purchase a large block of spectrum which it could use to offer wholesale services.

4.53 As we said in Annex 6 of our March 2012 consultation[34] on the 800 MHz and 2.6 GHz auction, we consider that there are likely to be significant advantages to promoting competition between national wholesalers, rather than on-going wholesale access regulation. Competition at the wholesale level involves competition over more of the value chain than competition solely at the retail level. Key dimensions of quality are determined at the national wholesale level, such as data rates and coverage. Compared to regulation, the competitive process is likely to be far more effective at delivering the quality levels that consumers want, and at delivering new and innovative services. In particular, there is potential for regulatory failure in setting a regulated price of wholesale access. If set too high, it would fail to promote retail competition. But if set too low, it could have the effect of chilling the incentives to invest of the regulated national wholesaler(s).

4.54 Promoting competition through an auction award is, we believe, more likely to promote consumers' interests than on-going wholesale access regulation. This is consistent with the strategic principle that Ofcom has used since the 2005 Telecoms Strategic Review of promoting competition at the deepest level of infrastructure at which it will be effective and sustainable. It is consistent with the approach we took in the 800 MHz and 2.6 GHz spectrum auction in 2013.

4.55 BT suggests that there is a lack of competition in the wholesale market. We disagree. In our 2011 Infrastructure Report[35] we stated that in the UK there were 35 mobile virtual network operators (MVNOs). These retailers were being supported by the four national mobile network operators (MNOs), who were also retailing themselves. In

[33] http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/responses/Espirito_Limited.pdf
[34] http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/annexes/2nd_Condoc_Annex_6.pdf
[35] http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/bbspeeds2011/infrastructure-report.pdf The 2014 Infrastructure Report will be published shortly.

total, across the sector, 16% of voice minutes and 14% of mobile data were associated with MVNOs.

Question 4.1: Do you agree with our proposals for categories and lot sizes in the auction? If you disagree please provide evidence for your position.

Question 4.2: Do you have any other comments or views relating to the overview of the spectrum?

Section 5

UK Broadband holding in the 3.4 GHz band and contiguity

5.1 UK Broadband secured spectrum rights in the 3.4 GHz band covering most of the country via auction in 2003. It acquired further rights through spectrum trading after the auction. Its rights were subsequently consolidated into a single UK wide licence which would have expired in 2018. The licence is currently made up of two non-adjacent 20 MHz spectrum blocks (at 3480-3500 MHz and 3580-3600 MHz).

5.2 In October 2013, we consulted on a proposal to consolidate the UK Broadband holdings within this band into a single 40 MHz contiguous block at 3560 to 3600 MHz before the award of the 3.4 GHz band. In June 2014 we issued a consultation on UK Broadband's application for an extension of the licence. We stated in the consultation document that we had decided not to proceed with relocating UK Broadband's holding in the 3.4 GHz band at that stage. Following consideration of responses, we published on 9 October 2014 a statement[36] setting out our decision to make indefinite UK Broadband's licence (in relation to its existing split spectrum holding).

5.3 Our auction proposals in this document provide an opportunity for UK Broadband to achieve contiguous spectrum. If they participate in the auction, other winning bidders in the award could also be guaranteed a contiguous spectrum assignment. We set out below how we propose to achieve this. In the next section of this document on auction design, we again refer to the impact of the UK Broadband holding in considering different approaches.

Benefits of holding contiguous spectrum

5.4 In the June 2014 consultation[37] on the UK Broadband licence variation request we suggested that larger contiguous assignments would give operators (a) the flexibility to deploy larger channel sizes and (b) reduce technical constraints, due to a lower number of spectrum boundaries between licensees.

5.5 The relocation of the UK Broadband holding would:

- reduce the number of operators with a split assignment (UK Broadband itself and, possibly, one[38] of the winning bidders) and
- remove one, and possibly two, boundaries between adjacent operators that could exist following the 3.4 GHz auction if UK Broadband's holding did not move.

(a) Flexibility over carriers and channel widths

5.6 Where an operator has a block of contiguous spectrum it has the flexibility to choose the number and size of channels that it uses to provide services. For example, if an operator has a contiguous block of 40 MHz then it can choose to deploy two channels of 20 MHz or aggregate them into one channel of 40 MHz. It can then

[36] http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf
[37] Paragraphs 5.103 to 5.124
[38] We recognise that there is a remote possibility that there could be more than one split assignment.

manage resources between these two channels as it chooses without needing to consider the uses of any other networks that might lie between these two 20 MHz channels where there is a split assignment. We believe the increased flexibility associated with a contiguous block should help support efficient use of spectrum.

(b) Spectrum boundaries

5.7 Whenever there is a boundary between operators there is a potential for interference, including some loss of coverage or capacity. It is possible to reduce the risk of interference, for example by:

- higher performance filtering;
- intelligent scheduling of resources;
- careful location of transmit sites; or
- synchronisation of the networks.

5.8 Each of these mitigation measures are effective in different scenarios and the choice of mitigation may depend on a number of factors related to the adjacent network such as deployment, business case and typical customer usage profile. Alternatively an operator may choose to accept any performance degradation which means that they accept the interference environment caused by the adjacent licensee. This is likely to lead to increased interference and thus lower peak throughput and capacity of the particular cells. A licensee might determine that this is a reasonable degradation in their opinion.

5.9 Cooperation between adjacent operators is desirable to maximise the benefits of any mitigations. However, all of the above approaches come with some cost, loss of flexibility and / or service degradation. In addition, the interaction between operators adds complexity and may require a degree of compromise which may not always be easy to achieve. The actual cost of these boundaries depends on the approach of different operators and how they decide to deploy and operate their networks in line with their licence conditions. We consulted on licensed use without guard bands or restricted blocks between adjacent licensees as part of our wider consultation on technical conditions for the award (our February 2014 consultation). we now consult on further proposals to encourage or mandate synchronisation. Synchronisation would also provide some mitigation against the adverse impact of any non-contiguous assignment. Details are contained in the technical licence conditions section of this document.

Re-assignment of UK Broadband's current spectrum holding if UK Broadband participates in the auction

5.10 As described below and in detail in the next section, we propose to proceed with a two stage auction, including a principal stage and an assignment stage. We further propose that while only 150 MHz in the 3.4 GHz band will be available in the auction at the principal stage, UK Broadband's current 40 MHz holding will be added to the frequencies to be allocated in the assignment stage if UK Broadband participates in the auction. That is UK Broadband must give up their current holding of 40 MHz if they wish to participate in the auction. UK Broadband could then be named either as a guaranteed winner of 40 MHz at the principal stage (thereby qualifying for participation in the assignment stage) or as a guaranteed participant in the

assignment stage. UK Broadband would need to qualify for participation in the auction even if it only wanted to participate in the assignment stage.

5.11 In that circumstance, UK Broadband will be allocated 40 MHz contiguous spectrum in the assignment stage, and the winning bidders for the 150 MHz available in the principal stage will be allocated the remaining 150 MHz. UK Broadband and other participants in this stage of the auction will be guaranteed contiguous spectrum, but its precise location in the band will depend on any bids made in the assignment stage. In other words, UK Broadband would have to bid if it wanted to obtain a specific position within the band, as would the winning bidders in the principal stage. UK Broadband would be issued with a new licence for the frequencies allocated to it in the auction. The conditions of such a licence would be consistent with the conditions of all other licences for the spectrum[39]. UK Broadband would (in addition to any sums bid in the assignment stage) pay annual licence fees on its new licence for 40 MHz of spectrum from July 2018[40].

5.12 If UK Broadband wanted to obtain additional spectrum in the auction it would have to apply to qualify as a bidder in the qualification stage of the auction and then bid in the principal stage of the auction.

5.13 We propose that if UK Broadband participates in the auction and is assigned different frequencies from its current holding in the 3.4 GHz band, it will be allowed a period of time to move to the new frequencies. We propose that this should be 6 months from the date of the commencement of the new, post-auction, licence which would be issued shortly after winning bidders' frequency allocations are determined.

5.14 Where another licensee has won spectrum currently held by UK Broadband, both UK Broadband and the new licensee(s) will be required to co-operate in order to protect UK Broadband's existing services until these have migrated to other spectrum. Such measures will only be needed until UK Broadband has retuned any sites and, with the transition period being a maximum of 6 months, we do not expect that these requirements will materially limit the deployment plans of any new licensee.

Question 5.1: Do you agree with our proposals for achieving contiguity, and if not please provide further explanation.

[39] We stated in the statement on the variation of UK Broadband's licence that we will vary its licence conditions to be consistent with those of other licences for the spectrum award once the licence conditions have been finalised by our consultation process and we have made our decision. UK Broadband will therefore have licence conditions consistent with those of other licences for the spectrum award irrespective of its participation in the award.

[40] That is the date UK Broadband would be required to start paying an annual licence fee (ALF) in relation to its current licence if UK Broadband did not participate in the auction and retained its current licence

Section 6

Auction Design

Summary

6.1 In the Overview section, we set out our proposals for the packaging of the spectrum that will be offered in the 2.3 and 3.4 GHz auction.

6.2 This section sets out our proposals for the design of the auction. These take into consideration the expected demand. We first set out the objectives for this particular award. We set out our consideration of the feedback we received to our 2013 auction of spectrum in the 800 MHz and 2.6 GHz bands and the responses to the Call for Inputs (CFI) we published in October last year and to the technical coexistence consultation of February this year. In light of that consideration, we assess which auction design is likely to be best at meeting the objectives we set.

6.3 We seek views on our auction proposals.

6.4 The proposed auction comprises two stages: the principal stage and the assignment stage. The principal stage determines how much spectrum each bidder wins in each lot category. The assignment stage determines the exact frequencies for the spectrum won by the bidders in the principal stage.

6.5 We consider that the most suitable auction format depends on the circumstances and the nature of the demand for the spectrum on offer. We have developed detailed proposals for two auction formats for the principal stage – the Simultaneous Multi-Round Ascending Auction (SMRA) and the Combinatorial Clock Auction (CCA).

6.6 We believe both formats, in the detailed implementation we propose, are robust approaches for our award and would meet the objectives we have identified. We have successfully used the CCA on several occasions, including in the 2013 auction, and we believe this format is the best format under many circumstances. However, we believe the SMRA has some important advantages given the specific circumstances of this award. We are proposing an SMRA auction process based on a number of assumptions, which we set out.

6.7 We also recommend a sealed-bid, single-round format with a second-price rule for the assignment stage. We discuss the advantages and disadvantages of this pricing rule.

6.8 The section concludes with our proposed range of reserve prices for the award.

6.9 We set out in Annex 6 a draft high level description of the auction procedures we are proposing in relation to the two formats being considered. This document aims at illustrating how both formats work in practice. It is not an attempt to draft the regulations for the award and is likely to change as a result of the public consultation.

6.10 In March 2014, the NAO published “4G radio spectrum auction: lessons learned”[41], an analysis of the 2013 auction with recommendations for Ofcom for future spectrum auctions. We understand the NAO recommends that Ofcom balances an auction

[41] Available at http://www.nao.org.uk/wp-content/uploads/2015/03/4G-radio-spectrum-auction-lessons-learned.pdf

design's benefits against any complexity and uncertainty for bidders. We have taken this into account in our proposal.

6.11 DotEcon were appointed to advise Ofcom on auction design for this award.

Objectives for the auction

6.12 Our duty of furthering the interests of citizens in relations to communications matters, and to further the interest of consumers, where appropriate by promoting competition, is of primary importance to this award. We believe this duty is best achieved by designing the auction in a way that facilitates the allocation of the spectrum to those bidders that are most likely to put it to the most efficient use and deliver the highest possible value to society. This should fulfil our duties to secure the optimal use of the spectrum and to promote innovation in the market.

6.13 Our statutory duties are more likely to be achieved through the following additional objectives :

a) The design should be simple where possible, without unduly compromising the efficient outcome of the auction.

b) 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.

6.14 We believe these objectives are consistent with the feedback we received in the context of our 2013 auction and in the responses to our consultations, as explained below.

Call for Inputs (CFI) and Coexistence Consultation

6.15 In the CFI we published in October 2013, we invited respondents to express their views on the method of award for our forthcoming auction.

6.16 For a multiple-category auction, most of the responses favoured either a CCA or an SMRA.

6.17 Other formats or variants of these two formats were also put forward. These included the simplified version of the CCA adopted by New Zealand and a format called Pause, by Professor Frank Kelly.

6.18 A confidential respondent noted that if Ofcom chose a CCA, we should analyse how various policy measures interact with the latter and ensure that a multiple round auction facilitates price discovery.

6.19 BT encouraged Ofcom to design the auction to make it as simple and transparent as possible to bidders, with a view to minimise complexity and the opportunities for gaming.

6.20 In the technical consultation on coexistence with adjacent spectrum bands we published in February 2014, we asked for views on whether we should hold a market led award through an auction process. The responses largely reflected those made in response to the Call for Inputs.

Auction formats considered

6.21 We considered a wide range of potential formats for the principal stage of the auction which we narrowed down to two – a CCA and an SMRA with generic lots. We were unconvinced that for this award the other formats considered would introduce significant benefits as compared to the widely used versions of the SMRA and the CCA. The SMRA and the CCA are well-understood and widely tested formats commonly used for spectrum auctions. In particular, they have been widely used in Europe in the context of the recent multi-band auctions. The majority of the respondents to our consultations who express a view on auction format favoured using either an SMRA or a CCA.

6.22 We have considered the particular circumstances of this award and developed standard versions of the SMRA and the CCA into a "best-fit" version of each format for this auction. We were, however, minded that very significant departures from the standard versions of these formats would erode the benefits inherent to each design and from using a well-tested approach, while increasing the exposure to unforeseen outcomes.

6.23 Both formats follow the same stages, but they differ with regards to the principal stage.

Figure 3 Outline of the stages of each auction format

Auction stages	Application	Qualification	Principal	Assignment	Grant
SMRA	Application	Qualification	Primary rounds	Assignment stage	Licence granted
CCA	Application	Qualification	1. Clock rounds 2. Supplementary bid round	Assignment stage	Licence granted

Simultaneous Multi-Round Ascending (SMRA) Auction

6.24 The SMRA is an open ascending multi-unit auction that takes place over a number of rounds. In this format, bids are placed for individual lots, and the auction proceeds in successive rounds with increasing prices, until there are no new bids. A points-based activity rule is often used, under which bidders may only decrease or maintain their level of demand from one round to the other, as measured by the number of eligibility points[42]. 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. The traditional implementation of the SMRA allows bidders to place bids for specific frequency lots (say 2350-2355). However, the SMRA has also been used with frequency-generic lots in recent years (say 5 MHz somewhere in the band between 2350 and 2390 MHz). With generic lots, bidders are awarded a number of lots at the end of the principal stage of the auction, and then proceed to an assignment stage to determine the exact location of their frequencies.

6.25 As set out in the previous chapter, we propose proceeding on the basis of generic lots for each of the two categories (one for 2.3 GHz band and one for 3.4 GHz band)

[42] Eligibility is explained in a subsection later in this section of the document

within this award. This reduces the chances of a non-contiguous assignment and allows for a speedier process. However, it also means that if bidders have a strong preference for a particular part of the band, they will only be able to express that in the assignment stage. We assume that it is possible for bidders to manage preferences for a particular part of the band in the assignment stage of the auction.

6.26 The SMRA with generic lots has been used in several recent multi-bard spectrum awards in Europe. Examples include Germany, Italy, Spain, Portugal, Greece and the Czech Republic.

6.27 In the following paragraphs we identify risks related to the standard SMRA. We then go on, in the following sub-section, to describe how we have sought to mitigate these concerns by introducing a number of improvements to the standard design.

6.28 An inherent problem with the standard SMRA is that while bids are placed for individual lots, bidders may not know how much they are prepared to pay for each individual lot without knowledge of type and quantity of spectrum they will secure at the end of the auction. Bidders may value an individual lot more if they know they will also obtain other lots. This is known as an aggregation risk. But, because they have to bid for each lot individually, the value bidders place on a lot requires them to make an assessment about how likely it is that they will secure additional spectrum at the end of the auction.

6.29 The standard SMRA nominates Standing High Bidders at the end of each round. This is helpful as it means bidders know what they will win and what they will pay if the auction were to close at that point. However, it may create difficulties when bidders want to move their demand from one category to another if they do not have sufficient eligibility points, or if they need to wait until they are outbid to do so. This is known as a substitution risk. The standard SMRA may create an 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. This is called strategic demand reduction. Bidding for a large number of lots in the SMRA increases the likelihood of generating excess demand. Excess demand, in turn, triggers increases in the price for all lots the bidder is bidding on. As a consequence, bidders may decide to reduce demand, under the expectation that this will prevent prices from rising.

Generic lot categories

6.30 As explained above and in the previous section, we are proposing two categories (one for 2.3 GHz band and one for 3.4 GHz band) of generic lots each of 5 MHz. All lots within each category are identical: they all represent the right to use 5 MHz of spectrum in the relevant spectrum band.

6.31 We are also proposing generic lot categories: bidders do not bid and prices are not calculated for each individual lot within each category. Rather, there is a single, common price level for each lot within each category, and bidders respond to this round price by bidding for a number of lots. If demand is equal or greater than supply at the current price, then the price goes up in the following round. If demand is lower than supply, the price stays the same.

6.32 Standing High Bidders are established on the basis of bids received for lots in each category at the end of the round

Break ties for the whole category

6.33 When demand exceeds the number of available lots at a given price level, we need a rule to determine which bids are Standing High Bids.

6.34 We propose to rank randomly all bidders who placed bids in any given round and then provisionally allocate all lots available to each bidder in turn until there are no more lots available. Under this approach, only the last bidder provisionally allocated lots may become Standing High Bidder on fewer lots than the number of lots they bid for.

6.35 This rule reduces aggregation risks – that is, the risk that a bidder wins some but not all the lots they bid for. In addition, we are making it easier for bidders to move their demand across categories.

6.36 A possible drawback of this approach is that it may disclose some information about the structure of demand which could facilitate strategic demand reduction[43]. We believe, however, this is unlikely to be a major problem because the information about demand would always be incomplete as we are proposing a strict information policy (as explained below).

6.37 Finally, we propose that, whenever a bidder wishes to place new bids at a given price level, they will need to raise any Standing High Bids they may hold at the previous price level to the new price level. This allows for a speedier bidding process with little downside. It could reduce the flexibility bidders might otherwise have to express a preference to acquire extra lots at a different price, but we do not expect to set large price increments from one round to the next.

Specification of a minimum requirement

6.38 The responses to the October, 2013 CFI indicate that for many of the potential bidders there is a minimum quantity of spectrum below which spectrum has little or no value. Based on the responses we received, we believe a sensible minimum threshold to be at most 20 MHz. We are also assuming that this minimum threshold is the most significant source of 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 are in particular assuming that there are no strong complementarities between spectrum in the 2.3 GHz band and spectrum in the 3.4 GHz band. In other words, we assume that bidders acquiring spectrum in one band do not substantially increase their value in the other band. Where there are complementarities between spectrum bands or in spectrum beyond 20 MHz in a band, we are assuming they can be managed in the course of the auction.

6.39 To protect bidders from being stranded with a quantity of spectrum which is below this minimum threshold, we are proposing to allow bidders to specify before the auction starts, a minimum requirement of spectrum in each category in multiples of 5 MHz, up to 20 MHz. Even if they are Standing High Bidder on some spectrum, bidders will not be allocated less spectrum in a lot category then their specified minimum requirement. .

[43] It could facilitate strategic demand reduction if it provides an indication to bidders about the number of lots that could fit in with the bids from their competitors. This would happen, for instance, if in a sequence of rounds, bidders would be able to perceive a pattern in the number of their bids that became Standing High Bids.

6.40 We note a potential downside to allowing bidders to specify a minimum requirement per band. It may allow bidders to place large bids which have a relatively low chance of becoming winning bids. This in turn may incentivise strategic bidding aiming purely at pushing up prices in a given category. We are therefore proposing that the maximum amount of spectrum that may be included in the minimum requirement is 20 MHz. This is equal to half of the total spectrum available in the 2.3 GHz band. In addition, if a bidder specifies a minimum requirement in one or both bands, we propose that they will only be allowed to submit bids which ensure that their minimum requirement is met in all bands.

6.41 We considered allowing the minimum requirement to apply across categories, instead of applying to each category individually. This would, however, expose bidders to the aggregation risk of ending up with less than 20 MHz in any of the bands. We are not proposing this option, as this risk is inconsistent with the responses we received in the CFI. We therefore propose that the minimum requirement would apply to each category individually.

Activity rule and limits on eligibility to bid

6.42 The SMRA we propose adopts a points-based activity rule, which means that in any given round the bidder's "activity" may never exceed their "eligibility". Each lot will have a number of eligibility points (the number of eligibility points per lot are set out in a section below). The bidder's activity is the sum of the eligibility points of all the lots they submit bids in a given round and of all the lots for which the bidder holds Standing High Bids (in lot categories where the bidder does not submit any bids and which are not withdrawn by the bidder in the round). The bidder's eligibility in the first round is given by the deposit provided by the bidder. After the first round, the bidder's eligibility is equal to their activity in the most recent round (in which the bidder did not submit a waiver).

6.43 A bidder may waive the right to bid in a round by using a "waiver". We are proposing to allow bidders to use a maximum of 3 waivers. A bidder who submits a waiver in a round will not have their eligibility level adjusted in the following round, even if their activity level is lower than their eligibility. Waivers may assist bidders when they need some additional time to make a decision or want to observe other bidders' behaviour before making a decision. Waivers may be particularly helpful in assisting bidders who wish to move demand across categories. For instance, if a Standing High Bidder in a given band wishes to switch to bid on the other band, they may use a waiver to see if they are outbid first, instead of withdrawing (which is explained below and risks forfeiting the lot value). We are limiting the number of waivers a bidder may use in order to avoid undermining the price discovery process.

6.44 Some SMRA auctions include a phased activity rule, where the activity rules are tightened in different phases. In the early phases a bidder only needs to bid a fraction of their eligibility to be able to maintain eligibility in the following round. The advantage is that bidders might wish to observe demand for a particular type of spectrum ("key lots") in order to infer what the likely final prices for this spectrum will be before committing their full demand. This may happen when there are strong value complementarities between lots. Bidders might wish to wait until the price of the lots needed for a minimum requirement is settled to start bidding on additional lots. In the 2.3 / 3.4 GHz award, there are no clear "key lots" for which prices could settle first. The lots needed for the minimum requirement are indistinguishable from the additional lots and they will tend to have the same price. Also, as discussed above, we assume there are no strong complementarities across categories. There would be some risk in adopting a phased activity requirement in our award, as it

might allow bidders to under-represent their demand, which would undermine price discovery. It could also incentivise strategic demand reduction by allowing bidders to test outcomes that are mutually beneficial. For these reasons, we are not proposing a phased activity requirement.

Withdrawals

6.45 We are proposing to allow bidders to withdraw their Standing High Bids in any given category and in any given round. By withdrawing their standing highs bids, bidders free up eligibility which they can then use to bid on another category. Withdrawals therefore partially mitigate substitution risks in the SMRA.

6.46 However, we believe there is a risk that withdrawals could provide opportunities for gaming. In particular, bidders might bid in one category with the sole intent to push up prices before leaving that category altogether. To avoid this, we recommend the bidder forfeits the lot value from their deposit if there are unsold lots as a consequence of a bidder, or more than one bidder, withdrawing their Standing High Bids. They will be liable to pay the full price of all the lots from which they withdrew. This means that, even if the number of unsold lots is lower than the number of lots withdrawn by a bidder, they will be liable to pay the price of all the lots they withdrew, without receiving those lots.

6.47 We do not propose a restriction on the number of withdrawals each bidder may use during the course of the auction, or on the number of times a bidder may withdraw their Standing High Bids. However, we are proposing that a bidder must withdraw all their Standing High Bids in a lot category if they use a withdrawal.

Information policy

6.48 Before the auction begins, we propose to disclose the total number of qualified bidders, and their identity. We understand this may in some circumstances be a concern on the grounds that it could potentially facilitate strategic demand reduction (as explained at 6.29). We are aware that some countries that have run SMRAs in the past have chosen not to disclose this type of information to bidders in advance of the auction. However, limiting the information provided to bidders during the auction, as described in the next paragraph, assists in mitigating those bidding strategies.

6.49 During the auction, we propose not to disclose information about aggregate demand at round prices. We believe this information could facilitate strategic demand reduction since bidders might be able to infer the point in the auction at which reducing demand would bring an auction to an earlier end. Instead, we propose to only notify bidders of prevailing round prices, which will only increase if all lots are provisionally allocated at the previous round price (and will remain unchanged otherwise).

6.50 A limited amount of information also reduces the chances of tacit collusion, as bidders have less opportunity to signal their intentions to their competitors.

6.51 We are proposing a strict information policy during the auction. More details about the information we propose providing to bidders, including in relation to other bidders and bids, are available in the illustrative auction procedures (Annex 6).

Combinatorial Clock Auction (CCA)

6.52 The CCA is a multi-unit two-phased bidding process. The first phase is known as the clock rounds. In this phase, bidders place bids for a number of lots in each category, at the prices set by the auctioneer at the start of each round. The auction proceeds in successive rounds, in which the price for lot categories for which there is excess demand is increased, until there is no excess demand for any lot category. A points-based activity rule similar to the one described for the SMRA has been commonly used, although there are alternative approaches that can provide additional flexibility during the clock rounds (as explained below). The second phase is called the Supplementary Bids Round, and is a single-round sealed-bid process where bidders may increase their bids for the packages they bid on during the clock rounds and place bids for other packages (subject to constraints aimed at ensuring that bidding is consistent with the preferences reflected in the bids they submitted during the clock rounds). As with the SMRA, these two phases will be followed by an assignment stage of the auction to determine the exact location of spectrum to be awarded to each successful bidder.

6.53 A distinctive feature of the CCA is that 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. This means that, if bidders have a minimum requirement, they can ensure they never win less spectrum than their minimum requirement by never bidding on less than their minimum requirement

6.54 Most CCAs, including those run by Ofcom, have used a constraint on the relative amount that can be bid for different packages in the Supplementary Bids Round (a so-called Relative Cap). When a bidder moves from bidding on package A, to bid instead on package B which has fewer eligibility points during any given clock round, they are setting a constraint on how much they can bid for package A in the Supplementary Bids Round, relative to the amount bid for package B. The maximum amount they can bid for package A is the maximum bid placed on package B plus the price of the extra lots in the round when they contracted demand.

6.55 At the end of the Supplementary Bids Round, all bids placed in both the clock rounds and the Supplementary Bids Round are brought together and the one combination of bids[44] that maximises total value is selected[45]. Bids included in that combination are winning bids. A 'base price' for each winning bid is also calculated according to a second price rule. A second price rule requires bidders to pay an amount that is just sufficient to ensure that no other bidder or coalition of bidders was prepared to pay more than for that package

6.56 This is a format which has also been widely used in recent European multi-band awards, including Switzerland, Netherlands, Ireland, Austria, Slovakia and Slovenia.

6.57 The CCA has been used successfully by Ofcom, including in the 2013 800 MHz and 2.6 GHz auction, although in different circumstances, as discussed below.

6.58 We have considered enhancements to the detail of the CCA design which apply some of the lessons learned from the 2013 auction. These include feedback we

[44] Including a maximum of one bid per bidder.
[45] In some implementations of the CCA, each combination of bids includes the sum of the bid amounts of all bids in the combination plus the sum of the reserve price of any lots that would remain unallocated if each bidder was assigned the lots specified in their selected bid (or no lots if no bid has been selected for that bidder).

received from stakeholders and the NAO. In the sections below, we describe the enhancements: changes to the activity rule which aim to make the final clock round more indicative of the final outcome of the auction - both in terms of allocation of spectrum and prices paid. This should contribute to more informative clock rounds and reduce the scope for unpredictability in the Supplementary Bids Round. The enhancements reduce the uncertainty associated with the second price rule, which should minimise both the potential for surprise outcomes and the challenges faced by budget-constrained bidders.

6.59 Certain aspects of the 800 MHz and 2.6 GHz award will not be present in the 2.3 and 3.4 GHz auction. In the 2013 auction:

i) there were three spectrum bands in the auction organised into six lot categories, whereas in this award we are planning to have two bands organised into two lot categories;

ii) there was dynamic spectrum reservation (spectrum floors), which we are not proposing for this award;

iii) there was competition between those bidders wanting individual (standard-power) licences and those bidders wanting concurrent (low-power) licences in the 2.6 GHz band, which will not be a feature of this award.

Relaxed activity rule

6.60 The CCA enables bidders to express their full range of preferences, within certain restrictions aimed at ensuring consistent bidding behaviour. In the Supplementary Bids Round, bidders are allowed to express their demand for all alternative packages they may wish to acquire.

6.61 In order to make the clock rounds more informative for bidders we are recommending, in certain circumstances set out in the illustrative auction procedures (Annex 6), a relaxed activity rule to overcome difficulties associated with moving demand from one band to another at the clock round prices.

6.62 The relaxed activity rule allows bidders to submit bids during the clock rounds for packages that exceed their eligibility in a particular round, provided that doing so is consistent with the relative preferences shown up to that point of the auction. The submission of bids above the bidder's eligibility may in some instances require raising the bids on other packages to ensure consistency. These are called chain bids and are described in more detail in Annex 6.

6.63 This activity rule was used in the Irish Multi-Band Spectrum Award[46] and also in the Canadian 700 MHz auction[47].

6.64 We believe these rules will allow for more informative clock rounds, particularly when coupled with the final price cap.

[46] More information available at http://www.comreg.ie/_fileupload/publications/ComReg1252.pdf
[47] More information available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf10598.html

Final price cap

6.65 In addition to a relaxed activity rule in the clock rounds, if we run a CCA, we propose adding a further constraint to the range of allowable bids in the Supplementary Bids Round. This is in addition to the Relative Cap.

6.66 This further constraint is called a Final Price Cap. A Final Price Cap constrains the supplementary bids that bidders may place on all packages, except the one they bid for in the final clock round (the Final Clock Package).

6.67 The Final Price Cap limits the supplementary bid on any package A to the highest bid placed on the Final Clock Package plus the difference in value between package A and the Final Clock Package at the final clock round prices. In other words, if a bidder wishes to bid for lots in addition to their Final Clock Package, their maximum bid for each of those extra lots will be the clock price in the final clock round. Similarly, the maximum supplementary bid that a bidder may place on a package that is smaller than their Final Clock Package is the maximum bid placed on their Final Clock Package minus the difference in value between the two packages at the final clock round prices.

6.68 The Final Price Cap aims at providing a strong incentive for bidders to always bid for their preferred package during the clock rounds. This is because in certain circumstances the Final Price Cap imposes a tighter constraint, than the Relative Cap[48].

6.69 A consequence of the Final Price Cap is that the final clock round is likely to be a better indication of the final outcome of the auction in terms of allocation of spectrum.

6.70 In particular, if there are no provisionally unsold lots at the end of the clock rounds, and if no bidder has submitted a relaxed primary bid in the final clock round, the final outcome of the auction is guaranteed to be the outcome of the clock rounds (provided that none of the bidders who bid for a non-zero package in the final clock round are excluded for some reason from the auction at this stage)[49].

6.71 If there are provisionally unsold lots at the end of the clock rounds, bidders may be able to ensure that they win their Final Clock Package by placing a so-called "knock-out bid"[50]. A bidder who submits such a bid for their Final Clock Package and does not raise any bids for other packages above their price in the final clock round is guaranteed to win their Final Clock Package[51].

[48] If a bidder does not place a relaxed bid during the final clock round when they could have done so, then the Final Price Cap will set a tighter constraint on the bid amount for this package. If a bidder does not place a relaxed bid for their preferred package in the final clock round, the Final Caps applicable to this package may be too tight to allow the bidder to express their relative preference between this and the Final Clock Package.

[49] Bidders in this circumstance have already bid at the final clock round prices for all the lots included in their Final Clock Packages. Given that no bidder may bid for extra lots at a price which exceeds the final clock round prices, no bidder may be outbid and, therefore, the final clock round outcome cannot be altered.

[50] A "knock-out" bid is a Supplementary Bids Round bid that raises the value of the bid for the Final Clock Package by the value of all provisionally unsold lots at the end of the clock rounds.

[51] This strategy may not be available to bidders who submit a relaxed primary bid in the final clock round. In this circumstance, bidders may only be able to ensure that they win one of a number of packages they have bid for during the clock rounds but not necessarily the Final Clock Package.

6.72 This Final Price Cap allows bidders to make a better assessment of the maximum price they may need to pay to win spectrum, which may allow them to submit a set of bids that will ensure they obtain a desired result without having to reveal what their full valuation was for the packages on which they bid.

Price driving

6.73 Increasing the predictability of the provisional outcome at the end of the final clock round reduces uncertainty. But it is possible that this could allow bidders to submit risk-free bids[52] in the Supplementary Bids Round aimed at pushing up the prices paid by their competitors.

6.74 We believe the impact of such strategies is limited, as prices may only rise above the prices prevailing in the final clock round if there are provisionally unsold lots at the end of the clock rounds. Under the relaxed activity rule we expect the flexibility in the clock rounds to be increased, reducing the likelihood of provisionally unsold lots.

6.75 In addition, price-driving bids are constrained by the Relative and Final Price Caps, which require consistency with the preferences revealed in the rounds where bidders reduced eligibility. Therefore, bidders may only be able to marginally raise bids for packages they wish to acquire without risk.

6.76 This is because in order to deviate materially from true valuations, a bidder would need to adjust their bidding strategy during the clock rounds. Failing to bid for the most profitable package in the later rounds introduces a risk of ending up with the wrong package in the final clock round.

6.77 While we are aware that the Final Price Cap creates more certainty about the final outcome, this information might be used, even in a limited extent, to bid strategically to increase competitors' prices. However, we consider it likely that that the benefits the Final Price Cap gives in that it allows bidders to make a better assessment of the likely outcome and maximum price they will have to pay, outweigh the risks.

Information policy

6.78 The information policy we would propose for the CCA is similar to our proposal for the SMRA. In particular, we propose disclosing the number and identify of the qualified bidders in advance of the auction. During the clock rounds, we would not disclose information about the level of aggregate demand.

6.79 Knowledge about the level of aggregate demand in each lot category at the end of each clock round may have benefits to bidders. In particular, in circumstances where there is common value uncertainty, that is, the value of the spectrum is common but unknown to bidders, information about the level of aggregate demand may allow individual bidders to improve their estimates about how much the spectrum is worth. We have provided that information to bidders in the previous CCAs we ran.

6.80 However, we also note that disclosing this type of information might allow bidders to assess whether the clock rounds are reaching the end. In the extreme, this can facilitate tacit collusion. More generally, it may increase the scope for bidders to bid strategically, which would ultimately reduce the information value of the clock rounds.

[52] Risk free bids occur when a bidder knows that a particular bid cannot be a winning bid due to other bids they have put forward.

6.81 For instance, if bidders know the clock rounds are not likely to end soon, they may bid for a larger package than they would otherwise, based on their valuations, in an attempt to relax their Relative Cap. A more relaxed Relative Cap, in turn, allows bidders more room to place bids in the Supplementary Bid Round that impact the prices paid by their competitors. In addition, bidders might try to bring the clock rounds to an earlier end. This might be for instance aimed at generating excess supply in the final clock round and therefore cause greater uncertainty about the final outcome and prices.

6.82 We believe a greater degree of uncertainty about whether the clock rounds are nearing an end should discourage such behaviour, especially with the Final Price Cap (which should provide incentives for bidders to bid in such a way as to end the clock rounds with their preferred package).

6.83 We therefore propose not to provide information on aggregate demand during the clock phase.

6.84 At the end of the final clock round, we propose to inform bidders about the number of provisionally unallocated lots. This will allow all bidders to calculate their knock-out bids, as explained above. We considered not disclosing this information, as it may provide room for risk-free bidding purely aimed at raising the prices paid by other bidders. However, we believe the greater certainty provided to bidders outweighs the disadvantages.

6.85 More details about what information we will provide to bidders are available in Annex 6.

Eligibility ratio and deposit (which apply to both SMRA an CCA formats)

6.86 Each lot has a certain number of eligibility points associated with it. The eligibility points are used to establish a rate of substitution between lots in different categories, which applies during the SMRA auction and during the clock rounds of the CCA. For instance, a 2:1 eligibility ratio means that bidders are able to substitute one lot in the first category for two lots in the second category.

