



Improving consumer access to mobile services at 3.6GHz to 3.8GHz

Statement and Consultation

Publication date: 28 July 2017

Closing Date for Responses: 22 September 2017

About this document

This document confirms Ofcom's intention to expand spectrum access for mobile services in the 3.6GHz to 3.8GHz band. This band has been identified by the UK and EU as part of the primary band for 5G.

In addition, this document sets out our proposed approach to existing users of the band. Our proposal is to remove current authorisations for fixed links and no longer take registered satellite earth stations with a receive component in the 3.6GHz to 3.8GHz band into account for frequency management purposes, after an appropriate period of notice. The effect of our proposed approach would be to enable future mobile services in the 3.6GHz to 3.8GHz band to be deployed in many areas from around 2020, but not necessarily nationwide before 2022.

We are consulting on our proposed approach, and will publish a further Statement in due course setting out our decision and providing an update on how we expect to make the band available for mobile services.

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Section 1

Executive Summary

Background

- 1.1 Mobile connectivity is increasingly becoming an everyday necessity for consumers and businesses. Mobile data traffic per subscriber has increased tenfold over the last five years, reaching 1.3GB per month in July 2016.
- 1.2 We expect that this growth will continue. Consumers are increasingly accessing the internet from their smartphones, and using high capacity applications, such as streaming HD video and gaming on mobile devices. Increasing demand for greater speeds and capacity is driving technology developments in wireless connectivity.
- 1.3 5G is the next generation of wireless technologies and is being designed to provide greater capacity, offer greater reliability, and deliver faster speeds, with the potential to enable innovative new services across different industry sectors. The first wave of commercial products is expected to be available in 2019-2020. However, initial pre-commercial trials are already expected to start from 2018.
- 1.4 The Government has set out a clear ambition that the UK should be a global leader in 5G to take early advantage of its potential and help to create a world-leading digital economy that works for everyone, with high quality coverage where people live, work and travel.
- 1.5 Spectrum is a critical enabler of 5G, and we have already taken the first steps towards making spectrum available for 5G services by identifying suitable spectrum at low (700MHz), medium (3.4GHz to 3.8GHz) and high (26GHz) frequencies. The 3.4GHz to 3.8GHz band has been identified as the primary band for 5G in Europe.
- 1.6 On 11 July 2017, we published our decision to award frequencies in the neighbouring 3.4GHz to 3.6GHz band, setting out our intention to carry out the auction later in 2017.
- 1.7 The 3.6GHz to 3.8GHz band is currently used by receiving satellite earth stations and fixed links to deliver broadcasting and data communications services. However, the band is lightly used in the UK compared to other satellite and fixed link bands and its use is focused in a limited number of locations. In addition, UK Broadband (recently acquired by H3G) has a UK-wide licence to use 84 MHz of this band to provide electronic communications services.

October 2016 consultation

- 1.8 In our October 2016 consultation *Improving consumer access to mobile services at 3.6 to 3.8GHz* (the October consultation), we explained that we have considered this band a high priority band for future mobile use since 2014. We noted that this frequency band can provide the large bandwidths anticipated to be required for 5G services, and that it is part of the wider 3.4GHz to 3.8GHz band which is already harmonised for mobile use within Europe. While part of the 3.6GHz to 3.8GHz band is already authorised for electronic communications networks, we proposed expanding spectrum access for mobile services, including 5G, to the rest of the 3.6GHz to 3.8GHz band. We also set out analysis showing that coexistence

between current users of the band and mobile would be challenging. Ofcom currently coordinates the band to manage the interference environment in order to provide benchmark spectrum quality for registered users. Benchmark spectrum quality is designed to ensure that the levels of interference experienced by registered receivers in the band would not normally be expected to exceed certain defined levels. The analysis suggested that maintaining benchmark spectrum quality for current users could prevent the deployment of mobile services using this band across large parts of the UK, including some densely populated areas such as greater London.

1.9 To enable mobile services in this band we outlined two policy options:

- **Option A:** retain existing users' current authorisations under the Wireless Telegraphy Act 2006 (the WT Act) to (i) transmit for fixed links, and (ii) receive for satellite earth stations registered under grants of Recognised Spectrum Access for Receive Only Earth Stations (RSA for ROES) and permanent earth station (PES) licences within the 3.6GHz to 3.8GHz band;
- **Option B:** remove existing users' authorisation under the WT Act to transmit for fixed links and no longer take registered satellite earth stations with a receive component in the 3.6GHz to 3.8GHz band into account for frequency management purposes.

Making the 3.6GHz to 3.8GHz band available for mobile services

1.10 After analysing the responses to the October consultation and further information provided by stakeholders on current use of the band, we have decided to make the 3.6GHz to 3.8GHz band available for mobile use as soon as practicable, and to award the remaining 116 MHz in the band for future mobile services.

1.11 Making this additional spectrum available for mobile services will support meeting increasing consumer demand for mobile data, as well as delivering new and improved mobile services, including 5G. This band is particularly suitable for future mobile services including 5G because:

- the large bandwidth can support higher data rates and provide increased capacity to support large numbers of connected devices, and enable higher speeds to concurrently connected devices;
- it can support mobile services including 5G across wide areas, as it can be deployed using macrocells over existing grids;
- it has already been harmonised for mobile and identified as part of the primary band for introducing 5G in Europe, with potential for devices to become available as early as 2019-20.

1.12 We believe that making the remaining 116 MHz in the band available for mobile services will result in greater benefits for UK citizens and consumers, make optimal use of the spectrum, and give effect to our duties regarding competition and innovation.

1.13 Given this decision, we will not issue any further fixed links licences, PES licences, or grants of RSA for ROES using these frequencies.

- 1.14 As a result of the geographic concentration of existing users, there are areas in which these frequencies could be used from today, for trials and pre-commercial deployments. Ofcom can make spectrum available to facilitate trials and pre-commercial deployments, including for 5G, to support innovation in the UK.

Consultation on proposed approach for satellite earth station and fixed links users

- 1.15 Given the locations of current users of the band, there are areas of the country in which these frequencies could become available for mobile use as soon as they are awarded. These include most of the north of England and Wales, Northern Ireland and southern Scotland. However, there are large parts of the UK where mobile roll out would be significantly constrained under current coordination arrangements. This includes some densely populated areas including greater London.
- 1.16 To facilitate deploying future mobile services including 5G in the band across the UK, we propose to remove current authorisations for fixed links and no longer take registered satellite earth stations with a receive component in the 3.6GHz to 3.8GHz band into account for frequency management purposes – option B in the October consultation – following appropriate notice periods.
- 1.17 We consider that this approach will result in greater net benefits to citizens and consumers than maintaining existing authorisations, by supporting the delivery of innovative mobile services to wider areas. In particular, option B would remove the constraints on mobile roll out including in a number of densely populated areas including greater London where we would expect there to be the highest demand for mobile data services.
- 1.18 We also expect that most, if not all, of the benefits currently delivered by services in this band could continue to be achieved using alternative frequencies and technologies. As a result, we consider that the benefits of enabling more widespread future mobile services in the band outweigh the costs and disruption to existing registered users of doing so.
- 1.19 We will also shortly write to licensees and grant holders in the band setting out details of how, under option B, we would propose to implement our proposals by (i) varying existing authorisations for satellite earth stations operating under PES licences and grants of RSA for ROES and (ii) revoking licences for fixed links.
- 1.20 The effect of our proposed approach would be to enable future mobile services in the 3.6GHz to 3.8GHz band to be deployed in many areas from around 2020, but not necessarily nationwide before 2022.
- 1.21 Once we have taken account of responses to this consultation, we will publish a further statement setting out our decision in due course, and provide an update on how we expect to make the band available for mobile services.

Facilitating future coexistence for satellite earth stations

- 1.22 Our proposed approach aims to remove constraints on mobile roll out arising from existing coordination requirements. Under option B, once the changes take effect, satellite earth station operators would be able to choose to continue to operate in the 3.6GHz to 3.8GHz band on a licence exempt basis. In practice, their ability to

continue to receive without service-impacting levels of interference will vary according to site characteristics and mobile roll out patterns.

- 1.23 To facilitate continued operation of satellite services in the band where possible, we will explore applying localised restrictions in future mobile licences, where these would not have a material impact on mobile deployment. Such conditions would place technical restrictions on a mobile network operator deploying base stations in the immediate vicinity of satellite earth station sites. In general, we would expect these arrangements to apply to relatively small areas. However, we will consider larger areas if these would not have a material impact on mobile deployment.
- 1.24 We will engage stakeholders in developing this approach to localised mobile restrictions, taking account of the following considerations:
- our objective to ensure consumers right across the UK can benefit from new mobile services including 5G;
 - that any constraints on mobile deployment should be kept to a minimum, and will not prevent Mobile Network Operators (MNOs) from offering mobile services in the area affected;
 - that any proposals should take account of local site and topology characteristics;
 - ensuring MNOs are able to meet demand across the UK by deploying mobile services using this spectrum on existing macrocells.