6.87 We propose to assign one eligibility point to each lot in both categories. This would allow bidders to substitute lots across different categories on a per MHz basis. We believe that setting eligibility points at a ratio different from one would unnecessarily create barriers to switching with the SMRA. Although we do not think lots in 2.3 GHz and 3.4 GHz bands are likely to be seen by bidders as perfect substitutes, we believe they may be substitutes on a per MHz basis at some price ranges. In the CCA, with the relaxed activity rule we propose, the choice of the eligibility point ratio is not critical because bidders will be allowed to bid on packages of lots for which they do not have enough eligibility, under conditions aimed at incentivising truthful bidding.

6.88 Along with their application, applicants will need to submit an initial monetary deposit which might be forfeited in whole or in part if the applicant subsequently breaches the award regulations. In addition, before the first round of the auction, qualified bidders will need to provide an additional deposit to Ofcom which will determine the bidder's initial eligibility level. The current value of the lot will also be forfeited if a Standing High Bidder withdraws and there are no subsequent bids on the withdrawn lots. Any interest made by Ofcom while holding the deposits will be returned to the Consolidated Fund.

6.89 We propose that the initial eligibility will correspond to the maximum number of lots that could be acquired by the bidder. To note, the total deposit provided by the bidder must be greater than the sum of reserve prices for the lots they intend to bid on. Ofcom will provide guidance on the deposit requirements for all possible initial eligibility levels.

6.90 At any point during the auction, Ofcom may require bidders to increase their deposits up to an amount equal to the highest bid submitted by the bidder.

6.91 We have considered the option of setting the initial eligibility as the minimum number of lots that could be acquired by the bidder with the deposit provided. We are, however, minded that this might disadvantage bidders only or primarily interested in the 3.4 GHz band. We would welcome views from stakeholders.

Residual risks

6.92 We believe the two auction formats we have described are robust and would work well in this particular auction. They include the mitigations needed to ensure a proper balance between risks which are of different degree and nature. The balance takes into consideration the particular objectives we have set out for the award, and results in a number of residual risks being present in both formats even after we have applied mitigations. These residual risks may lead to undesirable consequences in the auction. It is helpful to focus on these consequences as a means to decide which format to choose.

6.93 We have identified six possible, inter-related consequences which we believe are the most relevant, given our two best-fit formats. In our formats, we believe the risk posed by these consequences is relatively low. We explain them in more detail in the following sub-sections:

a) There may be some unsold spectrum, even though there is demand for that spectrum at the reserve price.

b) The auction generates “artificially low prices” due to strategic bidding.

c) Bidders may be prevented, or find it more difficult, to always bid for their most preferred spectrum.

d) Bidders may face difficulties developing and gaining approval for their bidding strategy within their organisation.

e) Bidders may not be aware of the price they will have to pay until the end of the auction.

f) The auction may generate a result which might surprise bidders and may therefore be perceived as unfair.

a) The risk of unsold spectrum

6.94 In the SMRA, bidders may only bid at round prices. In the CCA, although bidders may also only express their preferences at round prices during the clock rounds, the Supplementary Bids Round allows them to express a wider range of preferences at different price levels.

6.95 The fact that bidders are allowed to express a larger set of bids covering a wider range of their preferences in the CCA means there is a relatively lower likelihood of ending up with unnecessarily unsold lots, even though there was demand for it at least at the reserve price.

6.96 Failing to allocate some spectrum when there is demand for it at the reserve price may conflict with our objective of promoting optimal use of the spectrum. Because the SMRA assigns Standing High Bidders at the end of each round, this format normally does not generate unsold lots when there was demand for them at least at the reserve prices. In our detailed implementation, however, there are two particular circumstances when the SMRA might generate unsold lots, when there is demand for it at the reserve price:

i) if the minimum requirement specified by one or more bidders applies; and/or

ii) if one or more bidders withdraw their Standing High Bids from a category and there are no subsequent bids for that spectrum.

6.97 The risk of unsold lots generated by i) is mitigated by the rule we are proposing to select Standing High Bids in the SMRA, as a result of which we only expect a maximum of one bidder in each category to be in a position where they are Standing High Bidder but may fall below their minimum requirement (if they have set one). On the other hand, making the bidder forfeit the value of the lots from their deposit if ii) happens mitigates the risk of unsold lots.

6.98 In conclusion, we believe the residual risk of generating unsold lots is higher in the SMRA, compared to the CCA.

b) "Artificially low prices"

6.99 As noted previously, we believe the SMRA, in its traditional implementation, may be vulnerable to strategic demand reduction, where all or a number of participants reduce their demand to keep prices low. In an extreme scenario, with a reduced number of participants, the SMRA may facilitate market division (i.e. the spectrum is allocated at the reserve prices).

6.100 In the CCA, bidders are able to express their preferences at a wider range of price levels in the Supplementary Bids Round. This is due to the fact that a bidder may place bids in the Supplementary Bids Round that guarantee that their bidding for large packages does not put upward pressure on the prices paid in the event that they win a smaller package. We therefore believe the CCA is not as vulnerable to strategic demand reduction as the SMRA is.

6.101 We have limited the risk of strategic demand reduction in the detailed implementation of the SMRA through our proposals to reduce the level of information provided to bidders during the auction. We also propose to set reserve prices which take the incentives of bidders to reduce demand for strategic purposes into consideration.

6.102 Reducing information about excess demand increases the risk a bidder faces when contracting demand for strategic reasons. With limited information about the level of aggregate demand, bidders will not know for certain whether reducing the level of their own demand will effectively put less pressure on prices, or whether it will simply limit the amount of spectrum they may bid for in the following rounds.

6.103 In conclusion, we believe the residual risk of generating artificially low prices, with consequences for the efficiency of the auction, are higher in the SMRA than in the CCA.

c) Difficulty in bidding for preferred spectrum

6.104 The SMRA requires bidders to manage substitution and aggregation risks (as set out at 6.28 and 6.29). These risks may create difficulties in the way bidders go about devising their bidding tactics although some bidders may prefer to see how the auction evolves and adjust their bids accordingly.

6.105 The CCA fully avoids aggregation risk as all bids are for packages of lots which are accepted or rejected in their entirety. The CCA does not pose substitution risks to bidders, as in the Supplementary Bids Round bidders can express the whole range of their relative preferences for packages in different categories. However, the CCA works best when bidders are able to work out in advance their full valuations for all packages of interest.

6.106 There are three mechanisms by which we propose to mitigate aggregation and substitution risks in the SMRA:

a) allowing bidders to specify a minimum requirement of up to 20 MHz in each category;

b) ensuring in each category only one bidder at most can be Standing High Bidder on fewer lots then they bid for;

c) allowing bidders to withdraw their Standing High Bids under certain circumstances. The forfeiture of the value of the lot from their deposit imposed in this instance if there is no new Standing High Bidder may still inhibit bidders from switching (particularly at the late stages of the auction, when there is likely to be less excess demand in each category).

6.107 By assigning the same number of eligibility points to all lots in the auction, we are also facilitating switching across categories. This improvement relies on the assumption that bidders will wish to substitute lots on a MHz basis.

6.108 We believe the most important instrument to deal with both aggregation and substitution risks is the minimum requirement per band. The degree to which the minimum requirement is effective in dealing with both these risks depends on whether the assumption we made about the structure of demand is correct.

6.109 Aggregation and substitution risks should also be lower under the assumption we made about the supply structure in this award, namely that we will have two lot categories: one for the 2.3 GHz spectrum and another for the 3.4 GHz spectrum. With extra categories in either of the bands, substitution between categories within the same frequency band might add complexity. If our assumptions are correct, we believe there is a limited risk of an inefficient outcome from the residual aggregation and substitution risks or of putting particular bidders at an advantage.

6.110 In conclusion, we believe the residual difficulty in bidding for the most preferred spectrum is higher in the SMRA than in the CCA.

d) Difficulty agreeing bidding strategies within organisations

6.111 Bidders may face difficulties outlining their bidding strategy within their organisation with the CCA. In theory, the CCA generates reasonable incentives for straightforward bidding, but this requires bidders to work out in advance their full valuations and commit to them. However, valuing spectrum over a 20 year licence duration is difficult. This may pose problems to bidders to agree their position within their organisation as this would need to be agreed in advance, since changing strategy or increasing budgets during the auction is likely to lead to difficulties in the Supplementary Bids Stage. This issue is particularly important when there is significant uncertainty as to how much the spectrum is worth and when bidders are inexperienced in this type of auction.

6.112 In addition, rules in the CCA are relatively complex and may be difficult to explain. This may create further difficulties in how bidders deal with their internal organisation structures before, during and after the auction.

6.113 The SMRA, on the other hand, only requires bidders to place a bid at an increment above the price at which their competitors bid, and therefore there is no need to commit to a full valuation in the auction. In addition, once a bidder is outbid in an SMRA, they have the opportunity to bid back in the following round, which may provide more certainty to bidders.

6.114 As a consequence, rules in the SMRA are relatively simple and the outcome of the auction is easily understood and explainable within a bidding organisation.

6.115 Perceived problems for the bid teams explaining and agreeing a position internally across their organisation, caused by the CCA, may have an impact on efficiency in some circumstances. Namely, if the bidding strategy of one or more bidders is significantly altered and, as a consequence, they acquire less spectrum than they would otherwise. Better prepared, and more experienced, bidders may be at an advantage. That said, in theory, better preparation can lead to more straightforward, sometimes referred to as truthful, bidding, which is incentivised by the second price rule.

6.116 In conclusion, we believe the residual governance difficulties are higher for some bidders in the CCA than in the SMRA.

e) Knowing the price to pay

6.117 The single-round Supplementary Bids Round in the CCA, together with the second-price rule, exposes bidders to some degree of price unpredictability. This may be especially problematic for budget-constrained bidders. In fact, these bidders face in the Supplementary Bids Round a fundamental tension between different bidding strategies, as any of their bids may be successful. They may choose to bid their full budget for a larger package of lots and their true value for a smaller package of lots. However, this will make it more likely that they win the smaller package. Instead, they may choose to bid their full budget for a larger package and adjust the value they place on the smaller package accordingly. However, this reduces the chances of the bidder winning anything. Finally, they may choose to place bids based on their true valuations even if this involves some bids being placed above the bidder's budget (with the bidder knowing the spectrum is likely to cost less than the price bid due to the second price rule). This would expose the bidder to the risk that, in the event they win, the opportunity cost price will exceed their budget.

6.118 In the SMRA bidders know how much they are liable to pay at every stage of the auction. The only exception occurs when a bidder chooses to withdraw their Standing High Bids, as there will be uncertainty as to whether there will be demand to absorb those withdrawn bids in following rounds. If not, then the bidder will be liable to forfeit the value of the lot from their deposit.

6.119 Financial uncertainty may result in an inefficient outcome if some bidders change their bidding strategies and, as a result, win fewer lots than they would otherwise win based on their valuations. Or if budget constrained bidders form the wrong expectations during the auction and, as a result, fail to win the spectrum which they would have won based on their valuations. As explained, budget constrained bidders are particularly at risk, and competition in the market may be affected as a consequence of financial uncertainty during the auction.

6.120 We have attempted to mitigate this concern in the CCA by proposing a relaxed activity rule, together with a Final Price Cap, which should make prices in the final clock round more indicative of final auction prices. Budget constrained bidders are assisted by the clock rounds, which should provide relevant information that allows them to form reasonable expectations as to what packages they are likely to win. Budget constrained bidders are further assisted by the Final Price Cap, in particular if their budget is above the knock-out bid, as explained above. In any case, bidders will only know exactly how much they will be liable to pay when the auction ends, (although bidders never have to pay more than they bid).

6.121 A pay-as-bid rule in the CCA would completely solve the financial uncertainty resulting from the CCA[53]. We do not, however, believe that a CCA is likely to perform well with a pay-as-bid rule (at least without fundamental changes to the auction design). This would create a significant level of complexity to bidders, who will need to formulate expectations about how much they expect other bidders to bid for all packages of lots. If expectations are wrong, the outcome may be inefficient. We believe changing the pricing rule of the CCA to pay-as-bid would expose bidders and Ofcom to a number of risks which outweigh any possible benefits.

6.122 In conclusion, we believe the residual financial uncertainty is higher in the CCA than in the SMRA.

f) “Surprise” or perceptions of unfair outcomes

6.123 In addition to financial uncertainty, the sealed-bid nature of the Supplementary Bids Round in the CCA and the second-price rule expose bidders to a degree of uncertainty regarding the final outcome. The latter may surprise bidders, and, in addition to that, may be perceived as being unfair. For instance, the prices paid for similar quantities of spectrum by two or more bidders may differ if underlying opportunity costs differ. The perception of unfairness may be further compounded if some, but not all, bidders successfully engage in strategies aiming at pushing up the prices paid by their competitors.

6.124 The SMRA, because bidders may always have the opportunity to bid back if they are outbid, provides a higher sense of control to bidders. In addition, in the SMRA we are proposing, all bidders should pay essentially the same price per lot in each category, thereby reducing the possibility that the result will be perceived as unfair.

[53] Romania ran an auction with a pay-as-bid rule which has some similarities to the CCA.

6.125 The traditional versions of the SMRA discourage strategies purely aimed at raising prices paid by competitors by subjecting bidders to the risk of ending up winning the spectrum they are bidding on.

6.126 The possibility of generating a surprise or unfair outcome is only a concern to efficiency if it changes the way bidders bid and, as a consequence, they win less spectrum than they should win, based on their valuations. But the anticipation of a possibly unfair or surprise outcome may discourage participation in the auction, particularly by less experienced bidders, and this may have an impact on competition.

6.127 The uncertainty of the CCA is a consequence of essential features of this format, the second-price rule and the Supplementary Bids Round. We have included mitigations in the CCA which reduces uncertainty, in particular in the Supplementary Bids Round. Unfortunately, these mitigations also make it easier for bidders to place bids in the supplementary round aiming purely at raising prices paid by competitors.

6.128 In the SMRA, rules which facilitate switching or which aim at assisting bidders with their aggregation risks and which reduce the risk of winning the spectrum bidders are bidding on may incentivise bidders to place bids purely aimed at driving up prices. However, we believe the SMRA in our detailed implementation strikes a reasonable balance between these two opposing effects. In other words, we still consider the SMRA significantly discourages price-driving bids by subjecting bidders to the risk of winning the spectrum.

6.129 In conclusion, we believe the possibility of surprise or unfair outcomes is higher in the CCA than in the SMRA.

Provisional Conclusion

6.130 We do not believe any of the residual risks, outlined at paragraph 6.93 onwards, would present a serious threat to our award and either format would work well. The choice between the SMRA and the CCA should be based on an assessment of which risks are the most relevant for this particular award.

6.131 In essence, we understand this trade-off to be between possible inefficiencies from subjecting bidders to some degree of complexity and uncertainty in the CCA, and, on the other hand, possible inefficiency resulting from potential strategic demand reduction and creating some difficulties in how bidders manage substitution and aggregation risks with the SMRA.

6.132 Our preliminary assessment is that, for this particular award, we have the right policies to deal effectively with the residual risks of the SMRA in a way which renders the complexity and the uncertainty of the CCA unnecessary.

6.133 We believe this assessment takes due account of the findings presented by the NAO in their publication “4G radio spectrum auction: lessons learned” from March 2014 and also the feedback we received in our consultations.

6.134 This assessment is based on a number of assumptions about the structure of demand and supply in this auction. We do not believe it is inconsistent with our decision to choose a CCA for the 2013 auction.

6.135 We are assuming a structure of demand for this award which is considerably simpler that the one we faced in the 2013 auction. In particular, in the 2013 auction we

believed it was reasonable to assume there were potentially strong complementarities between spectrum in the 800 MHz band, suitable for coverage, and spectrum in the 2.6 GHz band, suitable for capacity. With strong complementarities both across and within bands, a combinatorial auction like the CCA offers the greater prospects of an efficient outcome. Our first assumption about supply greatly simplifies the spectrum packaging which, in turn, reduces the scope for substitution and aggregation risks. In the 2013 auction, spectrum packaging was complex, due to the existence of a concurrent low power category and four generic standard-power categories. Furthermore in the 2013 auction a dynamic form of spectrum reservation, called spectrum floors, was used. This form of reservation would be very complicated to implement in an SMRA, and much more suited to a CCA.

6.136 We will re-assess our provisional conclusion in light of evidence from stakeholders that shows that one or more of these assumptions do not hold, and any evidence on the balance of risks we face with this auction.

Assignment Stage

6.137 Upon completion of the principal stage of the auction, which determines the amount of spectrum that each bidder wins in each lot category, we will hold an assignment stage to determine the exact location of the spectrum won by each bidder. The details of the assignment stage, including the rules, are not dependent upon the format chosen for the principal stage of the auction.

6.138 We are recommending a single-round, sealed-bid auction where bidders are invited to bid for the exact location of their frequencies, amongst the permissible assignment plans (explained below).If there is only one permissible assignment plan, then bidders will be assigned the frequencies corresponding to the spectrum they won in the respective band in accordance with this assignment. If, as is more likely, there are multiple assignments that meet these requirements, then bidders who would be assigned alternative frequencies in different assignments will be invited to submit bids for these alternative options. We then identify the highest value combination of bids that can be accommodated separately for each category.

6.139 Bidders do not have to submit assignment bids to be assigned frequencies that correspond to the amount of spectrum they won in the principal stage. Therefore, participation in the bidding process of the assignment stage is optional.

6.140 For the 2.3 GHz band, we 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. Any unsold spectrum will form a contiguous block. We believe this rule is likely to lead to the most efficient use of the spectrum.

6.141 As discussed in section 5, for the 3.4 GHz band, in the event that UK Broadband participates in the auction and we are therefore able to move their current holding into a contiguous block, we propose a similar rule to the one we propose to apply to the 2.3 GHz band.

6.142 If UK Broadband does not participate in the auction, the 3.4 GHz band available for assignments to winners in the principal stage will be split in two sub-bands: a sub-band with 70 MHz (3410 MHz - 3480 MHz) and another sub-band with 80 MHz (3500 MHz – 3580 MHz).

6.143 We believe that in this circumstance we should prioritise assignment plans in which each winner is assigned a single contiguous frequency block. Any unsold spectrum would form a contiguous block within each sub-band. This will be feasible in a large number of possible combinations of spectrum amounts from the principal stage.

6.144 However, and as we noted in the previous section, in some circumstances, there may not be any assignment plan where every bidder is assigned a single contiguous block of spectrum. For instance, in the event that three bidders win 50 MHz each in the principal stage of the auction, it is not possible to assign a single contiguous block to each one of them. Although we believe such circumstances are unlikely to arise, we recognise they are possible[54].

6.145 In the event that there is not a single assignment plan that guarantees contiguity to all winning bidders and to any unsold spectrum (within each sub-band), we propose to prioritise assignment plans where bidders which won at least four lots in the principal stage are not assigned any block of less than 20 MHz[55].

6.146 A possible consequence of this is there may be more than one winning bidder assigned a split assignment. For instance, if there are two winning bidders in the principal stage, and each wins 75 MHz, the only way to ensure that no bidder is awarded a contiguous block of less than 20 MHz is to award a split assignment to both winning bidders[56].

6.147 We propose to prioritise assigning a minimum bandwidth of 20 MHz, as opposed to minimizing the number of split assignments. Being awarded less than 20 MHz in isolation may be a significant concern, at least to some bidders. In addition, we believe that, if we mandate synchronisation (as described in the technical licence conditions section of this document), bidders who are awarded an assignment split into blocks no less than 20 MHz each will not be significantly harmed.

6.148 We note that we propose to restrict assignment plans to those where all unsold spectrum is contiguous within each band (or sub-band in the 3.4 GHz band, in the event UK Broadband does not participate in the auction).But we are not proposing to restrict the assignment plans to those where the unsold spectrum is located in a particular part of the band (or sub-band). We invite stakeholders' views on whether this is the right approach, or whether we should impose a restriction on where the unsold spectrum should be located.

6.149 In the event that we cannot find one single assignment plan that meets the requirement set out above, then we would consider those assignment plans that minimise the number of split assignments[57].

6.150 In the event a bidding process for the assignment stage is needed, Ofcom will schedule a single round of bidding in which the relevant bidders may submit bids for their preferred frequency assignments.

[54] We believe this is very unlikely to occur. As shown in Annex 7 out of a total 240 possible permutations of allocation, only 33 would require a split assignment, assuming no assignment was of more than 80 MHz.

[55] In addition all unsold spectrum would form contiguous blocks within each sub-band. We understand this does not affect the number of assignment plans that meet the requirement.

[56] According to the note prepared by DotEcon at Annex 7, given the assumptions they have made, this could only occur if there are 5 or 6 winners and, even then, there are only 4 outcomes out of 143 permutations where this is possible.

[57] Also, as before, all unsold spectrum will form contiguous blocks within each sub-band.

6.151 In such circumstance, we propose that assignment stage prices, which are additional to base prices, are calculated using a second price rule. We believe a pay-as-bid rule would create complexity for bidders. In a pay-as-bid auction bidders may wish to bid below their valuations in order to extract some surplus, in the event that they are awarded a location that they bid for. To do this, bidders will need to form expectations as to how other bidders are likely to bid. If the expectations that bidders make are wrong, we may fail to assign the frequencies in accordance with bidder's valuations, which would result in an inefficient outcome

6.152 This may be especially problematic if UK Broadband does not participate in the auction, and the number of lots won by each bidder is such that we cannot guarantee a contiguous assignment to all. Under that circumstance, it is desirable that bidders express their true preferences for a contiguous assignment and that the locations of each bidder's holdings reflect their true valuations.

6.153 This pricing rule was also adopted in our 2013 auction.

6.154 A final price for each bidder is also calculated, which combines the base price, resulting from the principal stage of the auction, and any additional prices arising from the Assignment Stage.

Reserve Prices

6.155 In previous auctions there have been costs of remediation out of the relevant award bands, which we highlighted, for example, for the 800 MHz and 2.6 GHz award[58]. We note that MOD will incur significant costs remediating out of the 2.3 and 3.4 GHz bands. The reserve prices set out below are broadly in line with these remediation costs.

6.156 As we noted in the first consultation on our 2013 auction[59], the approach Ofcom had previously used was to set reserve prices at a level that was sufficient to deter frivolous bidding. That approach was not considered appropriate to some of the spectrum released in that auction for reasons, some of which are also relevant to our current award. Low reserve prices, for example, may provide incentives for bidders to tacitly collude. It may also incentivise individual bidders to bid for a lower number of lots than they would otherwise in the expectation that this will allow them to win less spectrum, but a lower price.

6.157 These risks mean that we do not believe setting reserve prices purely to deter frivolous bidding would be appropriate in this case.

6.158 However, high reserve prices will reduce the margin for price discovery during principal stage of the auction. Price discovery allows bidders to improve their individual expectations about the likely value of the spectrum, and adapt their bidding strategy accordingly. We understand there is uncertainty about the value of the bands to be awarded, particularly of the 3.4 GHz band. Therefore, it is desirable that we allow bidders to adapt their expectations during the auction.

6.159 A high reserve price may also discourage participation, particularly from smaller bidders. There are many possible uses for the spectrum, and we believe the auction should not preclude any of these.

[58] http://stakeholders.ofcom.org.uk/binaries/consultations/combined-award/summary/combined-award.pdf See paragraph 8.114

[59] Available at http://stakeholders.ofcom.org.uk/consultations/combined-award/

6.160 We recommend setting reserve prices at a level that provides room for relevant price discovery, while still addressing concerns about tacit collusion and strategic demand reduction. We believe this level should take into consideration benchmarks for commercial value.

Benchmarks for commercial value

6.161 For the 2013 auction we commissioned a study of the value of the spectrum. While we could undertake a similar study to estimate the value of the 2.3 and 3.4 GHz spectrum, this would be less useful than for the 2013 auction. There have been few recent awards/auctions of the 2.3 and 3.4 GHz bands which could be relevant to us, so opportunities for meaningful international benchmarking are limited. Any estimation would have to be based on assumptions about similar bands (e.g. 2.6 GHz), and other relevant considerations such as the current and likely future availability of equipment.

6.162 We believe the price of the 2.6 GHz spectrum which was sold in the 2013 auction provides a more meaningful benchmark for setting reserve prices for both the 2.3 GHz and the 3.4 GHz spectrum we are awarding. However, this evidence needs to be interpreted carefully.

6.163 2.6 GHz spectrum, like both the 2.3 and 3.4 GHz, is suitable for providing additional capacity, and the results of the 2013 auction reflect the most recent valuations of the UK operators for this type of spectrum. We have no evidence that market conditions have changed substantially since then. This is therefore likely to be the best benchmark for the actual willingness of UK operators to acquire extra capacity spectrum.

6.164 Although we believe the results of the 2013 auction provide a relevant reference point for both the 2.3 GHz and the 3.4 GHz spectrum, we also believe that the 2.3 GHz is likely to be worth more than the 3.4 GHz band. This assumption is based on the following evidence:

a) there is a wider availability of equipment in the 2.3 GHz band compared to the 3.4 GHz band;

b) according to the responses we received in the context of our consultations, 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

c) the 2.3 GHz has slightly more favourable propagation characteristics.

6.165 The 2013 auction made two types of 2.6 GHz spectrum available, paired and unpaired.

6.166 The 2.6 GHz unpaired spectrum provides a reference point when considering reserve prices for the 2.3 GHz unpaired spectrum. The propagation characteristics of both the 2.3 GHz and the 2.6 GHz bands are similar, they are both internationally harmonised and they are both for TDD use. However, at present there is wider equipment availability for the 2.3 GHz band than for the 2.6 GHz unpaired spectrum

at the time of the 2013 auction[60]. It is quite possible, therefore, that the 2.3 GHz band is more valuable than the 2.6 GHz unpaired band in the 2013 auction.

6.167 It may also be useful, therefore, to consider the reference point of the 2.6 GHz paired band. There are similarities in terms of propagation characteristics between both bands and both the 2.6 GHz paired spectrum at the time of the auction and the 2.3 GHz band have good equipment availability[61]. However, we recognise that FDD duplexing is significantly more widely used in the UK than TDD. This may translate into the 2.3 GHz band being only a proportion of the value of 2.6 GHz paired, and we take this into account in our interpretation of the evidence.

6.168 For the 3.4 GHz spectrum there is currently a lower degree of development of the equipment ecosystem[62], which may affect its value in the short term, even if in the slightly longer term it may be more comparable to the 2.6 GHz unpaired spectrum at the time of the 2013 auction.

6.169 A combinatorial auction was used in the 2013 award, so prices were calculated for entire packages and not for particular bands. One approach is to attempt to decompose the package prices by band (which can be done for some winners, but not in all cases). A second approach is to examine the highest losing bids (and lowest winning bids) in the auction for 2.6 GHz paired spectrum to attempt to identify a market-clearing price at which demand for spectrum would match the available supply in the band[63]. We consider these two methods firstly for the 2.6 GHz unpaired band in the 4G auction and then for the 2.6 GHz paired spectrum. After presenting this benchmark evidence, we consider our proposals for reserve prices for each of the 2.3 GHz and 3.4 GHz bands.

2.6 GHz unpaired

6.170 The analysis of benchmarks for 2.6 GHz unpaired spectrum is complicated by bids in the 2013 auction being varied both between bidders and for some bidders involving significantly different amounts per MHz for different 5 MHz lots. As a consequence there is a significant difference between the figures derived from the two methods outlined above.

6.171 For the first method, the clearest decomposable price for this spectrum is Vodafone's, and this is £2.45 million per 5 MHz[64].

6.172 The second method of the market-clearing price is complicated by there being no linear price (i.e. the same price per MHz for all lots in the band) which would clear the

[60] In April 2013, according to the Global mobile Suppliers Association (GSA), there were 123 LTE user devices in the 2.6 GHz TDD band (http://www.gsacom.com/downloads/pdf/GSA_Overview_of_the_LTE_devices_ecosystem_080413.php4). In July 2014, according to the GSA, there were 361 LTE user devices available in the 2.3 GHz TDD band (http://www.gsacom.com/downloads/pdf/GSA_lte_ecosystem_report_140714.php4)

[61] In April 2013, according to the GSA, there were 280 LTE user devices available in the 2.6 GHz FDD band and in July 2014 as noted above there were 361 LTE user devices in the 2.3 GHz TDD band.

[62] In July 2014, according to the GSA, there were 24 LTE user devices available in the 3.4 -3.8 GHz band. We recognise there will also be WiMax devices in the band.

[63] We referred to this method in the August 2014 consultation on ALF as the marginal bidder analysis.

[64] More information about the derivation of this figure is available at pages 19 and 20 of annex 6 of the consultation on the ALF. The other winner of 2.6 GHz TDD in the auction was Niche (BT), but we have only been able to derive a range for its price of this spectrum between £1.19m and £8.31m per 5 MHz.

market, given the bids made[65]. However, H3G made a bid for the entire category at £6.67m per 5 MHz. A linear market-clearing price would need to be as high as this level to price out the demand from H3G[66].

2.6 GHz paired

6.173 For the 2.6 GHz paired band, the two methods yield broadly consistent results.

6.174 The clearest decomposable auction price for the 2.6 GHz paired spectrum is for EE at £26m per 5 MHz. For the other winners, Niche (BT) and Vodafone, we are not able to determine these prices uniquely but they range between £21.2m and £30.3m per 5 MHz[67].

6.175 For the second method, as we set out in the context of our recent ALF consultation, we favoured an estimate of £27.5m per 5 MHz for the 2.6 GHz paired spectrum.

Proposed reserve prices for 2.3 GHz and 3.4 GHz

6.176 Given the uncertainties about the most relevant benchmarks and the range of evidence for the 2.6 GHz unpaired band, we are not consulting on a single figure, but a range of reserve prices for the 2.3 GHz spectrum. The bottom of the range is £2.5m per 5 MHz lot, which is 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 £5m per 5 MHz lot. This is still within the range of figures for 2.6 GHz unpaired. It also takes into account the potential for the 2.6 GHz paired spectrum as a relevant benchmark, although it is still only a relatively low proportion of this benchmark (generally less than 20% of the benchmark figures).

6.177 Given the risk that the 3.4 GHz band is lower value and the concern of inadvertently setting a reserve price too high for this spectrum, we are proposing a lower reserve price of £1m per 5 MHz.

6.178 In summary, we are proposing the following reserve prices:

i) A figure in the range from £2.5m and £5m per 5 MHz lot in the 2.3 GHz band; and

ii) A figure of £1m per 5 MHz lot in the 3.4 GHz band.

6.179 Under our proposals, and with eight 5 MHz lots in the 2.3 GHz band and thirty lots in the 3.4 GHz band, the sum of reserve prices ranges from £50m to £70m.

[65] As discussed in the August 2014 consultation on ALF, this is also the case for the other bands in the 2013 award, 800 MHz and 2.6 GHz FDD. However, the auction was able to clear the market because it took account of the non-linearities in bids, e.g. the auction prices were significantly non-linear.

[66] But a higher linear price would lead to excess supply in the band because H3G's demand would be choked off, but so also would be the demand of one of the winners, Vodafone, for 10 MHz at the margin.

[67] More information is available on table A6.6, included in annex 6 of the consultation we published in August 2014 on Annual Licence Fees (ALF) for 900 MHz and 1800 MHz spectrum, available at http://stakeholders.ofcom.org.uk/binaries/consultations/annual-licence-fees-900-MHz-1800-MHz/annexes/Annexes_1-7.pdf

Question 6.1: Do you agree with our recommendation for an SMRA? If not, please explain why.

Question 6.2: 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?

Question 6.3: Do you agree with our proposals for the CCA? Do you have any other comments or views on this proposal?

Question 6.4: Do you agree with our proposals for the assignment stage? Do you have any additional views or comments?

Question 6.5: Do you have any other comments on auction design?

Question 6.6: 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?

Section 7

Competition issues for the award

Introduction

7.1 This section of the consultation considers the potential effects on competition arising from the upcoming award of spectrum at 2.3 GHz and 3.4 GHz, and potential modifications to the mobile spectrum trading regulations.

7.2 To assess whether we need to take specific measures to address potential competition concerns in the auction, we consider:

- the responses we received on this issue from our October 2013 Call for Inputs;
- the potential competition concerns raised by the auction, explaining why we consider it important for competition that there remain four credible national wholesalers and why very asymmetric spectrum distributions may raise competition concerns in the long term;
- the likelihood of very asymmetric distributions actually arising from the award if we do not take competition measures in the auction;
- the potential risks of intervening; and
- some options for actions we could take in the award, and our assessment of these different options.

7.3 We propose to apply a cap on the amount of additional spectrum that a company may acquire such that its overall holding of relevant spectrum is set at an equivalent level to the overall cap as in the 2013 800 MHz and 2.6 GHz auction. Key factors in determining whether a band is relevant include the range of user devices, international harmonisation for mobile use, spectrum availability in the short to medium term and constraints on spectrum use for mobile access. Based on our assessment of what spectrum will be relevant for mobile access in the future, we propose to set this cap at 310 MHz.

7.4 Given that we consider what spectrum will be relevant to mobile access in the future, we also propose to amend the mobile trading regulations to reflect this. We propose to include 1.4 GHz, 2.3 GHz and 3.4 GHz spectrum in the mobile trading regulations, with the 3.4 GHz spectrum consisting of both the spectrum being released by the MOD and UK Broadband's current holdings at 3.4 GHz (as set out at the end of this section).

October 2013 Call for Inputs

7.5 In our October 2013 Call for Inputs we noted that the planned 2.3/3.4 GHz auction might raise potential competition concerns, although the extent of these was uncertain. We stated our intention to conduct a more detailed assessment as part of our consultation process. We asked stakeholders for their views on this and in particular whether some form of competition measure, such as a cap on spectrum holdings, would be justified.

Responses to the October 2013 Call for Inputs

7.6 Responses to the call for inputs revealed polarised views on whether or not a spectrum cap should be applied. Almost all of the responses were submitted confidentially. As a result, the main arguments for and against intervention in the award are grouped together below under general themes in order to maintain that confidentiality.

Other arguments in favour of competition measures

7.7 One stakeholder agreed with our suggestion that the spectrum would primarily be used to provide additional capacity rather than coverage and argued that capacity would be a dominating factor for competition. However, it disagreed with our assertion that it was unclear the extent to which an operator with existing large spectrum holdings would gain a competitive advantage over its rivals if it acquired a large proportion of this spectrum. Rather, it believed it was clear that there were fundamental concerns associated with asymmetric distribution of spectrum.

7.8 It raised concerns that, following the 2013 auction, there was now a greater risk that holders of large amounts of spectrum would be able to share the costs of ensuring that holders of smaller shares remain subject to capacity constraints. It also referred to our statements in the competition assessment for the 2013 auction that national wholesalers would need at least 10-15% of the total paired spectrum available after the auction in order to have enough capacity to be credible.

7.9 It further argued that if certain smaller operators are not guaranteed protection from larger spectrum holders acquiring further spectrum, in particular in the 2.3 GHz band, this could result in a threat to competitive national wholesale provision. Smaller operators may, it said, fall below the share of total spectrum that Ofcom believes is sufficient for the current intensity of competition to be maintained.

7.10 The respondent argued that a cap tighter than 36% of mobile spectrum (roughly equivalent to the cap in the 2013 auction) would be necessary and suggested a 25% cap on each band (separately on 2.3 GHz and 3.4 GHz spectrum) on entities with more than 25% of current holdings. It believed separate caps were necessary due to the differences in propagation characteristics of the spectrum and the different stage of development of device ecosystems for the two bands.

7.11 BT said measures were needed to ensure that spectrum did not simply end up in the hands of the four existing national wholesalers because it believed that they had an interest in ensuring smaller players cannot obtain sufficient spectrum to compete.

7.12 BT stated that spectrum caps, such as those imposed in the 2013 auction, were probably the simplest approach but emphasised that in its view any caps would need to address existing as well as new holdings. It suggested that we should devise spectrum caps to ensure that more than four players will win spectrum in this auction.

7.13 Another stakeholder referred to our statement in the competition assessment for the 2013 auction that the caps were the “minimum necessary” to guard against excessive spectrum concentration. In its view, spectrum capacity in the UK continues to be very unevenly distributed between MNOs, creating a risk to competition in mobile markets. It argued that, absent a safeguard cap, larger operators could acquire spectrum to inhibit expansion by rivals with smaller spectrum shares, who may then struggle to deliver the capacity and average data rates needed to act as a significant competitive constraint on the market.

7.14 It also referred to some international evidence from the USA and Austria that it thought highlighted the risks to competition when there were no caps in auctions or when the caps were set too high. It agreed with a 36% cap, particularly if applied to the 2.3 GHz spectrum, but said that the 3.4 GHz spectrum could potentially be excluded from this or be subject to a separate cap.

7.15 Another stakeholder suggested that, with demand for mobile data rising so rapidly, it is very hard to foresee the impact on future competition of uneven holdings of high bandwidth access spectrum.

7.16 It suggested an overall access cap for the 2.3 GHz award, set at the same absolute level as that set in the 2013 auction (2x105 MHz). It also argued there was no need for a spectrum cap to encompass backhaul spectrum (in which it included the 3.4 GHz spectrum), nor should the tradability of licences be subject to Ofcom consent.

7.17 One stakeholder said that a cap on the total amount of this spectrum would open up possibilities for smaller companies and niche operators, while also reducing the likelihood of large companies 'squatting' on spectrum.

Arguments against competition measures

7.18 Other stakeholders did not think that a cap applying to 2.3 or 3.4 GHz spectrum would be justified. One stakeholder argued that all of the mobile network operators would still have sufficient scale to compete, even if they did not acquire any additional spectrum in the award. It believed that there was no need for competition measures in the auction because of the amount of spectrum and the number of likely bidders, and Ofcom's ability to use ex post powers.

7.19 Another stakeholder argued that the suggested 36% level was arbitrary and said that the demand and supply conditions were potentially different to those considered for the 2013 auction.

7.20 Another stakeholder did not believe that it is appropriate or necessary to place a cap on the amount of spectrum available. It believed it was unlikely that asymmetric distribution would arise in these spectrum bands and, in any event, the ability to trade spectrum should ensure that competitive market forces prevail.

Potential competition concerns

7.21 In the sub-section below, we describe why some outcomes from the award could cause us to be concerned about competition in the long term (in the absence of any limitations of freedom by way of spectrum caps).

7.22 We first describe why we consider it important to have at least four national wholesalers. We then show the extent of mobile data growth, and why we consider that national wholesalers will need to continue to add capacity in order to remain competitive, and that spectrum is important for adding capacity.

7.23 We explain how very asymmetric spectrum distributions could lead to reduced competition. We then discuss the spectrum that is relevant to this competition assessment and consider potentially asymmetric distributions that could result from the award. Our provisional view, on which we are consulting, is that there are potential outcomes from the 2.3/3.4 GHz award that could result in very asymmetric spectrum distributions and which have the potential to reduce competition in the long term.

Importance of having at least four credible national wholesalers

7.24 In the 2013 auction, we decided that it was in consumers' interests for us to take measures to ensure there were at last four credible national wholesales and to prevent highly asymmetric distributions of spectrum. To achieve this, we set aside a reservation of spectrum for a fourth national wholesaler and we set caps on the amount of sub-1 GHz spectrum and on the total amount of relevant spectrum any operator could hold.[68]

7.25 Below we summarise why we considered in the 2013 auction that having at least four credible national wholesalers was in consumers' interests[69]. We believe these reasons remain relevant.

7.26 By national wholesaler we mean companies that control wholesale access to national Radio Access Networks (RANs).[70] By credible we mean that each national wholesaler exerts an effective constraint on its rivals in terms of factors such as the provision of high quality services, competitive prices, and choice and innovation. These factors contribute to the overall competitiveness of the market. There are currently four such national wholesalers, namely EE, H3G, Telefónica and Vodafone.

7.27 In the 2013 auction, we said that competition "can constrain firms from increasing prices or lowering quality, give them sharper incentives to invest and innovate, and make it more difficult to coordinate their prices and services so as to avoid competition."[71] We considered that "competition between the four existing national wholesalers operating in the UK currently delivers a wide range of benefits for consumers of mobile services"[72].

7.28 A reduction in competition could allow the remaining national wholesalers "profitably to set higher prices, to invest less in new services, and to be less innovative, than would be the case in a more competitive market. This would be likely to be to the advantage of those remaining national wholesalers. However, the result of such a change is likely to be worse outcomes for consumers, such as in higher prices, reduced choice and delayed access to improved or new services. This would not be consistent with our duty under section 3(5) of the Communications Act 2003 in furthering the interests of consumers to have regard, in particular, to their interests in respect of choice, price and quality of service." [73]

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[68] The spectrum that was reserved was partly determined by bidding in the auction, and was 2x5 MHz of spectrum at 800 MHz. The spectrum caps were set at 2x27.5 MHz for sub-1 GHz spectrum and 2x105 MHz for overall spectrum holdings.

[69] For a longer explanation of our reasons for wanting to have at least four national wholesalers after the 4G award, see paragraphs 4.12 to 4.24 of *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf

[70] In practice, by 'national' RANs, we mean RANs that provide coverage to a high portion of the UK population. We use the term national wholesaler rather than the more widely used "Mobile Network Operator" (MNO), since owners of sub-national RANs are also network operators, albeit on a much smaller scale. Additionally, national wholesalers could share or contract for access to national RANs and still be in a position of controlling wholesale access but not operating the network.

[71] Paragraph 4.19, *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012.

[72] Paragraph 4.20, *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012.

[73] Paragraph 4.21, *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012.

7.29 Importantly, in the 2013 auction, we did not consider that ensuring there were at least four national wholesalers would necessarily mean significantly higher fixed costs compared to having fewer national wholesalers. In particular, because there are significant fixed costs involved in RANs, it may be in consumers' interests to have fewer networks than national wholesalers, through network sharing arrangements.

7.30 Whilst this reduces end-to-end competition, it may be in consumers' interests - provided that national wholesalers are able to share assets without compromising their ability and incentive to compete independently. In the competition assessment for the 2013 auction, we focussed on promoting competition in wholesale markets without taking a strong view on whether it may be in consumers' interests to have sharing arrangements (which would depend on the detail of those agreements)[74].

7.31 In addition to the four national wholesalers, retail competition in mobile also involves Mobile Virtual Network Operators (MVNOs) and what we call sub-national RAN operators. Sub-national RAN operators are those who own RANs but who are not national wholesalers because they operate only in a limited part of the UK. For example, these operators may provide access to certain sites (typically indoors) and operate some low-power radio access equipment. As we discuss from paragraph 7.83 below, BT and UK Broadband hold mobile spectrum and could become important sub-national RAN operators for mobile competition in the future.

7.32 However, as in the 2013 auction, we do not consider the existence of MVNOs and sub-national RAN operators reduces the need for strong competition at the national wholesale level. This is because entities such as sub-national RAN operators and MVNOs need wholesale access to national RANs on terms that allow them to compete in order to provide a retail offering that appeals to mainstream consumers. Competition at the national wholesale level is likely to be a prerequisite for this access to be obtained commercially[75].

7.33 Without sufficient competition at the national wholesale level, regulation could be used to mimic this competitive pressure (for example, as in some fixed telecoms markets). This can produce outcomes that are better than no regulation at all, but not necessarily as good as competition in terms of furthering consumers' interests.

7.34 As in the 2013 auction, we continue to regard competition at the national wholesale level as being key to enabling strong competition at the retail level, and that having at least four credible national wholesalers is in consumers' interests.

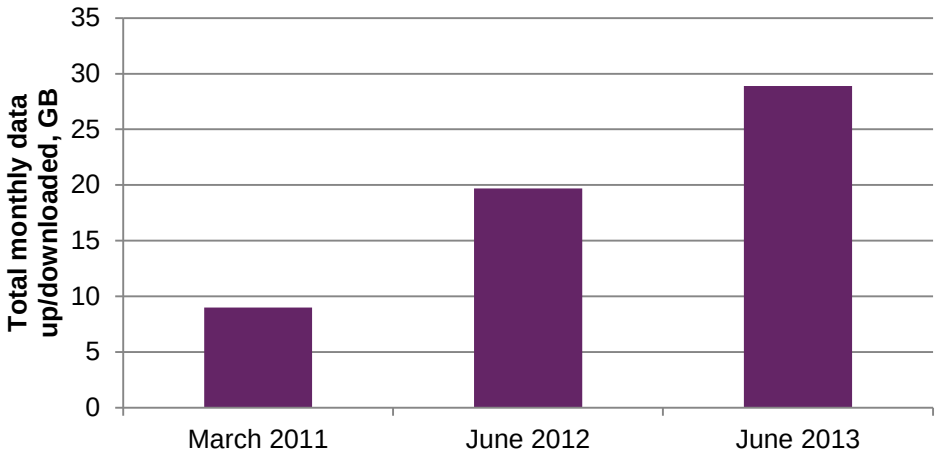
Growth in demand for mobile data

7.35 Demand for mobile data services is growing rapidly, as shown by Figure 4 below.

[74] For more explanation on why we consider it possible for national wholesalers to share assets see paragraphs 2.23 to 2.26 of Ofcom's *Second consultation on assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues*, 17 February 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/annexes/2nd_Condoc_Annex_6.pdf
See also paragraphs 5.38 to 5.46 of Annex 6 of our March 2011 consultation on the 4G award: http://stakeholders.ofcom.org.uk/binaries/consultations/combined-award/annexes/Annex_6.pdf

[75] For more explanation on why we see the national wholesaler layer as key for mobile competition, see from paragraph 2.19 in Annex 6 of Ofcom's *Second consultation on assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues*, 17 February 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/annexes/2nd_Condoc_Annex_6.pdf

Figure 4: Increase in data use on mobile networks[76]



7.36 This shows that data traffic carried by UK mobile networks more than doubled between March 2011 and June 2012 and went up by approximately 50% between June 2012 and June 2013[77].

7.37 Demand is expected to continue growing, with one estimate forecasting that demand for mobile data in 2030 could be 45 times higher than it was in early 2014, with the traffic carried on mobile networks (after allowing for traffic offloaded to Wi-Fi networks) increasing 25 times[78]. Whilst long term forecasts are inherently uncertain, it seems fairly clear that there will continue to be significant growth of mobile data.

General concern about very asymmetric spectrum shares

7.38 Given the growing demand for mobile data, we expect national wholesalers to need to add capacity in the long term in order to remain credible.

7.39 They can do this in a number of different ways:

- Using more spectrum – capacity will, in part, depend on the quantity and type of spectrum to which a national wholesaler has access;
- Improving network topology – increasing the number of cells, changing the mixture of cell sizes and their location;
- Improving technology – spectral efficiency can be improved with new technology.

7.40 An operator with a smaller spectrum share may therefore be able to achieve the same capacity as an operator with a larger spectrum share by, for example, building new sites.

[76] This figure was produced originally in Ofcom's, *Mobile Data Strategy*, November 2013. http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/summary/MDS_Condoc.pdf

[77] See also Ofcom's *Infrastructure Report: 2013 update*, October 2013, http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2013/

[78] See paragraph 1.2, Ofcom's Mobile Data Strategy, 28 May 2014, http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/statement/statement.pdf

7.41 At least in part, the value of spectrum in the auction might be expected to reflect the avoided costs of building additional sites. In this case, the capacity and total costs of an operator with a low share of spectrum could be the same as an operator with a high share of spectrum, if the one with a low share built more sites to compensate for having less spectrum.

7.42 However, the reason that an operator has a small spectrum share may be due to strategic investment by rivals in the auction. In this case, it may be unable to obtain additional spectrum and end up with such a small share that it is too expensive for it to expand its network in order to compete effectively. We explain this in more detail from paragraph 7.96 below.

7.43 Even without strategic behaviour in the auction, we still have some concerns about very asymmetric spectrum holdings. Operators with low spectrum shares will tend to have higher marginal costs of adding capacity than operators with high spectrum shares. This is because they will tend to need to build more sites to increase capacity[79].

7.44 There is considerable uncertainty about how the market may develop long term. For example, there is uncertainty about the extent of mobile data growth. If demand growth turns out to be much higher than expected it could mean that an operator with high marginal costs becomes less relevant as a competitive force in the industry. Such an operator could become capacity constrained and have reduced incentive to compete for new customers given the investment in sites that would be required to serve additional customers[80]. This potential reduction in competition could be detrimental to consumers.

7.45 While we have concerns about very asymmetric spectrum holdings, we do not consider that all operators need to have the same, or close to the same, shares of spectrum in order for there to be strong competition. This is because:

- Spectrum is not the only way of adding capacity, as we have described above. Operators with smaller shares of licensed spectrum than their competitors may be able to deliver comparable levels of capacity by relying on other approaches to adding capacity.

- In any case, it is not necessary for national wholesalers to have the same capacity as the operator with the largest spectrum share in order to be capable of being a competitive constraint on rivals. For example, national wholesalers can have different market shares, may have compensating strengths in other areas (e.g. customer services), or may still be able to deliver services to many

[79] This assumes that the operator is unable to increase its share of spectrum. Although spectrum licences acquired in an auction are tradable, spectrum trades are expected to occur infrequently. To date, the only spectrum trade that has occurred in the UK has been the divestment by EE of 2x15 MHz of 1800 MHz spectrum, as a merger condition. Also, if an operator became very constrained due to lack of spectrum, other operators may have strategic reasons for not selling spectrum to that operator. We note that in addition to the costs of building new mobile sites, there may also be other restrictions on the ability of mobile operators to expand capacity through building new sites, for example, due to difficulties of obtaining landlord or planning permission.

[80] We would expect these arguments to hold even when national wholesalers take part in network-sharing agreements, since joint network deployment will generally only extend to where both partners agree to build. If one partner has a low share of spectrum and needs to build additional cell sites, for instance, it may need to do this independently.

consumers by choosing commercial strategies that avoid providing services to the heaviest data users[81].

7.46 A certain degree of asymmetry in spectrum holdings may reflect differences in operators' commercial strategies and expectations about the future. Such asymmetries may give rise to consumer benefits (e.g. through increased scope for innovation).

7.47 Notwithstanding this, if operators' shares of spectrum become very asymmetric, we could potentially have a concern if the market were to develop in a way that the difference in spectrum shares did start to matter in a way that reduced competition.

7.48 We can distinguish between two ways in which this could happen. First, there could be a reduction in competition, even though there remain four credible national wholesalers. For example, this could be because one of them is not able to compete quite as strongly at least for some customer segments. Second, one of the existing national wholesalers may be so weakened that it ceases to be credible. This would be a material change in the market structure potentially resulting in a significant reduction in competition. For the reasons we discuss below, we consider that both outcomes are unlikely, with the second risk being very unlikely.

Spectrum relevant to the assessment

7.49 In considering the importance of spectrum holdings in respect to competition among national wholesalers we need to identify which bands are relevant.

7.50 A key factor in determining whether a band is relevant is whether there will be a reasonable range of user devices. If the spectrum is internationally harmonised for mobile use, this is more likely to be the case. Other factors are whether the spectrum is available in the short to medium term and whether there are any material constraints on the use of that spectrum for mobile access.

800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2.6 GHz spectrum are relevant

7.51 In our competition assessment for the 2013 auction we identified the spectrum held by national wholesalers in the 900, 1800 and 2100 MHz bands to be relevant for our analysis - in addition to the spectrum subsequently auctioned in that award (800 MHz and 2.6 GHz). The 2.6 GHz part of the 2013 auction included both paired and unpaired spectrum, both of which counted towards the spectrum we considered relevant to the overall spectrum cap imposed in the 2013 auction[82].

[81] The distribution of data consumption is skewed such that the heaviest data users account for a significant share of total data consumption. See paragraphs 4.45 to 4.50 of Ofcom's *Infrastructure Report 2013 Update*, 24 October 2013, http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/infrastructure-report/IRU_2013.pdf

[82] As for the overall spectrum cap for the 4G award, we have not included all of the 50 MHz of the unpaired 2.6 GHz spectrum as being relevant to this assessment. This is because the top 5 MHz of 2.6 GHz and the lowest 5 MHz of any individual company's holding in the unpaired 2.6 GHz band are restricted, to manage the risk of interference between users of unpaired spectrum as well as between users of unpaired spectrum and users of paired spectrum. Below we propose to adopt the same approach to the unpaired 2.6 GHz for the cap we propose for this award. For more explanation of the treatment of the unpaired 2.6 GHz in the overall spectrum cap in the 4G award, see paragraphs 6.67 and 6.68 and Section 10 of *Assessment of future mobile competition and award of 800 MHz and 2.6*

7.52 We see no reason to revise our assessment that these bands should be included in any competition assessment. All of the bands are harmonised in Europe and there are (or will be) a wide range of mobile devices capable of using the frequencies.

2.3 GHz spectrum is relevant

7.53 The additional spectrum now being made available in this award is also likely to be used for mobile broadband and we consider it relevant to this competition assessment.

7.54 In respect to the 2.3 GHz band, the European Electronic Communications Committee (ECC) has adopted a decision setting out harmonised technical and regulatory conditions for mobile broadband (TDD) use. Although Member States are not required to implement this decision, the European Commission has mandated further work which is expected to result in a formal Commission Decision harmonising the 2.3 GHz band. Unlike the ECC decision, Member States will be required to implement the Commission Decision.

7.55 Around 60 countries worldwide have either assigned the 2.3 GHz band to mobile operators to deliver wireless broadband services or have announced their intention to do so within the next two years. TD-LTE networks using part of the 2.3 GHz band have already rolled out in countries including Australia, China, India, Indonesia, Nigeria, Oman, Korea, Russia, Saudi Arabia, South Africa and Sri Lanka.

7.56 Equipment designed to operate in the 2.3 GHz band is already being developed. According to the Global Suppliers Association (GSA), 361 LTE user devices supporting use in the 2.3 GHz band were on the market in July 2014.

3.4 GHz spectrum is relevant

7.57 The 'ecosystem' for user devices in the 3.4 GHz band is some years behind the 2.3 GHz band in terms of development. For the purposes of this competition assessment, the 3.4 GHz band includes the 40 MHz of spectrum already held by UK Broadband. In the competition assessment for the 2013 auction, we did not consider UK Broadband's spectrum at 3.4 GHz to be relevant. This was firstly because the spectrum is high frequency (higher than 2.6 GHz) and secondly because there was not yet an international 'ecosystem' for user devices or network equipment to the extent of the mainstream mobile spectrum frequencies.

7.58 Since the competition assessment for the 2013 auction, momentum for using the 3.4 GHz band has continued to grow. For example, a Commission Decision mandating mobile use of the 3.4 band with a preferred TDD arrangement was published in May 2014 (although with an FDD arrangement as an available alternative if some territories chose to adopt it). Some end user equipment is available for this band – although in lower quantity than for the 2.3 GHz band - and more is being developed all the time. We now expect there to be a reasonable selection of user devices that use this band in the medium term.

7.59 The 3.4 GHz band is already used for wireless broadband in a number of countries. In Europe there have been authorisations in Estonia, Germany, Ireland, Italy, Latvia, Macedonia, Norway, Spain, Sweden, Switzerland, Portugal and the UK (by UK

GHz Statement, Ofcom, 24 July 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf

Broadband). By July 2014 six TDD networks had been launched commercially in the 3.4 GHz band in Bahrain, Belgium, Canada, the Philippines, Spain and the UK.

7.60 Whilst we anticipate there will be a reasonable selection of user devices for the 3.4 GHz band in the future, the band is still higher frequency than the other bands we consider relevant for mobile access. We discuss this further from paragraph 7.73 below, where we conclude that the 3.4 GHz band is likely to be relevant for adding capacity.

1.4 GHz spectrum is relevant

7.61 In addition to the 190 MHz of spectrum in the 2.3 and 3.4 GHz bands being made available for mobile broadband use via auction (plus the 40 MHz held by UK Broadband in the 3.4 GHz band), a further 40 MHz of spectrum in the 1.4 GHz band (L-band) may also become available.

7.62 This further spectrum (1452-1492 MHz) is currently held by Qualcomm, which has requested a change of licence conditions to allow the frequencies to be used for mobile broadband. It is likely to be used for supplementary downlink, which adds additional downlink capacity to existing paired FDD arrangements. The Qualcomm request is subject to a separate consultation by Ofcom, in which we propose to grant this licence variation[83].

7.63 The 1452-1492 MHz spectrum is in the process of being harmonised for mobile broadband use in Europe, and a Commission Decision is now pending. We expect Qualcomm to promote the use of this spectrum for supplementary downlink. It plans to make available suitable chipsets by 2015[84]. We expect equipment capable of using these frequencies to be available in the future. For this reason, we believe we should also include the 1.4 GHz spectrum as relevant for our competition assessment, assuming we grant Qualcomm's licence variation request.

No other bands are relevant

7.64 We have considered whether any other spectrum bands should be included in our assessment. In particular, whether the UK Broadband holdings in the 3.6 and 3.9 GHz bands may be relevant. The 3.9 GHz spectrum is not yet harmonised and we do not believe there will be a reasonable selection of user devices for that spectrum. While the 3.6 GHz spectrum is harmonised for mobile broadband use (like the 3.4 GHz spectrum, though only in Europe at present), there are geographical constraints on the use of the 3.6 GHz spectrum for mobile access. In particular, in the UK the band is shared with permanent Earth stations for satellite services: whilst not huge in number, co-channel sharing requires large co-ordination distances and leads to exclusions in a number of significant areas. We have therefore assessed that these spectrum bands should not be included in our competition assessment.

7.65 Finally, as with our assessment for the 2013 auction, we consider the unpaired 2.1 GHz spectrum is unlikely to be relevant to competition in the mobile market. To date, these frequencies have not been used for mobile broadband in the UK (or anywhere else, as far as we are aware). It is not clear that mainstream devices will become

[83] http://stakeholders.ofcom.org.uk/consultations/licence-variation-1.4ghz/?a=0
[84] Qualcomm response to Ofcom's consultation on Mobile Data Strategy, January 2014, http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/responses/Qualcomm.pdf

available for this band. We therefore do not consider that this band is relevant at present.

Summary of spectrum bands relevant for assessment

7.66 Our provisional view is therefore that spectrum in the following bands is relevant to our assessment: 800 MHz, 900 MHz, 1.4 GHz, 1.8 GHz, 2.1 GHz (paired only), 2.3 GHz, 2.6 GHz and 3.4 GHz[85]. We refer to this as relevant mobile spectrum in the rest of this section.

Asymmetric spectrum scenarios possible after the auction

7.67 Current holdings of mobile spectrum are as shown in Figures 5 and 6 below.

Figure 5: Current shares of relevant mobile spectrum[86]

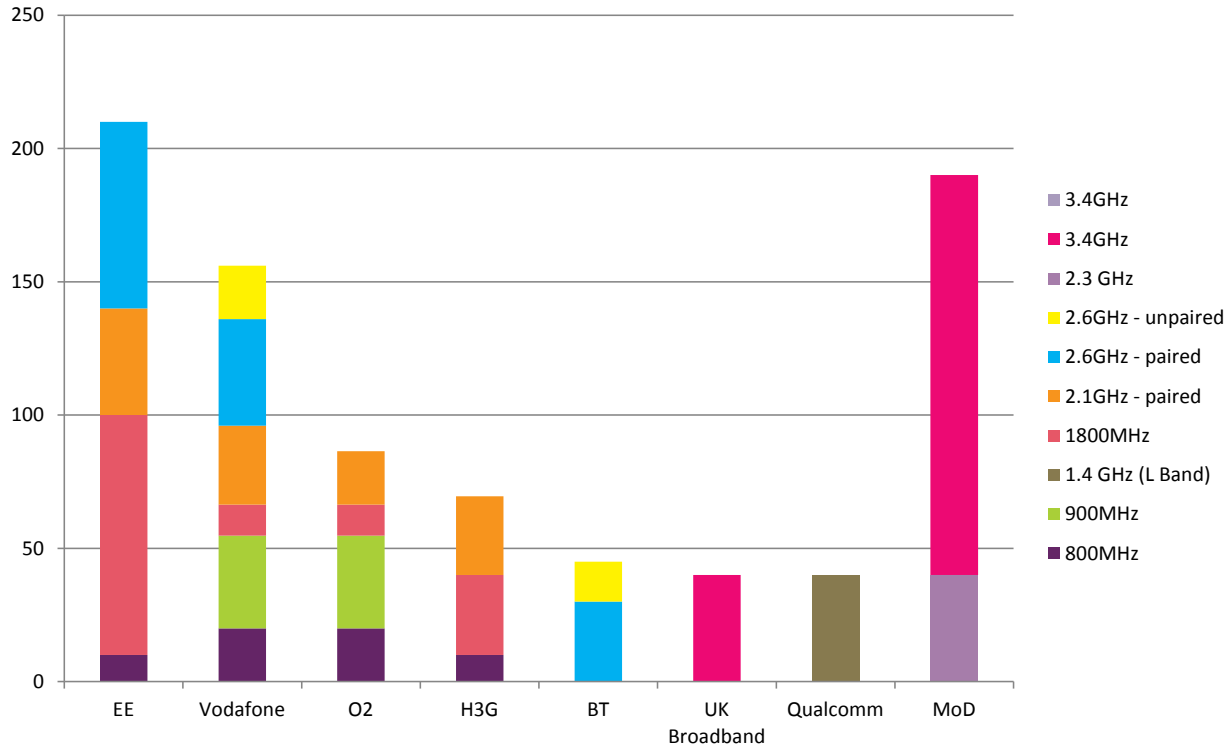
	EE	Vodafone	O2	H3G	BT	UKB	Qualcomm	MoD
Shares of spectrum included in 4G overall cap	37%	28%	15%	12%	8%	–	–	–
Shares of spectrum up to and including 3.4 GHz	25%	19%	10%	8%	5%	5%	5%	23%

[85] More specifically, the spectrum we consider relevant to our assessment is 791-821 MHz, 832-862 MHz, 880.1-914.9 MHz, 925.1-959.9 MHz, 1452-1492 MHz, 1710.1-1781.7 MHz, 1805.1-1876.7 MHz, 1920-1979.7 MHz and 2110.3-2169.7 MHz, 2350-2390 MHz, 2500-2690 MHz and 3410-3600 MHz.

[86] The spectrum included in the percentages in the first row of this table sum to 566.9 MHz. This is made up as follows. EE has 210 MHz of relevant spectrum, consisting of 10 MHz at 800 MHz, 90 MHz at 1800 MHz, 40 MHz at 2.1 GHz and 70 at 2.6 GHz. Vodafone has 156 MHz of spectrum in total, consisting of 20 MHz at 800 MHz, 34.8 MHz at 900 MHz, 11.6 MHz at 1800 MHz, 29.6 MHz at 2.1 GHz, 40 paired at 2.6 GHz and 20 MHz unpaired at 2.6 GHz. Telefónica has 86.4 MHz of spectrum in total, consisting of 20 MHz at 800 MHz, 34.8 MHz at 900 MHz, 11.6 MHz at 1800 MHz and 20 MHz at 2.1 GHz. H3G has 69.5 MHz of spectrum in total, consisting of 10 MHz at 800 MHz, 30 MHz at 1800 MHz and 29.5 MHz at 2.1 GHz. BT has 45 MHz of spectrum in total, consisting of 30 MHz paired at 2.6 GHz and 15 MHz unpaired at 2.6 GHz. See footnote 82 above for an explanation of why we do not include all of the unpaired 2.6 GHz in Vodafone's and BT's holdings. The spectrum included in the percentages in the second row of the table includes the spectrum included in the first row plus the relevant spectrum held by UK Broadband, Qualcomm and MOD. This sums to 836.9 MHz in total. This is made up as follows. UK Broadband has 40 MHz at 3.4 GHz, Qualcomm has 40 MHz at 1.4 GHz and the MoD holds 190 MHz in total, consisting of 40 MHz at 2.3 GHz and 150 MHz at 3.4 GHz.

7.68 Figure 6 below shows how these shares are made up of blocks of spectrum at different frequencies.

Figure 6: Current holdings of relevant mobile spectrum



7.69 Given these current holdings, the table below illustrates some potential extremes of spectrum holdings following the trade of spectrum at 1.4 GHz by Qualcomm and the award of the 2.3 GHz and 3.4 GHz spectrum currently held by the MOD. It shows the outcomes where one of the four national wholesalers obtains all of the relevant mobile spectrum.

Figure 7: Spectrum shares if operators win all/no additional spectrum[87]

	EE	Vodafone	O2	H3G	BT	UKB
EE wins all newly available spectrum	**53%**	19%	10%	8%	5%	5%
Vodafone wins all newly available spectrum	25%	**46%**	10%	8%	5%	5%
O2 wins all newly available spectrum	25%	19%	**38%**	8%	5%	5%
H3G wins all newly available spectrum	25%	19%	10%	**36%**	5%	5%

7.70 The most asymmetric distributions of spectrum possible in the future are if EE or Vodafone obtained all of the newly available spectrum. As shown in Figure 7, if EE obtained all the 230 MHz of newly available spectrum, it would have 53% of relevant spectrum, leaving all other operators with 47% between them. If EE and Vodafone together acquired all 230 MHz of spectrum, they would hold around 71% of spectrum between them. Other operators would hold less than 30% between them.

Distinctions between different spectrum bands

Some bands may be better for adding capacity than other bands

7.71 In the spectrum shares calculated above, we have treated all bands as being equal. However, we recognise that different bands have different characteristics and some will be more valuable to network operators than others.

7.72 For this competition assessment, neither treating all spectrum bands equally nor considering the likely value of the different bands to operators will necessarily capture precisely the issues of relevance. We ideally want to have an understanding of the relative importance of different bands in terms of their significance for adding capacity in the long term, particularly in high demand areas, as our competition concern relates to the marginal cost of adding to capacity. But the value of the bands to operators currently could be influenced by other factors, such as the ability to provide wide area coverage and the availability of end user devices in the short term. We consider the relative importance of the different bands for adding capacity in the long term is unclear.

Particular uncertainty over the importance of 3.4 GHz spectrum for adding capacity

7.73 Some responses to the October 2013 Call for Inputs suggested that because of its frequency the 3.4 GHz spectrum would be used for backhaul rather than mobile access, at least initially. If used for backhaul, it would not be relevant to our competition concern which relates to mobile access capacity rather than backhaul.

7.74 Most responses to the consultation suggested that the 3.4 GHz spectrum would ultimately be used for mobile access. We consider this likely, but even if this is the

[87] The table includes the spectrum that formed the 4G overall cap, plus the spectrum at 1.4 GHz, 2.3 GHz and 3.4 GHz that we are considering (including UK Broadband's 40 MHz at 3.4 GHz).

case, there is particular uncertainty about the importance of the 3.4 GHz band, which is higher frequency than other relevant bands.

7.75 On one hand, if the 3.4 GHz spectrum is used for macrocells, we consider it likely that, other things equal, it will not tend to be as good for adding capacity as lower frequencies (on a per MHz basis). While in theory a MHz of a high frequency band and a low frequency band can carry the same amount of information, in practice higher frequencies like 3.4 GHz do not propagate so well, so may be less effective at adding capacity where it is needed.

7.76 On the other hand, if the 3.4 GHz spectrum were used for small cells located in buildings or on street furniture, then it may be very effective in adding capacity as spectrum can be re-used in a much denser way than with macro cells. It is therefore possible that the 3.4 GHz spectrum might be very relevant to adding capacity and to our competition concerns.

7.77 However, it is also possible that if the 3.4 GHz spectrum were used for small cells rather than macro cells, it could be less relevant to our competition concerns because:

- It may be sufficient for many small cells to use other bands and technologies such as Wi-Fi with licence exempt spectrum[88]. This might mean that having a limited share of licensed spectrum may not be so important. We note that currently a large proportion of data used by mobile devices is via Wi-Fi. Estimates vary, but some estimates put the proportion of data that goes over Wi-Fi at 80% in the UK[89]. However, we recognise that Wi-Fi spectrum can be congested and does not give the mobile operator the same control (and revenue potential) as using licensed spectrum.

- To the extent small cells are deployed at consumers' premises, there may be limited value from having a large amount of spectrum using those small cells. Having more spectrum would allow higher speeds and more capacity in the area covered by the small cell, but provided an operator has sufficient spectrum for the small cells to be adequate for the consumer, there may be limited benefits from additional spectrum.

7.78 We therefore consider that the 3.4 GHz band is likely to be relevant for adding mobile data capacity in the future, but that there is uncertainty about its relative importance compared to other spectrum.

We calculate only unweighted spectrum shares

7.79 Because of the uncertainty about the relative importance of different bands in the long term, we have only calculated unweighted spectrum shares for the different companies.

[88] Ofcom exempts some equipment from the need to hold a wireless telegraphy licence when using some spectrum. As this spectrum is available to anyone using compliant equipment, licence exemption does not provide users with any form of protection from other users.
[89] For example, page 146, *Study on Impact of traffic off-loading and related technological trends on the demand for wireless broadband spectrum*, prepared for the European Commission DG Communications Networks, Content & Technology, 2013, http://bookshop.europa.eu/en/study-on-impact-of-traffic-off-loading-and-related-technological-trends-on-the-demand-for-wireless-broadband-spectrum-pbKK0113239/

No competition concerns for 2.3 GHz spectrum independent of the 3.4 GHz spectrum

7.80 We have also considered whether the award of the 2.3 GHz spectrum raises specific issues, such that that spectrum should be considered separately from the 3.4 GHz spectrum. This is in line with some responses to the October 2013 Call for Inputs, which proposed measures specifically related to the 2.3 GHz spectrum.

7.81 We recognise that in the short term there is likely to be a better selection of user devices that use 2.3 GHz spectrum than 3.4 GHz spectrum. However, our provisional view is that this does not raise any significant competition concerns. This is because, regardless of the auction outcome, we consider that all four national wholesalers have sufficient spectrum to be credible competitors in the short term. In the long term, we consider it likely that there will also be a reasonable selection of user devices that can use the 3.4 GHz spectrum.

7.82 Also, for the reasons set out above, we consider it likely that the 3.4 GHz band will have some importance for adding capacity in the long term, even if this turns out to be less than for other bands. Given this, and the much larger amount of 3.4 GHz spectrum compared to the 2.3 GHz spectrum, we do not consider that there are significant competition concerns that relate only to the 2.3 GHz spectrum. We therefore propose only to consider the 2.3 GHz and 3.4 GHz spectrum together.

Potential relevance of BT and UK Broadband

7.83 In addition to the four national wholesalers, BT and UK Broadband may also have more impact on mobile competition in the future. The spectrum that BT and UK Broadband hold is relatively high frequency which would make it difficult for them to provide national coverage. We do not therefore consider they could become national wholesalers considering their current spectrum holdings and any further holdings they may acquire in this auction. However, they can contract with one of the four national wholesalers for a national coverage service, which they can then combine with services provided with their own spectrum. We regard it as potentially very positive for competition that BT and UK Broadband also have spectrum that could become important for mobile competition[90].

7.84 We understand BT's and UK Broadband's plans to be as follows:

- **BT** plans to offer an 'inside out' mobile service that would involve small cells using its own 2.6 GHz spectrum in combination with wholesale services it buys from EE under an MVNO type agreement (for when BT's consumers are outside areas covered by its own mobile network). These services may be particularly attractive to consumers who are heavy data users[91].

- **UK Broadband** currently offers consumers in central London a broadband service which it provides wirelessly using its 3.4 GHz spectrum, along with other

[90] Part of the rationale for the competition measures we took in the 800 MHz and 2.6 GHz auction was to ensure that there were at least four national wholesalers who would be able to wholesale a national layer of service to sub-national RAN networks such as BT and UK Broadband.

[91] For example, see slides 34 and 35 of: http://www.btplc.com/Sharesandperformance/Quarterlyresults/PDFdownloads/q414-slides.pdf BT launched mobile services for businesses in July 2014, but we understand that this does not yet make use of its 2.6 GHz spectrum. See http://www.btplc.com/News/Articles/ShowArticle.cfm?ArticleID=C23FAC1B-7C86-4565-B55D-84E82AF2F448

spectrum. In the future, it intends to expand its network and offer a national mobile service making use of its own network combined with national mobile coverage through an MVNO type arrangement with one of the four national wholesalers[92].

7.85 Each of BT and UK Broadband may be able to offer services using their own mobile spectrum combined with a national coverage service from a national wholesaler. This could mean they may be able to offer services that are superior to some national wholesalers in particular locations. It is also possible that BT and UK Broadband will sell the capacity they have in particular locations to one or more of the four national wholesalers. This could be one way a national wholesaler that had a small share of spectrum could obtain additional capacity.

7.86 This means that even if one or more of the existing four national wholesalers becomes capacity constrained in some high demand areas, retail competition could still be strong.

Provisional conclusion on competition concerns

7.87 For the reasons explained above, we consider it is possible that (in the absence of any restrictions in the award process) very asymmetric spectrum holdings might arise and that these in turn might to lead to reduced competition, especially if there is strong data demand growth.