Awarding the 3.6GHz to 3.8GHz band

- 1.25 To ensure timely availability of spectrum we are minded to deliver a future combined award in 2019 of:
- the remaining 116 MHz being made available in the 3.6GHz to 3.8GHz band; and
 - the 700MHz spectrum which is expected to become available by mid-2020.
- 1.26 We will consult on proposals for the future award in due course.

UK Broadband

- 1.27 Following the recent acquisition by H3G, we will consider issues relating to the UK Broadband licence at 3605MHz to 3689MHz further and consult on proposals at a later date if necessary.

Section 2

Introduction

- 2.1 Ofcom is responsible for managing the radio spectrum to ensure that it is used in the most efficient and effective way for the overall benefit of UK citizens and consumers.
- 2.2 Our direction and spectrum priorities were set out in our 10-year Spectrum Management Strategy¹ in 2014, in which we identified addressing future mobile data demands as a priority, recognising the importance of improving mobile coverage and availability of new mobile services. This work underpinned our Mobile Data Strategy,² which identified the 3.6GHz to 3.8GHz band as a high priority for providing additional mobile services.

The October consultation

- 2.3 In October 2016, we published our consultation *Improving consumer access to mobile services at 3.6 to 3.8GHz* (the October consultation).³ In it we proposed making the spectrum in the 3.6GHz to 3.8GHz band not assigned for electronic communications services (116 MHz of the 200 MHz) available for future mobile services including 5G. These frequencies are currently used by fixed links and satellite earth stations; current use of the band is described in section 4.
- 2.4 Alongside the October consultation, we published technical analysis showing that coexistence between mobile and existing users of the band would be challenging under current coordination criteria. We therefore set out two policy options on how we could approach coexistence:
 - **Option A: retain** existing users' current authorisations under the Wireless Telegraphy Act 2006 (the WT Act) to (i) transmit for fixed links, and (ii) receive for satellite earth stations registered under grants of Recognised Spectrum Access for Receive Only Earth Stations (RSA for ROES) and permanent earth station (PES) licences within the 3.6GHz to 3.8GHz band. Under this option we would continue to take satellite earth stations with a receiver component in the 3.6GHz to 3.8GHz band into account for frequency management purposes; and
 - **Option B: remove** existing users' authorisation under the WT Act to transmit for fixed links and no longer take registered satellite earth stations with a receiver component in the 3.6GHz to 3.8GHz band into account for frequency management purposes.
- 2.5 Our specific proposals are discussed in more detail throughout sections 5 to 8 of this document, which also provide an overview of stakeholders' responses to our consultation questions, and our assessment of the issues raised.

¹ *Spectrum Management Strategy*, Statement, April 2014, https://www.ofcom.org.uk/_data/assets/pdf_file/0021/71436/statement.pdf

² *Mobile Data Strategy*, Update, June 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0033/79584/update-strategy-mobile-spectrum.pdf

³ *Improving consumer access to mobile services at 3.6 to 3.8 GHz*, Consultation, October 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0035/91997/3-6-3-8ghz-consultation.pdf

Overview of consultation responses and stakeholder engagement

- 2.6 We received a total of 36 responses to our October consultation which closed on 15 December 2016. Four respondents submitted wholly confidential responses.⁴
- 2.7 Following the October consultation, we issued a statutory information request to registered satellite earth stations receiving transmissions in this band under a PES licence or grant of RSA for ROES. We also conducted bilateral meetings with satellite earth station and fixed link licensees and grant holders to ensure we fully understood how their services operate, the way they currently use the band, and the benefits these services deliver to UK citizens and consumers. We have fully considered and taken account of all information provided by stakeholders in the preparation of this document.

Structure of this document

- 2.8 This document comprises:
- **a statement** setting out our decision to make the 3.6GHz to 3.8GHz band available for mobile services; and
 - **a consultation** on our proposed approach to existing authorisations in the 3.6GHz to 3.8GHz band in making the band available for mobile.

The closing date for responses is **22 September 2017**.

- 2.9 The rest of this document is set out as follows:
- Section 3 explains our statutory duties when regulating the use of spectrum in the UK;
 - Section 4 describes how the 3.6GHz to 3.8GHz band is currently used;
 - Section 5 sets out our decision to make the 3.6GHz to 3.8GHz band available for mobile services;
 - Section 6 explains our updated analysis and findings on coexistence between existing users and future mobile services;
 - Section 7 explains our proposed approach to existing registered users of the band following the decision to make the band available for mobile services, in light of our consideration of options A and B set out in the consultation and alternative approaches suggested by stakeholders;
 - Section 8 sets out our proposed implementation approach and how this would affect existing users of the band, as well as our policy on applications for new authorisations, and our intended approach to the UK Broadband licence;
 - Section 9 summarises the decisions and proposals set out in this document and sets out our next steps;

⁴ All non-confidential responses are published on our website at <https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz>

- Annexes 1 to 4 set out how to respond to this consultation, our consultation principles, response cover sheet and the questions we are consulting on;
- Annex 5 provides additional detail about the assumptions and conclusions of the updated coexistence analysis we have carried out since the October consultation;
- Annex 6 summarises the responses we received to the October consultation and our responses to the issues raised;
- Annex 7 is a glossary.

Section 3

Legal framework

- 3.1 In making the decisions set out in this statement, Ofcom acts within a framework defined by both EU and UK law. In the context of considering the future use of the 3.6GHz to 3.8GHz band, Ofcom has specific duties and powers related to the management of radio spectrum. The legal framework was set out in the October consultation and the full detail is not repeated here. However, we highlight the following aspects.

Duties under the Communications Act 2003

- 3.2 Section 3 of the Communications Act 2003 (the Communications Act) 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.
- 3.3 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.
- 3.4 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 the desirability of encouraging the availability and use of high speed data transfer services throughout the UK.
- 3.5 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.
- 3.6 Section 3(7) states that where it appears to us that any of our general duties conflict with each other in a particular case, we must secure that the conflict is resolved in the manner which we think is best in the circumstances. In practice, this involves a balancing exercise, taking into account the relative weight and importance of each competing objective and applying the principle of proportionality.

Duties under the Wireless Telegraphy Act 2006

- 3.7 Section 3 of the WT Act 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 use of the spectrum.
- 3.8 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.

European harmonisation decisions relating to the 3.4GHz to 3.8GHz band

- 3.9 On 21 May 2008, the European Commission adopted a decision which sought to harmonise the conditions for the availability and efficient use of the 3.4GHz to 3.8GHz frequency band for terrestrial systems capable of providing electronic communications services in the EU (the Commission Decision).⁵
- 3.10 In relation to the 3.6GHz to 3.8GHz band, the decision provided that Member States should designate, by 1 January 2012, 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. These parameters include the deployment of fixed, nomadic, or mobile networks. Any award of the 3.4GHz to 3.8GHz band must be compliant with the Commission Decision.
- 3.11 The Commission Decision was amended in May 2014, when the European Commission adopted Commission Implementing Decision 2014/276/EU, which established technical parameters for electronic communication services that are authorised to use the 3.4GHz to 3.8GHz band. EU Member States must make sure that spectrum licences issued for electronic communication services in these bands are aligned with these parameters. For the 3.6GHz to 3.8GHz band, these parameters, as articulated in the CEPT⁶ Report 49,⁷ correspond to TD-LTE spectrum access technology.
- 3.12 The Commission Decision (as amended) has been implemented in to UK law by way of Statutory Instrument 2016 No. 495.⁸ This statutory instrument states that Ofcom must designate and make available, on a non-exclusive basis, the 3.4GHz to 3.8GHz frequency band for terrestrial electronic communications networks, in compliance with the technical parameters for high power TD-LTE mobile networks.

Impact assessment

- 3.13 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 practice policy-making. This is reflected in Section 7 of the Communications 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 our activities.
- 3.14 In the October consultation, we explained that we believed there was a case for making the remaining 116 MHz of the 3.6GHz to 3.8GHz band not currently assigned to electronic communications services available for future mobile services,

⁵ Commission Decision 2008/411/EC, May 2008, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008D0411&from=EN>.

⁶ The European Conference of Postal and Telecommunications Administrations, CEPT, includes all 48 European countries including Russia. CEPT is where technical work for spectrum is carried out.