7.88 Some possible award outcomes result in spectrum distributions that are so asymmetric they cause us concerns. Given their existing holdings, the outcomes that cause us most concern are if EE and/or Vodafone acquired all of the newly available spectrum. In this situation, their shares of spectrum would be substantially higher than those of the other operators.

7.89 If Telefónica and H3G did not obtain any additional spectrum in the award, their shares would be around 10% or less of relevant spectrum. In the competition assessment for the 2013 auction, we considered that there was a material risk that a national wholesaler would not have enough capacity to be credible if its share of spectrum was below 10-15%. Therefore, two out of the four current national wholesalers could be at the bottom of this range or slightly below it. In responses to the October 2013 Call for Inputs, some stakeholders emphasised this and considered we should take measures to prevent such outcomes.

7.90 However, we did not consider in the competition assessment for the 2013 auction that having a share of spectrum at or below the 10-15% range automatically meant that an operator was not a credible national wholesaler[93]. We recognised that it was a simple measure that does not take into account the differences in spectrum of different frequencies and other factors. For example, they both now hold some sub 1 GHz spectrum, which is particularly good for providing services over wide areas and

[92] See paragraph 3.6, *Variation of UK Broadband's 3.4 GHz Licence - Statement*, Ofcom, 9 October 2014, http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

[93] See, in particular, from paragraph 4.69 of *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf

indoors[94]. We consider they are both likely to have suitable spectrum to remain credible national wholesalers, especially in the short and medium term.

7.91 In the long term, we consider it possible that the market might develop such that the smaller spectrum shares of Telefónica and H3G result in them becoming weaker competitors, especially for customers with high data demands. In the worst case, they may cease to be able to offer a reasonable national coverage layer, but we consider that very unlikely given their existing spectrum holdings.

7.92 Unlike at the time of the competition assessment for the 2013 auction, there are now other companies that hold relevant mobile spectrum. Specifically, UK Broadband holds 3.4 GHz spectrum and BT holds 2.6 GHz spectrum. Provided there is sufficient competition from national wholesalers to provide BT and UK Broadband with a sufficiently good national coverage layer, then BT and UK Broadband should be able to retail mobile services which can make use of their own mobile spectrum. In this way, BT and UK Broadband may be able to exercise some competitive constraint at the retail level that is in addition to competition between the national wholesalers. Or BT and UK Broadband could offer additional capacity to the national wholesalers with smaller spectrum shares, either through a spectrum trade or wholesaling services in areas where they have capacity. The spectrum holdings of BT and UK Broadband therefore tend to reduce our concern about the risk from the low spectrum shares of Telefónica and H3G, and this is an important difference to the situation before the 2013 auction.

Summary

7.93 In summary, if EE and/or Vodafone (the two companies with the largest spectrum shares currently) were to obtain all of the newly available spectrum we have some concerns that this may reduce competition in the long term. If this were to happen then, because the mobile market is very large, even a small reduction in competition could potentially result in substantial consumer harm.

7.94 However, whether this happens or not is uncertain, as it depends on technical and market conditions that are difficult to predict. For example, it may depend on the extent of demand growth, how the 2.3 GHz and 3.4 GHz spectrum is used, and on whether using licence exempt spectrum (such as Wi-Fi at 2.4 GHz and 5 GHz) may be a substitute to some extent.

Likelihood of very asymmetric spectrum distributions

7.95 For the reasons set out below, we consider it unlikely that EE and Vodafone would have very high shares of relevant mobile spectrum (such as greater than 40%) after the auction even without measures in the auction. Rather, we expect there will be several winners of spectrum in the auction, given the large amount of spectrum available.

Strategic investment in spectrum in the award to weaken rivals

7.96 The allocation of spectrum in the auction will be determined by the relative bids that participants make. This in turn is likely to be determined by their expected difference in profits from supplying wholesale and retail services with and without the spectrum.

[94] Also, if we attached less weight to the large amount of 3.4 GHz spectrum, because it is the highest frequency spectrum, then the shares of Telefónica and H3G would also tend to rise.

7.97 We distinguish between two sources of value (i.e. profits) in bidding for spectrum[95]:

- **Intrinsic value** – The present value of additional profits a bidder expects to earn when holding the spectrum compared to not holding it - in the absence of any strategic considerations to obtain spectrum to reduce competition in mobile services from the existing level.

- **Strategic investment value** – The present value of additional expected profits earned from bids aimed at affecting the future structure of competition in mobile services by depriving one or more competitors of spectrum.

7.98 The intrinsic value placed by a bidder on a given frequency and amount of spectrum is affected by a number of factors, including the bidder's existing holdings of spectrum, the bidder's existing position in the market, the bidder's technical and organisational capabilities, and the bidder's expectations about the profits it can generate from the spectrum.

7.99 The strategic investment value may arise if the spectrum in the auction is a strategic asset that can influence the state of competition in mobile markets. In this case, it may be profitable for an operator to obtain spectrum because it weakens competitors and so allows the operator to offer higher prices and/or lower quality, with less risk that customers would respond by switching (as customers would have fewer alternatives than before).

7.100 So even if an operator has a higher intrinsic value for some spectrum than other bidder(s), it may fail to acquire the spectrum in the auction if it is the victim of strategic investment by another operator(s). In this situation, we would expect consumers to be made worse off by the spectrum going to the highest bidder in the auction, because competition would be weaker[96].

7.101 In considering strategic investment in this way, we are not supposing that bidders, individually or collectively, will act in a prohibited manner in the auction. Our concern is to consider whether strategic investment by one or more bidders, in pursuit of rational commercial goals, might result in an outcome that made the market less competitive.

7.102 However, we consider that strategic investment in spectrum is unlikely in this award, for the following reasons:

- If all other factors were equal, we would expect operators with a low share of spectrum currently to have a higher intrinsic value for spectrum than rivals with a high share of spectrum currently. This is because those with a low spectrum share are likely to obtain the greatest network cost savings from obtaining more spectrum (because they will need to add to capacity more in order to meet forecast demand). This tends to increase the cost of strategic investment.

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[95] In the US, the terms 'use value' and 'foreclosure value' have been used, which we understand to be similar in meaning to what we mean by intrinsic value and strategic investment value. See for example, page 10 and 11 of the US Department of Justice's submission to the Federal Communications Commission, *In the matter of policies regarding mobile spectrum holdings*, April 2013, http://www.justice.gov/atr/public/comments/295780.pdf

[96] For a fuller explanation of the theoretical possibility of such outcomes, see paragraphs 4.158 to 4.166 in *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf

- There is a large amount (190 MHz) of spectrum in the award[97]. A bidder trying to prevent others obtaining any spectrum would need to acquire all of this spectrum, which would tend to push up the price.

- It is unclear that such strategic investment would reduce competition, as this may depend on technical and market conditions that are difficult to predict.

- There is no obvious focal point for the division of spectrum in the auction between the operators with large spectrum shares currently.

Differences in intrinsic values

7.103 Even without strategic investment by some operators, outcomes with highly asymmetric spectrum distributions could still arise, because of differences in intrinsic values. Each bidder's valuation partly comprises a value common to all bidders, but the expectations about this common value may differ. For example, different operators may take very different views about overall future mobile data demand growth. Other things being equal, the higher a bidder's expectations about future data growth, the higher will be its intrinsic value for spectrum.

7.104 However, in the absence of any spectrum caps, we would consider it unlikely that this award will result in very asymmetric distribution of spectrum because of differences in intrinsic values. This is partly because operators with low spectrum shares currently will tend to have higher intrinsic values, and partly because of our proposed auction design. Our proposed auction design helps to reduce common value uncertainty by allowing for a process of price discovery, where bidders may adapt their expectations by observing some information about other bidders' behaviour.

Preliminary conclusions on likelihood of very asymmetric spectrum distributions

7.105 Our provisional view is that if we were to hold the auction without any competition measures it would be unlikely a very asymmetric distribution of spectrum would arise. However, whilst we consider it unlikely, we consider it is possible that such an outcome could still arise if there were no competition measures in the auction.

Risks of intervention – preventing outcomes that would be in consumers' best interests

7.106 While we want to prevent outcomes that are detrimental to consumers' interests because they reduce competition, we recognise there are risks to intervening in the auction. In particular, there is the risk that the intervention has negative effects and works against consumers' interests by preventing outcomes that would be beneficial.

7.107 For example, interventions capping the spectrum that could be obtained by the two companies with the largest shares currently (i.e. EE or Vodafone) may increase their costs and reduce the quality of their services, which could be against consumers' interests. A specific concern relates to reducing their ability to obtain large blocks of contiguous spectrum, which may be required to provide very fast download speeds. Such services may be valued by some mobile consumers and may also allow mobile

[97] We recognise that of this 190 MHz of spectrum only 40 MHz is at 2.3 GHz. However, for the reasons set out from paragraph 1.80 above, we consider that there are not significant competition concerns that relate to the 2.3 GHz independent of the distribution of the 3.4 GHz spectrum.

operators to exert more of a competitive constraint on fixed-line services. There is a risk that competition measures would reduce the ability of EE and Vodafone to offer such services.

7.108 It is also possible that asymmetric spectrum holdings will help to encourage innovation by those with small spectrum shares. If some operators are unable or unwilling to outbid EE and Vodafone for mobile spectrum, they may develop other innovative ways of increasing their capacity (for example, through greater use of licence exempt spectrum) or find other ways of offering services that are attractive to consumers.

7.109 There is also a risk of any competition measures distorting bidding behaviour in spectrum auctions in a way that leads to undesirable outcomes. For instance, there is a risk that operators may choose to bid less than their intrinsic value for spectrum, because they expect that if they fail to obtain spectrum in one auction, Ofcom would take measures in the future that would assist them e.g. by enabling them to obtain spectrum more cheaply in the future. If operators do not bid their intrinsic values for the spectrum, this could lead to inefficient spectrum allocations that were not in consumers' interests.

7.110 Some competition measures could also add complexity to the auction design, which we want to avoid if possible in case this complexity leads to inefficiencies in the auction.

7.111 The likelihood and scale of any detrimental unintended consequences are related to the degree of intervention. The greater the intervention, the greater the likelihood and scale of detrimental effects on consumers from unintended consequences.

Potential competition measures

7.112 Recognising both the competition concerns and the risks of any intervention, we consider four main options:

- Option 1 – no competition measures in the award;
- Option 2 – spectrum cap at a level equivalent to the 2013 auction cap;
- Option 3 – spectrum cap set at a tighter level than in the 2013 auction; and
- Option 4 – spectrum reservation.

7.113 While these appear the most likely options to us, we remain open to other options that stakeholders may identify.

Option 1 - No competition measures in the award

7.114 This option would not impose any restrictions in the auction relating to the distribution of relevant mobile spectrum for competition reasons. This is the least interventionist option.

7.115 This option would not prevent one or two operators from acquiring a very large share of spectrum. As an extreme, if the operator with the largest share currently (i.e. EE) obtained all 230 MHz of spectrum, it would have 53% of relevant mobile spectrum,

and if Vodafone obtained all of the newly available spectrum it would have 46%[98]. However, we regard such outcomes as being highly unlikely.

7.116 This option would be most attractive if we consider the risk of a competition problem arising from a very asymmetric distribution of spectrum to be low, relative to concerns about the risks of intervention.

Option 2 – Spectrum cap at a level equivalent to the 2013 auction cap

7.117 This option involves imposing a cap on the overall level of spectrum that any individual operator could hold, with the cap being set at a level equivalent to the overall spectrum cap set in the 2013 auction. This is around 37%[99]. In the competition assessment for the 2013 auction, we considered this struck an appropriate balance in terms of the risk to competition of very asymmetric spectrum distribution and the risk of preventing outcomes that were in consumers' interests.

7.118 This cap would relate to all of the spectrum we consider to be relevant to mobile competition. If our final view on what spectrum is relevant is in line with our proposals (as set out in paragraph 7.66 above), a cap at around 37% would mean that any individual operator could not hold more than 310 MHz of relevant mobile spectrum[100].

7.119 In the event that there was a change in relevant mobile spectrum holdings before the auction, then what an operator would be able to obtain would also change to reflect that. For example, if an operator obtained the 40 MHz of 1.4 GHz spectrum from Qualcomm before the auction, then what it could obtain in the auction would reduce by 40 MHz compared to what it would otherwise be (since we have included the 1.4 GHz in the set of spectrum we consider relevant for our assessment).

7.120 Assuming that the auction would be for packages with a minimum size of 5 MHz, a cap set at 310 MHz (or around 37% or relevant mobile spectrum) would imply restrictions on three operators:

- **EE** would be prevented from obtaining more than 100 MHz of additional mobile spectrum (from any combination of 1.4 GHz, 2.3 GHz and 3.4 GHz spectrum); [101]
- **Vodafone** would be prevented from obtaining more than 150 MHz of additional mobile spectrum;[102] and

[98] The 230 MHz of spectrum includes the 40 MHz of 1.4 GHz spectrum that Qualcomm currently holds. In assuming there is this much spectrum available for national wholesalers, we are assuming that Qualcomm's licence variation request is granted and the spectrum is traded.

[99] We referred to this as being 36% in the October 2013 Call for Inputs. However we now consider it is more accurate to regard it as being 37%. The overall spectrum cap in the 4G award was 2x105 MHz, which to make comparison between paired and unpaired easier, we now express as 210 MHz of spectrum. This 210 MHz represented 37% of the 567 MHz of spectrum that we considered relevant for mobile competition in that award. This 567 MHz consisted of 60 MHz at 800 MHz, 69.6 MHz at 900 MHz, 143.2 MHz at 1800 MHz, 119.1 MHz at 2.1 GHz, 140 MHz at 2.6 GHz (paired) and 35 MHz at 2.6 GHz (unpaired). At 35 MHz, the amount of unpaired 2.6 GHz spectrum we considered relevant for the overall cap was less than the 50 MHz actually allocated. The reasons for this are explained in footnote 82 above.

[100] In calculating this 310 MHz, we include all 190 MHz that will be included in the auction. We consider that there are unlikely to need to be guard bands limiting the use of any of this spectrum as we consider that it is likely to be synchronised.

[101] In terms of spectrum relevant to the cap, EE currently holds 210 MHz of spectrum in total, consisting of 10 MHz at 800 MHz, 90 MHz at 1800 MHz, 40 MHz at 2.1 GHz and 70 at 2.6 GHz.

- **Telefónica** would be prevented from obtaining more than 220 MHz of additional mobile spectrum[103]. Telefónica would therefore only be restricted in the 2.3 and 3.4 GHz award if it obtained Qualcomm's 1.4 GHz in advance of the award.

7.121 Other operators would be unconstrained by the cap because, even if they obtained all of the new spectrum available (from 1.4 GHz, 2.3 GHz and 3.4 GHz spectrum), they would have less than 310 MHz of relevant mobile spectrum.

7.122 A cap at this level would prevent very asymmetric holdings of spectrum. In particular, neither EE nor Vodafone would be able to acquire all the relevant new spectrum individually.

7.123 However, it would still be possible that only the two operators that currently have the highest spectrum shares (i.e. EE and Vodafone) would acquire spectrum in the auction. In such an outcome, they would together have around 71% of the relevant mobile spectrum, leaving less than 30% for other market participants.

Option 3 – Spectrum cap set at tighter level than in the 2013 auction

7.124 This option would involve a tighter spectrum cap than the overall cap that applied in the 2013 auction. Specifically, we consider a cap so that no operator can hold more than 280 MHz of relevant mobile spectrum, which represents around a third of the total. As with Option 2, this cap would apply to the same set of spectrum we have considered relevant for our assessment and would reflect what operators held at the time of the auction (so taking account of any trades in advance of the auction). The limit of 280 MHz assumes that the relevant mobile spectrum is as we have assumed in paragraph 7.66 above.

7.125 Assuming that the auction would be for packages with a minimum size of 5 MHz, a cap set at 280 MHz (as an example) would imply the following restrictions:

- **EE** would be prevented from obtaining more than 70 MHz of additional mobile spectrum;
- Vodafone would be prevented from obtaining more than 120 MHz of additional mobile spectrum;
- Telefónica would be prevented from obtaining more than 190 MHz of additional mobile spectrum; and
- H3G would be prevented from obtaining more than 210 MHz of additional mobile spectrum[104].

7.126 Other operators would be unconstrained by the cap because, even if they obtained all of the new spectrum available, they would be below the cap.

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[102] In terms of spectrum relevant to the cap, Vodafone currently holds 161 MHz of spectrum in total, consisting of 20 MHz at 800 MHz, 34.8 MHz at 900 MHz, 11.6 MHz at 1800 MHz, 29.6 MHz at 2.1 GHz, 40 paired at 2.6 GHz and 25 unpaired at 2.6 GHz.

[103] In terms of spectrum relevant to the cap, Telefónica currently holds 86.4 MHz of spectrum in total, consisting of 20 MHz at 800 MHz, 34.8 MHz at 900 MHz, 11.6 MHz at 1800 MHz and 20 MHz at 2.1 GHz.

[104] In terms of spectrum relevant to the cap, H3G currently holds 69.5 MHz of spectrum in total, consisting of 10 MHz at 800 MHz, 30 MHz at 1800 MHz and 29.5 MHz at 2.1 GHz.

7.127 A cap at around a third of relevant mobile spectrum would prevent spectrum holdings being as asymmetric as would be possible with a cap at 37%. We have considered a cap of 280 MHz specifically because it would ensure that a reasonably sized block of spectrum - at least 40 MHz - of the additional mobile spectrum could be obtained by one or more parties other than the two operators which currently have the highest spectrum shares (i.e. EE and Vodafone) even if they acquired spectrum up to the limit set by the cap. The most EE and Vodafone could acquire would be around 66%, meaning 34% would be available for other market participants.

Option 4 – Spectrum reservation (potentially combined with a high overall spectrum cap)

7.128 This option involves reserving spectrum for companies other than EE and Vodafone, which have the largest spectrum shares currently. This would ensure that other operators were able to obtain some spectrum in the 2.3/3.4 GHz award. For example, we could reserve 40 MHz of spectrum in this way. If we reserved 40 MHz, this could either be of particular spectrum (for example, the 2.3 GHz or the 3.4 GHz), or the auction could be designed such that bidding in the auction determined which 40 MHz of spectrum was reserved.

7.129 Like Option 3, this option would prevent the outcome in which the two operators with the largest current shares of spectrum acquired all of the newly available spectrum.

7.130 This option could also be combined with an overall spectrum cap that would limit what any individual operator may hold. For example, it could be combined with an overall cap set as in Option 2.

Assessment of options

Competition concern

7.131 If EE and/or Vodafone were to obtain all the newly available spectrum, we have some concerns that this may reduce competition in the long term. However, whether such an asymmetric spectrum distribution would reduce competition or not is uncertain, as it depends on technical and market conditions that are difficult to predict.

7.132 Even with Option 1 (no measures in the award), we consider that an outcome of very asymmetric spectrum shares is unlikely. However, if such an outcome were to come about, it could result in substantial consumer harm given the importance of the mobile market[105].

Distinctions between different bands

7.133 As discussed above, we recognise that in focussing on overall spectrum shares we are treating all relevant mobile spectrum as being equal, whereas it is possible that the usefulness of different bands in terms of adding capacity in the long term may differ. For example, it is possible that, the 3.4 GHz spectrum may be less important to our competition concerns than other bands.

[105] See paragraph 4.22 of *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz Statement*, Ofcom, 24 July 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf

7.134 However, given the uncertainties of how important the different bands will be in the long term, we have focussed on comparing unweighted spectrum shares, which treats all relevant mobile spectrum equally.

Balancing our competition concern with the risks of intervention

7.135 In considering the four options set out above, we need to balance our competition concerns with the potential risk of doing more harm than good by intervening in the award to prevent such distributions.

7.136 The likelihood and scale of any detrimental consequences are related to the degree of intervention. The greater the intervention, the greater the likelihood and scale of unintended detrimental effects on consumers.

7.137 We consider that the risk of unintended detrimental consequences would be higher if we were to take measures specifically related to 2.3 GHz, rather than to both the 2.3 GHz and 3.4 GHz spectrum combined. This is because there is only 40 MHz of the 2.3 GHz spectrum and it is likely to be more valuable spectrum. It is likely to be more valuable partly because the ecosystem of user devices is more developed than at 3.4 GHz, and partly because it is at a frequency that is easier for some operators to incorporate into their existing networks.

7.138 Because we do not consider there are significant competition concerns raised by the 2.3 GHz award independent of the 3.4 GHz spectrum (see paragraph 7.82 above), we have only considered measures relating to both the 2.3 GHz and 3.4 GHz spectrum combined. We include the 3.4 GHz spectrum in all the measures we consider because we believe it will be used to provide mobile access in the future (as discussed from paragraph 7.57 above).

Ability for Ofcom to act later

7.139 Another consideration affecting our assessment is our ability to act later if competition problems did materialise. However, it may be difficult in practice to detect such competition problems and any later intervention would take time, meaning that any competition problems may persist for some years.

7.140 Another way we could act if our competition concerns materialised would be to take spectrum related measures in subsequent awards. For example, we could take measures in the likely 700 MHz auction. However, an auction of 700 MHz spectrum is not likely to take place for some years.

7.141 Similarly, in relation to Options 2-4, we note that if we did impose competition measures in the auction, but it later becomes clear that the intervention had negative effects, this might be mitigated (at least partially) through a spectrum trade. However, it may be some years before it became clear that our intervention in the auction had negative effects.

7.142 Therefore, there may be risks of damaging consumers' interests for some years either if we did not intervene sufficiently and competition concerns arose, or if we intervened when doing so was unnecessary.

Evaluation of options

7.143 As set out above, even with Option 1 (no measures in the award), we consider it unlikely that the auction would result in a very asymmetric spectrum distribution. For

the same reason, i.e. that it is unlikely any one operator would acquire a very significant proportion of the available spectrum even in the absence of any constraint, we consider that a cap at the level in Option 2 (approximately 37%) is unlikely to bite. If it does not constrain operators in this way, the resulting spectrum distribution would be unaffected by the imposition of the cap. We therefore consider Option 2 is unlikely to prevent potentially desirable outcomes, and that the risk of adverse consequences arising under either option is low.

7.144 However, whilst the balance of risk is similar between the options, we consider that the harm, if it were to arise, would be greater under Option 1 than under Option 2. In the absence of any cap, there is the possibility for very asymmetric spectrum holdings to arise, which could in turn lead to a material reduction in competition. If such a reduction in competition were to occur, however unlikely, it would result in significant detriment to consumers. On the other hand, whilst it is possible that operators may be constrained in the amount of spectrum they are able to acquire under Option 2, we consider that even the most constrained operator would nonetheless still be able to acquire a large amount of spectrum under this option. We accept that if the cap were to bite at this level it is also possible that it may prevent an outcome that is desirable[106]. But we consider that the harm from this is unlikely to be as large as the potential harm to consumers from a reduction in competition given that a cap at this level would still give substantial flexibility to all bidders. On balance, we therefore consider that if a cap at the level in Option 2 were to bite, that would probably be in consumers' interests. Our provisional view is therefore that Option 2 is preferable to Option 1.

7.145 We now consider whether we should impose more restrictive measures than Option 2. We note that a cap as in Option 2 would not prevent an outcome in which EE and Vodafone – taken together – obtained all of the newly available spectrum. While we also consider this outcome relatively unlikely, if it were to occur, we consider there may be a risk to competition, depending on how the market develops in the future.

7.146 Both the tighter cap in Option 3 (of around a third of relevant mobile spectrum) and the reservation in Option 4 (for example of 40 MHz) tend to reduce the potential competition concerns, as they limit the extent to which the distribution can be very asymmetric. However, with these stronger interventions, there would be a greater risk of unintended consequences, potentially preventing outcomes that may be in consumers' interests. For example, the cap of 280 MHz with Option 3 would prevent the company with the largest share of relevant mobile spectrum currently (i.e. EE) from obtaining more than 70 MHz of spectrum in the auction and hence may prevent it from obtaining a very large block of contiguous spectrum that might be beneficial when aiming to provide very fast download speeds[107].

7.147 If the reservation in Option 4 were set at 40 MHz, then either of Option 3 or Option 4 would ensure that 40 MHz of spectrum in the auction was obtained by a company other than EE and Vodafone. However, Option 4 would provide slightly more

[106] For example, by restricting the spectrum that EE can obtain, there is a risk it raises EE's costs and limits the services it can offer, potentially leading to poorer outcomes for consumers. For example, if EE obtained 40 MHz of 1.4 GHz spectrum or 40 MHz of 2.3 GHz spectrum, then it could not obtain more than 60 MHz of 3.4 GHz spectrum, which would preclude it from obtaining a very large band of contiguous spectrum. Such holdings may be necessary to deliver the fastest speeds with 5G. Similar issues may arise for Vodafone, but to a lesser extent, as it could buy more spectrum in the auction under such a cap.

[107] Studies have shown that, with 80 MHz of contiguous, high frequency spectrum, 5G technology could achieve speeds comparable to fixed superfast broadband. However, studies have also shown very high speeds are possible with non-contiguous spectrum.

flexibility, in terms of the distribution of spectrum between EE and Vodafone, which is a potential advantage of Option 4 compared to Option 3[108].

7.148 With Option 4, we consider that a reservation of 2.3 GHz spectrum specifically would be too restrictive (for the reasons given in paragraph 7.137 above). We would therefore want to allow a reservation of either 2.3 GHz or 3.4 GHz, with this being determined by bidding in the auction. Compared to Option 3, a disadvantage of this approach is that it would add complexity to the auction design. Because the benefits of Option 4 in terms of additional flexibility are modest relative to the cost of additional auction complexity, we prefer Option 3 to Option 4.

7.149 Option 3 would involve a tighter overall cap than we imposed in the 2013 auction. We note that it would have been possible for two operators to acquire around 74% of spectrum between them in the 2013 auction. In this award, because of existing holdings, if we set a cap at the same level as in the 2013 auction (i.e. Option 2), the most the two largest holders of spectrum could obtain is only around 71% of relevant mobile spectrum.

7.150 We do not consider there are strong reasons for imposing a tighter overall cap on spectrum holdings now compared to the 2013 auction. For instance, the spectrum in question at 2.3 and 3.4 GHz is not clearly more important for competition than the spectrum considered in the 2013 auction. Also, there do not appear to have been changes in the competitive landscape since the 2013 auction that would suggest our competition measures should have been significantly more restrictive - though it may be too early to make a firm judgment about the long term impact of the 2013 auction.

Proposals for competition measures in auction

7.151 On balance, our current proposal is that some competition measures are justified in the 2.3/3.4 GHz auction because if we did not take any measure (Option 1), this involves a certain risk to competition. Whilst this is low in terms of likelihood, it could be significant for consumers if it were to materialise.

7.152 In terms of the possible measures we could adopt, we propose Option 2 i.e. that there should be an overall spectrum cap at a level broadly equivalent to the overall cap in the 2013 auction. Assuming that our final view on what spectrum is relevant is in line with our proposals (as set out in paragraph 7.66 above), this would imply a cap of 310 MHz. This would impose some constraints on the amount of spectrum that EE, Telefonica and Vodafone could obtain in the auction, but would still allow them considerable flexibility in the auction. We consider this to be a proportionate measure, given the different risks. Our view is that more interventionist options are not justified, because the risk they could prevent outcomes that could be beneficial for consumers outweighs our competition concerns.

7.153 Our provisional view is therefore that it is proportionate to impose a cap at 310 MHz as it provides a safeguard against future potential competition concerns that may arise from very asymmetric spectrum holdings but does not go further than

[108] We note that the Federal Communications Commission (FCC) in the US has chosen to adopt a policy involving a reservation of spectrum in an upcoming set of auctions, setting aside up to 30 MHz of spectrum for operators that hold less than 33% of relevant spectrum. However, these auctions are for sub-1 GHz spectrum, particularly important for achieving widespread coverage. See http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db0602/FCC-14-63A1.pdf and http://www.fcc.gov/document/fcc-adopts-revised-mobile-spectrum-holdings-policies

necessary in order to do so. While we consider it unlikely these concerns would arise, if they did arise, they could lead to significant consumer harm.

Including 1.4 GHz, 2.3 GHz and 3.4 GHz Spectrum in Mobile Trading Regulations

7.154 Taking competition measures in the auction could be ineffective if those measures could be circumvented by a spectrum trade immediately after the auction.

7.155 The spectrum at 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2.6 GHz is already covered by the Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011 (the "Mobile Trading Regulations")[109]. This means that our consent is required for any trade of this spectrum, and we reserve the right to conduct an *ex ante* competition check before giving consent.

7.156 In the future we also expect spectrum at 2.3 GHz, 3.4 GHz, and 1.4 GHz (if we vary Qualcomm's licence to allow that spectrum to be used for mobile broadband) to be relevant for mobile access. Our reasons for this are set out from paragraph 7.49 above. Given this, we propose to amend the Mobile Trading Regulations to include spectrum from 1452 MHz to 1492 MHz, from 2350 MHz to 2390 MHz and from 3410 MHz to 3600 MHz. This includes the existing UK Broadband spectrum in the 3.4 GHz band.

7.157 We propose to make this change shortly before the PSSR award. Before the PSSR award, a trade of the 1.4 GHz spectrum would not raise competition concerns. This is because the amount of 1.4 GHz spectrum is relatively small in the context of the spectrum that will shortly become available. We therefore see no need to include the 1.4 GHz spectrum in the Mobile Trading Regulations until shortly before the start of the auction.[110]

7.158 The Mobile Trading Regulations specify the types of transfer that are authorised, and allow a wide measure of flexibility. For more information on the types of transfer, see our Spectrum Trading Guidance document.[111]

Question 7.1: do you agree with our approach to considering what spectrum is relevant to this competition assessment? Please give reasons for your views.

Question 7.2: do you agree with our view that spectrum at 800 MHz, 900 MHz, 1.4 GHz, 1.8 GHz, 2.1 GHz (paired only), 2.3 GHz, 2.6 GHz and 3.4 GHz is relevant for this competition assessment? Please give reasons for your views.

Question 7.3: do you agree that very asymmetric spectrum holdings could give rise to competition concerns? Please give reasons for your views.

Question 7.4: do you agree with our proposal to impose an overall spectrum cap in the auction equivalent to the overall spectrum cap in the 2013 auction? If our assessment of what spectrum is relevant is correct, do you agree with the proposal for an overall spectrum cap at 310 MHz? Please give reasons for your views.

[109] http://www.legislation.gov.uk/uksi/2011/1507/made/data.pdf and http://www.legislation.gov.uk/uksi/2013/646/pdfs/uksi_20130646_en.pdf

[110] The types of spectrum trade that are possible are set out from paragraph 7.21 of http://stakeholders.ofcom.org.uk/binaries/consultations/combined-award/summary/combined-award.pdf

[111] http://stakeholders.ofcom.org.uk/spectrum/spectrum-trading/

Question 7.5: do you agree with our proposals to amend the Mobile Trading Regulations shortly before the PSSR award so as to include relevant spectrum at 1.4 GHz, 2.3 GHz and 3.4 GHz? Please give reasons for your views.

Question 7.6: do you have any other comments on our assessment of competition effects from the award?

Section 8

Non-Technical Licence Conditions

Introduction

8.1 In this section we set out the non-technical licence conditions that we propose to include in the licences issued as part of this award in the 2.3 GHz and 3.4 GHz bands. Licences will contain the minimum necessary restrictions on the permitted use of the spectrum bands to avoid harmful interference, and to ensure compliance with our statutory duties and international obligations.

8.2 Given the similar nature of the service(s) to be rolled out in these bands, many of the non-technical licence conditions will be the same or similar for licences awarded in each band. Where there are differences we will highlight these. Copies of the proposed licences can be found in Annexes 8 and 9 of this document.

8.3 This section outlines our thinking on the proposed non-technical licence conditions relating to the following areas:

- licence commencement and duration;
- the duration of the initial period, our limited rights for revoking the licence during this period and any additional powers we have following the initial period;
- the territorial extent of licences;
- the payment of licence fees;
- making the Wireless Telegraphy licences tradable in secondary markets;
- non-technical restrictions;
- access and inspection;
- modification, restriction and closedown;
- coverage obligations;
- rollout obligations; and
- provision of information to promote efficient use of spectrum.

Licence commencement and duration

8.4 Consistent with pervious awards carried out by Ofcom, we propose that the auctioned licences should:

- have an indefinite duration, subject to revocation as set out below;
- have an initial period of a specified duration, as discussed below;

- be revocable before the expiry of the initial period on the limited grounds set out below and

- be revocable from any point after the expiry of the initial period on the grounds set out below. But also for spectrum management reasons, subject to us giving five years notice and such notice not being given in advance of the final five years of the initial period.

Duration of the licence

8.5 Licences will initially be granted for an indefinite duration. However, certain licence conditions will only apply after an initial period has been completed. These include provisions relating to the payment of fees and the grounds that Ofcom can revoke a licence.

Duration of the initial period

8.6 The licence will include an initial period starting from the date of issue of the licence. Ofcom has previously considered what the minimum operational term of a licence should be to be long enough to efficiently earn an appropriate return on the investment and has considered this to be twenty years.

8.7 We will issue licences soon after the conclusion of the auction, when winning bidders have made any outstanding payments to cover their licence fees, and we see no reasons to delay the start of the initial period after that. We therefore propose that the initial period for the new licences should be for twenty years, commencing on the date that the licences are granted.

Rights to revoke licences during the initial period

8.8 The initial period is designed to provide licensees with security of tenure for investment planning purposes. During the initial period, we would not be able to revoke licences for spectrum management reasons. The licence would only be revoked during the initial period, in the following circumstances:

- At the request or with the consent of the licensee;

- for non-payment or late payment of the relevant licence fee;

- if there has been a breach of any of the terms of the licence;

- if the licensee has not complied with the auction regulations under which the licence was awarded, including any financial provisions including guarantees;

- if the licensee has not complied with any requirement of any relevant trading regulations;

- we may at any time, by notice in writing, revoke or vary licence terms if it appears to us to be necessary or expedient to do so in the interests of national security, or for the purposes of complying with a Community obligation of the UK or with any international agreement or arrangements to which the UK is party; or

- if it appears necessary or expedient to do so for the purpose of complying with a direction by the Secretary of State under Section 5 of the Communications Act or section 5 of the WTA.

Additional conditions after the initial period

8.9 Once the initial period has expired, the licence will remain in force and continue to be held by the licensee. We propose that two additional conditions would then apply:

- one providing that we may revoke the licence on spectrum management grounds on five years' notice; and
- one relating to additional licence fees that would then be payable.

8.10 We believe that it is appropriate for us to have the power to revoke or vary the licences that are the subject of this award after the end of the initial period. This reflects the greater uncertainty that will exist in the more distant future about the conditions that will make for optimum use of spectrum.

8.11 Market mechanisms should promote efficient use of spectrum, and be more successful in this respect than widespread reliance on regulatory controls. The tradability and liberalisation of spectrum are key elements of a market-based approach and provide licensees with the flexibility to use their spectrum efficiently. However, there may be circumstances in which regulatory intervention is justified in the public interest (for example, to overcome a specific market failure such as problems of co-ordination caused by high transaction costs). A power to take regulatory action, if justified, in relation to the use of the spectrum in the long term will be achieved by us having the power to revoke the licence on spectrum management grounds after the end of the initial period.

8.12 After the first 20 years, we are likely to apply annual fees and therefore require the provision in the licence to do so. The mechanism and levels of any such fees are discussed in paragraphs 8.24 onwards.

Territorial extent of licences

8.13 The territorial extent of the licences will differ due to on-going use in some areas by the MOD. The MOD has 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. MOD indicated that it wished for any off-shore deployments to be coordinated with MOD prior to deployment. This will include areas of internal waters as well as territorial seas[112].

8.14 In addition, we are also seeing an 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 band[113].

8.15 Given the restrictions on deployments at sea and niche applications that we wish to enable, the options available to us are to:

- not to extend the licences to cover internal waters and territorial seas[114] but instead issue separate individual localised licences; or

[112] 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

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

- include internal waters and territorial seas in the award licence but place a coordination requirement on the licensee.

8.16 When deciding on this matter, we also need to take into account our duties under the WT Act and Communications Act regarding the efficient use of spectrum and the extent that spectrum is available to use.

8.17 Our preferred approach is not to include territorial seas or areas of internal waters adjacent to territorial seas in the licence. However we consider that in the case of streams, rivers or other watercourses which form part of such internal waters[115] such streams, rivers or watercourses would only be excluded where they were more than 2km wide.[116] If anyone requires use in this area, we will consider authorising, when requested, localised individual licences off-shore on a first come first served basis, subject to MOD coordination. These licences would enable operators to use spectrum at specific locations, but on the basis that they cannot claim protection from nor cause interference to MOD systems or UK licensees[117].