⁷ CEPT Report 49, March 2014, <http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP049.PDF>

⁸ The 1452-1492MHz and 3400-3800MHz Frequency Bands (Management) Regulations 2016, April 2016, http://www.legislation.gov.uk/uksi/2016/495/pdfs/uksi_20160495_en.pdf. These Regulations replaced the 3400-3800MHz Frequency Band (Management) Regulations 2008, which implemented Commission Decision 2008/411/EC prior to its amendment in 2014.

having regard to the likely benefits to be derived from doing so and the potential impact on affected stakeholders, including existing users of the band. Section 5 of this document confirms our decision, following consultation, to make this spectrum available for mobile services.

- 3.15 In the October consultation we also set out two broad policy options for making the band available for mobile services, and sought views from stakeholders on the associated costs and benefits. We explained that we planned to make proposals based on one of these options, informed by the evidence received in response to the consultation.
- 3.16 Sections 7 and 8 of this document set out our proposed approach for implementing our decision to make the 3.6GHz to 3.8GHz band available for mobile in relation to existing users' authorisations in the band, including our assessment of the likely benefits and impacts of implementing our proposal.

Equality impact assessment

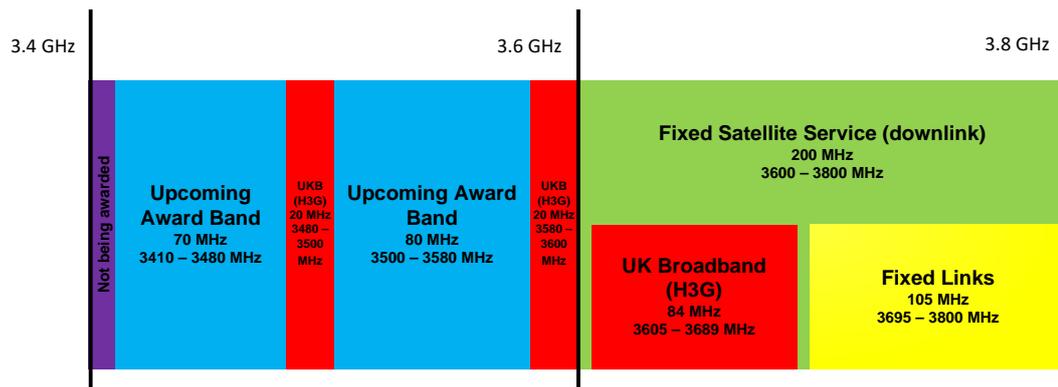
- 3.17 Ofcom is also required to assess the potential impact of all its functions, policies, projects and practices on the equality of individuals to whom those policies will apply. An equality impact assessment (EIA) assists Ofcom in making sure that it is meeting its principal duty of furthering the interests of citizens and consumers regardless of their background or identity.
- 3.18 We do not consider that our proposals for the 3.6GHz to 3.8GHz band are likely to have a greater impact on any protected groups of stakeholders, including (among others) groups protected by Northern Irish equality legislation, as compared to their impact on UK citizens and consumers generally.

Section 4

Current use of the 3.6GHz to 3.8GHz band

- 4.1 In this section, we explain the services currently operating in the 3.6GHz to 3.8GHz band, and consider stakeholders’ responses to our October consultation question on how the band is used.
- 4.2 Frequencies in the 3.6GHz to 3.8GHz band are used for fixed links, fixed satellite services (to receive space-to-Earth transmissions), and wireless broadband (provided by UK Broadband). Presently, fixed links, wireless broadband and fixed satellite services share the band on a first come, first served basis, subject to our coordination and technical frequency assignment criteria.⁹
- 4.3 The distribution of these applications by frequency within the 3.4GHz to 3.8GHz band is illustrated in Figure 1 below.

Figure 1: Spectrum use in the 3.4GHz to 3.8GHz band, by application and frequency



Fixed links

- 4.4 Fixed links in the 3.6GHz to 3.8GHz band are used to convey voice or data traffic wirelessly between specified geographic locations. They support a variety of applications, including connections to broadcasting sites, mobile backhaul, and high frequency trading.
- 4.5 At the time of the October consultation, with respect to the 3.6GHz to 3.8GHz band there were 35 fixed links operating across the UK. The number of licences has since reduced to 26, two of which will expire on 28 November 2019. These bidirectional licensed links fall within the 3.6GHz to 3.8GHz band on the lower duplexes of four 2 x 30 MHz channels and are paired with the corresponding upper

⁹ OfW 446, October 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0017/92204/ofw446.pdf; and the principles of OfW188, January 2008, https://www.ofcom.org.uk/_data/assets/pdf_file/0027/85086/coordination_processes.pdf

duplex channels within the 3.8GHz to 4.2GHz band.¹⁰ The distribution of these links in frequency is shown in Table 1.

Table 1: Distribution of fixed links within the 3.6GHz to 3.8GHz band

	Channel 4	Channel 5	Channel 6	Channel 7
Frequencies	3695MHz to 3725MHz	3725MHz to 3755MHz	3755MHz to 3785MHz	3785MHz to 3815MHz
Number of links	5 (including one temporary link)	6 (including one temporary link)	8	7
Locations	Scottish Islands and Mainland Thames Estuary	Southampton and the Isle of Wight Scottish Islands and Mainland South London and Kent	Scottish Islands and Mainland Aberdeen South-east	Scottish Islands and Mainland Aberdeen South-east

4.6 Figure 2 below illustrates the locations of fixed links authorised to use this band in the UK. It shows that there are a number of fixed links between the Scottish mainland and the Isle of Lewis, and the mainland and Shetland and Orkney. There are also links connecting London and the south-east, between Southampton and the Isle of Wight, and near to Aberdeen.

Fixed satellite services

4.7 Satellite earth stations use the 3.6GHz to 3.8GHz band for satellite downlink from geostationary satellites. The wider 3.6GHz to 4.2GHz band (C-band) is favoured by the satellite industry in tropical regions because of the good global coverage and relatively low propagation losses and tolerance of high rainfall conditions. Typically, the band is used in the UK to support broadcasting contribution and distribution from overseas, as well as data communications; the majority of current registered use is above 3.7GHz.

4.8 The ‘receive’ components of satellite earth stations are authorised under licence exemption regulation.¹¹

¹⁰ These correspond to channels 4–7 within the 4GHz band, which is equivalent to 3695MHz to 3815MHz paired with 4015MHz to 4135MHz. As noted in section 4 of the October consultation, channels 1–3 (3605MHz to 3695MHz paired with 3825MHz to 3915MHz) are already closed to new applications for fixed links licences. Channels 8–9 (3815MHz to 3875MHz paired with 4135MHz to 4195MHz) operating above the 3.6GHz to 3.8GHz band remain open.

¹¹ *The Wireless Telegraphy Apparatus (Receivers) (Exemption) Regulations 1989 (SI1989/123)*, January 1989, <http://www.legislation.gov.uk/uksi/1989/123/contents/made>

- 4.9 Ofcom also coordinates the band based on frequency management criteria for satellite earth station receivers registered¹² for specific frequencies through two regulatory products:
- PES licences under the WT Act, under which we also authorise transmission at given frequencies (in the case of the 3.6GHz to 3.8GHz band these will be around 6GHz); and
 - grants of RSA for ROES.
- 4.10 Current Ofcom coordination criteria manage the interference environment in order to provide benchmark spectrum quality for registered users. Benchmark spectrum quality is designed to ensure that the levels of interference experienced by registered receivers in the band would not normally be expected to exceed certain defined levels, which vary according to the licensing product. Ofcom achieves a benchmark by taking into account registered receivers when coordinating new deployments between the different users.
- 4.11 At the time of our October consultation there were 14 sites with satellite earth stations registered under PES licences, receiving in the 3.6GHz to 3.8GHz band; and 5 sites with satellite earth stations registered under grants of RSA for ROES (one of which is also registered under a PES licence). The number of sites with satellite earth stations registered under PES licences has since fallen to 12,¹³ while there continue to be 5 sites with satellite earth stations registered under grants of RSA for ROES (one of which is also registered under a PES licence). There is also some degree of unregistered use in this band for receiving space-to-Earth transmissions, in addition to Crown usage. Figure 2 below shows the geographic location of the registered satellite earth stations. Most are situated at sites in the south-east, although there are also sites located in the West Midlands, south-west, and north of Scotland.

¹² In this document we use the term “registered users” to denote satellite earth station receiver components which appear in Schedule 2 of a PES licence or Schedule 1 of a grant of RSA for ROES registered with frequencies in the range 3.6GHz to 3.8GHz; and, where relevant, authorised licensed fixed links in this range.

¹³ The figures for registered satellite earth stations exclude [X<]

Figure 2: Geographic distribution of fixed links and registered satellite earth stations receiving at 3.6GHz to 3.8GHz¹⁴



UK Broadband licence

- 4.12 In addition to fixed links and satellite services, an 84 MHz block within the 3.6GHz to 3.8GHz band is already authorised for electronic communications networks (which includes mobile and fixed communications). It is currently licensed to UK Broadband, which provides wireless broadband services using an LTE network in and around London, Reading and Wiltshire in the 3605MHz to 3689MHz range.¹⁵

¹⁴ This map does not show the two temporary licensed fixed links, which are located in Kent and Essex.

¹⁵ This is paired with another 84MHz at 3925MHz to 4009MHz, although UK Broadband uses the two blocks independently of each other. UK Broadband also holds a separate licence authorising it to use 2 x 20 MHz in the neighbouring 3.4GHz to 3.6GHz band, as shown in Figure 1 above.

- 4.13 When UK Broadband seeks a new deployment, it must submit technical information about that base station to Ofcom. We use that information to assess whether the new base station is likely to undermine benchmark spectrum quality for existing satellite earth stations and fixed links, using the principles set out in Ofcom's coordination guidelines.¹⁶ UK Broadband is not permitted to deploy new base stations unless the application is passed by the coordination process.

We confirmed how the band is used in the October consultation

- 4.14 In our October consultation, we sought comments on our description of how the 3.6GHz to 3.8GHz band is used by the services set out above. We showed that use was concentrated geographically for both satellite earth stations and fixed links. We noted that the band's current use is lighter for satellite earth stations than in other bands. We also stated that fixed link use of the band is also significantly lighter than in other bands.
- 4.15 Specifically, we asked:
- Question 1: Do you have any comments on the use of the 3.6GHz to 3.8GHz band by existing services?

Stakeholder responses

- 4.16 A number of stakeholders set out the importance of the wider C-band (including 3.8GHz to 4.2GHz) for a range of global satellite services, given the particular characteristics of C-band. Some told us they hoped to grow their C-band services. Some respondents provided additional information about specific current C-band uses (including in the 3.6GHz to 3.8GHz band) by earth stations which include:
- broadcasting contribution and distribution, principally from overseas;
 - Ministry of Defence (MOD) use at Bude in Cornwall;
 - the BBC's monitoring service;
 - support for EGNOS (European Geostationary Navigation Overlay Service), a pan-European satellite navigation system used for safety critical applications;
 - communications with remote locations, including offshore; and
 - examples of licence exempt use.
- 4.17 UK Broadband noted that its use of the 3.6GHz to 3.8GHz band could expand in future.
- 4.18 Several, predominantly mobile, respondents agreed with our observation that current use of the band is geographically limited.
- 4.19 The UK Space Agency and techUK noted that whilst the number of licences and RSAs issued in the band was relatively low, this may understate the use of the

¹⁶ https://www.ofcom.org.uk/_data/assets/pdf_file/0017/92204/ofw446.pdf. As set out in footnote 9, channels 1–3 (3605MHz to 3695MHz paired with 3825MHz to 3915MHz) are already closed to new applications for fixed links licences.

band by the satellite sector. They suggested that given limited terrestrial use to date, receive only users may not have felt a need to apply for an RSA for ROES.

Our assessment

- 4.20 We welcome the additional information respondents provided on specific use cases to inform our analysis, and have updated our understanding of the band based on the information we received.
- 4.21 We note that there is likely to be continued use of wider C-band frequencies to deliver global satellite services such as broadcast contribution and distribution from overseas, along with data communications, given its importance in tropical zones for tolerance of high rain rates and its good global coverage. At the same time, we have noted that whilst our Space Spectrum strategy (see paragraph 5.53) identified potential for growth in a number of different satellite applications including satellite broadband and earth observation, this growth was not associated with, or reliant upon, use of the 3.6GHz to 3.8GHz band in the UK.¹⁷
- 4.22 We have been made aware of some cases where users are or may be receiving from satellites using the 3.6GHz to 3.8GHz frequencies at sites on a licence exempt basis. We are unable to quantify the number of such users, but have not been made aware of anything that suggests there is extensive licence exempt use.

¹⁷ *Space Spectrum*, Statement, January 2017, https://www.ofcom.org.uk/_data/assets/pdf_file/0030/96735/Statement-Space-Spectrum.pdf

Section 5

Decision on making the 3.6GHz to 3.8GHz band available for mobile services

- 5.1 In this section, we consider the responses we received to our October consultation, and how these have informed our decision on making the band available for mobile services.

Our proposal

- 5.2 In section 6 of our October consultation, we said that the 3.6GHz to 3.8GHz band could play an important role in addressing the increasing demand for mobile data services including by being one of the first bands in Europe (and beyond) for 5G services.
- 5.3 We considered that the 3.6GHz to 3.8GHz band is particularly useful for future mobile services because it is already harmonised in Europe and the large bandwidth available can provide the necessary capacity to support the provision of faster mobile data services to a high number of connected devices.
- 5.4 We also noted that although these frequencies are currently used to provide services that deliver benefits to UK citizens and consumers, they are lightly used when compared with other bands. We considered that making the band available for mobile services would result in greater benefits for UK citizens and consumers and deliver optimal use of spectrum. We also considered that this would have the potential to help us fulfil our duties regarding competition and innovation.
- 5.5 On this basis, we set out a provisional view in the October consultation that we should make the remaining 116 MHz of the band not currently assigned to UK Broadband available for future mobile use.
- 5.6 We asked stakeholders the following questions:
- Question 2: Do you agree with our identification of a trend towards the use of mobile in the 3.6GHz to 3.8GHz band?
 - Question 3: Do you agree with our high level proposal to make 116 MHz within the 3.6GHz to 3.8GHz available for mobile and 5G services, bearing in mind our statutory duties and the high level trends we have identified?

Stakeholder responses

- 5.7 Of the 36 responses we received to our October consultation, 25 agreed that there is a trend towards the use of the 3.6GHz to 3.8GHz band for mobile services.¹⁸ Agreement came from both mobile and satellite stakeholders. Only three respondents (two Fixed Wireless Access (FWA) stakeholders and the UK Space Agency) disagreed that there was a trend towards wider use of the band for mobile services.

¹⁸ Eight stakeholders did not give a view on whether they agreed.

- 5.8 Most respondents supported our high level proposal to make the remaining 116 MHz in this band available for mobile services, although there were differing views on how to implement this. A number of stakeholders identified supporting international developments, in particular the Radio Spectrum Policy Group (RSPG)¹⁹ Opinion and European technical work.
- 5.9 Mobile stakeholders were strongly supportive of making the band available for mobile services given its suitability for a range of mobile applications including increasing data capacity and 5G services. Many called for the band to be made available for mobile quickly.
- 5.10 Some respondents suggested the benefits generated by use of this band for mobile services would be significant, and provided examples of the expected economic benefits from additional 4G and 5G mobile services in general terms. Telefonica cited a 2012 Analysys Mason report which found that mobile services in general accounted for 58%, or £30.2bn, of the total value of spectrum to the UK economy,²⁰ as well as a Capital Economics Research estimate from 2012 that the roll out of 4G networks will provide a £75bn boost to the UK economy.²¹ Stakeholders noted that estimating the benefits for 5G is difficult at this stage, however the IET estimated that future 5G services will be pivotal in sustaining a £28bn²² market for the next 10-15 years. Ericsson expected that faster speeds enabling new 5G services will have a positive impact on GDP.
- 5.11 Most satellite stakeholders were prepared to accept the high level proposal to make the band available for mobile services as long as it went alongside plans for sharing the spectrum to enable their continued operation.
- 5.12 However, FWA stakeholders and some satellite stakeholders were sceptical about the prospects for widespread use and viability of this band for mobile services, given how other spectrum bands are used by MNOs and the propagation characteristics of these frequencies.
- 5.13 The UK Space Agency observed that mobile parameters were not finalised and there was no global harmonisation of the band, whilst some respondents pointed out that previous attempts to use this spectrum for terrestrial broadband had not been very successful. The UK Space Agency also argued that making the band available for mobile would discourage satellite sector growth.
- 5.14 Ordnance Survey suggested that given the challenges of making this band available for mobile services, we should focus on making mmWave spectrum available for 5G.

¹⁹ The Radio Spectrum Policy Group is a high level advisory group that assists the European Commission in the development of radio spectrum policy and is chaired by one of the Member States. The Opinion is discussed in paragraph 5.41.

²⁰ Analysys Mason, *Impact of radio spectrum on the UK economy and factors influencing future spectrum demand*, November 2012, <https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand>

²¹ EE, "4G to provide UK with annual economic boost reaching 0.5% GDP by the end of decade", April 2012, <https://explore.ee.co.uk/our-company/newsroom/4g-provide-uk-annual-economic-boost-reaching-05-gdp-end-decade>

²² Based on the current annual value of UK mobile networks at £15bn and fixed telecoms at £13bn per year.