8.18 We believe that this approach would enable the spectrum to be used in localised areas where needed, whilst ensuring that the UK operators and MOD are not interfered with. We do not believe that this would have a significant impact on the value of the spectrum or the business cases of potential bidders as holders of the award licences will be free to apply for off-shore licences.

8.19 We considered the alternative approach of extending the rights to cover territorial seas and areas of internal waters. This could have potentially allowed for off-shore operators to enter into a commercial agreement with the licensees. However, given a number of factors including the MOD operational requirements, the niche market for off-shore systems, and the remote and restricted access to these sites, we believe it would be better for Ofcom to retain the rights for wireless deployments within these areas to ensure the efficient use of the spectrum.

2.3 GHz band

8.20 The proposed licence 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. As indicated above, territorial seas or any areas of internal waters adjacent to territorial seas would also be excluded (but this exclusion would not apply to rivers, streams and watercourses that are less than 2km wide).

8.21 We previously proposed in in our February Consultation that there will be an exclusion zone of approximately 170km surrounding St Kilda. Since the consultation we have refined the description to be used in the licence and the exclusion zone would now be described as covering the Outer Hebrides, the Isle of Skye and the Small Isles. In addition, we proposed licensees would need to coordinate with MOD

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[114] As defined in the Territorial Sea Act 1987 http://www.legislation.gov.uk/ukpga/1987/49/contents.
[115] 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.
[116] This definition ensures that there are no restrictions in narrow areas of internal waters such rivers or bodies of water such as lakes and ponds, which would therefore be treated in the same manner as deployments on land.
[117] We propose that any localised licence will require compliance with European recommendations covering international coordination such that field strength at the coast does not exceed the recommended level for international coordination for the particular band and this will be described in that licence.

around St Kilda, Aberporth, Oakhanger, Colerne and Menwith Hill. Our ongoing discussions with MOD regarding other military systems in the 2.3 GHz band suggest that the MOD is likely to direct us to put in place some coordination of a similar nature around an additional one or two sites, such as Boscombe Down.

3.4 GHz band

8.22 The proposed licence would now cover the whole of the United Kingdom (in the CFI we indicated that Northern Ireland was not included). The licences would not extend to the Channel Islands and the Isle of Man. As indicated above, territorial seas or any areas of internal waters adjacent to territorial seas would also be excluded (but this exclusion would not apply to rivers, streams and watercourses that are less than 2km wide).

8.23 We previously proposed in the Technical Consultation that licensees would need to coordinate with 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 are yet to conclude on these. In addition, our ongoing discussions with MOD regarding Navy systems suggest that the MOD is likely to direct us to put in place some coordination around a small number of coastal locations, including but not limited to Portsmouth. The exact number of sites and the extent of any coordination are still being evaluated and we will provide an update prior to the award of the spectrum.

Licence fees

8.24 In respect of each licence, the licence fee for the initial period would be determined through the Award Process. We would deduct the licence fee from that licensee's bid deposit (unless the licence fee exceeds that licensee's bid deposit, in which case the relevant winning bidder would be required to pay us the shortfall before we grant the licence) in accordance with the Auction Regulations.

8.25 After the initial period has ended, as advised in paragraph 8.12, licences would be subject to a provision that would enable Ofcom to impose an on-going additional annual fee. The mechanism and level of the fees would depend on our general approach to fees for the use of this spectrum at the time, and how that general approach relates to these licences and to our statutory duties. The level of the fees cannot therefore be determined now. 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.

8.26 However, for the 40 MHz of spectrum held by UK Broadband, this would not apply. Instead, if, as set out in section 5, UK Broadband were to participate in the auction, and a new licence were issued for the frequencies allocated to it in the auction, we propose UK Broadband would pay an annual licence fee from 2018, in line with its current licence. We will consult closer to the time on the exact detail of any fee.

Spectrum trading

8.27 We are proposing that the award licences will be made tradable by amending the Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011[118] (the "Mobile Trading Regulations") to include the new frequency bands of the 2.3 GHz and 3.4 GHz bands (as well as, as set out in section 7, the 1.4 GHz band). In line with

[118] http://www.legislation.gov.uk/uksi/2011/1507/made/data.pdf

Ofcom's policy and in accordance with the provisions of the Mobile Trading Regulations we are proposing that the licences will be tradable, but not leasable. This is the same as other licences covered by the Mobile Trading Regulations. We plan for these regulations to come into force shortly before the award. Further discussion is in section 7 of this document.

Non-technical restrictions on use

8.28 We do not propose to impose any non-technical restrictions on the use to which the spectrum could be put in the licences (such as specifying the type of service that should be offered, the technology that should be deployed or the equipment that should be used).

Access and inspection

8.29 In accordance with our standard spectrum licence conditions, we propose that licensees will be required to permit any person that we authorise to have access to and to inspect the radio equipment specified in the licence at all reasonable times. This is to ensure that the licensee is using the radio equipment in accordance with the conditions of the Licence.

Modification, restriction and closedown

8.30 We propose to include a provision that would permit 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 has breached the terms of its licence; or
- use of radio equipment is or may be causing or contributing interference to the operation of other authorised radio equipment; or
- it appears to be necessary or expedient to do so in the event of a national or local state of emergency.

8.31 Again, this is a standard provision in all WTA licences issued by Ofcom.

Coverage

8.32 In the October 2013 Consultation and CFI we proposed that we would not impose any coverage obligations for this award. The responses to the document did not contradict that view.

8.33 Previously we have included a coverage obligation in one 800 MHz licence and all 2100 MHz licences.

8.34 At 800 MHz, the coverage requirement on Telefonica is for them to cover 98% of the UK population indoors with 95% population in England, Scotland, Wales and Northern Ireland. This will likely lead to 99% or more outdoor population coverage in the UK. This must be achieved by the end of 2017 although they have committed to meeting this up to 2 years early through their network sharing agreement with Vodafone. We believe EE and H3G are likely to provide similar coverage with their networks too.

8.35 The obligation on all holders of 2100 MHz licences is that they cover (by mid-2013) 90% of the UK population. On 7 November 2013, Ofcom announced[119] that the mobile operators EE, Three and O2 had all met an obligation to cover 90% of UK homes by June 2013. One operator, Vodafone, had failed to meet the obligation, reaching 88.66%. However, on 31 January 2014 we announced[120] that all operators had met the coverage requirement.

8.36 We have considered whether similar obligations should be placed on 2.3 and 3.4 GHz licensees. In broad terms, the 2.3 GHz and 3.4 GHz bands have similar characteristics to the 2.6 GHz band, on which no coverage obligations are placed. The additional spectrum in the 2.3 and 3.4 GHz bands is widely considered as spectrum that will provide additional capacity for mobile networks, or may be used to support backhaul connectivity for small cells operating on other frequencies such as 4G (at 2.6 GHz, 1800 MHz or 800 MHz) or 3G (at 2.1 GHz or 900 MHz) rather than coverage. Therefore forcing a licensee to provide coverage with these new spectrum bands will lead them to use macro cells with high cost and may result in the spectrum not being fully released. It will also mean that at least some benefits to citizens and consumers may not be realised.

8.37 Given a wide area coverage target at 800 MHz, and the incremental cost of base stations with today's technology we might expect that these MNOs will deploy other bands to provide additional capacity if there is a demand for it. We therefore intend not to include any coverage obligations in licences issued as part of this award.

'Use it or Lose it' clause

8.38 In our October 2013 Consultation and CFI we considered whether or not to apply licence conditions requiring spectrum holders to make use of the frequencies they acquire in the form of a "use it or lose it clause" - or risk having them taken away. In the CFI we stated a preference not to include such as provision. The responses to the document did not contradict that view.

8.39 As we stated in the earlier document, we do not consider that imposing obligations such as these are in the interests of consumers and citizens. This is for a number of reasons:

- we believe that such conditions are very difficult to make workable in practice because of the problem of defining what constitutes 'use' and therefore the trigger for an enforced sale or revocation;
- there may be entirely legitimate reasons for spectrum remaining unused – the licensee may be holding back until it sees a suitable commercial opportunity or until the technology it wishes to use is ready;
- imposing such an obligation also has the potential to distort and/or chill the incentives to invest in the spectrum, and so reduce the benefits for consumers and citizens which the award would otherwise create.

8.40 There are also specific factors in respect of the 2.3 and 3.4 GHz spectrum which we believe make 'use it or lose it' inappropriate. In particular, we believe this spectrum

[119] http://stakeholders.ofcom.org.uk/binaries/consultations/2100-MHz-Third-Generation-Mobile/statement/verification-results.pdf?utm_source=updates&utm_medium=email&utm_campaign=3g-coverage
[120] http://media.ofcom.org.uk/2014/01/31/3g-mobile-coverage-requirements-now-met/

could 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.

8.41 That said, as with all licences issued by Ofcom these are not exclusive. As stated in paragraph 5.67 of the 800 MHz and 2.6 GHz Competition Assessment 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. For example, if a key public policy objective could only be met through use of this spectrum, and the licensees were unwilling or unable to meet this objective, but other users could, Ofcom may grant additional licences for the use of some or all of these frequencies, with appropriate safeguards to appropriately manage the risk of interference.

Sharing

8.42 There is an emerging concept being discussed internationally regarding dynamic spectrum access. This covers a number of approaches including the use of geolocation databases, Licensed Shared Access (LSA) and cognitive devices. These discussions relate the ability of users to share spectrum in a dynamic way by utilising unused frequencies (white space). This temporary sharing could be time constrained, e.g. for milliseconds or a month, or confined geographically, e.g. to rural areas. The utilisation of white space, for example, could permit licensees to access more spectrum, which could be used to provide extra capacity or greater download speeds to end users.

8.43 For some of these approaches to work, licensees would need clarity on mechanisms for sharing to assess the impact on their quality of service. We would expect such information be outlined in a licence condition. At present dynamic spectrum access is still evolving and we do not feel that it is necessary to include any specific condition relating to it in the award licence.

8.44 In the future if the regulatory environment changes, we may consider consulting on the possibility of varying licences to include provisions that would enable dynamic sharing if needed.

PMSE access

8.45 Where there is a requirement for spectrum access to support peak demand events, access will be coordinated on a case by case basis with the award licensees. We will 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. This request will be made not later than six weeks before the event although it is likely that a request would be earlier. A response will be needed not later than four weeks before the event to allow time to assess whether the spectrum can be used and factor this into the channel plan.

8.46 The information we require to coordinate access to the award bands and assess compatibility between new services and PMSE is set out in Clause 3 of the draft licences provided in Annexes 8 and 9.

8.47 Our analysis, as set out in the technical coexistence consultation, indicates that the requirement for additional spectrum is low and therefore we expect requests for coordinated access to the 2.3 GHz and 3.4 GHz bands to be infrequent.

Provision of information to facilitate optimal spectrum use

8.48 In line with our duty to manage the spectrum efficiently, we propose to include a condition in the licences to require licensees to provide us, on request, with general information regarding their equipment and use of frequencies, or the roll-out of their network. From time to time, we may publish information received on the number of base stations and frequency use in areas throughout the UK.

8.49 We note that we have powers under both the Communications Act 2003 (section 135 to 146) and the WTA (sections 32 to 34) to require third parties to provide us with information in certain circumstances. However, we consider that there remains a benefit in requiring licensees to compile and maintain basic details relating to the radio equipment that they are using pursuant to the licence so that it is readily available in the event that it is needed, for example, in cases of alleged interference.

8.50 The provision of information to Ofcom 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.

8.51 The information would also be used to assist with the work being undertaken to conduct a spectrum inventory across the European Union, as required by Commission Decision 2013/195/EU[121]. This work forms part of the Radio Spectrum Policy Programme[122] that sets out the strategic policy objectives for spectrum by the EU.

8.52 We consider that this approach is objectively justified to fulfil our statutory duties and objectives, transparent, proportionate and does not discriminate between licensees. It is in line with similar provisions placed on the licences for the 800 MHz and 2.6 GHz award. We are particularly interested in the views of stakeholders on what information they think would help to facilitate efficient use of spectrum and secondary trading, and on the impact of the disclosure of this information might have on licence holders.

Conclusions

8.53 The main specific non-technical conditions that we are currently proposing to include in the WTA licences to be issued as a result of the 2.3 GHz and 3.4 GHz awards are set out in Figure 8.

[121] 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

[122] http://ec.europa.eu/digital-agenda/rspp-roadmap-wireless-europe

Figure 8: 2.3 GHz and 3.4 GHz proposed non-technical licence conditions

Proposed Licence conditions	2.3 GHz licences	3.4 GHz licences
Licence duration	Indefinite period	Indefinite period
Duration of Initial licence period	20 years	20 years
Territorial extent of licences	Great Britain but excluding territorial seas and certain internal waters. Outer Hebrides, Isle of Skye and Small Isles are also excluded.	United Kingdom but excluding territorial seas and certain internal waters.
Coordination requirements	Subject to minor co-ordination requirements around some MOD sites	Subject to minor co-ordination requirements around some MOD and aeronautical radar sites
Licence fees	Award fee for initial period. Annual Licence fee after initial period to be determined at a later date.	Award fee for initial period. Annual Licence fee after initial period to be determined at a later date.
Spectrum Trading	Fully tradable subject to Ofcom giving its consent to a trade prior to it being implemented. This may require a competition assessment to be conducted. Leasing would not be permitted at this time.	Fully tradable subject to Ofcom giving its consent to a trade prior to it being implemented. This may require a competition assessment to be conducted. Leasing would not be permitted at this time.
Non-technical restrictions	No type of service, technology or specific equipment requirements	No type of service, technology or specific equipment requirements
Rollout/ Coverage/ Use it or lose it obligations	None but the licences are not exclusive and Ofcom may decide to authorise other users in the band to meet policy objectives	None but the licences are not exclusive and Ofcom may decide to authorise other users in the band to meet policy objectives
Providing information	Requirement to provide information regarding equipment and use of frequencies, or the roll-out of networks when requested. Requirement to provide	Requirement to provide information regarding equipment and use of frequencies, or the roll-out of networks when requested. Requirement to provide

	information on request to support use by PMSE on an ad hoc basis.	information on request to support use by PMSE on an ad hoc basis.

Question 8.1: 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?

Question 8.2: Do you have any comments on our proposals relating to the territorial extent in the award licences?

Question 8.3: 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?.

Question 8.4: Do you have any comments on other proposed non-technical licence conditions and the draft licences at Annexes 8 and 9?

Section 9

Technical Licence conditions

9.1 This Section provides a summary of comments we have received in response to our consultation "Technical coexistence issues for the 2.3 and 3.4 GHz award" of 19 February, 2014 (the February Consultation) in relation to the technical licence conditions for the spectrum to be awarded.

9.2 We received thirteen responses[123] to questions we asked on Technical Licence Conditions of the February Consultation, three were confidential and two had confidential parts (only six stakeholders responded to all of the questions). We have also had further discussions with some stakeholders to explore the issues they raised. We have treated the details of these conversations as confidential.

9.3 This section is split into two parts:

- The first part, paragraphs 9.6 to 9.91 considers the technical licensing policy around the use of the restrictive and permissive masks, and sets out our views on synchronisation;
- The second part, paragraphs 9.92 to 9.120, considers in-band and out-of-band power levels.

9.4 In each part, we have provided an overview of the responses received and our analysis. In light of those responses and our further analysis, we also set out further proposals for the technical licensing conditions and seek stakeholder views. In particular:

- We seek stakeholder views on two possible options which seek to encourage synchronisation, both of which would be implemented through an Inter-operator Synchronisation Procedure.
- We propose that indoor small cells should be exempt from synchronisation.
- We provide further clarification on our position on power control for femto cells.
- We propose to include the out of band power limits above 2403 MHz that are in ECC Decision (14)02.
- We propose a position with regard to the out of block levels applicable in UK Broadband's spectrum holding of 3605 – 3689 MHz.

9.5 A decision in relation to these proposals, and those set out in the February Consultation will be made next year. Draft licences are attached at annexes 8 and 9; they would implement our proposals set out here and in our February consultation.

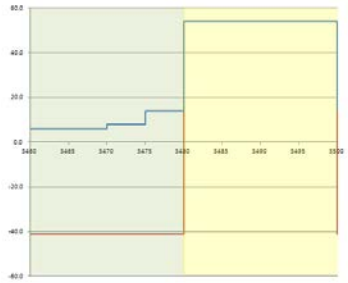
[123] http://stakeholders.ofcom.org.uk/consultations/pssr-2014/?showResponses=true

Part 1: Technical Licensing options

Summary of proposals set out in the February consultation

9.6 In the February Consultation, we proposed to permit two block edge masks and the following conditions.

Figure 9: Summary of proposals set out in the February consultation

Option 3: 	An option of two out of block masks in the adjacent licensee's block: • A permissive mask to protect where there is a bilateral agreement in place between two licensees (blue line). This may be where the networks are fully or partially synchronised • A restrictive mask to protect use where no bilateral agreements are in place (red line) All assigned spectrum may be used at maximum power. All spectrum is assigned to licensees, without any guard band, restricted block (where part of the block has power restrictions), or a fixed transitional region between licensees imposed to allow filter roll-off to meet the restrictive mask. Therefore if the restrictive mask was used an internal guard band would be needed to allow for the filter roll-off. Licensees are free to negotiate more permissive out of block emissions by bilateral agreement.

9.7 For further more details on the analysis of the options we considered, see Section 13 of the February consultation.

Summary of responses on licensing options

9.8 The majority of our proposals in relation to technical licence conditions were the same or similar for each of the 2.3 GHz and 3.4 GHz band. Unless otherwise indicated, stakeholder responses summarised below, and Ofcom's further comments relate to both bands.

Transitional regions between licensed blocks of spectrum

9.9 Seven respondents agreed with our proposal not to have a dedicated transitional region (or guard band) between blocks for licenses in the 2.3 GHz and the 3.4 GHz band.

9.10 The following specific points were raised:

- Huawei and a confidential respondent suggested transitional regions should be avoided to maximise usable spectrum for mobile use. A similar point was made

by UK Broadband and another confidential respondent highlighting that it maximises spectrum efficiency;

- UK Broadband highlighted that complying with the restrictive mask will achieve the same result as applying a transitional region;

- EE highlighted that the transition block of 5 MHz that is required in non-synchronized deployment should be included in the licences (effectively as a restricted block). This restricted block could be converted to a normal block dependent on synchronization being agreed by the licensees concerned. They also highlighted that the ability to serve customers with a controlled quality of service has a value independent of absolute capacity and therefore has questioned our view of looking at overall increases in capacity over some additional risks of interference in some problematic environments.

Our preference to include both the permissive (synchronised) and restrictive (unsynchronised) masks

9.11 There were mixed responses to our stated preference to permit both the restrictive and permissive mask (depending on the circumstances), with the slight majority of responses wishing to have the ability to choose the mask.

9.12 The following specific points were raised:

- GTI, Bolloré Telecom, Huawei, and a confidential respondent all made similar comments on the fact that the permissive mask (with synchronisation) allows a UK operator to take advantage of the global equipment eco system at low cost. They noted that this is more critical for small cells. The restrictive mask requires additional costs to be incurred to meet the custom filtering requirement. Whilst a number of other stakeholders expressed a desire for both masks to be permitted, in subsequent conversations, many of these have also indicated that use of global equipment is extremely important to them. This implies use of the permissive mask.

- Bolloré Telecom highlighted that if a licensee implements the restrictive block edge mask, this forces other licensees to implement custom filtering when they are using the permissive mask in order to avoid interference as a result of receiver performance limitations.

- A confidential respondent expressed the view that both the restrictive and permissive masks need to be available to permit flexible behaviour between licensees and to allow them the flexibility to choose for any given circumstances.

- EE wanted it to be clearly stated that the masks can be relaxed, based on mutual agreement between adjacent spectrum users.

Our preference not to require synchronisation between different networks

9.13 There were mixed views on our preference for not requiring synchronisation between different users of the frequency band.

9.14 The points in support of synchronisation are summarised below.

- It has been suggested by several respondents that there could be delays to deployments of networks in the absence of a synchronisation agreement. One confidential respondent provided an example where the lack of suitable synchronisation rules effectively caused a delay for nearly 2 years in India. The reasons given for the possibility of a delay were:

    - Bolloré Telecom thought licensees may have different timescales for their deployment plans, and that there may not always be an equal incentive to come to an agreement if one licensee's chosen uplink to downlink (UL/DL) ratio causes more interference to the other operators;

    - A confidential respondent indicated that an operator may have an incentive to delay agreement on synchronisation to prevent one or more other operators from being able to use all their spectrum without delay;

    - Huawei said that if one party wanted to deploy a network before a synchronisation agreement was formed, they could face two costly scenarios: either needing to retrofit external filtering (to meet the restrictive mask) if another operator chooses a different UL/DL pattern; or rollout with expensive filtering (to meet the restrictive mask), to find out later that the adjacent operator is using the same UL/DL pattern without the additional costs of filtering (i.e. the permissive mask).

- A confidential respondent expressed concern that if a bilateral agreement cannot be made between licensees then there is a risk that up to 10 MHz of guard band may be required between adjacent licensees. This could lead to an inefficient use of spectrum as those guard bands would remain unused for mobile broadband services;

- Huawei highlighted that full synchronisation amongst mobile operators is becoming universally adopted around the world, as it maximises spectrum efficiency and reduces network rollout costs (as there is no need for customised equipment). Operators in China, India and Nigeria have chosen the full synchronisation; operators in Hong Kong and the Philippines are expected to follow.

9.15 Global TD-LTE Initiative highlighted that it is better for the regulator to decide on full synchronisation or no synchronisation when licensing, in order to remove the uncertainty or delay in spectrum utilisation. It is probable agreements with multiple licensees would be needed. They also suggested that work would need to be done to co-ordinate the synchronisation parameters before the licenses were issued; for example, agreement on the UL/DL frame structure and special (S) sub-frame structure to be used by multiple licensees.

9.16 Other respondents stated that a decision on synchronisation should be left to mutual agreement between adjacent network licensees.

- UK Broadband highlighted that requiring synchronisation would potentially deny licensees the flexibility they need to innovate and adapt to commercial requirements. They also highlighted mandatory synchronisation might restrict their ability to be flexible and adaptive to change their UL/DL ratios as their products and services develop. EE and a confidential respondent also said that it ought to be left to licensees to decide the UL/DL ratios.

- UK Broadband also highlighted that a requirement for synchronisation could lead to an operator having also to use the spectrum for download only to match their neighbour, and this then flowing on down the band, imposing the same requirement on all licensees. They also suggested that such restrictions on the use and application of the spectrum would have a detrimental impact on competition and choice in service provision.

Other issues put to Ofcom

9.17 Bolloré Telecom suggested to Ofcom that synchronisation would not be required for indoor small cells due to mitigating factors such as low power, average inter-femto cell distance, and wall penetration loss.

Our comments and further consultation

9.18 The responses to the questions we asked in the February consultation document and our follow up conversations with some stakeholders have led us to think further on how to enable use of the permissive mask. This is likely to include synchronisation as all or part of the solution. If an agreement between operators uses only the permissive mask, then the question on whether to have a set aside transitional region is obsolete. If a solution was adopted whereby the restrictive mask is still available, then discussions on the use of the transitional region or restricted block could still be relevant.

9.19 We consulted in February on the option of having a lower power restricted block. The restricted block reduces the utility of part of the spectrum, by restricting the power level in part of a licensee's spectrum holding. We also proposed having no guard bands. Although this may give less protection in some problematic interference environments, analysis suggests a higher spectral efficiency is achieved if there is no spectrum gap (see Real Wireless analysis[124]). Given that respondents suggested that use of global equipment is important and this implies use of the permissive mask then our view remains that we prefer to maximise the utility of spectrum available and maximise the potential capacity that can be used for data services. Our proposal to have no guard bands or restricted blocks set aside between licensees would give the flexibility for a licensee to use the entire spectrum block for high power or to apply measures in their own spectrum to give themselves additional protection if they thought it was appropriate.

9.20 We summarise four key issues from the responses to the consultation and further discussions with stakeholders which we should consider in developing our position on block-edge-masks (BEMs) within the bands. These four key issues are:

- The risk of delays where the spectrum is not used because of lack of agreement over synchronised transmissions;
- Desire to use global equipment;
- Optimising spectrum utilisation/efficiency;
- The desire for flexibility in setting downlink and uplink ratios.

[124] http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Capacity_Impacts.pdf

9.21 We discuss these issues further in paragraph 9.22 to 9.91. We also ask additional questions within this consultation to further develop our policy and seek stakeholder views.

Risk of delays in spectrum being used

9.22 Past experience in the UK indicates that co-ordination agreements between licensees can take some time to achieve. We also believe that uncertainty over which mask can be used could present a risk of delays to deployments, as hardware changes (and thus additional cost) will likely be needed to move from one mask to another.

9.23 The responses to our Call for Inputs and subsequent discussions with stakeholders, suggest that different operators have different timescales for deployments using the spectrum. There is therefore in our view a material risk that a licensee with later plans for the spectrum may not have an incentive to come to agreement early, due to uncertainty around their own plans. In this instance other licensees would need to decide whether to deploy with the restrictive mask initially, using additional filters and an internal guard band, or wait until multi-operator discussions have come to a suitable level of maturity, when they may be able to deploy using the permissive mask.

9.24 We see a clear benefit of giving as much certainty as possible at the time of the award, so that operators can then assess how their plans fit with a proposed frame profile and make more informed bidding choices.

Desire to use global equipment

9.25 We understand that additional hardware filtering will be required in base station equipment to meet the required baseline levels of the restrictive mask. These filters will be specific to the exact spectrum allocation of each licensee and will result in specific equipment for each licensee. The permissive mask does not require any additional filtering and so harmonised global equipment can be used that can select different operating channels through software configuration.

9.26 If specific equipment for each operator is needed, it would mean that it is unlikely that base station products could be generic and as a consequence they would need to be manufactured and stocked in batches. There is also the increased cost of the additional filter requirements to consider. This is likely to result in less economy of scale and thus the overall equipment costs may be greater. For small cells, we believe this additional cost could be around 10% of the base station cost. This could be a significant cost increase for a business model based on high volume, low cost cell deployments. In its response Huawei suggested that pico/femto cells should be allowed to meet baseline levels of -15 or -19 dBm respectively. This implies that 17 to 21 dB of additional filtering is needed to comply with the restrictive mask. These values are similar to those provided in a confidential response.

9.27 A confidential respondent showed us a filter for a similar band. The filter provides around 25dB of additional rejection, 5 MHz away from edge of a 20 MHz block. However, the filter has a physical volume that is comparable to the size of some small cells, which can have volumes of only 0.7 litres (although larger cells can be up to 11 litres depending on manufacturer, design of the small cell and the required power output). This filter size is therefore significant, with filters being unable to be fitted within the same enclosure of some of the smaller volume small cells.

Spectrum utilisation/efficiency

9.28 To meet the -36dBm / 5 MHz baseline level of the restrictive mask, a licensee would typically need an additional 5 MHz guard band for filter roll-off. The permissive mask would not require any such guard band. For a wider allocation (i.e. greater than 40 MHz pass band) the guard band may need to be greater due to limitations of filter design. This could, if they agreed, be shared between adjacent licensees, leaving 2 x 2.5 MHz per block boundary per licensee (5 MHz in total). If there is not an agreement between the licensees, this could lead to up to 10 MHz (5 MHz either side) set aside per licensee.

9.29 Without the certainty that an agreement could be reached to share these guard bands, then a potential licensee bidding in the auction may need to assume the worst case and bid for an additional 10 MHz of spectrum. This could lead to a loss of usable spectrum.

9.30 3GPP, the international standard body developing LTE standards has specified seven different configurations of frame structure for TD-LTE[125], which provide a different ratio of uplink and downlink traffic within a frame. We have modelled the effective bandwidth available for each of the seven traffic configurations, assuming all of the spectrum is available for traffic with the permissive mask, versus the use of the restrictive mask where some spectrum is used for the filter roll-off and not used for traffic. We look to compare the potential advantages of spectrum utilised for uplink and downlink under each option.

9.31 We set out below the effective bandwidth scaled by the relevant proportion of uplink and downlink sub-frames when a restrictive mask and a permissive mask are used. We do not take into account the special (S) sub-frames used for switching between downlink to uplink. We assume that the spectrum holding is 40 MHz. For a restrictive mask, we assume that 5 MHz is needed for filter roll-off for each spectrum boundary. We therefore assume 30 MHz is available for traffic. For a permissive mask, we assume all of the 40 MHz can be used for traffic. (To assist looking at the different configurations, we have coloured the downlink heavy configurations purple, the uplink heavy configurations blue, and the configuration with the same amount of uplink and downlink is coloured pink.)

[125] 3GPP TS 36.104, Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception

Figure 10: Effective bandwidth calculations for different TD-LTE traffic configurations using the restrictive and permissive mask

			For downlink traffic		For uplink traffic	
			Restrictive mask	Permissive mask	Restrictive mask	Permissive mask
3GPP Traffic configuration number	Number of downlink sub-frames	Number of uplink sub-frames	Effective bandwidth assuming 2 x 5 MHz for filter roll-off, MHz	Effective bandwidth, MHz	Effective bandwidth, MHz	Effective bandwidth, MHz
0	2	6	6	8	18	24
1	4	4	12	16	12	16
2	6	2	18	24	6	8
3	6	3	18	24	9	12
4	7	2	21	28	6	8
5	8	1	24	32	3	4
6	3	5	9	12	15	20

9.32 Figure 10 shows, in this worked example, that if a licensee wants to use a downlink heavy configuration (2, 3, 4, or 5), there is little point in going to the trouble of using a restrictive mask with a very heavy downlink configuration (configuration 5) compared with using a more modest downlink heavy configuration (for example configuration 2) but remaining on a permissive mask.

9.33 This is not quite the case for a licensee who wants an uplink heavy configuration (0 or 6). Figure 10 shows that in this case, the effective bandwidth for uplink traffic is higher in almost all cases when using the restrictive mask compared with any of the other configurations using the permissive mask.

9.34 For our February Consultation, we commissioned Real Wireless to study the potential for synchronisation and the potential spectral efficiency benefits of including transition regions (or internal guard bands) in spectrum between high power blocks.[126] The study looks at capacity benefits in a network and considers the effect of an adjacent network. It compared synchronised scenarios with neighbouring operators using 20 MHz carriers who are both using the permissive block edge masks. It also compared adjacent operators which were using the restrictive mask with each possible TD-LTE traffic configuration combination (and every sub-frame offset) with 0, 5, 10 MHz transitional regions between the carriers. The results suggested that although there were scenarios where there may be additional interference with the permissive mask, there were clear overall spectral efficiency benefits of synchronisation in the real life scenarios modelled.

9.35 We think that there are generally advantages of licensees synchronising with other networks, in terms of both utilising more spectrum available and using it efficiently.

[126] http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/annexes/Capacity_Impacts.pdf

Flexibility in downlink and uplink ratios

9.36 We consider three different types of flexibility that may be desirable to a licensee.

Flexibility in certain scenarios

9.37 We believe that where there is contiguous coverage it is likely to be favourable to synchronise to avoid co-channel interference within your own network. This is shown in the study of "Network Time-Synchronisation in TDD Base LTE-Advanced Systems". That study looks at the spectrum efficiency advantages of synchronisation in a network using 100 MHz spectrum around 3.5 GHz. It does not consider the effect of networks in adjacent spectrum. The analysis shows a 20 ~ 50% gain in UL cell throughput with synchronisation within the modelled network, compared to when the network did not have synchronisation. At the cell edges, full synchronisation gave a much better cell throughput in both the uplink and downlink.

9.38 There may, however, be scenarios where it is beneficial to use different frame structure proportions to suit a particular circumstance, for example to better match high upload requirements at sporting events.

9.39 In addition, we are also aware of developments within Release 12 of the 3GPP standard for LTE that will enable small cells[127] (at least pico or femto cells) to change UL/DL configuration to adapt to the current traffic needs in the network. This Release is due to be complete in December 2014. Release 13, which is due for completion in March 2016, may contain further enhancements to UL/DL configuration if they are needed. Based on this, we think it is highly likely that technology will exist in the future that will allow a licensee to be more flexible with the traffic configuration within its network, particularly for small cells.

A different requirement across the network

9.40 We highlighted above that there are some advantages of licensees synchronising within their own network and with other networks, in terms of both utilising more spectrum available and using it efficiently. However we note that some licensees may have different preferences for an agreed frame structure for synchronisation.

9.41 The two 3GPP configurations 0 and 6 have higher proportions of uplink and may be more suitable for an Internet of Things type communications or security cameras. However, we did not receive any responses to our Call for Inputs[128] that indicated that these types of deployment, which are biased towards uplink traffic, were under consideration for these bands at this stage.

9.42 These uplink heavy applications are not necessarily data intensive and may still be practical using a download heavy traffic frame structure; however, it might not be the optimal use of spectrum for the application.

Change of requirements in the future

9.43 It is difficult to predict traffic profiles or network requirements in the future. However, it is reasonable to think licensees may want some flexibility in setting their traffic frame

[127] http://www.3gpp.org/DynaReport/FeatureOrStudyItemFile-580027.htm
[128] 2.3 and 3.4 GHz spectrum award: consultation on a 3.4 GHz band plan, varying UK Broadband Limited's licence and a call for inputs on other aspects of the award , http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/

structure proportions in order to respond to different scenarios or changing business cases.

9.44 In an Ericsson paper (2012)[129] the authors state: "*In most measured networks, there have been no major changes in uplink/downlink traffic ratios for the past two years. However, there are a few exceptions, the ratio of uplink traffic volume has slightly decreased in a few mobile PC-dominated networks with high P2P application usage (mainly in Asia). This is a result of increasing smartphone traffic volume shares and hence decreasing P2P traffic share from mobile PCs. On the other hand, the proliferation of online storage services (such as Google Drive and iCloud) and increasing popularity of mobile photo and video uploads to social networking sites will increase the uplink traffic volumes in the future*"

9.45 An input paper to International Telecommunication Union Study Group 5 from a telecommunications provider in the Nordic and Baltic countries[130], states that the load of the mobile networks have become unbalanced and the traffic in the downlink direction is about 10 times higher than in the uplink direction. Only in two years the difference between the uplink and downlink traffic has increased from 1:2 to 1:10.

Summary of our comments and further consultation

9.46 In consideration of what we have set out above:

i) it is our priority that licensees can 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;

ii) we acknowledge that base station equipment that must have operator specific filters (to meet the restrictive mask) may lead to some inefficiencies in the spectrum use or additional costs that may be passed on to consumers;

iii) we wish to avoid inefficient use of spectrum which may cause additional costs that may be passed on to consumers and

iv) we wish ensure that licensees have some flexibility to change their frame structure proportions.

9.47 We also recognise the importance of giving some certainty in relation to deployment timescales and parameters at the time of the award, so bidders can assess how their plans fit with a proposed synchronisation profile and subsequently make more informed bidding choices.

9.48 We do not think that allowing the first operator to roll out services to dictate the frame structure (as highlighted by UK Broadband) would necessarily lead to the most efficient spectrum use for the whole band. This approach could potentially encourage some licensees to deploy early and may lead to a heavily biased uplink or downlink profiles being chosen. This would force the synchronisation profile based on the first mover. This may also encourage the deployment of the odd umbrella base stations to gain the first mover advantage.

[129] http://www.ericsson.com/res/docs/2012/ericsson-mobility-report-november-2012.pdf
[130] "Uplink-Downlink Assymetry in mobile LTE networks", TeliaSoneraAB, document reference R12-WP5D AR-C-0556

9.49 Instead, we are proposing two possible options that would enable licensees to deploy with the permissive masks without needing to come to agreements with neighbouring licensees. Both options assume some level of synchronisation.

9.50 We therefore are consulting on two possible options to encourage or mandate synchronisation. Specific details will be described in an Inter-operator Synchronisation Procedure (see paragraphs 9.80 to 9.91):

- 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 agreed 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 restricted 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.

9.51 With both options, the details of the required parameters will be provided by Ofcom under the licence by specifying a synchronisation procedure. In either option, there is some additional flexibility if licensees agree and propose amendments to this procedure. In certain circumstances there can be additional bilateral/multilateral agreements between the licensees in the band. For more information on the Inter-operator Synchronisation Procedure see paragraphs 9.80 to 9.91.

9.52 Our proposals on the suggested frame structure and the reasoning for this are set out below in paragraphs 9.63 to 9.72.