- 5.15 A number of stakeholders put forward alternative approaches for achieving 5G use in the band. These are considered in section 7 and the summary of responses in annex 6.

Our assessment

- 5.16 In reaching our decision on whether to make the remaining 116 MHz in the 3.6GHz to 3.8GHz band available for mobile services we have taken into account the following factors which were considered in the October consultation and discussed in stakeholder comments:
- growing demand for mobile data driven by consumers' take up of existing services and new and innovative wireless services, including those enabled by 5G technologies;
 - the suitability of this spectrum to deliver higher speed and capacity, enabling new services, and improved quality of service;
 - international developments to make this band available for mobile, including the development of a device ecosystem; and
 - current use of this spectrum and the impact of making the band available for mobile on existing users and the benefits currently delivered through the band.

Additional spectrum is an important enabler for meeting growing consumer demand for mobile data services and enabling innovative 5G services

Demand for mobile services continues to grow

- 5.17 Consumers increasingly rely on wireless connectivity as an everyday necessity where they live, work and travel, and consequently mobile data traffic per subscriber has increased tenfold over the last five years, from 0.1GB in March 2011 to 1.3GB in June 2016.²³
- 5.18 This strong growth in mobile data use has been driven by a number of factors, and is expected to continue. Amongst other things, consumers are increasingly accessing the internet from their smartphones, and these have overtaken laptops as the most popular device for going online.²⁴ Some consumers are also increasingly using high capacity applications, such as streaming HD video and gaming on mobile.
- 5.19 Emerging wireless technologies, allowing for increased network flexibility, will make new services possible and make existing services work better and faster, further driving mobile data use.
- 5.20 Although projections of future growth are uncertain, there is a broad consensus that mobile data consumption will increase sharply over the next decade – potentially by a factor of 10 to 100. Such a rapid growth in demand places pressure on MNOs to increase their network capacity in order to meet growing consumer expectations.

²³ *Connected Nations 2016*, December 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0035/95876/CN-Report-2016.pdf, p.45

²⁴ *Communications Market Report 2016*, Research Document, August 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf

5G: a new generation of wireless technologies

- 5.21 5G is the next generation of mobile technologies and is being designed to provide greater capacity for wireless networks, offer greater reliability, and deliver extremely fast data speeds, enabling innovative new services across different industry sectors.
- 5.22 5G technologies are under development, and are likely to include both an evolution of existing technologies and new radio technologies. 5G is being developed in parallel with the continuing improvement of 4G to support faster speeds, more capacity and better quality of experience.
- 5.23 In February 2017, we published our *Update on 5G spectrum in the UK* (the 5G Update).²⁵ This document provided an overview of the diverse services and applications that 5G is being designed to enable. These can be grouped into three different classes:
- **Enhanced Mobile Broadband.** Together with an evolution of the services already provided by 4G, 5G is expected to provide faster and more reliable mobile broadband, offering a richer experience to consumers.
 - **Massive Machine Type Communications.** The Internet-of-Things (IoT) – where gadgets and devices wirelessly connect to the internet and each other – is happening on existing networks. Its technology is being used in everything from smart homes to wearables. 5G should help the evolution of IoT services and applications and improve interaction between different platforms. Possible future applications could include real-time health monitoring of patients; optimisation of street lighting to suit the weather or traffic; environmental monitoring and smart agriculture.
 - **Ultra-Reliable and Low Latency Communications.** 5G networks are being designed to be more reliable and have very low latencies (network delays). This could make them suitable for applications such as connected and driverless cars and smart manufacturing.
- 5.24 The 5G Update set out that one of our aims is to ensure that spectrum will not inhibit the roll out of 5G technologies in the UK, and that citizens and consumers across the UK can benefit from 5G services. It also explained the international process which led to the identification of different spectrum bands to meet the future requirements of 5G services and applications (700MHz, 3.4GHz to 3.8GHz, and 26GHz as bands for 5G in Europe), and our programme of work with regards to these bands.

²⁵ *Update on 5G spectrum in the UK*, Statement, February 2017
https://www.ofcom.org.uk/_data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

- 5.25 In March 2017, the UK Government published its 5G Strategy.²⁶ The strategy built on recommendations made in the National Infrastructure Commission (NIC)²⁷ and Future Communications Challenge Group (FCCG)²⁸ reports on 5G.
- 5.26 The strategy sets out the Government's ambition that the UK should be a global leader in 5G, and reinforces our support for 700MHz, 3.4GHz to 3.8GHz and 26GHz as 5G pioneer bands. The strategy also confirms that the Government agrees with the NIC that there should be high quality 5G coverage where people live, work and travel.
- 5.27 The strategy notes the potential growth and productivity benefits and opportunities that 5G could bring to the UK. Whilst noting that estimates are by their nature speculative, it refers to recent reports illustrating the potential gains from 5G. In particular:
- The FCCG's report suggesting that UK leadership in 5G could result in the opportunity to create £173 billion of incremental UK GDP growth over a ten year period from 2020 to 2030;²⁹
 - IHS Economics/ IHS Technology estimated that 5G will enable USD\$12.3 trillion of global economic output in 2035.³⁰

Additional spectrum is an important enabler for MNOs to meet demand and deliver improved services

- 5.28 Additional network capacity will be needed to meet growing consumer demand for mobile services, including future 5G applications.
- 5.29 Network capacity to meet demand for mobile data is delivered by a combination of number of sites and spectrum, and is impacted by the technology and spectrum used at each site. MNOs have a number of options to increase capacity including increased roll out of existing spectrum to additional locations, technology improvements, building additional sites and deploying more spectrum.
- 5.30 However, as set out in our Mobile Data Strategy Update,³¹ current evidence suggests that deployment of more efficient technology using existing mobile

²⁶ DCMS and HM Treasury, *Next Generation Mobile Technologies: A 5G strategy for the UK*, March 2017, <https://www.gov.uk/government/publications/next-generation-mobile-technologies-a-5g-strategy-for-the-uk>

²⁷ NIC, *Connected Future*, December 2016, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577906/CONNECTED_FUTURE_ACCESSIBLE.pdf

²⁸ FCCG, *UK strategy and plan for 5G & Digitisation – driving economic growth and productivity*, January 2017, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf

²⁹ FCCG, *UK strategy and plan for 5G & Digitisation – driving economic growth and productivity*, January 2017, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf, from page 30.

³⁰ DCMS and HM Treasury, *Next Generation Mobile Technologies: A 5G strategy for the UK*, March 2017, <https://www.gov.uk/government/publications/next-generation-mobile-technologies-a-5g-strategy-for-the-uk>, page 28.

³¹ *Mobile Data Strategy: Update on our strategy for mobile spectrum*, Update, June 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0033/79584/update-strategy-mobile-spectrum.pdf

spectrum will not be sufficient, on its own, to meet future demand growth. Improving capacity by building additional sites also presents challenges, including costs and site availability. We therefore consider that making additional spectrum available for mobile services is a key enabler for delivering increased network capacity.

- 5.31 Additional spectrum is also important to enable the development and roll out of new and improved mobile services, including 5G, for all UK citizens and consumers. As set out in our 5G Update, the different services and applications 5G is being designed to enable, as listed in paragraph 5.23, are likely to require different spectrum bands with differing technical characteristics.³² For example, wider bandwidths will be required to deliver higher speeds and capacity. Whilst there is still uncertainty around the precise bandwidth requirements for 5G,³³ we consider that at least 80 MHz is likely to be needed in medium frequency bands to meet the 5G (IMT-2020) requirements.^{34 35}

3.6GHz to 3.8GHz: Suitability for future mobile services including 5G

- 5.32 We remain of the view set out in the October consultation that the 3.6GHz to 3.8GHz band could play an important role in addressing the increasing demand for mobile data services in the medium to long term, and enabling the delivery of new and improved mobile services by being one of the first bands used in Europe (and beyond) for the roll out of 5G services.
- 5.33 As set out below, this view is supported by:
- the technical characteristics of the band;
 - international activity for use of the band for mobile services; and
 - the emerging device ecosystem for the band.

Technical characteristics

- 5.34 The technical characteristics of the 3.6GHz to 3.8GHz band underline its suitability for future mobile services including 5G, and the case for making additional spectrum in this band available for these services.
- 5.35 The 3.6GHz to 3.8GHz band offers a large amount of bandwidth and therefore could provide a significant amount of capacity for mobile networks to meet future demand, and support the roll out of 5G services. Compared to existing mobile bands, spectrum at 3.6GHz to 3.8GHz offers the bandwidth for higher data rates

³² *Update on 5G spectrum in the UK*, Statement, February 2017,

https://www.ofcom.org.uk/_data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

³³ The ITU has not reached a final position in relation to minimum bandwidth requirements for IMT 2020 (5G standard). The latest relevant document is available in draft and will be considered for final adoption later this year: <https://www.itu.int/md/R15-SG05-C-0040/en>

³⁴ *Award of the 2.3 and 3.4 GHz spectrum bands*, Statement, July 2017,

https://www.ofcom.org.uk/_data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf

³⁵ This is set out in Draft New Report ITU-R M.[IMT-2020.TECH PERF REQ] *Minimum requirements related to technical performance for IMT-2020 radio interfaces*. It sets out the minimum requirements to be included in the IMT-2020 family of technologies (i.e. to be considered as a 5G technology), has been agreed by ITU-R Working Party 5D and is due to be adopted by ITU-R by the end of 2017.

<https://www.itu.int/md/R15-SG05-C-0040/en>.

and increased capacity to support large numbers of connected devices, and enable higher speeds to concurrently connected devices.³⁶

- 5.36 Emerging technologies to support mobile deployment using 3.6GHz to 3.8GHz will enable deployment using existing macrocells. This means that 3.6-3.8GHz could be used to provide mobile services including 5G across wider areas, building on existing macrocell networks.³⁷
- 5.37 The fact that the spectrum can be deployed on existing macrocells means that, in principle, the deployment of future mobile services including 5G would be quicker and cheaper over wider areas of the country than would be the case were new sites needed, or only small cells available.
- 5.38 We do not consider that spectrum at high frequencies above 24GHz (e.g. mmWave) is a substitute for spectrum at 3.6GHz to 3.8GHz. Whilst mmWave spectrum offers very large bandwidths providing very high capacity and can support very low latency applications, given the short range nature of this spectrum it is likely to be deployed in high demand areas, or in specific locations or premises requiring services with very high capacity, rather than to provide services and capacity over wider areas.

International activity for use of the 3.6GHz to 3.8GHz band

- 5.39 Our assessment is also informed by increasing European and international activity around making this band available for mobile services including 5G.
- 5.40 The October consultation set out the international context for our proposal to make the 3.6GHz to 3.8GHz band available for mobile. In particular, we noted the decision of the European Commission requiring EU Member States to make the 3.4GHz to 3.8GHz band available for electronic communication services (see paragraphs 3.9-3.12). The Commission Decision notes that the band offers significant potential for deploying dense and high speed wireless broadband networks to provide innovative electronic communications services to end users. It adds that the use of this band for wireless broadband should contribute to the economic and social policy objectives of the Digital Agenda for Europe.
- 5.41 In November 2016 the RSPG, the high level group of national spectrum authorities that advises the European Commission on spectrum issues, published an Opinion on spectrum bands for next generation 5G wireless networks which identified a strategic roadmap for 5G in Europe.³⁸ This Opinion identified the 3.4GHz to 3.8GHz band as the primary band for 5G services in Europe, with the possibility to put Europe at the forefront of 5G deployment.

³⁶ We anticipate that emerging massive-MIMO (Multiple-Input Multiple-Output) technologies will enable the use of multiple antennas to serve multiple users at the same time with a higher data rate, increasing capacity and providing a more consistent quality of service. For the 3.6GHz to 3.8GHz band the reduced wavelength compared to lower frequencies enables the use of a higher number of antenna elements within the same antenna radome dimensions.

³⁷ An increased cell range can be delivered through beamforming as a result of the higher number of antennas.

³⁸ RSPG, *Strategic Roadmap Towards 5G for Europe: Opinion on spectrum related aspects for next-generation wireless systems (5G)*, November 2016, http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

- 5.42 We have already set out our plans to make the lower part of the 3.4GHz to 3.8GHz 5G primary band available for mobile. On 11 July 2017, we published a Statement and associated documents for the award of 150 MHz of spectrum in the 3.4GHz to 3.6GHz range (3410MHz to 3480MHz and 3500MHz to 3580MHz) and 40 MHz of spectrum in the 2.3GHz band. The auction for these frequencies is scheduled for later in 2017.³⁹
- 5.43 A growing number of European countries have now awarded at least a portion of the band for mobile services, or are considering doing so. For example, France⁴⁰ announced plans in June to make the 3.6GHz to 3.8GHz band available for 5G mobile networks, with the 3600MHz to 3680MHz band being made immediately available for 5G trials. Germany⁴¹ is also currently consulting on policies to enable 5G use of the 3.4GHz to 3.8GHz band. With Ireland⁴² having recently completed its auction of 350 MHz across the 3.4GHz to 3.8GHz band, we understand that a total of 12 Member States have awarded or assigned frequencies in the 3.6GHz to 3.8GHz band, and a further 12 are in the process of doing so.
- 5.44 These developments make clear that the 3.6GHz to 3.8GHz band (as part of the wider 3.4GHz to 3.8GHz band) will play a significant role in addressing the increasing demand for mobile data services in Europe by being one of the first bands used for future 5G services.
- 5.45 At present, there is limited evidence of 3.6GHz to 3.8GHz mobile networks being rolled out in other parts of the world, beyond Europe. However, the January 2017 GSA Evolution to LTE Report finds that Bahrain, Argentina, Slovakia and Ivory Coast have already seen the deployment of 3.6GHz to 3.8GHz networks, with trials ongoing in Norway. A number of countries worldwide have also set out plans to make part of the 3.6-3.8 GHz band available for mobile services or are considering doing so.⁴³

An emerging device ecosystem

- 5.46 In our October consultation, we noted that the equipment ecosystem at 3.6GHz to 3.8GHz was developing but that the number of devices capable of accessing the band for 4G mobile broadband was continuing to grow. There is now more evidence of an emerging device ecosystem for this band, with devices potentially available as early as 2019-20.
- 5.47 We are aware that the Essential PH-1,⁴⁴ which is due to be released in Q3 2017, will have support for the band, but are not aware of any currently available UK mobile handsets that can use the band. The April 2017 GSA report on the Status of

³⁹ *Award of the 2.3 and 3.4 GHz spectrum bands: Competition issues and Auction Regulations*, Statement, July 2017, <https://www.ofcom.org.uk/consultations-and-statements/category-1/award-of-the-spectrum-bands>

⁴⁰ See *ARCEP synopsis of responses to its consultation on new frequencies for superfast access* (arcep.fr), June 2017

⁴¹ Bundesnetzagentur, *Frequencies for 5G – Key Elements and Identification of Demand*, https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html

⁴² ComReg, *3.6 GHz Band Spectrum Award*, June 2017, <https://www.comreg.ie/industry/radio-spectrum/spectrum-awards/3-6ghz-band-spectrum-award/>

⁴³ GSA White Paper *The future of IMT in the 3300-4200 MHz frequency range*, June 2017 <https://gsacom.com/paper/future-imt-3300-4200-mhz-frequency-range/>

⁴⁴ <https://www.essential.com/>

the LTE User Devices Ecosystem⁴⁵ showed that there were 93 devices available for this band, but we understand that none of these were mobile handsets at the time the report was published.⁴⁶

- 5.48 We also understand that some chipsets cover the wider 3.4GHz to 3.8GHz band, thus potentially enabling products to operate in 3.6GHz to 3.8GHz on the same timescale as the 3.4GHz to 3.6GHz band. It is therefore possible that the device ecosystem will develop at a similar pace to the 3.4GHz to 3.6GHz band, with devices potentially available as early as 2019-20.⁴⁷
- 5.49 This view is consistent with Analysys Mason's report submitted by H3G as part of its response to the consultation on the award of the 2.3 and 3.4GHz spectrum bands,⁴⁸ in which it argued that "(...) there is now increasing focus on spectrum in the 3.4–3.8GHz range as being the most promising for early 5G deployment in Europe. Hence, we understand that most of the effort of major mobile vendor towards commercialising 5G is now focused on 3.4–3.8GHz and on the 26–28GHz frequencies in the millimetre-wave region."⁴⁹
- 5.50 European technical work on this band has moved forward following a European Commission mandate to the CEPT⁵⁰ to review the suitability of the technical conditions for the 3.4GHz to 3.8GHz band to ensure they are suitable for 5G. In parallel, the Electronic Communications Committee (ECC)⁵¹ is also reviewing its own technical conditions for the band. International harmonisation will allow device manufacturers to take advantage of economies of scale, thereby allowing for quicker and easier development of devices that can use the band.

Current use of the 3.6GHz to 3.8GHz band

- 5.51 While the 3.6GHz to 3.8GHz band is used for the delivery of services by fixed links and fixed satellite services which provide a range of benefits for UK consumers, as set out in section 4 above it is relatively lightly used in the UK compared to other frequency bands. Current authorised use of the band is also focused in a small number of locations. There are areas of the country where mobile services could be deployed without affecting existing registered users.