9.53 We have summarised what we believe are the key advantages and disadvantages of each option in Figure 11.

Figure 11: A table of the advantages and disadvantages of the different the two consultation options

Option 1	
Advantages	**Disadvantages**
Licensees can deploy immediately using either the proposed frame structure (or equivalent) and the permissive mask or any other frame structure and the restrictive mask.	Some bidding uncertainty may still exist as there may be some occasions were bidders won't want to use the defined frame structure and will need to make a decision about the amount of spectrum they need to account for a possible internal guard band. A licensee may also choose to acquire additional spectrum for an internal guard band to give additional protection of their base stations in light of the possibility of their neighbours not using the same synchronised frame structure.
Small cells can be deployed with the permissive mask as long as they use the required frame	

structure. We also discuss below a proposal to not require low power indoor small cells to synchronise and therefore they can use the permissive mask irrespective of the frame structure used.	
This option enables a range of different business models / applications to be adopted using a different frame structure albeit with the restrictive mask. Licensees retain flexibility (albeit at some additional cost of filters) to use different TDD frame structures in all or part of the network if they choose without reference to their neighbours. For example alternative frame structures in localised geographic areas such as stadium or indoor locations where it may be worth the additional costs. As there is a clear option for proceeding with no neighbour agreements, this may also make negotiations simpler for licensees.	This additional flexibility may increase the risk of interference for both the licensee that wishes to change its frame structure and the licensee that is on the agreed frame structure. A licensee using the agreed frame structure in the adjacent spectrum with the permissive mask could have a higher risk of being interfered with due to the selectivity performance of their base station, even if the neighbour has limited its emissions to the restrictive mask. However, we think for the licensee using the restrictive mask, some equipment designs with increased filter requirements for the downlink will result in increased protection from the neighbour transmissions in the uplink direction. The additional risk of interference is explained further in Annex 10 of this document.
Option 2	
Licensees can deploy immediately using the mandated frame structure. There is greater certainty at the time of the auction as to what neighbouring spectrum users will be doing. There will also be bidding certainty that internal guard bands will not be needed.	
There will not need to be any operator specific variants of base stations as they will all be using the permissive mask. This removes the difficulty for any small cells as these can be deployed with the permissive mask in all cases. As highlighted in Option 1, we also discuss below a proposal to not require some low power indoor small cells to synchronise with the permissive mask.	
Interference between adjacent licensees will be reduced as the neighbour will always be synchronised (unless agreed otherwise for specific locations).	Some of the advantages of TDD may be lost by imposing a fixed DL/UL frame structure, unless agreed otherwise between licensees. However, some frame structure combinations pose more risk of interference than others, therefore allowing for some flexibility in a controlled way may be a preferable option.

9.54 Both of the options described above meet our policy objective that spectrum can start being used shortly after the auction. This mitigates our concern that a delay in reaching agreements between licensees will result in spectrum being left unused for some time.

9.55 Option 1 has the potential for some increased risks of interference in certain scenarios, but it also offers the benefits of greater flexibility over Option 2.

9.56 With Option 1, it is possible to have one licensee operating with the preferred frame structure and the permissive mask, whilst the neighbour licensee is using the restrictive mask with a different frame structure. In some frame structure combinations there would be a downlink to uplink clash. A licensee's base station could be receiving the uplink when a base station in adjacent spectrum is transmitting on the downlink; in this case there may be some desensitisation[131] of the receiving base station.

9.57 When licensees are using the permissive mask, there is potential for interference from the high power transmissions in neighbouring spectrum to occur over reasonably large distances. This can be possible from more than just the immediately adjacent licensees. 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. The risk increases if the spectrum is used for macro cells with a downlink heavy or even a downlink only frame structure.

9.58 These risks do not occur with Option 2. We recognise that Option 2 therefore provides a greater certainty over the interference environment. However, there is less scope for flexibility in using different frame structures. There may still be some scope for flexibility in Option 2 with indoor small cells and depending on the success of co-operation between licensees.

9.59 Some frame structure combinations pose more risk of potential interference than others. We recognise that due to the asymmetric interference risk, there may be some benefit for licensees to agree some flexibility in a controlled way. For example, it may be more difficult to co-ordinate a heavier downlink option, due to increased risks of interference to users of neighbouring spectrum. Conversely, it may be easier to agree a more uplink heavy configuration due to a lower risk of interference to neighbours base stations. These negotiations are possible under either Option.

9.60 For more information on the risk of interference of Option 1 and potential preferable configurations to be used with managed flexibility through the Inter-operator Synchronisation Procedure, see Annex 10.

9.61 As set out below, our research shows that networks typically have a capacity requirement that is heavier in the downlink than the uplink. In many cases there are clear advantages of synchronisation for downlink heavy traffic profiles, in terms of both utilising more spectrum available and using it efficiently. Taking these benefits into account, flexibility to use another traffic profile with the restrictive mask for another downlink heavy frame structure may only have limited value.

9.62 We currently have no preference for one option over the other. We therefore seek further views and evidence to assist us in reaching our decision.

[131] Desensitisation levels represent a noise rise at the base station so that the capacity, throughput and the maximum range of the cell are potentially reduced.

Uplink / Downlink Profiles

9.63 When considering our proposals for synchronisation, we need a particular frame structure that is not a significant compromise for any licensee within the band.

9.64 Sandvine[132] reports that the proportion of mobile downlink traffic is currently several times larger compared to mobile uplink traffic, see Figure 12.

Figure 12: Mean monthly ratio of downlink to uplink traffic

Continent	Mean monthly ratio of downlink to uplink traffic[133].
Europe	5:1
North America	7:1
Asia-Pacific	8:1

9.65 In response to our technical consultation, Huawei also provided us some commercial examples of TD-LTE configurations chosen to date. These all use a ratio of 3:1. Some confidential responses also suggested that as long as the extreme downlink or uplink heavy cases were avoided, then any of the remaining downlink orientated cases would be acceptable.

9.66 Within 3GPP there are ongoing discussions[134] around making available configurations for TD-LTE for supplementary downlink, for example a frame structure of 10:0:0, but we understand that this is not supported by all industry stakeholders.

9.67 We therefore think that it is reasonable to assume an initial position that a TDD frame structure with a greater proportion of downlink sub-frames would support most traffic profiles to date.

9.68 Some stakeholders have indicated in their responses to our Call For Inputs[135] that the 3.4 GHz band in particular could be used for small cell backhaul and potentially a radio access solution later. We assume that the proportion of traffic is similar for both requirements.

9.69 Whilst we propose that the licences are issued on a technology neutral basis, the harmonisation for the bands and discussions with stakeholders suggest that TD-LTE is the candidate technology most likely to be deployed using the spectrum. Where we must define some technology specific parameters in order to enable the permissive mask to be used, we have used those based on TD-LTE.

[132] https://www.sandvine.com/downloads/general/global-internet-phenomena/2014/1h-2014-global-internet-phenomena-report.pdf

[133] It should be pointed out that the traffic asymmetry and spectrum asymmetry are two different terms, even though they are closely correlated. For example, in a LTE FDD network a cell average traffic throughput on the downlink could require multiple times more spectrum when carried on the uplink.

[134] http://www.3gpp.org/DynaReport/FeatureOrStudyItemFile-580027.htm

[135] 2.3 and 3.4 GHz spectrum award: consultation on a 3.4 GHz band plan, varying UK Broadband Limited's licence and a call for inputs on other aspects of the award, http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz/

9.70 Around the world existing WiMAX operators are increasingly migrating their networks so that they are also compatible with LTE. There are plans for more convergence between WiMAX and LTE, in particular to enable WiMAX networks to take advantage of the economies of scale that is increasingly available for LTE networks[136].

9.71 However, WiMAX remains a candidate technology, potentially more likely for small cell backhaul or fixed deployments in the 3.4 GHz band. WiMAX has an option of a number of frame structures, of which some are very similar to TD-LTE frame structures. However WiMAX standards at the moment only offer frame structures where the downlink proportion is greater or equal to 50% and a frame length of 5ms. At the present time only the LTE configurations 1 and 2 (2:2 and 3:1) meet these requirements[137].

9.72 TD-LTE configuration 2 (a 3:1 profile) is also consistent with the views presented above that traffic is likely to be biased towards more downlink than uplink. Our proposals are therefore based around this TD-LTE configuration or equivalent frame structure[138] if a different technology is used.

Synchronisation of small cells

9.73 In response to our February Consultation, Bolloré Telecom suggested that synchronisation should not be required for indoor small cells due to mitigating factors such as low power, average inter-femto cell distance and wall penetration loss.

9.74 For the purposes of this exemption from synchronisation, we define small cells as operating at a power levels not exceeding 24 dBm EIRP per carrier.

9.75 To date, base stations are typically synchronised using the clock signal from GPS satellite reception[137]. For indoor deployments there may be additional challenges to synchronise where the satellite signal cannot be easily received. ECC Report 216[10] gives an outline of the status of technologies available to facilitate synchronisation, including whether the technology is available for both LTE and WiMAX and the scope of the technique to be used for indoor base stations. The Small Cell Forum has also produced a report[139] on synchronisation for LTE small cells. There are various options for synchronising indoor base stations, however we recognise there may be some additional challenges in an indoor environment.

9.76 Work is progressing within 3GPP to update the standard to define mechanisms for dynamically changing the UL/DL configurations in small cells to suit different traffic scenarios. Their analysis shows that there can be some benefits to the capacity of a network to dynamically change the UL/DL configurations depending on traffic conditions and the interference environment.

9.77 We have assessed the interference risk in different scenarios in Annex 9. This includes small cells to small cells interference in domestic environments, and small cells to macro cells in other environments. Our analysis suggests that if small cell equipment is compliant with the 3GPP standard for out-of-band emissions, there is a very limited risk of interference to other small cells in domestic environments.

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[136] http://www.wimaxforum.org/press-release/a-plan-for-wimax-advanced-in-support-of-td-lte-convergence

[137] ECC Report 216, “Practical guidance for TDD synchronisation.”, http://www.erodocdb.dk/doks/doccategoryecc.aspx?doccatid=4

[138] An equivalent frame structure is when downlink and uplink sub-frames are aligned and transmitted at the same time.

[139] SCF075 Synchronisation for LTE small cells, http://www.scf.io/en/documents/all_documents.php

9.78 Indoor small cells may be deployed in a similar environment to higher power macro cells, for example, shopping centres, sport's stadiums, train stations. There could therefore remain some risk of interfering with macro cells if they are particularly close by, e.g. within approximately 100 – 325m, if they are not synchronised. For further information on this calculation including additional mitigating factors which could reduce this estimated distance see Annex 10.

9.79 In light of what is set out above, we propose that small cells in these environments, if they used an EIRP of less than 24 dBm per carrier, would not need to be synchronised.

Inter-operator Synchronisation Procedure

9.80 For each of the two options to encourage inter-operator synchronisation and use of the permissive mask we propose to impose under the licence an Inter-operator Synchronisation Procedure that licensees would have to comply with in order to use the permissive mask.

9.81 ECC Report 216[140] states that agreement needs to be reached on the following issues in order to deploy synchronised TDD mobile networks in a multi-operator context (without guard bands).

a) A common phase clock reference (e.g. UTC[141])

b) and accuracy/performance constraints, either using their own equipment to provide the clock, or sharing the same phase/time clock infrastructure;

c) A compatible frame structure (including TDD UL/DL ratio) in order to avoid uplink/downlink transmissions overlapping;

d) 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.

e) The terms & conditions where cross-operator synchronisation must apply and/or may not be required (e.g. geographical areas, isolated base stations/deployments…);

f) How to update those parameters.

The report advises that Inter-network synchronisation conditions can be agreed at the national level and implemented nationwide or limited to a given area (regional) as appropriate.

Our proposal

9.82 The licence will require compliance with the Inter-operator Synchronisation Procedure and will specify the conditions under which the permissive mask may be used. In order to provide certainty to bidders at the time of the award, we propose that an initial version of this procedure will form part of the Information Memorandum and will subsequently be issued with the licences.

[140] ECC Report 216, "Practical guidance for TDD synchronisation.", http://www.erodocdb.dk/doks/doccategoryecc.aspx?doccatid=4
[141] Co-ordinated Universal Time

9.83 We have held some informal conversations with some equipment manufacturers in order to determine what might be a suitable set of initial parameters that will enable synchronisation – these are provided in Figure 13 below. We propose that a separate procedure will be issued for each band as the licensees will likely be different and those procedures can therefore be separately developed over time as necessary. We welcome comments against our proposals.

Figure 13: Proposals for key criteria in Inter-operator Synchronisation Procedure

Criteria	Our proposal
A common phase clock reference	An agreed time for the start of the frame aligned with UTC (Co-ordinated Universal Time).
A compatible frame structure	TD-LTE configuration 2 (also referred as 3:1) or an equivalent[142] 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[142] guard period if a different technology is used.
Accuracy/performance constraints	We propose that there should be alignment to the reference clock with an accuracy of +/- 3 µs. The ECC Report 216 highlights for current mobile technologies the order of magnitude of clock drift between base stations is about 1 to 3µs.
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.	We are concerned that there is not undue delay holding up licensees wanting to use the spectrum. It may not be critical that this is defined straight away if there are limited deployments. Once licensees start using adjacent blocks of spectrum in similar locations, it would be helpful to have this issue addressed. This could be a mutual commitment to identify misalignments with the reference clock by more than 3 µs and rectify it within 24 hours of an issue being identified.
The terms & conditions where cross-operator synchronisation may not apply/be required	Cross operator synchronisation is required to use the permissive mask on a national level for all types of deployments, except **indoor[143] small cells** using an EIRP less than or equal to 24 dBm per carrier.
How to update the Inter-operator Synchronisation Procedure	Licensees to inform Ofcom of any proposal to change. Ofcom to update Inter-operator Synchronisation Procedure and to send updates to licensees. This is further explained in the paragraphs below.

9.84 We are seeking views from stakeholders on the Inter-operator Synchronisation Procedure to allow bidders to have the necessary certainty so that they may

[142] 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.
[143] "Indoor use" means inside buildings or places in which the shielding will typically provide the necessary attenuation to protect wireless telegraphy against harmful interference.

determine how they may use the spectrum and how much spectrum they require for their plans.

9.85 Our proposals detailed above are as simple as possible and will apply to all circumstances of deployment. We therefore recognise that once the award is complete that licensees may wish to include additional relevant details or define particular circumstances where different conditions should apply. We anticipate within the first 12 months is a likely timeframe. If all licensees agree, then Ofcom will issue an updated version of the procedure for the relevant band(s). We expect any changes will be software configurable and so we do not expect any discussions or resultant revision to prevent any licensee from deploying immediately after the award without risk.

9.86 We also expect that changes in consumer behaviour and developments in technology may require changes to be made to the Inter-operator Synchronisation Procedures over time that better suit the needs of the licensees.

9.87 Commission Decision 2014/276/EU (for 3.4 GHz) and ECC Decision (14)02 (for 2.3 GHz) state that less stringent technical parameters may be used if agreed between licensees; this may cover synchronisation issues or other technical parameters. These less stringent technical parameters need to be agreed within the Inter-operator Synchronisation Procedure and may include and are not limited to:

- Advances in capabilities in technology over time may allow different scenarios to be considered;

- Permanently deciding that some transmitters in some physical areas use a different synchronisation profile with the permissive mask.

9.88 We would expect the licensees seek consensus amongst themselves before proposing changes to Ofcom. There may also be circumstances where Ofcom issues a new version of the procedure despite not all licensees being in agreement with the change. In these circumstances, we will be guided by our duties under the WT Act and any change will be subject to consultation with the relevant parties. Licensees can approach Ofcom with proposed changes to the procedure, however we would look favourably on those proposals that have the agreement of all licensees.

9.89 Ofcom's role would be to issue each subsequent version of the Inter-operator Synchronisation Procedure. Ofcom will issue a new version of the procedure to all licensees.

9.90 There may also be cases where temporary bi-lateral or multi-lateral agreements are appropriate. For example, where licensees wish to make temporary deployments to service a particular sporting or national event. Under these circumstances it may be more appropriate for licensees to come to bilateral or multilateral agreements with each other. The licensees would have to ensure that they were not causing interference to other licensees not included in the agreement. In the event of any disagreement about interference, Ofcom would request to see evidence of the bilateral or multilateral agreements.

9.91 We seek views on the details required to give sufficient certainty at the time of the award and to allow for deployments to occur without delay. We are seeking views both on the proposed parameters and on the level of detail in our proposal. Following responses to this consultation, we may also conduct discussions with relevant stakeholders if we think it necessary to clarify or further develop our proposal.

Part 2: Power limits

Summary of our consultation position on power limits

9.92 The two tables below show the power levels we proposed in the February Consultation for base stations and user terminals. The out-of-block limits apply to the permissive and restrictive mask, were discussed in Part 1 of this chapter.

Figure 14: Power limits 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	
Out of block baseline power limit (BS)	**Permissive mask (synchronised)**	**Restrictive mask (unsynchronised)**	**Permissive mask (synchronised)**	**Restrictive mask (unsynchronised)**
	Min(PMax [144] – 43, 13) dBm / 5 MHz EIRP per antenna	-36 dBm/5 MHz EIRP per cell	Min(PMax – 43, 13) dBm /5 MHz EIRP per antenna	-34 dBm /5 MHz EIRP per cell
	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**	**-10 to -5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge**	**-5 to 0 MHz offset from lower block edge 0 to 5 MHz offset from upper block edge**	**-10 to -5 MHz offset from lower block edge 5 to 10 MHz offset from upper block edge**
	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna	Min(PMax – 40, 21) dBm / 5 MHz EIRP per antenna	Min(PMax – 43, 15) dBm / 5 MHz EIRP per antenna
	The transition region extends below 2350 MHz and above 2390 MHz.		The transition region extends below 3410 and above 3600 MHz.	
Other levels to protect MoD systems	Below 2340: -36 dBm / 5 MHz EIRP per cell		Below 3400: -59dBm / MHz EIRP per cell[145]	
Coordination requirements	Yes		Yes	

[144] Where PMax is the maximum carrier power for the base station in question, measured as EIRP and is used in the baseline and transitional region levels.

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

Figure 15: Power limits for user terminals

	2.3 GHz		3.4 GHz	
In block power limit	Mobile or nomadic Radio Equipment	Fixed or installed Radio Equipment	Mobile or nomadic Radio Equipment	Fixed or installed Radio Equipment
	25 dBm TRP[146] (Licence exempt)	25 dBm EIRP (Licence exempt)	25 dBm TRP (Licence exempt)	35dBm/5 MHz EIRP (Not licence exempt)

Summary of responses and our comments

9.93 The majority of our proposals in relation to technical licence conditions were the same or similar for each of the 2.3 GHz and 3.4 GHz band. Unless otherwise indicated, stakeholder responses summarised below, and Ofcom's further comments relate to both bands.

9.94 We have provided our current view against the responses received. There are however some dependencies on our decisions around technical coexistence with adjacent services and the further proposals in this consultation. We will therefore be making our final conclusions in a statement next year.

Maximum in band power limit for base stations

Summary of responses

9.95 The majority of respondents agree with our proposed maximum in power limit for base stations in both bands. However there were two requests from confidential respondents to allow for a higher transmit power in some circumstances. They highlighted that there may be some cases where a higher power may be useable without detriment to other users. For example higher powers could be allowed for limited antenna heights or restricted only at specific locations that need additional protection.

Our comments

9.96 We expressed in the February Consultation that:

- For the 2.3 GHz band, we did 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.
- A higher EIRP in the 3.4 GHz band would likely require additional coordination requirements around a number of users which in some cases would be impractical to implement.

9.97 No respondents have suggested that we have been too cautious in our analysis of the coexistence with these systems and therefore we remain of the view that the in-

[146] 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.

block powers that we consulted on should not be increased. We will provide an update and in some cases further analysis of compatibility of mobile broadband systems using the bands with other systems in adjacent bands in a technical update later this year.

Maximum in band power limit for user terminals

Summary of responses

9.98 The majority of respondents agree with our proposed maximum in power limit for user terminals in the 2.3 GHz and 3.4 GHz band.

9.99 Huawei proposed a higher power for the 3.4 GHz mobile or nomadic radio equipment of 32 dBm (licence exempt) instead of our proposal of 25 dBm. For fixed or installed user terminals they proposed a higher power of 32 dBm instead of our proposed 25 dBm for 2.3 GHz terminals, and 45 dBm / 5 MHz instead of our proposal of 35 dBm / 5 MHz for the 3.4 GHz terminals. It was suggested that these higher power 3.4 GHz fixed terminals should still need to comply with any relevant cross border requirement.

9.100 Although EE agreed with our proposal, it had some concern about the risk of interference to base stations from a fixed terminal device being used at a high height. In particular it was concerned that the 35 dBm / 5 MHz EIRP for 3.4 GHz fixed or installed user terminals is too high with UE antenna height more than 1.5 m, as it may create interference to the adjacent licensee uplink due to the limitation of base station receiver selectivity/blocking. They also highlighted that the base station adjacent channel selectivity/blocking is specified by 3GPP for mobile user equipment at 1.5m height at ground level; and that CEPT has not studied the impact on the adjacent block uplink due to fixed or installed radio application with UE antenna height at more than 1.5m.

9.101 The European Hearing Instrument Manufacturers Association (EHIMA) and Siemens proposed that the in band power for 2.3 GHz user equipment should be lower in the top 3 channels, which we understand after clarification to mean between 2360 and 2390 MHz.

Our comments

9.102 Our proposed user terminal powers for 2.3 GHz are consistent with the least restrictive technical conditions presented within ECC Decision (14)02 and those put forward in draft CEPT Report 55 in response to the Commission's Mandate. The work done to date has taken into consideration systems above 2400 MHz. As part of our ongoing work on technical coexistence, we are working with EHIMA to undertake further measurements and testing for relevant systems above 2400 MHz and plan to publish the results of this work later this year.

9.103 The European Commission Decision 2014/276/EU sets out a power limit of 25 dBm for both the mobile and fixed user terminal in the 3.4 GHz band. However, it states "*Member States may relax the limit set out in Table 7 under certain circumstances, for example fixed terminal stations, provided that protection and continued operation of other existing use in the 3400-3800 MHz band is not compromised and cross-border obligations are fulfilled."* CEPT Report 55 and ECC Decision (14)02 has a very similar provision for the 2.3 GHz band.

9.104 We auctioned the 2.6 GHz band early in 2013 with the licence allowing fixed user terminals to use a higher power of up to 35 dBm / 5 MHz. This aligns with our proposal for in the 3.4 GHz band. We are not proposing to allow for higher user terminal powers in the 2.3 GHz band due to concern of interference to both MOD systems and other systems and remain of the view that 25 dBm TRP is appropriate for the 2.3 GHz band.

9.105 Linkem Network and Aria Network[147] have successfully deployed synchronised networks in Italy for customers with fixed user terminals with EIRP's of the order of 37 dBm in the 3.4 GHz band[148], suggesting that the use of higher power fixed terminals is possible.

9.106 We acknowledge that there may be specific geometries and circumstances whereby a high power fixed terminal could cause some desensitisation of a base station in neighbouring spectrum. However, we believe that it is likely that fixed user terminals will be adapted from transmitters for mobile user equipment, with the additional EIRP provided by a directional antenna, thereby limiting this additional power to some directions only. Additionally, in practice, fixed user equipment may use power control (if adapted from mobile user equipment), so will transmit when needed only at the power level required; meaning in many instances it may not be using the maximum licensed power. Fixed terminals may also be deployed on the side of a building providing some screening from the fixed terminal in certain directions.

9.107 We believe that, in the unlikely event some interference did occur to a neighbouring base station, then this would reduce the quality of the signal and result in some degradation of throughput whilst the fixed terminal was transmitting. Complete loss of service would therefore be highly unlikely.

9.108 We would like to enable the least restrictive technical conditions without onerous regulatory requirements to facilitate higher powers being used for fixed user terminals. We believe that the higher powers for fixed user terminals that we have proposed for the 3.4 GHz band may be helpful for business models that wish to use the spectrum for small cell backhaul. Some responses to our previous Call for Inputs suggested this may be the case in the short term.

9.109 Our proposal remains that fixed user terminals with an EIRP greater than 25 dBm are not licence exempt; therefore we would expect that a fixed terminal using a higher power would also have to comply with the relevant synchronisation requirement for the band.

Other issues put to Ofcom

9.110 EE expressed concern with the proposed out of band power limits below 3400 MHz. "*To facilitate the widest equipment economies of scale we urge Ofcom to adopt least restrictive equipment harmonized standards. In this context we note that the country specific CEPT Report 49 requirements for protection of military radar below 3400 MHz of -59dBm/MHz EIRP are excessively challenging for a system deployed at 3410 MHz and would prevent operator purchase of standard supplier equipment. We suggest that discussion occurs between Ofcom and the MOD with a view to relaxing*

[147] "Issues relevant to a preferred frequency arrangement for the 3.4-3.6 GHz band - Italy, Best Practice on Synchronization for 3.4-3.6 GHz band", ECC PT1 meeting 43, Berlin, 2-3 May 2013.
[148] They indicated that fixed user terminals had transmit powers going into the antenna of 23dBm up to 27dBm, with antenna gains ranging from 2dBi up to 14 dBi. We have assumed a 23 dBm transmitter has a 14 dBi antenna gain, to give an EIRP of 37 dBm.

the requirements of CEPT Report 49 options A and B to an EIRP of -59dBm/MHz EIRP at 3350 MHz". Huawei and a confidential respondent also expressed some concerned over the power level below 3400 MHz.

9.111 Two confidential responses along with Huawei also raised concern with the proposed out of band power limits below 2340 MHz. It was highlighted that unlike the additional baseline at 3.4 GHz, the one required by Ofcom for the 2.3 GHz band is specific to the UK and will increase costs of supplied equipment.

9.112 The Bluetooth Special Interest Group highlighted that Ofcom needs to consider the new out-of-band emission limits above 2403 MHz that are the result of the recent work for the EC Mandate.

Our comments

9.113 We are working with MOD to see if more relaxed limits could be used in practice below 2340 MHz and below 3400 MHz whilst still ensuring that there is adequate protection of MOD systems.

9.114 We are specifically working to see whether the requirement to protect MOD systems below 3400 MHz can be relaxed to -50 dBm / MHz (option B baseline limit, from the Commission Decision 2014/276/EU).

9.115 We are also discussing with MOD whether the baseline level below 2340 MHz can be relaxed in certain circumstances (noting that we have already proposed that transition regions will apply between 2340 and 2350 MHz). Huawei proposed in its response that pico and femto cell should have a baseline of -15 or -19 dBm / 5 MHz respectively below 2340 MHz. The discussions with MOD are ongoing, however we are investigating whether the requirement can be relaxed from -36 dBm / 5 MHz to around -20 dBm / 5 MHz in certain conditions (likely to be limited to small cells) which would be similar to the proposal from Huawei and another confidential response.

9.116 We are minded that we should relax these levels where possible in order to allow deployment of generic equipment (of all cell sizes). The technical analysis is still ongoing with the MOD in order to support these proposals to relax the baseline levels in these two circumstances and we will confirm in our subsequent statement.

Further consultation

9.117 The Commission Decision for the 3.4 GHz band requires that femto cells use power control. This is also provided for in the ECC Decision for the 2.3 GHz band. This comes from the need to reduce interference from equipment that may be deployed by consumers and may thus not be coordinated with surrounding networks. We propose that this should be incorporated within our licence for both bands.

9.118 Since our technical consultation in February, the ECC Decision (14)02 has been finalised with new out-of-band limits to protect systems above 2400 MHz. We propose to apply this limit to our licenses within the 2.3 GHz band.

9.119 Figure 16 shows the additional baseline requirements above 2400 MHz for unsynchronised and synchronised base stations. Coexistence analysis showed that they need to apply at frequencies above 2403 MHz. We propose to adopt these limits in line with the rest of Europe.

Figure 16: Additional baseline requirements above 2403 MHz BS BEM out-of-band EIRP limits

BEM element	BS EIRP	Power limit
Additional baseline	P_{Max} > 42 dBm	1 dBm / 5 MHz
Additional baseline	24 dBm < P_{Max} ≤ 42 dBm	(P_{Max} -41) dBm / 5 MHz
Additional baseline	P_{Max} ≤ 24 dBm	-17 dBm / 5 MHz

9.120 In addition, we note that the licence conditions that UK Broadband has for its spectrum above 3605 MHz are not the same as those that we propose for the 3.4 GHz band award (including UK Broadband's spectrum at 3480- 3500 and 3580 – 3600 MHz). We therefore propose that the restrictive baseline level shall 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.

Question 9.1: 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.*

Question 9.2: Do you agree with our proposed frame structure of LTE configuration 2 or equivalent*?*

Question 9.3: Do you agree with our proposal that indoor small cells, with power levels up to 24 dBm EIRP, do not need to synchronise?

Question 9.4: Do you agree with our approach in the Inter-operator Synchronisation Procedure?

Question 9.5: 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?

Question 9.6: 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.

Question 9.7: Do you agree with our approach for power control for femto cells?

Question 9.8: Do you agree with our position to adopt the new power limits above 2403 MHz?

Question 9.9: 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?

Question 9.10: Do you have any other comments on the proposed technical licence conditions and the draft licences attached at annexes 8 and 9?

Section 10

Next Steps

10.1 As part of this consultation, we will hold a workshop in December 2014 to discuss our proposals. Room will be limited, but anyone interested in attending should contact Ofcom as soon as possible using this response address: Spectrum.award.event@ofcom.org.uk

10.2 Once we have considered all the consultation responses, we will publish, in draft, proposed Regulations that detail the arrangements and processes for the auction. We expect at the same time to publish a statement and information memorandum.

10.3 We will also publish shortly a technical update relating to the award. This will focus on responses to our February 2014 consultation on coexistence with usage in adjacent spectrum bands, in particular relating to Wi-Fi and other licence–exempt uses and will provide details of further work we have done since. We will also provide an update on satellite and radar and coexistence. PMSE is dealt with in the statement referred to above and technical licence conditions are dealt with in this document.

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 23 January 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/howtorespond/form, 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 to the address below, marked with the title of the consultation.

Keith Gibbins
3rd Floor
Spectrum Policy Group
Riverside House
2a Southwark Bridge Road
London SE1 9HA

A1.5 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Keith Gibbins on 020 7981 3742.

Confidentiality

A1.8 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your

response should be kept confidential, can you please specify what part or whether all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.9 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.10 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk

Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish a statement in 2015.

A1.12 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/static/subscribe/select_list.htm

Ofcom's consultation processes

A1.13 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.14 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.15 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

A1.16 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 www.ofcom.org.uk/consult/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

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

To : Keith Gibbins, Spectrum Policy Group, Ofcom

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 ☐

Whole response ☐

Part of the response ☐

Name/contact details/job title ☐

Organisation ☐

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

Consultation questions

Question 4.1: Do you agree with our proposals for categories and lot sizes in the auction? If you disagree please provide evidence for your position.

Question 4.2: Do you have any other comments or views relating to the overview of the spectrum?

Question 5.1: Do you agree with our proposals for achieving contiguity, and if not please provide further explanation.

Question 6.1: Do you agree with our recommendation for an SMRA? If not, please explain why.

Question 6.2: 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?

Question 6.3: Do you agree with our proposals for the CCA? Do you have any other comments or views on this proposal?

Question 6.4: Do you agree with our proposals for the assignment stage? Do you have any additional views or comments?

Question 6.5: Do you have any other comments on auction design?

Question 6.6: 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?

Question 7.1: Do you agree with our approach to considering what spectrum is relevant to this competition assessment? Please give reasons for your views.

Question 7.2: Do you agree with our view that spectrum at 800 MHz, 900 MHz, 1.4 GHz, 1.8 GHz, 2.1 GHz (paired only), 2.3 GHz, 2.6 GHz and 3.4 GHz is relevant for this competition assessment? Please give reasons for your views.

Question 7.3: Do you agree that very asymmetric spectrum holdings could give rise to competition concerns? Please give reasons for your views.

Question 7.4: Do you agree with our proposal to impose an overall spectrum cap in the auction equivalent to the overall spectrum cap in the 2013 auction? If our assessment of what spectrum is relevant is correct, do you agree with the proposal for an overall spectrum cap at 310 MHz? Please give reasons for your views.

Question 7.5: Do you agree with our proposals to amend the Mobile Trading Regulations shortly before the PSSR award so as to include relevant spectrum at 1.4 GHz, 2.3 GHz and 3.4 GHz? Please give reasons for your views.

Question 7.6: Do you have any other comments on our assessment of competition effects from the award?

Question 8.1: 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?

Question 8.2: Do you have any comments on our proposals relating to the territorial extent in the award licences?

Question 8.3: Do you have any views on the merits of 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?

Question 8.4: Do you have any comments on other proposed non-technical licence conditions and the draft licences at Annexes 8 and 9?

Question 9.1: 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.

Question 9.2: Do you agree with our proposed frame structure of LTE configuration 2 or equivalent?

Question 9.3: Do you agree with our proposal that indoor small cells, with power levels up to 24 dBm, do not need to synchronise?

Question 9.4: Do you agree with our approach in the Inter-operator Synchronisation Procedure?

Question 9.5: 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?

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Question 9.7: Do you agree with our approach for power control for femto cells?

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Question 9.9: 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?

Question 9.10: Do you have any other comments on the proposed technical licence conditions and the draft licences attached at annexes 8 and 9?

Annex 5

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
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
ALF	Annual Licence Fees
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.
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.
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
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
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.
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.
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
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
WiFi	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

Annex 6

Illustrative auction procedures

A6.1 This annex sets out illustrative auction procedures for each of the auction formats we have proposed. This is to show how the auction might work in each case. This is not an attempt to draft Regulations for the award. The procedures will inevitably change as a result of amendments to the auction design, to take account of responses to this consultation or as we prepare the draft regulations. More work will be needed to develop the auction regulations and we shall consult again on draft regulations. We are publishing these illustrative procedures to help consideration of the practical implementation of the auction designs we propose.

A6.2 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. In the second stage (the 'assignment stage'), Ofcom will determine the specific frequencies to be assigned to each bidder.

Lot structure

A6.3 Use of frequency generic lots

A6.4 The award mechanism will consist of two distinct stages, as in other recent auctions run by Ofcom. In the first stage (the principal stage), the spectrum available will be offered as 'frequency-generic' lots grouped into 'lot categories'. Each frequency-generic lot will correspond to a 5 MHz block in a given frequency range, but will not be linked to specific frequencies. 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 to be assigned to each bidder in each category, i.e. the total bandwidth assigned to each bidder in each of the frequency ranges corresponding to lot categories.

A6.5 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 of the frequency ranges corresponding to lot categories, the potential 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.

A6.6 In the event there are alternative band plans in which some bidders would be assigned different frequencies, such bidders may be invited to bid for their preferred option.

A6.7 This approach minimises the scope for fragmented assignments within each band. It is expected that this will benefit all potential bidders by reducing uncertainty and simplifying bidding decisions in the principal stage.

A6.8 Spectrum packaging

A6.9 Following Ofcom's Call for Inputs in October 2013 and stakeholder responses to this consultation, the working assumption is that all lots in both the 2.3 GHz and 3.4 GHz bands will be assigned in 5 MHz blocks.

A6.10 The responses to the Call for Inputs suggest that bidders are likely to require a minimum bandwidth of greater than 5 MHz to be able to use the spectrum they acquire. Bidders may wish to acquire spectrum in blocks greater than 5 MHz to achieve efficient use of spectrum. Therefore, the proposed rules place specific emphasis on safeguarding bidders against outcomes where they end up winning spectrum but do not achieve their desired minimum bandwidth. Moreover, the proposed rules are designed to minimise the risk that bidders win only a subset of the lots they bid for beyond this minimum.

A6.11 Aggregation risks are absent with the CCA, but are a concern in the traditional SMRA auction format. To mitigate aggregation risks in the SMRA, we propose:

- to allow each bidder to optionally specify a minimum spectrum requirement of up to 20 MHz, in which case the bidder would not be awarded any lots on which they hold the Standing High Bid at the end of the SMRA bidding phase that are not consistent with their minimum requirement;
- to adopt a process for establishing standing high bidders that minimises the number of bidders who would win fewer lots than they have bid for in a given category; and
- to allow for the withdrawal of Standing High Bids, subject to a possible requirement to pay committed bids, in order to facilitate switching aggregations of lots across different categories.