⁴⁵ GSA, "LTE User Devices Ecosystem – 7,847 devices announced", April 2017, <https://gsacom.com/paper/lte-user-devices-ecosystem-7847-devices-announced/>

⁴⁶ These are likely to be FWA devices.

⁴⁷ There is further consideration of evidence relating to the emerging device ecosystem for the 3.4GHz to 3.8GHz band in *Award of the 2.3 and 3.4 GHz spectrum bands*, Statement, July 2017, https://www.ofcom.org.uk/_data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf

⁴⁸ *Award of the 2.3 and 3.4 GHz spectrum bands*, Consultation, November 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0026/93545/award-of-the-spectrum-bands-consultation.pdf

⁴⁹ Analysys Mason, *Consequences of Ofcom's categorisation of frequency bands in its latest consultation on the award of the 2.3GHz and 3.4GHz spectrum bands*, January 2017, https://www.ofcom.org.uk/_data/assets/pdf_file/0018/100971/Three-Annex-13-Analysys-Mason-spectrum-timing-study.PDF, page 47.

⁵⁰ European Commission, *Mandate to CEPT to develop harmonised technical conditions for spectrum use in support of the introduction of next-generation (5G) terrestrial wireless systems in the Union*, December 2016, http://ec.europa.eu/newsroom/document.cfm?doc_id=42093

⁵¹ The Electronic Communications Committee (ECC) is one of the three business committees of the European conference of Postal and Telecommunications (CEPT).

- 5.52 In section 6 below we set out our updated coexistence analysis which shows that future mobile services and existing fixed links and satellite earth stations could coexist, but that this would require large geographic separation distances for mobile deployment in the band. The impact of making the band available for mobile on existing users is therefore dependent on the decisions we take regarding existing authorisations in the band. We set out our proposed approach, including our assessment of the potential impacts on existing users, in section 7.
- 5.53 We have noted concerns raised by stakeholders in the satellite sector that making the band available for mobile services might limit the potential for satellite use of the band to grow, depending on the implementation approach. In our assessment we have taken account of our recent review of the space sector's use of spectrum in our Space Spectrum strategy⁵² which did not identify these frequencies as a key growth band, or any specific area of demand reliant upon 3.6GHz to 3.8GHz. The review identified potential growth areas for satellite applications, particularly satellite broadband and earth observation, but highlighted the Ka-band, Ku-band and X-band as important bands to support this.
- 5.54 We have considered stakeholder proposals relating to use of the band for FWA in section 7 and annex 6.

Our decision on making 3.6GHz to 3.8GHz available for mobile services

- 5.55 As explained in section 3, we have statutory duties related to (among others) securing the optimal use of spectrum, furthering the interests of UK citizens and consumers, promoting competition and encouraging investment and innovation in electronic communications services.
- 5.56 We are also required by statute to make the 3.6GHz to 3.8GHz band available for electronic communications services, and have already made 84 MHz in this band available for this purpose.
- 5.57 Having considered the responses to the October consultation and the factors set out above we have decided to make the remaining 116 MHz of spectrum in the 3.6GHz to 3.8GHz band not currently assigned for electronic communications services available for mobile services through a future award.
- 5.58 We consider that making the spectrum available for mobile data use has the potential to deliver significant benefits for UK consumers and citizens, including by:
- **Providing additional capacity to enable mobile networks to meet growth in demand for mobile data services across the UK.** As noted above, the 3.6GHz band offers a large amount of bandwidth which will enable higher capacity and data rates than lower frequency bands, and provide a good quality of service to a large numbers of users at one time. This will support efficient network deployment by mobile operators to deliver increased network capacity. The ability for MNOs to deploy the spectrum using existing macrocell networks is also expected to support deployment in many areas across the UK.
 - **Enabling new and improved mobile services, including 5G, with an improved quality of service.** This spectrum is part of the primary band for

⁵² *Space Spectrum*, statement, January 2017, https://www.ofcom.org.uk/_data/assets/pdf_file/0030/96735/Statement-Space-Spectrum.pdf

introducing 5G in Europe. With the potential for devices to become available as early as 2019-20 this band has the potential to support the early launch of 5G services in the UK. This will contribute to the development of innovative mobile services as well as promoting competition in the mobile market.

- **Ensuring optimal use of the spectrum in the 3.6GHz to 3.8GHz band.** Current use of the band is relatively light and geographically focused in a small number of locations. Making the band available for mobile will support the delivery of increased benefits from the use of these frequencies across the UK.
- 5.59 We therefore consider that making the spectrum available for mobile services is consistent with our statutory duties and in particular will give effect to our duties regarding the promotion of competition and innovation, ensuring the optimal use of spectrum, and encouraging the availability and use of high speed data services throughout the UK. Making additional spectrum available for future mobile services including 5G is likely to support improvements in consumer mobile data services, as well as the early development and adoption of new mobile services, including 5G applications.
- 5.60 We expect that the benefits resulting from our decision will be greater the sooner the spectrum can be used for mobile services, once a device ecosystem is available. Our objective is therefore to make the band available as soon as practicable.
- 5.61 The benefits of our decision will also be greatest if the spectrum is made available for mobile services including 5G in as many areas as possible across the UK. Whilst the spectrum characteristics of 3.6GHz to 3.8GHz can support wide deployment, the area over which mobile services could be deployed will depend on the approach we take with regards to existing registered users of the band. We consider this further in the following sections.

Section 6

Coexistence between mobile and current band users

Our October consultation analysis

- 6.1 As set out in section 4, we manage the interference environment for fixed links and satellite earth stations (registered under PES licences and/or with RSAs for ROES) operating in the 3.6 GHz to 3.8GHz band by coordinating additional use of the band on a first come first served basis to maintain benchmark spectrum quality for registered receiver components.
- 6.2 The current coordination approach requires an application for each new transmitter in the band. When considering such applications, we assess whether the proposed transmitter would be expected to undermine benchmark spectrum quality for existing users over a large radius (in many cases over 100km). New transmitters are not permitted if they are expected to undermine benchmark spectrum quality for existing users.
- 6.3 The October consultation set out our analysis on whether existing fixed links and registered satellite earth stations could coexist with future mobile services. We sought to assess whether small cell and macrocell mobile base station deployments would be possible whilst maintaining the benchmark spectrum quality currently available to registered fixed links and satellite earth stations using the band.
- 6.4 Our analysis was based on two studies. The first study was a report we published in June 2015, commissioned from Transfinite.⁵³ This study considered a small cell deployment and only considered interference during normal weather conditions, referred to as long-term interference.⁵⁴
- 6.5 The second study, which we have updated for the purposes of this Statement (see paragraph 6.13 and annex 5), was based on an internal simulation using data extracted from Ofcom's licensing database in August 2016. This assessed coexistence with a macrocell deployment, accounting for both long-term interference and interference during anomalous propagation periods, referred to as short-term interference.⁵⁵ We used the same interference thresholds that we

⁵³ Transfinite Systems, *Geographic Sharing in C-band*, Final report, May 2015,

<https://www.ofcom.org.uk/research-and-data/technology/radio-spectrum/c-band-sharing>

⁵⁴ Long term interference thresholds are used to manage the interference conditions for a receiver that will occur most of the time. It is Ofcom policy to provide benchmark spectrum quality with respect to long-term interference for holders of fixed link licences, PES licences and grants of RSA for ROES. This ensures that I/N levels for registered satellite earth stations would not normally be expected to exceed -10 dB for more than 20% of the time. The criteria for fixed link licences are detailed in OfW446.

⁵⁵ Short term interference thresholds take into account an interfering signal being enhanced for short periods of time. Short-term interference usually occurs when atmospheric conditions lead to anomalous propagation conditions. It is Ofcom policy to provide benchmark spectrum quality with respect to short-term interference for holders of fixed link licences and PES licences. This ensures that I/N levels for registered satellite earth stations would not normally be expected to exceed 0 dB for more than 0.005% of the time. The criteria for fixed link licences are detailed in OfW446.

currently use to provide benchmark spectrum quality, when considering applications for new fixed links and UKB deployments in the 3.6GHz to 3.8GHz band.