A6.12 Lot categories

A6.13 The spectrum available would be offered in two generic lot categories

- 2.3 GHz: This category would contain eight frequency-generic 5 MHz lots in the frequency range 2350 MHz-2390 MHz; and
- 3.4 GHz: This category would contain 30 frequency-generic 5 MHz lots within the frequency range 3410 MHz-3600 MHz.

A6.14 Eligibility points

A6.15 The bidding process for the principal stage will proceed over one or more rounds (under both alternative auction formats). Bidding will be subject to activity rules to ensure that bidding is progressive, preventing bidders from withholding demand until relatively late in the auction. The specific activity rules proposed in each case are described in the sub-sections below; however, under both formats these involve measuring bidding activity on the basis of eligibility points, as follows:

- each lot will be assigned one eligibility point;
- 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.

A6.16 The activity rules are designed to prevent bidders from expanding their demand as prices increase. Bidders are attributed an eligibility level for each round, which determines what bids they can submit in the round. Bidders' eligibility levels are adjusted round by round with reference to each bidder's activity in the preceding round. As prices may only increase in the course of the auction, the eligibility level of a bidder may remain constant or decrease, but may not increase. Specifically, if the activity of a bidder is lower than the bidder's eligibility level in a given round, this will usually lead to a reduction in the bidder's eligibility.

A6.17 As all lots have the same bandwidth and eligibility points, bidders can switch between different categories on a MHz for MHz basis. Bidders may freely switch between combinations of lots with the same aggregate bandwidth without this affecting their eligibility for subsequent rounds. However, bidders may face some restrictions or trigger eligibility reductions when they reduce the total number of lots on which they submit or maintain bids.

Demand on application, initial deposit and qualification

A6.18 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 should 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.

A6.19 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 Information Memorandum and Regulations once these are published.

A6.20 After the deadline for withdrawal of applications, Ofcom will determine which applicants qualify as bidders for 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 bidders, and return the initial deposit to any applicants who fail to qualify.

A6.21 Before the first round of the auction takes place, qualified 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 number of lots that could be acquired by the bidder under the constraint that the sum of reserve prices for the lots 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.

A6.22 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

A6.23 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), as previous auctions run by Ofcom. 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.

A6.24 The auction will consist of two stages. In the first stage, the principal stage, bidders will bid for frequency-generic lots. On the basis of these bids, Ofcom will determine the bandwidth assigned to each bidder in each band. There follow two proposals for the procedures governing the bidding process in the principal stage for an SMRA auction or the alternative CCA. Following the principal stage, Ofcom will determine the assignment of specific frequencies to each bidder in the assignment stage. Bidders may be invited to bid for specific frequency ranges if there are alternative arrangements that would meet the conditions set by Ofcom for potential assignment band plans.

The principal stage

A6.25 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 (taking into account any bidder-specific round extensions in the CCA), 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 information about round results as specified within the rules for each format.

A6.26 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. The auction will then proceed to the assignment stage.

A6.27 Below we provide specific rules for the bidding process in the principal stage under each of the two shortlisted auction formats.

Option 1 - Simultaneous Multi-Round Ascending auction with generic lot categories

Overview of the bidding process

A6.28 The SMRA bidding process consists of one or more rounds in which 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 outbid 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 for a lot category does not meet the minimum requirement specified by the bidder for that lot category, explained below). Winners will then be required to pay the amount of their winning bids for the lots they have won.

Bids

A6.29 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, in the SMRA a bid will be for an individual lot; 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 a common round price will apply to all lots in each category, facilitating the making of bids through the EAS, where bidders will simply need to specify the number of lots sought in each category.

A6.30 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 is submitted).

A6.31 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.

A6.32 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 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.

A6.33 A bid is only valid if it is submitted during a round in accordance with the auction rules set out below.

A6.34 Bids submitted in the auction may only be withdrawn under specific circumstances and subject to potential penalties, as set out below.

Minimum spectrum requirements

A6.35 In their application, bidders may specify a minimum requirement ('MR') of up to four lots for each lot category. A bidder who specifies an MR will not be assigned any spectrum in a category if the number of lots they provisionally win at the end of the SMRA bidding process in that category is smaller than the MR they have specified for that category.

A6.36 Specifying an MR will also establish constraints on the bids that the bidder may submit. Specifically, the bidder will not be able to submit or withdraw any bids if this is not compatible with the bidder winning in each lot category either at least their MR or no lots at all.

A6.37 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 a lot category in their application will not, under any circumstances, be able to bid for, or win, fewer lots in that lot category than their MR.

The SMRA bidding process

A6.38 The SMRA bidding process will require one or more rounds, each round consisting of a fixed time window (subject to the provisions for extensions, described further below) 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 that will prevail in the 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 given round prices.

A6.39 Bidders may not specify a bid amount that differs from round prices.

Scheduling of rounds

A6.40 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.

A6.41 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 that will prevail in the round;
- the bidder's own eligibility level;
- the number of waivers the bidder has left (explained below);
- the standing high bids the bidder holds; and
- any applicable sums for which the bidder is currently liable in the event of a withdrawal (in accordance with the procedures set out below).

Bid submission during a round

A6.42 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 in the same submission. When a round is in progress, each bidder's EAS interface will provide a bid form.

A6.43 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 prevailing 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 and if the bidders bidding activity is less than the bidder's eligibility in the round, as explained 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.

A6.44 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.

A6.45 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.

A6.46 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.

A6.47 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.

A6.48 Bidders may not submit a waiver in the first round.

A6.49 A bidder may submit a decision not to place any bids in any round after the first round.

Valid bid combinations

A6.50 A bidder may only submit a combination of bids and withdrawals such that if the bidder were to win all of the bids submitted along with any standing high bids they may hold:

- the bidder would win, in each lot category, at least as many lots as their MR or no lots at all; and

- the bidder would not breach any applicable spectrum caps.

Bidding for lots when the bidder holds standing high bids

A6.51 Bidders may not submit any bids for lots in a lot category from which they are withdrawing existing standing high bids.

A6.52 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 increase their demand for lots in that category at the current price level by submitting 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

A6.53 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.

A6.54 Standing high bids in a lot category may only be displaced by bids for the same lot category submitted at a higher round price.

A6.55 For each lot category:

i) The EAS will determine the number of lots on which bids submitted in the round may become standing high bids (the 'remaining supply'). The lots in the remaining supply will include the following lots:

1. lots that had a standing high bid in the most recent round, but for which the standing high bid is cancelled due to the bidder submitting new bids for lots in that category in the most recent round in accordance with the rules above;

2. lots that did not have a standing high bid in the most recent round, or which had a standing high bid that was withdrawn in the most recent round;

3. lots that have a standing high bid at a price which is lower than the round price.

When assigning standing high bids, lots in the remaining supply will be provisionally assigned following the three-step order above. When displacing standing high bids for lots with a standing high bid at a price lower than the round price, the most recently established standing high bids will be displaced first.

ii) Bidders who submitted bids for lots in the lot category in the most recent round will be ordered at random, and each bid submitted in the most recent round will

be considered according to the bidder who has submitted the bid following this random order.

iii) The bids received in the most recent round for this lot category will become standing high bids on a lot in the remaining supply following the order of bids specified in (ii) and the order of lots specified in (i), until we have no more bids or no more lots in the remaining supply (whichever happens first).
In the event that the number of lots in the remaining supply exceeds the number of bids submitted in the most recent round in a given category, then:

- all bids submitted for lots in the category in the most recent round will become standing high bids; and

- some lots in the remaining supply will not be assigned a standing high bid from the bids submitted in the most recent round.

In the event that the number of lots in the remaining supply is smaller than the number of bids submitted in the most recent round in a given category, then:

- not all of the bids submitted for lots in that category in the most recent round will become a standing high bid, and it is possible that one bidder would end up holding standing high bids on fewer lots than they bid for; and

- all lots in the remaining supply will be assigned a standing high bid from the bids submitted in the most recent round.

A6.56 As a consequence of these procedures, 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.

Round prices

A6.57 For each round, Ofcom will specify the round price per lot for each lot category.

A6.58 In the first round, the round price for each lot category will be the reserve price for each lot in that category.

A6.59 In subsequent rounds:

- the round price will increase for lot categories in which all lots have a standing high bid at a price equal to the round price in the most recent round; and

- the round price for other lot categories will remain unchanged.

A6.60 Therefore, round prices may not decrease over the course of the rounds.

A6.61 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.

A6.62 Round prices will be specified in whole thousands of pounds.

Withdrawal of standing high bids

A6.63 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.

A6.64 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.

A6.65 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.

A6.66 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. In the event that several bidders withdraw their standing high bids, all of these bidders may be liable to pay.

Activity rules

A6.67 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.

A6.68 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).

A6.69 The activity of a bidder in a round cannot exceed the bidder's eligibility for that round.

Waivers

A6.70 Each bidder may submit up to three waivers during the auction. A bidder may submit a waiver (along with any bids they also wish to submit in the round) in any round in which their activity is lower than their eligibility, except the first 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.

A6.71 A bidder may submit a waiver even if they hold standing high bids on fewer lots than their MR, if applicable, in any lot category.

Default submissions

A6.72 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.

A6.73 The EAS will not make any other default submissions.

A6.74 To prevent the submission of a default waiver, bidders may submit a decision not to place any bids in the round, provided that doing so is consistent with the bidder either meeting their MR or not winning any lots in each lot category.

End of the SMRA bidding process

A6.75 The SMRA bidding process ends after the first round in which no bids, withdrawals or waivers (including default waivers) are submitted.

Determination of winning bids

A6.76 At the end of the SMRA bidding process, standing high bids will become winning bids, except for standing high bids held by a bidder in a category where the MR specified by the bidder exceeds the number of lots that the bidder holds standing high bids on.

Determination of base prices

A6.77 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 SMRA bidding phase

A6.78 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.

A6.79 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;
- which lot categories will require a price increment;
- the bidder's own eligibility level; and

- the number of waivers that the bidder has available for further rounds.

A6.80 At this stage, no information will be released about the bids submitted by other bidders.

A6.81 If the SMRA 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 SMRA 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.

A6.82 The EAS will provide the functionality to view and download the information provided after each completed round, once approved by the auctioneer.

Option 2 - Combinatorial Clock Auction

Overview of the bidding process

A6.83 The CCA bidding process consists of one or more clock rounds, followed by a Supplementary Bids Round. Unlike the SMRA, bids are made for packages of lots. After the Supplementary Bids Round, all bids submitted during the auction are evaluated in order to determine the feasible combination of bids that generates the greatest value.

Bids

A6.84 A bid consists of:

- a package of lots, specified as the number of lots in each lot category included in the package; and
- a bid amount, specified in whole thousands of pounds and which must be at least the sum of the reserve price of all lots included in the package.

A6.85 A bid applies only to the package of lots specified by the bidder, i.e. it will be considered in its entirety and will not be subdivided.

A6.86 During the clock rounds, bidders will be able to submit bids with bid amounts automatically determined by the EAS on the basis of prices set by the auctioneer. During the Supplementary Bids Round, bidders will be allowed to specify a discretionary bid amount for each of their bids, subject to a number of constraints explained below.

A6.87 Submitting a bid establishes a commitment to acquire, in the event that the bid is selected as a winning bid, the lots in the package for a total price that would be:

- at least the sum of the reserve price of all the lots included in the package; and

- no more than the bid amount specified in the bid.

A6.88 A bid is valid only if it is submitted during a round in accordance with the auction procedures set out below.

A6.89 Bids submitted in the auction cannot be withdrawn.

Revealed preference constraints

A6.90 We propose that the activity rules for the CCA use revealed preference constraints. These place restrictions on the bids a bidder can submit based on value differences implied by the bidder's earlier choices in some key rounds, as explained below.

A6.91 Suppose that a bidder chooses to bid package X over package Y when prices are PX and PY, respectively. A revealed preference constraint in relation to this choice would constrain the bid for Y to be at most:

- the current bid for X (which may have subsequently been increased above PX); plus
- the difference in prices when the bidder chose to bid for X instead of Y (PY - PX).

A6.92 This is the 'relative cap' on package Y.

A6.93 The relative cap requires that the final bids submitted by the bidder for X and Y be consistent with the preferences revealed in its choice. As a result, the bidder may only raise their bid for Y above the prices that applied when they made the constraining choice if they also raise their bid for X (the 'constraining package') in order to increase the relative cap on Y (the 'constrained package').

A6.94 Revealed preference constraints will determine the bids that a bidder can submit in the clock rounds and the Supplementary Bids Round. Specifically, revealed preference constraints will be applied in relation to choices made by bidders in rounds in which they lose eligibility due to a reduction in their bidding activity and in the final clock round. These constraints will result in relative caps, which may require the bidder to raise bids on packages for which they have bid during the clock rounds in order to be able to submit or raise bids for other packages. During the clock rounds, the revealed preference constraints arising from rounds in which a bidder has lost eligibility will determine which packages bidders may bid for in subsequent clock rounds. In some cases bidders may be able to bid for packages with an eligibility that exceeds their current eligibility level, although this may require the submission of 'chain bids' to raise the bid amounts on constraining packages. In the Supplementary Bids Round, revealed preference constraints will also limit the extent to which bidders may raise their bids for packages other than the package they have bid for in the final clock round. Further details are provided below.

The clock rounds

A6.95 A clock round consists of a fixed time window (subject to the provisions for extensions, described further below) 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 that will prevail in the round (the 'round prices');

- while the round is in progress, bidders may submit at most one clock bid, where the bidder specifies the package and the bid amount is calculated as the sum of round prices of the lots included in the package.

A6.96 Bidders may not specify a different bid amount for their clock bid.

A6.97 A clock bid applies only to the package selected by the bidder, and will not be decomposed into bids for subsets of the package at the corresponding round prices when selecting winning bids.

Scheduling of clock rounds

A6.98 Ofcom will specify in advance of the auction the minimum notice period that will be provided before the start of a clock round and a minimum round duration.

A6.99 When a round is scheduled, the following information will be made available to each bidder:

- the schedule for the round;
- the round price for each lot category that will prevail in the round;
- the bidder's own eligibility level; and
- the number of extension rights the bidder has available for the clock rounds (discussed below).

Bid submission during a clock round

A6.100 During each clock round, bidders may submit at most one clock bid using the bid form provided by the EAS.

A6.101 To submit a clock bid, a bidder will need to:

- specify, using the bid form provided by the EAS, the number of lots in each category that they wish to include in the package of their clock bid (the bid amount will be automatically calculated by the EAS as the sum of round prices of all lots included in the package);
- send the completed bid form to the auction server, so that the bid can be checked for validity against the auction procedures;
- provided that the bid specified by the bidder is valid according to the auction procedures, confirm submission of the clock bid (and any necessary chain bids, if applicable, as discussed below) using the confirmation form provided by the EAS.

A6.102 The bid submission process is only completed when the bidder has confirmed the submission. Bids sent to the server for validity checks but not confirmed will be discarded by the EAS.

A6.103 Upon receipt of a valid bid submission, the EAS interface will provide a confirmation page. Conversely, if the bid 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 the bid has been successfully received by the auction server, and to alert Ofcom if they suspect any problems have occurred.

A6.104 Once the auction server has received a confirmation of a valid bid submission in a round, the bidder will not be able to revise or withdraw this submission, or submit any further bids in the round.

A6.105 In the first clock round, each bidder must submit a clock bid for a package containing at least one lot. Any bidders who do not submit a clock bid in the first clock round will be excluded from the auction and may not have the full amount of their deposit returned.

A6.106 In subsequent clock rounds, bidders have the option to submit a 'zero bid', i.e. a bid for an empty package containing no lots (the 'zero package'). Any bidders who fail to submit a bid before the end of a clock round (taking account of any applicable extensions, as explained below) will have a zero bid automatically entered by the EAS on their behalf. A bidder who has submitted a zero bid in a clock round (either actively or by default due to failing to actively submit a bid) will not be able to submit any further clock bids (although they will still be able to submit bids in the Supplementary Bids Round).

Aggregate and excess demand

A6.107 At the end of each clock round, the EAS will calculate 'aggregate demand' in the round for each lot category as the sum of lots in that category included in all the clock bids submitted during the round. There is excess demand for a lot category in a given clock round if aggregate demand for that lot category in that round exceeds the number of lots available in that category. Conversely, there is no excess demand for a lot category if aggregate demand for that lot category in that round is less than or equal to the number of lots available in the category.

Round Prices

A6.108 For each clock round, Ofcom will specify the round price per lot for each lot category.

A6.109 In the first clock round, the round price for each lot category will be the reserve price for each lot in that category.

A6.110 In subsequent clock rounds:

- the round price for lot categories for which there was excess demand in the previous round will increase; and
- the round price for other lot categories will remain unchanged.

A6.111 Therefore, round prices may not decrease over the course of the clock rounds.

A6.112 The increase in round price of categories for which there is excess demand will be determined at Ofcom's discretion and may vary across lot categories and across clock rounds. Ofcom currently expects setting price increments of no less than 2% and no more than 20% from one clock round to the next.

A6.113 Round prices will be specified in whole thousands of pounds.

Package eligibility and bid activity

A6.114 Each lot available in the auction is assigned one eligibility point.

A6.115 The eligibility of a package is equal to the sum of eligibility points of all lots included in the package, and therefore is equal to the number of lots included in the package.

A6.116 The activity of a bid is equal to the eligibility of the package subject to the bid.

Bidder eligibility

A6.117 Each bidder will start each clock 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 smallest bid activity across all clock bids submitted by the bidder.

A6.118 Therefore, if a bidder submits a clock bid with an activity lower than the bidder's eligibility, then the bidder's eligibility for the following round will be reduced (and set equal to the activity level of the clock bid just submitted).

A6.119 Submitting a bid that leads to an eligibility reduction will also establish a revealed preference constraint on the bidder, as described below.

Revealed preference constraints in the clock rounds

A6.120 Clock bids for packages with eligibility greater than the bidder's eligibility level in the round will be subject to a revealed preference constraint in relation to the choice made in the last clock round in which the bidder had an eligibility level equal to or greater than the package eligibility.

A6.121 If round n is the last clock round in which the bidder's eligibility was greater than or equal to the eligibility of a package Y, and the bidder chose to bid for package X in round n, then the bidder may not submit a bid for Y that exceeds a relative cap defined as:

- the highest bid submitted by the bidder for X (which may be a bid submitted in an earlier round or a bid submitted along with the bid for Y, as explained below); plus
- the difference between the price of X and the price of Y in round n.

A6.122 We refer to the caps that result from these constraints as 'eligibility reduction caps'.

A6.123 A clock bid for a package with eligibility greater than the bidder's current eligibility level will be valid only if the bid amount is less than or equal to the corresponding eligibility reduction cap.

A6.124 Revealed preference constraints do not apply for packages with eligibility less than or equal to the bidder's current eligibility level.

Validity of clock bids

A6.125 Bidders may only bid for packages with eligibility no greater than the bidder's initial eligibility.

A6.126 Bidders may only bid for packages that they could acquire without exceeding any applicable spectrum caps.

A6.127 Bidders may only submit a clock bid if their eligibility level is greater than zero.

A6.128 Bidders may only submit a clock bid for a given package if:

i) the package has an eligibility that does not exceed the bidder's eligibility in the round; or

ii) the eligibility reduction caps on the bidder's clock bids are such that the bidder could submit a bid at round prices for the package without needing to increase its bid for any constraining package to an amount that exceeds the price of the constraining package at current round prices.

A6.129 In practice, this means that under some circumstances, a bidder may be able to submit a clock bid for a package with eligibility above that bidder's eligibility. Specifically, suppose that a bidder is subject to a revealed preference constraint which establishes an eligibility reduction cap on the bid they may submit for package Y, relative to their highest bid for package X and to the round prices prevailing in round n. Note that this also implies that the eligibility of the package exceeds the bidder's current eligibility level. The bidder would be able to submit a clock bid for Y if the difference in price between Y and X has decreased relative to the difference in round n such that a bid for Y would now be consistent with the value differences implied when they chose to bid for X instead of Y; i.e. the bid amount for X that would be required for the bidder to be able to bid for Y at prevailing round prices, given the revealed preference constraint, does not exceed the current price of X at prevailing round prices). It is also required that if the bid for X is also subject to an eligibility reduction cap, then any bid required on any constraining packages in order for the bidder to be able to bid for Y at round prices under their revealed preference constraints cannot exceed the price of the relevant constraining package at prevailing round prices.

A6.130 The clock bid entry form provided by the EAS will allow bidders to select a package with eligibility greater than the bidder's eligibility level. The EAS will then check whether the clock bid is valid given the bidder's eligibility reduction caps and the round prices in the relevant clock rounds, the minimum bid amounts for constraining packages that would be necessary for the bidder to be able to submit the clock bid, and whether the bidder would be required to submit any chain bids along with this clock bid (explained below).

A6.131 The EAS will also provide functionality to assist bidders in identifying when they may be able to submit a bid under (ii). Specifically, the EAS interface will allow bidders to maintain a list of provisional supplementary bids (explained further below). The list of provisional supplementary bids will automatically include all the non-zero packages for which the bidder has already submitted a clock bid. In addition, each bidder may enter additional packages in their list of provisional supplementary bids. When a clock round is in progress, the EAS interface will alert the bidder of the possibility of submitting bids under (ii) for any of the packages in their list of provisional supplementary bids.

Chain bids

A6.132 The bids submitted by a bidder must at all times satisfy the relevant revealed preference constraints. If the bidder wishes to submit a clock bid for a package with eligibility greater than their eligibility in the round, this may require increasing their bids for constraining packages. In this situation, the bidder will only be able to submit such a clock bid if they also submit any necessary bids for constraining packages at the minimum level required for the revealed preference constraints to be satisfied. We refer to these additional bids as 'chain bids'.

A6.133 Any chain bids submitted by the bidder are binding and may become winning bids. Note that chain bids will only be required for constraining packages, which therefore may only be packages for which the bidder has submitted a clock bid.

A6.134 The EAS will identify the need to submit any chain bids along with a clock bid in the clock bid entry form. The bidder will be presented with each one of the necessary chain bids. If the bidder wishes to submit these chain bids along with the clock bid, then the bidder will be required to confirm this in the form provided for confirming their bid submission. If the bidder does not confirm the submission of any chain bids that may be required, then the bidder will not be allowed to submit this clock bid.

End of the clock rounds

A6.135 The clock rounds end after a round in which there has been no excess demand for any lot categories. At this point, Ofcom will announce that the clock rounds have finished and that the auction will progress to the supplementary round.

A6.136 Ofcom may declare the end of the clock rounds earlier if we believe that moving directly to the Supplementary Bids Round would be in the general interest of running an efficient award process.

Information released at the end of a clock round

A6.137 At the end of each clock round the EAS will process clock bids to determine whether a further clock round is needed and, if so, any prices that need to increase. Information about a completed clock round will be made available to bidders only after the auctioneer approves the results for the clock round.

A6.138 If a further clock round is needed, the following information will be made available to each bidder on the EAS interface:

- the clock bid submitted by the bidder in the most recent clock round;
- the round prices for each lot category in the most recent clock round;
- which lot categories will require a price increment;
- the bidder's own eligibility level; and
- the number of extension rights they have available for the clock rounds (discussed below).

A6.139 If no further clock rounds are needed, then the following information will be made available to each bidder on the EAS interface:

- a message informing the bidder that the clock rounds have ended;
- the clock bid submitted by the bidder in the final clock round;
- the round prices for each lot category in the final clock round; and
- the aggregate demand for each lot category in the final clock round.

A6.140 No information will be released about the bids submitted by other bidders during the clock rounds.

A6.141 The EAS will provide the functionality to view and download this information for all completed clock rounds approved by the auctioneer.

The Supplementary Bids Round

A6.142 The Supplementary Bids Round consists of a single round of bidding in which bidders may submit bids ('supplementary bids') for alternative, mutually exclusive packages, regardless of whether the bidder submitted any clock bids for the same package. Supplementary bids are subject to the constraints set out below.

Scheduling of the supplementary round

A6.143 Ofcom will specify in advance of the auction the minimum notice period that will be provided before the start of the supplementary round and a minimum round duration.

A6.144 When the supplementary round is scheduled, the following information will be made available to each bidder:

- the schedule of the round;
- the bidder's provisional list of supplementary bids (explained below).

Revealed preference in the supplementary round

A6.145 Supplementary bids for packages with eligibility greater than the bidder's eligibility in the final clock round will be subject to an eligibility reduction cap in relation to the choice made in the last clock round in which the bidder had sufficient eligibility to bid for the package.

A6.146 If round n is the last clock round in which the bidder's eligibility was greater than or equal to the eligibility of a package Y, and the bidder chose to bid for package X instead, then the bidder may not submit a supplementary bid for Y that exceeds a relative cap defined as:

- the highest bid for X that the bidder has submitted in the clock rounds or submits in the Supplementary Bids Round; plus
- the difference between the price of X and the price of Y in round n.

A6.147 If the bidder submitted a valid bid for a non-zero package in the final clock round, supplementary bids for all packages except the 'final clock package' (the package bid for in the final clock round) will be subject to an additional revealed preference constraint in relation to the choice made in the final clock round.

A6.148 If the bidder bid for (non-zero) package X in the final clock round, then the bidder may not submit a bid for any other package Y that exceeds a relative cap defined as:

- the highest bid that the bidder submits for X; plus
- the difference between the price of Y and the price of X in the final clock round.

A6.149 We refer to the caps that result from these constraints as 'final price caps'.

A6.150 In the event that the final clock package had an eligibility less than or equal to the bidder's eligibility in the final clock round, the bid for the final clock package will be unconstrained. However, it is possible that bids for the final clock package are subject to an eligibility reduction cap. In this case, all of the bids that the bidder may submit in the Supplementary Bids Round will be subject to at least one revealed preference constraint.

Constraints on supplementary bids

A6.151 There will not be a cap on the number of packages for which a bidder may submit supplementary bids. However, bidders may only submit supplementary bids in accordance with the constraints set out below.

A6.152 Bidders may submit at most one supplementary bid for each possible package.

A6.153 Bidders may not submit a supplementary bid for a package containing zero lots.

A6.154 Bidders may only submit supplementary bids for packages with eligibility no greater than the bidder's initial eligibility.

A6.155 Bidders may only submit supplementary bids for packages that they could acquire without exceeding any applicable spectrum caps.

A6.156 Bidders may specify a discretionary bid amount for each of their supplementary bids subject to the following restrictions:

- Bid amounts must be in whole thousands of pounds.
- The bid amount for each package must be at least the sum of the reserve price of all the lots included in the package.
- The bid amount for each package must be at least the highest bid (clock or chain) already submitted by the bidder for the package.
- The bid amount for each package must not exceed the applicable eligibility reduction cap or final price cap determined by the bidder's revealed preference constraints established during the clock rounds.

List of provisional supplementary bids

A6.157 The EAS interface will provide a supplementary bids editor for bidders to enter, edit and maintain a list of provisional supplementary bids. This functionality will be available to bidders during the clock rounds, and also during the Supplementary Bids Round until they submit their list of supplementary bids. The EAS will provide up-to-date information about any applicable caps for the packages included in the list of provisional supplementary bids.

A6.158 The list of provisional supplementary bids will automatically include all of the non-zero packages for which the bidder has submitted clock bids. In addition, the interface will provide functionality for bidders to include additional packages in their list, and to upload a list of provisional supplementary bids from a file.

A6.159 Bidders will be able to specify the bid amount for their provisional supplementary bids, subject to the requirement that bid amounts must be at least:

- the sum of the reserve price of all the lots included in the package subject to the bid; and
- the highest bid amount that the bidder has already submitted for the package (if the bidder has already submitted any clock bids for the package).

A6.160 The EAS will report the highest bid already submitted for each package in the list of provisional supplementary bids, along with any applicable revealed preference constraints on the package.

A6.161 The EAS will allow bidders to enter bid amounts that do not satisfy the applicable eligibility reduction and final price caps. The EAS will assist bidders in identifying:

- whether any of their provisional supplementary bids breach the revealed preference constraints; and
- if necessary, which bids for constraining packages would need to be increased for all other provisional supplementary bids to be valid at the current bid amounts entered.

A6.162 Bidders will not be allowed to submit a list of supplementary bids unless all revealed preference constraints are satisfied.

Bid submission during the supplementary round

A6.163 When the supplementary round is in progress, bidders may submit a single list of supplementary bids using the EAS.

A6.164 To submit a list of supplementary bids using the EAS a bidder will need to:

- enter or edit a list of provisional supplementary bids that satisfies all constraints on supplementary bids (set out above);
- send the list of provisional supplementary bids to the auction server, so that it can be checked for validity against the auction procedures;
- provided that the all the bids in the list are valid according to the auction procedures, confirm submission of the list of provisional supplementary bids using the confirmation form provided in the bidder interface of the EAS.

A6.165 The submission process will be blocked if any of the provisional supplementary bids in the list are invalid. In such a case, none of the bids in the list will be accepted unless the bidder amends their list and completes the submission process with a valid list of supplementary bids.

A6.166 The process of submitting a list of supplementary bids is only completed when the bidder confirms the submission. A list of supplementary bids sent to the server for validity checks but not confirmed will be discarded by the EAS.

A6.167 Upon receipt of a valid submission of a list of supplementary bids, the EAS interface will provide a confirmation page listing the supplementary bids received by the EAS. Conversely, if the supplementary bids submission process fails, the EAS interface

will revert to the provisional supplementary bids editor. It is the responsibility of the bidder to check (through their bidder interface) that their list of supplementary bids has been successfully received by the auction server, and to alert Ofcom if they suspect any problems have occurred.

A6.168 Once the auction server has received a confirmation of a valid submission of a list of supplementary bids in the Supplementary Bids Round, the bidder will not be able to revise or withdraw this submission, or submit any further supplementary bids.

A6.169 Any bidders who fail to submit a list of supplementary bids before the end of the Supplementary Bids Round (taking account of any applicable extensions, as explained below) will lose the opportunity to submit supplementary bids. However, any bids submitted by the bidder during the clock rounds will still be considered in the determination of winning bids and base prices.

Determination of winning bids

A6.170 All valid bids received in the auction (unless cancelled by Ofcom due to a bidder breaching the auction procedures or failing to provide the required bid guarantee deposit, as explained below) are evaluated for the determination of winning bids and base prices.

A6.171 We define a 'feasible selection of bids' as a selection of bids such that:

- it includes at most one bid from each bidder; and
- the demand in all the bids in the selection can be met by the lots available in each lot category.

A6.172 The value of a feasible selection of bids is equal to the sum of the bid amounts of all bids in the selection, plus the sum of the reserve prices of any lots that would remain unassigned if bidders are assigned the lots specified in the bids selected.

A6.173 The winning bids must be a feasible selection of bids that achieves the maximum value across all feasible selections of bids. If there are multiple feasible selections of bids that achieve the maximum value across all feasible selections of bids, then winning bids will be a combination of bids amongst these that awards the greatest amount of spectrum. If there is still a tie based on the two criteria above, the winning bids will be selected at random amongst the tied combinations of bids.

Determination of base prices

A6.174 Base prices to be paid by winning bidders for the package awarded to them in the principal stage are based on the concept of opportunity cost.

A6.175 The opportunity cost of assigning to a subset of winners the lots they win is calculated as the difference between:

- the highest value across all feasible selections of bids which do not include any bids from the winners that are included in the subset and
- the sum of bid amounts of winning bids from the winners that are not included in the subset, plus the reserve price of any lots that remain unassigned after assigning to each winner the lots in their winning bid.

A6.176 The standalone opportunity cost of a winner is the opportunity cost of the subset of winners that includes only this winner.

A6.177 The base prices for winning bids must satisfy the following conditions:

- the base price for each winning bid must be at least the sum of the reserve price of all the lots included in the package subject to the bid;
- the base price for each winning bid cannot exceed the bid amount of the winning bid;
- the sum of base prices for each subset of winners (including subsets containing a single winner and the subset containing all winners) must be at least the joint opportunity cost for that subset of winners;
- the sum of base prices must be minimised across all possible sets of prices that meet the three conditions above.

A6.178 If there are multiple combinations of prices (one for each winning bidder) that satisfy the conditions above, then the base prices will be the unique combination of prices that minimises the sum of squares of the differences between each bidder's base price and their standalone opportunity cost across all sets of prices that satisfy all four of the conditions above.

Round extensions

A6.179 A round extension grants additional time for a bidder who has failed to submit bids before the scheduled end of round. Round extensions are specific to each bidder. A given round may only be extended once for a bidder, for a maximum extension time of 30 minutes.

A6.180 Bidders start the auction with three extension rights for the clock rounds. When a clock round extension is granted to a bidder, their extension rights for the clock rounds will be reduced by one. Ofcom may grant additional extension rights, either to all bidders or to specific bidders, at our absolute discretion. Additional extension rights can only be granted in the periods between rounds, and thus cannot be granted during a round. Therefore, a bidder who has started a clock round with no extension rights left may not have the round extended.

A6.181 A round extension for a bidder will be triggered automatically in the event that:

- the bidder has failed to make a submission by the scheduled end of the round;
- the bidder is eligible to make a submission in the round; and
- if the round is a clock round, the bidder has one or more extension rights left.

A6.182 More than one bidder may trigger a round extension simultaneously, in which case all bidders that have been granted a round extension will have an extension right deducted. However, bidders who do not have any extension rights left will not be granted a round extension, even if the round is extended for other bidders.

A6.183 When a round is extended for a bidder, the EAS will provide the revised deadline for the bidder to make their submission on the bidder's interface. The EAS will display a message on the interface of other bidders to alert them to the fact that the round

has been extended for another bidder, along with the revised deadline for that bidder's submission.

A6.184 The revised deadline for bidders who are granted a round extension will be 30 minutes later than the originally scheduled end of the round. However, the extension period may terminate earlier if all bidders for which the round has been extended submit their bid(s) before the revised deadline.

The assignment stage

A6.185 The specific frequencies assigned to bidders who have won any lots in the principal stage will be determined in the assignment stage.

A6.186 The assignment of specific frequencies will be determined independently for each band.

Possible assignment plans

A6.187 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.

A6.188 For the 3.4 GHz band, it may not be possible to assign to each winner all of the frequencies they have won in the principal stage (and any other frequencies that they might hold in the band, in the case that UK Broadband participates in the auction) as a contiguous frequency range. 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.

A6.189 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.

A6.190 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 frequencies that correspond to the spectrum they won in the principal stage. Therefore, participation in the bidding process of the assignment stage is optional.

Assignment bids

A6.191 The 'assignment options' for each bidder are determined by Ofcom in accordance with our determination of possible assignment plans.

A6.192 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.

A6.193 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.

A6.194 Submitting a bid establishes a commitment to pay an additional price that would be 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

A6.195 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.

A6.196 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

A6.197 When the assignment round is in progress, participating bidders may submit a single list of assignment bids using the EAS.

A6.198 The interface of the EAS will provide a bid form that lists all assignment options available to the bidder.

A6.199 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 the 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.

A6.200 The submission process will be blocked in 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.

A6.201 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.

A6.202 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.

A6.203 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.

A6.204 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

A6.205 The determination of winning assignments will be calculated independently for each band.

A6.206 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 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

A6.207 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.

A6.208 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.

A6.209 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.

A6.210 The standalone opportunity cost of a bidder is the opportunity cost of the subset of bidder that includes only this bidder.

A6.211 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.

A6.212 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

A6.213 At any point during the auction, Ofcom may require bidders to increase their deposit up to an amount equal to the highest bid submitted by the bidder. 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.

A6.214 Failure to make a sufficient additional deposit before the specified deadline may result in:

- the bidder being prevented from submitting any further bids (at least until the additional deposit is made);

- some or all bids submitted by the bidder in earlier rounds being cancelled; and/or

- the bidder being excluded from the auction.

Extraordinary events

A6.215 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.

A6.216 Bidders who breach the auction procedures may forfeit part or all of their deposit.

Information released at the end of the auction

A6.217 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.

A6.218 The current expectation is that Ofcom would also release all of the bid data from the auction.

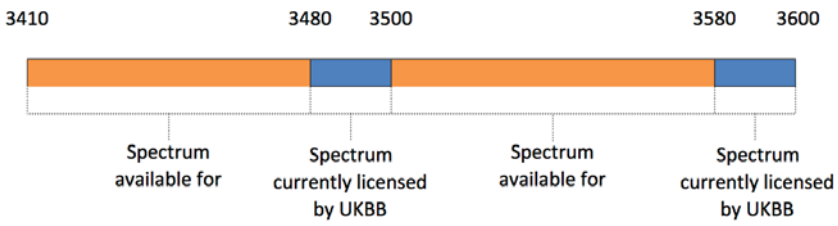
Annex 7

Fragmented assignments in the 3.4 GHz band

A note by DotEcon prepared for Ofcom

Background

A7.1 Ofcom is preparing the award of spectrum including frequencies in the 3.4 GHz band, and is considering whether to offer this spectrum in a single frequency-generic lot category. The 3.4 GHz band is currently fragmented by the lower frequency block licensed to UK Broadband, consisting of the frequency range 3480 MHz and 3500 MHz (UK Broadband's lower block), which splits the band into a lower block of 70 MHz and an upper block of 80 MHz, as shown below:



UKBB = UK Broadband

A7.2 If UK Broadband retains these frequencies, then it may not be possible to guarantee contiguous assignments to all winners of 3.4 GHz spectrum. This means that if the spectrum available in the band were offered in a single frequency-generic lot category, then it may be necessary to assign to some winners of spectrum in this category a split assignment consisting of some frequencies below UK Broadband's lower block and some frequencies above this block.

Split assignments

A7.3 As input to their assessment, Ofcom asked us to consider the extent to which split assignments can be avoided by discarding fragmented assignment plans in the assignment stage. To do so, we consider a range of potential allocations of frequency-generic lots amongst bidders, and determine in which of these a split assignment would be unavoidable if UK Broadband were to retain their current frequency assignment.

A7.4 Note that this exercise does not depend on choice of auction format used for the main stage of the auction. If either a CCA or SMRA were used with generic lot categories, including in particular the 3.4 GHz band, then the main stage of the auction would give rise to an outcome in terms of the amount of 3.4 GHz spectrum won, not the specific frequencies assigned. Therefore, the question considered here is whether those main stage auction outcomes (regardless of how they might have come about) can be implemented in assignments of contiguous frequencies to all winners, or if a winner might need to receive frequencies split into two contiguous blocks (which we refer to as a 'split assignment').

A7.5 We restrict our assessment to allocations in which:

- each winner of spectrum is allocated at least 20 MHz in this band, as responses to the Call for Inputs suggested that this might be the minimum bandwidth any bidder may require and this could be guaranteed in either of the proposed auction mechanisms for allocating spectrum; and

- each winner of spectrum is allocated at most 80 MHz in this band, as the maximum bandwidth available as a contiguous block in this band if UK Broadband are to retain their frequencies is 80 MHz, and therefore any bidder seeking more than 80 MHz in this category can be assumed to be bidding on the basis of its valuation for a split assignment.

A7.6 The maximum number of winners that is consistent with each winner obtaining at least 20 MHz is seven.

A7.7 In our assessment, we assume that there is no requirement that any unsold spectrum is retained as a single contiguous block above or below UK Broadband's lower block. Instead, we assume that it would be possible to leave some unallocated spectrum below and some above this block (however, unsold spectrum could be placed next to UK Broadband's current frequency assignments in the band). This flexibility in the treatment of unsold lots reduces the number of cases leading to a split assignment. Nevertheless, there are still cases in which one winner needs to receive a split assignment regardless of how unallocated lots are assigned frequencies.

A7.8 The following table provides an overview of possible outcomes that would require a fragmented assignment when lots are offered as 5 MHz blocks. We also report the total number of possible allocations (i.e. cases of a specific number of winners winning distinct amounts of spectrum). However, these cases cannot be treated as equally probable, so we would not recommend interpreting the number of split allocations as a proportion of the total number of allocations as a probability.

A7.9 It can be seen that the case in which there are three winners in this band creates the most cases of split assignments, but even in this case the number of cases are modest relative to the overall number of possible cases. Moving from three to four or more winners, the number of split assignments reduces, as the greater number of winners provides additional flexibility in terms of alternative positions of winners within the band to avoid a split.

A7.10 Of all allocations requiring a split assignment, we identify the allocations in which the assignment of a single winner can be split such that this winner receives at least 20 MHz in the lower and at least 20 MHz in the upper sub-bands with all other winners receiving contiguous assignments. In a few cases, the assignment of two winners need to be split so that each of these split winners receives at least 20 MHz in the lower and upper sub-band with all other winners being allocated contiguous frequency blocks. We only found four allocations that would not allow an assignment of at least 20 MHz in each sub-band to all winners.

Winners	**Number of possible allocations**	**Allocations requiring a split assignment** *(MHz won by winner1, MHz won by winner2, ...)*	**Allocations requiring split winner (at least 20MHz in each sub-band)** *(MHz won by winner1, MHz won by winner2, ...)*	**Allocations requiring two split winners (at least 20MHz in each sub-band)** *(MHz won by winner1, MHz won by winner2, ...)*	**Allocations with a winner receiving less than 20MHz in a sub-band** *(MHz won by winner1, MHz won by winner2, ...)*
1	13	*none*	*none*	*none*	*none*
2	89	Total: 1 • 75/75	*none*	Total: 1 • 75/75	*none*
3	240	Total: 33 • 40/45/45 • 45/45/45 • 40/45/50 • 45/45/50 • 35/50/50 • 40/50/50 • 45/50/50 • 50/50/50 • 40/45/55 • 45/45/55 • 35/50/55 • 40/50/55 • 45/50/55 • 30/55/55 • 35/55/55 • 40/55/55 • 40/45/60 • 45/45/60 • 35/50/60 • 40/50/60 • 30/55/60 • 35/55/60 • 25/60/60 • 30/60/60 • 40/45/65 • 35/50/65 • 30/55/65 • 25/60/65 • 20/65/65 • 35/40/75 • 30/45/75 • 25/50/75 • 20/55/75	Total 32: • 40/45/45 • 45/45/45 • 40/45/50 • 45/45/50 • 35/50/50 • 40/50/50 • 45/50/50 • 50/50/50 • 40/45/55 • 45/45/55 • 35/50/55 • 40/50/55 • 45/50/55 • 30/55/55 • 35/55/55 • 40/55/55 • 40/45/60 • 45/45/60 • 35/50/60 • 40/50/60 • 30/55/60 • 35/55/60 • 25/60/60 • 30/60/60 • 40/45/65 • 35/50/65 • 30/55/65 • 25/60/65 • 35/40/75 • 30/45/75 • 25/50/75 • 20/55/75	Total: 1 • 20/65/65	*none*
4	238	Total: 22 • 30/30/45/45 • 20/40/45/45 • 25/35/40/50 • 25/25/50/50 • 30/30/30/55 • 30/30/35/55 • 20/35/40/55 • 20/30/45/55 • 20/20/55/55 • 25/30/30/60 • 30/30/30/60	Total: 22 • 30/30/45/45 • 20/40/45/45 • 25/35/40/50 • 25/25/50/50 • 30/30/30/55 • 30/30/35/55 • 20/35/40/55 • 20/30/45/55 • 20/20/55/55 • 25/30/30/60 • 30/30/30/60	*none*	*none*

		• 25/25/35/60 • 25/30/35/60 • 25/25/40/60 • 25/30/30/65 • 25/25/35/65 • 20/30/35/65 • 20/25/40/65 • 20/20/45/65 • 25/25/25/75 • 20/25/30/75 • 20/20/35/75	• 25/25/35/60 • 25/30/35/60 • 25/25/40/60 • 25/30/30/65 • 25/25/35/65 • 20/30/35/65 • 20/25/40/65 • 20/20/45/65 • 25/25/25/75 • 20/25/30/75 • 20/20/35/75 • 25/25/25/35/40 • 20/20/20/45/45 • 25/25/25/25/50 • 20/20/20/35/55 • 20/20/20/25/65		
5	113	Total: 8 • 25/30/30/30/30 • 30/30/30/30/30 • 25/30/30/30/35 • 25/25/25/35/40 • 20/20/20/45/45 • 25/25/25/25/50 • 20/20/20/35/55 • 20/20/20/25/65	Total: 5 • 25/25/25/35/40 • 20/20/20/45/45 • 25/25/25/25/50 • 20/20/20/35/55 • 20/20/20/25/65	*none*	Total: 3 • 25/30/30/30/30 • 30/30/30/30/30 • 25/30/30/30/35
6	30	Total: 1 • 25/25/25/25/25/25	*none*	*none*	Total: 1 • 25/25/25/25/25/25

Annex 9

Draft 2.3 licence

Office of Communications (Ofcom)
Wireless Telegraphy Act 2006

[SPECTRUM ACCESS 2.3GHz LICENCE]

Licence no:	[xxx]
Date of issue:	[xxx]
Fee payment date [(from xx xx 20xx)]	**[**xxx] **(annually)**

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

   [xxxxxx]

   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 Act[149];

(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 [xxx 20xx)]; 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 Act[150].

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 sum payable in respect of this Licence is [£xxxx].

8. From [Date], 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 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

[149] These are regulations on spectrum trading.

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

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 to paragraphs 4 and 5 of 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 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; and

(b) the Outer Hebrides, the Isle of Skye and the Small Isles.

Interpretation

17. 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;

(f) the Schedule(s) form part of this Licence together with any subsequent Schedule(s) which Ofcom may issue as a variation to this Licence; and

(g) 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: [xxxxxx]

Schedule Date: **[xxxxx]**

Licence category: **[Spectrum Access Licence (2.3 GHz)]**

1. Description of Radio Equipment

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.

2. Interface Requirements for the Radio Equipment

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 xxxxx]

3. Special conditions relating to the Radio Equipment

b) 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.

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

c) 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.

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.

4. Co-ordination at frequency and geographical boundaries

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.

5. Synchronisation of networks

The Licensee shall ensure that the Radio Equipment is operated in compliance with the Inter-operator Synchronisation Procedure version [x] as notified to the Licensee by Ofcom.

6. International cross-border coordination

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.

7. Permitted Frequency Blocks

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] to [xxxx] MHz

8. Maximum power within the Permitted Frequency Blocks

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

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

9. Maximum power outside the Permitted Frequency Blocks

[THE CONSULTATION SETS OUT TWO OPTIONS FOR ENCOURAGING SYNCHRONISATION. THE LICENCE CONDITIONS WHICH WE PROPOSE FOR EACH OPTION ARE SET OUT BELOW. ONLY ONE OPTION WILL BE RETAINED IN THE FINAL LICENCE]

[OPTION 1 – LICENSEE CHOOSES FRAME STRUCTURE]

(a) Except as set out in condition 9(b) below, 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 requirements:

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

(b) Where the licensee uses the TDD frame structures as set out in the Inter-operator Synchronisation Procedure referred to in condition 5 above, 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 (the "Permissive Mask"):

-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) applies < -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 following band edge requirements apply:

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	[-36 dBm / 5 MHz] EIRP per cell	
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

[OPTION 2 – OFCOM MANDATES FRAME STRUCTURE]

The licensee must use the TDD frame structures as set out in the Inter-operator Synchronisation Procedure referred to in condition 5 above.

(a) 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 (the "Permissive Mask"):

-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) applies < -10 MHz offset from lower block edge > 10 MHz offset from upper block edge	Min(PMax – 43, 13) dBm /5 MHz EIRP per antenna

(b) The following band edge requirements apply:

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	[-36 dBm / 5 MHz] EIRP per cell	
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

10. Interpretation of terms in this Schedule

In this Schedule:

a) "dBm" means the power level in decibels (logarithmic scale) referenced against 1milliwatt (i.e. a value of 0dBm 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 20dBm 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 published 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) “measurement bandwidth” means the size of an individual spectrum segment within the specified frequency range that is used to measure compliance with the specified power limit;

h) “mobile or nomadic” means intended to be used while in motion or during halts at unspecified points;

i) “Permitted Frequency Blocks” has the meaning given to it in paragraph 6 of this Schedule;

j) PMax is the maximum carrier power for the base station in question, measured as EIRP;

k) “smart/intelligent low power repeater” means a repeater which operates with power not exceeding 24dBm 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.

l) “TDD” means the application of time-division multiplexing to separate outward and return signals.

m) “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

n) “upper block edge” means, in relation to each Permitted Frequency Block, the highest frequency in that Permitted Frequency Block.

Draft 3.4 licence

Office of Communications (Ofcom)
Wireless Telegraphy Act 2006

[SPECTRUM ACCESS 3.4 GHz LICENCE]

Licence no:	[xxx]
Date of issue:	[xxx]
Fee payment date [(from xx xx 20xx)]	**[**xxx] **(annually)**

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

   [xxxxxx]

   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 Act[151];

[151] These are regulations on spectrum trading.

(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 [xxx 20xx)]; 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")].

5. 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

6. 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 Act[152].

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 sum payable in respect of this Licence is [£xxxx].

8. From [Date], 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 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

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

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 to paragraphs 4 and 5 of 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 or the Isle of Man.

17. The areas excluded from this licence are:

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;

(f) the Schedule(s) form part of this Licence together with any subsequent Schedule(s) which Ofcom may issue as a variation to this Licence; and

(g) 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]**

Licence category: **[Spectrum Access Licence (3.4 GHz)]**

1. Description of Radio Equipment

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.

2. Interface Requirements for the Radio Equipment

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 xxxxx]

3. Special conditions relating to the Radio Equipment

o) 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:

vi) postal address (including post code);

vii) National Grid Reference, to at least 10 metre resolution;

viii) antenna height (above ground level), type, and boresight bearing east of true north (if applicable);

ix) radio frequencies which the Radio Equipment uses; and

x) Transmitted power expressed in dBm/5 MHz EIRP.

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

p) 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.

q) 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.

r) 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.

4. Co-ordination at frequency and geographical boundaries

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.

5. Synchronisation of networks

The Licensee shall ensure that the Radio Equipment is operated in compliance with the Inter-operator Synchronisation Procedure version [x] as notified to the Licensee by Ofcom.

6. International cross-border coordination

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.

7. Permitted Frequency Blocks

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] to [xxxx] MHz

8. Maximum power within the Permitted Frequency Blocks

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]

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

9. Maximum power outside the Permitted Frequency Blocks

[THE CONSULTATION SETS OUT TWO OPTIONS FOR ENCOURAGING SYNCHRONISATION. THE LICENCE CONDITIONS WHICH WE PROPOSE FOR EACH OPTION ARE SET OUT BELOW. ONLY ONE OPTION WILL BE RETAINED IN THE FINAL LICENCE]

[OPTION 1 – LICENSEE CHOOSES FRAME STRUCTURE]

(a) Except as set out in condition 9(b) below, 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 requirements:

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

(b) Where the licensee uses the TDD frame structures as set out in the Inter-operator Synchronisation Procedure referred to in condition 5 above, 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 (the "Permissive Mask"):

-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) applies < -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 following band edge requirements apply:

3405 MHz – 3410 MHz **3600 MHz – 3605 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
Below 3400 MHz	[-59 dBm/ MHz] EIRP per cell
Above 3605 MHz (see Note 2)	[- 34 dBm /5 MHz] EIRP per cell

Note 2: This limit shall not apply where the licensee of spectrum above 3605 MHz uses the TDD frame structure as set out in the Inter-operator Synchronisation Procedure

[OPTION 2 – OFCOM MANDATES FRAME STRUCTURE]

The licensee must use the TDD frame structures as set out in the Inter-operator Synchronisation Procedure referred to in condition 5 above.

(a) 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 (the "Permissive Mask"):

-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) applies < -10 MHz offset from lower block edge > 10 MHz offset from upper block edge	Min(PMax – 43, 13) dBm /5 MHz EIRP per antenna

(b) The following band edge requirements apply:

3405 MHz – 3410 MHz **3600 MHz – 3605 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
Below 3400 MHz	[-59 dBm/ MHz] EIRP per cell
Above 3605 MHz (see Note 2)	[- 34 dBm /5 MHz] EIRP per cell

Note 2: This limit shall not apply where the licensee of spectrum above 3605 MHz uses the TDD frame structure as set out in the Inter-operator Synchronisation Procedure

10. Interpretation of terms in this schedule

In this Schedule:

s) "dBm" means the power level in decibels (logarithmic scale) referenced against 1milliwatt (i.e. a value of 0dBm is 1 milliwatt);

t) "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), as measured during the "on" part of the transmission;

u) "femtocell" means Radio Equipment transmitting on the downlink frequencies, which operates at a power not exceeding 20dBm 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;

v) “Fixed or installed” means used or installed at specific fixed points;

w) "IR" means a United Kingdom Radio Interface Requirement published 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;

x) “lower block edge” means, in relation to each Permitted Frequency Block, the lowest frequency in that Permitted Frequency Block;

y) “measurement bandwidth” means the size of an individual spectrum segment within the specified frequency range that is used to measure compliance with the specified power limit;

z) “mobile or nomadic” means intended to be used while in motion or during halts at unspecified points;

aa) “Permitted Frequency Blocks” has the meaning given to it in paragraph 6 of this Schedule;

bb) PMax is the maximum carrier power for the base station in question, measured as EIRP;

cc) “smart/intelligent low power repeater” means a repeater which operates with power not exceeding 24dBm 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.

dd) “TDD” means the application of time-division multiplexing to separate outward and return signals.

ee) “TRP” means the total radiated power. This is the integral of the power transmitted in different directions over the entire radiation sphere, as measured during the “on” part of the transmission; and

ff) “upper block edge” means, in relation to each Permitted Frequency Block, the highest frequency in that Permitted Frequency Block.

Annex 10

Interference assessments of the different Technical Licence Conditions Options

A10.1 In Section 9 of this document we have set out our proposals for two possible options to encourage or mandate 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 agreed 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 restricted 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.

A10.2 With both options, the details of the required parameters will be detailed in an Inter-operator Synchronisation Procedure issued by Ofcom. In either option, there is some additional flexibility if licensees agree and propose amendments to this procedure. In certain circumstances there can be additional bilateral/multilateral agreements between the licensees in the band.

A10.3 This annex assesses the risk of interference with non-synchronised use under Option 1. It also looks at the risks of interference if flexibility is agreed through the specified processes. .

A10.4 We also assess interference from indoor small cells to support our proposal in Section 9 that they do not need to follow the required frame structure (synchronise).

Risk of interference in non-synchronised scenarios

A10.5 We assess the risk of interference by looking at the impact of different frame structures combinations as a result of different TD-LTE traffic configurations. Assuming different mixes of permissive and restrictive emission masks we assess the separation distances required to avoid interference.

Assessment of the impact of different frame structure combinations

A10.6 Whilst we propose that the licences are issued on a technology neutral basis, the harmonisation for the bands and discussions with stakeholders suggest that TD-LTE is the likely candidate technology for the spectrum. We have therefore focussed our analysis on the frame structures of TD-LTE.

A10.7 There are currently 7 different TD-LTE configurations standardised in 3GPP[153]. We have focussed the assessment on our proposal of configuration 2 (also known as 3:1). We believe that in certain circumstances other technologies can have an equivalent frame structure.

A10.8 If licensees' transmissions are synchronised it means that different licensees' base stations are transmitting at the same time and the user terminal stations are transmitting within the same times defined by the frame structure. If they are not synchronised and are using different frame structures, then a high power base station could be transmitting in a sub-frame when a base station in adjacent spectrum is trying to listen to a weak signal from a lower power user terminal or vice versa. We refer to this as a clash.

A10.9 We explore the probability of risks of interference by considering different combinations of TD-LTE configurations (frame structures). Some examples of these different combinations are shown in Figure 19.

A10.10 The possible interference scenarios if licensees' transmissions are not synchronised or become unsynchronised include:

- Transmission of Licensee A's downlink to licensee B's uplink or vice versa (D → U clash, also referred to as base station to base station interference)
- Transmission of Licensee A's uplink to licensee B's downlink or vice versa (U → D clash, also referred to as mobile to mobile interference).
- A clash with a special sub-frame (S), this can be in any direction.

A10.11 There is scope for limiting the risk of interference to the adjacent licensee with different a TD-LTE configuration as long as there is alignment of the start of the frames. This is shown in Figure 17 below where there are 6 clashes of the sub-frames, where identical configurations are chosen with a single sub-frame offset and Figure 18 where different configurations are compared.

Figure 17: Comparison of configuration 2 with itself and a single sub-frame offset

Configuration 2 (3:1)	D	S	U	D	D	D	S	U	D	D	Number of clashes
Configuration 2 with sub-frame offset of one.	D	D	S	U	D	D	D	S	U	D	6

A10.12 Figure 18 shows a comparison of TD-LTE configuration 2 (a 3:1 profile) with TD-LTE configuration 1 (a 2:2 profile), with no offset and then 1 or 2 sub-frame offsets.

Figure 18: Comparison of configuration 2 with configuration 1 with different offsets

Configuration 2 (3:1)		D	S	U	D	D	D	S	U	D	D	Number of clashes
compared to configuration 1	no frame aligned offsets	D	S	U	U	D	D	S	U	U	D	2

[153] 3GPP TS 36.104, Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception

	with different frame aligned offsets	D	D	S	U	U	D	D	S	U	U	8
		U	D	D	S	U	U	D	D	S	U	10

A10.13 Figure 19 below looks at the number of clashes when different TD-LTE configurations are frame aligned. It also looks at the types of clashes that are possible. It considers the scenario whereby a licensee changes its configuration compared to other licensees that are using the proposed TD-LTE configuration. In the first instance it considers the type of risk to the neighbour and then the type of risk for the licensee using the different solution.

A10.14 These risks are asymmetric. Generally base station to base station clashes (D →U) are regarded as higher risk as both the interferer and victim base stations can be using higher transmit powers above the clutter leading to potentially large interference zones. They are also static and so if interference does occur it is not transient as in the case of mobile to mobile interference (U→D).

Figure 19: Number and type of frame aligned clashes with configuration 2

TD-LTE configuration (referred to 6:2:2 or 3:1)	**Downlink : uplink : s-frame ratio**	**Total number of clashes (referred to TD-LTE configuration 2)**	**Number of D→U clashes** Risk to neighbour: base station to base station interference (or risk to own mobile stations)	**Number of U→D clashes** Risk to neighbour: mobile to mobile interference (or risk to own base stations)	**Number of D→S clashes** Risk to Special sub-frame (used for guard time)
0	2:6:2	4 / 10	0	4	0
1	4:4:2	2 / 10	0	2	0
3	6:3:1	4 / 10	1	2	1
4	7:2:1	3 / 10	1	1	1
5	8:1:1	2 / 10	1	0	1
6	3:5:2	3 / 10	0	3	0

A10.15 Figure 9 shows that some configurations have a greater number of clashes than others. It also shows that many combinations have an asymmetric risk of interference to the two operators.

- In some cases the risk of interference to the base stations of the neighbouring licensee using the synchronised mask can be less significant. For example if one uses a more uplink heavy configurations (e.g. 0, 1 or 6) then that licensee is likely to suffer greater interference compared with the adjacent licensee that remains on the 3:1 configuration.

- Conversely if a licensee that wishes to do something different uses a more downlink heavy configuration, then there is more risk of base station to base station interference for the licensee that remains on the 3:1 configuration.

A10.16 In the figure above, we have compared the scenario where licensees are all using a TD-LTE configuration that is currently available. However, within the 3GPP standards group there is a proposal for a supplementary downlink option of 10:0:0. This option, if it comes about, may have an additional risk of interference to the 2 uplink S sub-frames of the 3:1 configuration. The S-frames are important as they contain the downlink pilot, uplink pilot, and guard period to allow switching from downlink to uplink. This supplementary downlink frame structure therefore has the potential to be more detrimental to the licensees remaining on the proposed 3:1 configuration as there will be no uplink or S sub-frames that do not suffer a clash, unlike the current situation where there are at least some unclashed sub-frames.

A10.17 If a different technology to TD-LTE is used in the band, the potential risks could vary significantly depending on the number of sub-frame clashes. If the order of the uplink and downlink sub-frames is very different to the proposed 3:1 synchronised configuration, then the risk could be similar to the supplementary downlink option of 10:0:0.

A10.18 We have shown here that the risk of interference is directly related to the number of clashes between one frame and another and the direction of these clashes. Each frame structure combination can therefore lead to an asymmetric risk between two licensees with some combinations more likely to affect one licensee. In the following paragraphs we look at the impact of different block edge masks on this risk.

Risk of interference with different masks combinations

A10.19 The paragraphs above looked at the number of a clashes when different TD-LTE configurations are chosen. A clash in a sub-frame does not necessarily mean interference is caused. For example, if there is sufficient isolation, due to physical separation or other factors, between the transmitter and potential victim receiver then there will be no degradation in performance as a result of a clash. In the following paragraphs, we look at the required separation distances to avoid interference to a macro cell base station from another macro cell base station when they are not using the same frame structure, as we consider that this is generally the more sensitive scenario.

A10.20 We look at the following block-edge-mask combinations of interferer to victim that could arise under our proposals for Option 1:

- Restrictive block edge mask -> Permissive block edge mask

- Permissive block edge mask -> Restrictive block edge mask

A10.21 For comparison purposes we also consider the potential interference risk of adjacent licensees both using the restrictive masks.

A10.22 The two factors that contribute to whether a system is interfered with, are:

- out-of-band emissions of a transmitter in adjacent or nearby spectrum entering co-channel of the victim's receiver; the amount of these emissions are often described as the adjacent channel leakage ratio (ACLR).

- the victim receiver's ability to block out the transmissions of another transmitter in spectrum in adjacent or nearby spectrum; this performance is often descried as adjacent channel selectivity (ACS).

A10.23 The out-of-band emissions are defined by the Block-edge-masks based on CEPT harmonisation but mandated by us in the spectrum licence .The restrictive mask has a stricter out-of-band emission limit to limit the interference risk when systems are not synchronised with one another.

A10.24 Receiver selectivity defines how resilient the receiver is to adjacent signals. This is defined within international equipment Receiver performance is not defined within the CEPT harmonisation activities that are used to inform the mandatory Commission Decision for the 3.4 GHz band and an ECC Decision in the 2.3 GHz band, nor is it defined within our spectrum licences.

A10.25 Effective interference power seen by a neighbouring licensee is calculated considering the adjacent channel interference ratio ACIR. This is a function of the adjacent channel leakage ratio ACLR and adjacent channel selectivity ACS.

A10.26 For example, if we assume that a base station is transmitting at an EIRP of 61 dBm / 5 MHz and has to meet the restrictive mask of -36 dBm / 5 MHz. This requires an ACLR of 97 dB in the adjacent licensee's spectrum (we assume in our analysis that this is at least 5 MHz away). For the permissive mask, we assume the permissive baseline level of 13 dBm / 5 MHz. This requires an ACLR of 48 dB.

A10.27 We have commissioned the measurement of selectivity of two example TD-LTE base stations. The measurement ACS varied from 46 – 55 dB for a range of measurements with and without a guard band (of up to 10 MHz). We have taken the value for ACS of 50 dB to represent the basic ACS with a 5 MHz roll-off. Below we demonstrate the effect of a wider range of ACS values on the overall adjacent channel interference ration (ACIR) (assuming an EIRP of 61 dBm / 5 MHz).

A10.28 From our discussions with stakeholders[154] we understand that in order to meet the requirements of the restrictive mask baseline levels that additional hardware filtering will be needed. In at least some cases, this filter will be shared between transmit and receive for TDD operation, resulting in an improved ACS performance.

A10.29 Huawei suggested in its response to our February Consultation that a baseline for small cells in the order of -15 to -19 dBm / 5 MHz might be more appropriate than our proposed -36dBm / 5 MHz. This suggests that in order to meet the -36dBm/5 MHz baseline requirement that additional filtering with a 17-21dB rejection performance may be needed. Whilst this is for small cells we have assumed as an example an ACS with an additional 20dB of rejection.

A10.30 We have less clear information on the filter requirements for macro cells however we note that the difference in baseline levels between the permissive and restrictive masks is 47 to 50dB. Additional filtering of a similar amount might be needed. We also consider that good system design tries to match the level of ACLR with that of ACS in order that unnecessary requirements are not placed on either the transmitter or receiver. In our example, with an ACLR of 97dB, this would suggest an ACS of a similar value. In our subsequent analysis we have assumed that improvement in ACS as a result of additional filters required to meet the ACLR requirement of the restrictive mask may be either 20 or 40dB.

[154] See Section 9 for more details

A10.31 The equipment standards require that in all cases the receiver must meet a level slightly lower than 50dB irrespective of whether the operation is synchronised or unsynchronised. However in our subsequent analysis we also consider ACS options of 70 and 90dB which could be possible with equipment that has additional filtering.

Figure 20: Selectivity assumptions for base stations with a restrictive and permissive mask

Unsynchronised scenario	Assumed ACS (or selectivity) dB	Assumed ACLR dB	Calculated ACIR dB	Effective power seen in other operator's spectrum
Restrictive mask interfering to permissive mask	50	97	50	11 dBm / 5 MHz
	70	97	70	-9 dBm / 5 MHz
Permissive mask interfering to restrictive mask	50	48	46	15 dBm / 5 MHz
	70	48	48	13 dBm / 5 MHz
	90	48	48	13 dBm / 5 MHz
Restrictive mask interfering to restrictive mask	50	97	50	11 dBm / 5 MHz
	70	97	70	-9 dBm / 5 MHz
	90	97	90	-28 dBm / 5 MHz

A10.32 Figure 20 shows the combination of ACS and ACLR into ACIR for different combinations of interferer and victim mask. The table shows that the ACS parameter is dominating the calculations of the effective power seen in the other licensee's spectrum when the licensee using the restrictive mask is the potential interferer. In the scenarios modelled for the permissive mask interferer, additional ACS performance has no effect as the out-of-band emissions are the dominant factor.

A10.33 To estimate the separation distances between a transmitting and a receiving base station, we have used two different propagation models. For separation distances greater than 1km we have used the ITU-R P.452-14[155] propagation model. This model is not valid for distances less than 1km and so we have assumed that base stations are line of sight and used free space loss for separation distances up to 1km. We assumed an example map area in London with associated clutter and terrain height when using ITU-R P.452.

A10.34 In our calculations we have considered the interference power needed to cause a desensitisation of the LTE base station receiver by no more than 1dB. This is a common way to calculate the potential interference effect of another system on LTE systems. The desensitisation levels represent a noise rise at the base station or

[155] http://www.itu.int/rec/R-REC-P.452/en

user equipment so that the capacity, throughput and the maximum range of the cell are reduced.

A10.35 The calculations below consider the required separation distance to avoid desensitising base stations by 1dB using the different selectivity values in Figure 21.

Figure 21: Separation distances to avoid desensitising a macro cell base station from another macro cell base station

Unsynchronised scenario	Selectivity assumed dB	Path loss isolation calculated to avoid desensitising another operator's base station dB	Modelled separation distance between base stations to avoid desensitising another operator's base station Km
Restrictive mask interfering to permissive mask	50	126	~ 14
	70	106	1.4
Permissive mask interfering to restrictive mask	50	130	~ 15
	70	128	
	90	128	
Restrictive mask interfering to restrictive mask	50	126	~ 14
	70	106	1.4
	90	87	0.1

A10.36 The table above shows that given the options of the different block-edge-masks a significant factor on the risk of interference is the victim's base station receiver performance.

A10.37 These calculated separation distances are based on high power outdoor macro cell to macro cell interference. These separation distances would decrease if a lower transmit power is used and under circumstances where either the potential interferer and victim base stations were indoors and/or at a lower height.

A10.38 Under fully synchronised circumstances, licensees using generic base station equipment that meets the permissive mask will not suffer interference as there will be no sub-frame clashes. However, if another licensee in the band chooses a different TD-LTE configuration and deploys with the restrictive mask, (as is possible under Option 1 of our proposals), there could be circumstances where base stations in adjacent spectrum remaining on the permissive mask are at a greater risk of interference if there are sub-frame clashes. We expect that selectivity performance improves with greater frequency separation; however base stations that are not in immediately adjacent spectrum may also suffer some interference if there are clashes and the selectivity performance is around 50dB.

A10.39 The filter used to meet the restrictive mask may be shared between transmit and receive for TDD operation, so this means that the ACS could be enhanced by the filter requirements for more stringent out-of-band emissions. In this case the separation distances can be quite small.

A10.40 As a point of comparison, we consider the case of two unsynchronised base stations in adjacent spectrum both having the restrictive mask. In this case, if a base station does not have an ACS that is significantly better than the 3GPP standard, then there may be a similar risk of interference as when the adjacent base station has the permissive mask.

Summary

A10.41 With Option 1, it is possible to have one licensee operating with the preferred TD-LTE configuration and the permissive mask, whilst the neighbour licensee is using the restrictive mask with a different configuration. In some configuration combinations there would be a downlink to uplink clash in the frame structure. In this case the licensee remaining on the preferred 3:1 configuration may suffer some desensitisation, potentially over reasonably large distances. In other cases the licensee that has switched configuration may suffer interference to their base stations, however only in the case where they have switched to a more uplink heavy configuration.

A10.42 These risks do not occur with Option 2 as the same frame structure is used by all licensees. We recognise that Option 2 therefore provides a greater certainty over the interference environment. However, there is less scope for flexibility of different frame structures. There may still be some scope for flexibility in Option 2 with indoor small cells and depending on the success of co-operation between licensees, see paragraphs 9.80 to 9.91 on the Inter-operator Synchronisation Procedure.

A10.43 We recognise that due to the asymmetric interference risk, there may be some benefit for licensees to agree some flexibility in a controlled way. For example, it may be more difficult to co-ordinate a heavier downlink option, due to increased risks of interference to users of neighbouring spectrum. Conversely, it may be easier to agree a more uplink heavy configuration due to a lower risk of interference to neighbours base stations. These negotiations are possible under either Option.

Interference assessment from indoor small cells

A10.44 As we noted in Section 9, Bolloré Telecom proposed to us that indoor small cells do not need to synchronise due to mitigating factors such as low power, average inter-femtocell distance and wall penetration loss.

A10.45 For the purposes of this exemption from synchronisation, we define small cells as operating at a power levels not exceeding 24 dBm per carrier. So for our assessment we use an EIRP of 24 dBm over a 10 MHz carrier. We assess the potential impact to both other small cells and macro cells in the adjacent spectrum using the permissive mask (ie with no frequency separation).

A10.46 For our calculations we have modelled against the requirement in the 3GPP standard for ACLR of 45 dB (this is a slightly greater number than assuming a 20 dBm carrier with the permissive mask). We have assumed an ACS of 46 dB as representative of the lowest end of our measurements.

A10.47 We have modelled an assumed additional loss of 10 dB or 20 dB. These losses account for potential wall and antenna decoupling losses. Antenna decoupling loss depends on the relative geometry of the two base stations. We have a range of values[156] representing building penetration loss between 8.4 – 21.1 dB, which include the consideration of whether the small cell is considered shallow or deep into the building.

A10.48 To estimate the separation distances between a small cell and either another femto cell or a macro cell, the free space path loss model has been used.

A10.49 As for the analysis above between macro cells, the susceptibility of LTE systems has been assessed by considering the interference power needed to cause a specified desensitisation by 1dB.

A10.50 Figure 22 shows the interference assessment from indoor small cells.

Figure 22: Interference assessment from indoor small cells

Victim	Effective EIRP in victim channel dBm	Assumed additional loss dB	Minimum loss required to avoid a 1dB desensitisation to neighbour's base station dB	Modelled separation distance[157] to avoid desensitising another licensees base station m
small cell	-18.5	10.0	68.5	18
small cell	-18.5	20.0	58.5	6
macro cell	-18.5	10.0	93.5	325
macro cell	-18.5	20.0	83.5	100

A10.51 We recognise that our analysis in Figure 12 may lead to larger separation distances than we think will be likely in practice, for the following reasons:

- In reality base station equipment may have a better receiver performance than our assumed selectivity values and we would expect that small cells may have lower out-of-band emissions than specified by the 3GPP standard.

[156] Table A7.2, values taken from 2.6 GHz and assumed representative for both 2.3 GHz and 3.4 GHz, http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/Annexes7-12.pdf

[157] To estimate the separation distances below 1 km, the free space path loss model has been used.

- It is a requirement from the Commission Decision for the 3.4 GHz band and ECC Decision for the 2.3 GHz band, that femto cells use power control. Therefore it is likely that these small cells will use power control and have a lower average EIRP in many cases than we have assumed.

- Base stations may be able to tolerate more interference than the 1dB desensitisation that we assumed.

A10.52 Taking these factors into account with the separation distances calculated above, we think that there will be a very limited risk of interference to other small cells, particularly in domestic environments.

A10.53 In some circumstances, indoor small cells may be deployed in a similar environment to higher power macro cells, for example, shopping centres, sport's stadiums, train stations. As we are proposing that small cells with a maximum power of less than 24dBm per carrier do not need to be synchronised then there remains a small risk of desensitising the macro cell if they are in close proximity, of the order of 100 – 350m. The risk disappears if the small cells in this environment are synchronised with the adjacent licensee.