- 6.6 For satellite earth stations, our internal study had indicated that under the assumption of large-scale macrocell deployment at 3.6GHz to 3.8GHz, coexistence could be very challenging. In particular, we had modelled a large-scale macrocell deployment in London, and found that this would affect the benchmark spectrum quality at several different earth station sites (including Chalfont, Bedford, Crawley Court, Crowsley Park and Brookmans Park). Whilst we found that small cell deployments could enable a greater degree of coexistence, this would be likely to require significant deployment planning and site engineering to manage interference impacts; dense small cell deployment near satellite earth stations would be particularly challenging.
- 6.7 For fixed links, our analysis indicated that coexistence between small cells and macrocell base stations and fixed links could be very challenging in densely populated areas, such as the links in the south-east of England. We noted that macrocells could also cause interference to fixed links in rural areas.
- 6.8 We invited stakeholders to comment on our analysis by asking:
- Question 5: Do you agree with our assumptions, methodology, and conclusions with regards to potential coexistence between mobile and existing fixed links and satellite earth stations?

Stakeholder responses

- 6.9 In general, stakeholder responses agreed with our assumptions and approach to analysing coexistence, and the overall conclusion that mobile deployment would be expected to affect spectrum quality for registered receiving satellite earth stations and fixed links. This message was reiterated during our meetings with current registered band users.
- 6.10 There were, however, differing views on the extent of the constraints on mobile deployment that would be required to maintain benchmark spectrum quality. Some respondents noted that the large separation distances that could be required raised questions about the feasibility of sharing between mobile and other services, particularly in the south of England; the UK Space Agency said that interference to earth stations from mobile deployments 80km away could be expected. However, others cautioned that our coexistence studies might be too conservative. Access Technologies argued that our protection criteria for fixed satellite services do not adequately take into account the impact of clutter, and that their experience of propagation studies suggests that more realistic calculations could reduce the constraint on new users.
- 6.11 Some stakeholders criticised a lack of detailed information about a range of factors, including propagation assumptions and the density of small cells in our analysis, or said more detailed studies of specific sites would be useful. Several respondents argued it is impossible to carry out coexistence analysis accurately without knowing 5G specifications.

Our assessment

- 6.12 The models we adopted for this coexistence work use International Telecommunication Union (ITU) recommendations which specify assumptions for a

range of factors including propagation, antennas, deployment and traffic. We acknowledge that to some extent these models are likely to provide a conservative view, but consider that this provides a reasonable guide to the potential scale of the challenge of coexistence.

- 6.13 We have updated our internal studies since the October consultation publication to model a realistic simulated future UK-wide 5G macrocell network deployment, based on our updated understanding of the likely characteristics of potential 5G networks at 3.6GHz to 3.8GHz. For example, we updated our antenna model simulation to reflect ITU recommendation M.2101⁵⁶ to consider the effect of larger antenna configurations at base stations. Further details of our updated technical assumptions are provided in annex 5.⁵⁷

Updated results on satellite earth stations

- 6.14 We applied our updated simulation approach to consider registered satellite earth station sites in this band.⁵⁸ For each site, we identified the registered dishes and associated orbital locations most likely to receive interference from a mobile network,⁵⁹ and simulated the interference expected from our model network. For sites operating under PES licences we considered potential interference sources within 140km to take into account the potential impact of short-term interference.
- 6.15 The simulations identified the mobile base station sectors⁶⁰ which would be likely to undermine benchmark spectrum quality for the satellite earth station using our current coordination criteria. We also identified sectors which would be expected to contribute to degradation of spectrum quality below the current benchmark owing to the combined effect of multiple sectors (aggregate interference). This modelling enabled us to consider the likely scale of restrictions on future mobile deployment including 5G which could be needed to maintain the current benchmark spectrum quality for registered band users.
- 6.16 The new results confirmed the previous findings that macrocell deployments of 3.6GHz to 3.8GHz mobile services across the UK would be expected to cause interference to the reception of space-to-Earth transmissions at satellite earth station sites, resulting in a degradation of spectrum quality below the current benchmark.
- 6.17 The degree of expected interference varied by site according to a range of factors including local topology, proximity to major urban centres, availability of shielding at the earth station and earth station antenna type and direction. Our analysis took

⁵⁶ See *ITU-R Recommendation M.2101-1 (02/2017)*, February 2017, <https://www.itu.int/rec/R-REC-M.2101/en> This new model captures the effect of larger antenna arrays and was not available at the time we carried out our previous coexistence analysis.

⁵⁷ We have not published the full analysis owing to the use of commercially sensitive information to inform our modelling assumptions.

⁵⁸ We considered all registered satellite earth sites in the band with the exception of the Met Office site at Exeter. This is because the Met Office indicated in its consultation response that it did not use the 3.6GHz to 3.8GHz band.

⁵⁹ For example, dishes pointing towards a city centre, or having a low elevation.

⁶⁰ A cellular network provides coverage of an area by dividing it into cells; sectorisation involves dividing each cell spatially into sectors. Sectorisation is achieved by having a directional antenna at the base station that focusses transmissions into the sector of interest. Usually each cell is divided into one, three or six sectors. See, Tse, D. and Viswanath, P., 2005. *Fundamentals of Wireless Communication*. Cambridge: Cambridge University Press.

account of the shielding effect of local topology (trees, fences, buildings, etc.) and of the shielding effect along the path between macrocell and earth station.⁶¹

- 6.18 We considered potential mitigations that might enable a greater degree of sharing, such as reducing mobile transmission power, increasing antenna downtilt or using a more directional antenna array. Whilst these steps would reduce interference levels they would not be expected to maintain benchmark spectrum quality for all current registered users. Furthermore, such mitigations would increase the cost and complexity of mobile deployments.
- 6.19 Our analysis confirmed our previous conclusion that if we were to maintain the current coordination criteria and therefore the current benchmark spectrum quality for registered earth station users of this band, there would be significant constraints on mobile deployment. This effect is particularly widespread for satellite earth stations registered under PES licences, for which our current coordination criteria maintain benchmark spectrum quality in instances of short term interference, which can be created by transmitters located in a wider area than interference sources expected under normal conditions. Satellite earth stations registered under grants of RSA for ROES, for which we do not take into account short-term interference, generally affect smaller distances, although some are located near densely populated areas.

Updated results on fixed links

- 6.20 Using the same macrocell deployment simulation, we considered likely sources of interference to all mainland fixed links, a fixed link to the Isle of Wight, and a number of the fixed links connecting mainland Scotland to Orkney, Shetland and the Hebrides. We considered a range of 250km from the fixed link receiver to reflect the longer coordination distances we consider for fixed links using this band.
- 6.21 The new results confirmed the previous findings that coexistence between mobile and fixed links would be very challenging. As for earth stations, location, topology and antenna characteristics were key determinants of interference risks from mobile.

Findings on overall impacts

- 6.22 We combined the results to calculate the number of unique mobile sectors which could be denied to maintain current benchmark spectrum quality for fixed links and registered satellite earth stations.⁶² Our analysis suggested that under our current coordination approach around one quarter of mobile base station sectors across the UK could undermine benchmark spectrum quality for registered band users, although site engineering could mitigate some of these cases.⁶³

⁶² These calculations took into account the fact that some sectors would cause harmful interference to several satellite earth stations; by doing so we removed sectors which would otherwise be double counted.

⁶² These calculations took into account the fact that some sectors would cause harmful interference to several satellite earth stations; by doing so we removed sectors which would otherwise be double counted.

⁶³ This number accounts for the sum of the sectors (after removing double-counted sectors) likely to undermine benchmark spectrum quality for a registered satellite earth station or fixed link under a long-term single entry criterion, long-term aggregate criterion and (where relevant) short-term single-entry criterion.

- 6.23 Given the location of registered users of the band, these sectors are particularly concentrated in the south of England,⁶⁴ where around two fifths of sectors could be affected. This figure rises to over half of sectors in greater London.⁶⁵ By contrast there are many areas of the UK, such as most of the north of England, southern Scotland, Northern Ireland and Wales, where mobile roll out would only be expected to be negligibly affected by maintaining existing authorisations, if at all.

Coordination approach

- 6.24 As set out above, under the current coordination approach for the band, we require an application to be made for each new transmitter in the band, in order to assess the expected impact on benchmark spectrum quality for existing users over a large radius. Our analysis found that the presence of existing registered users could prevent the deployment of mobile services over large radii, in some cases requiring constraints on mobile deployment over 100km away from the registered user site. This approach is unlikely to support efficient and quick deployment of nationwide mobile networks.
- 6.25 Furthermore, given the locations of many of the current users of the band, it is likely that any future mobile deployment in, for example, parts of southern England (including greater London) would need to avoid causing interference towards sites in multiple directions. This would be the case even if we were to introduce a simplified coordination mechanism to deliver current levels of benchmark spectrum quality, such as based on geographic protection zones – which would be expected to be large and overlap in many cases.

Conclusions

- 6.26 Taken together, the October consultation responses, discussions with stakeholders and the updated coexistence analysis all confirm the main technical conclusions we put forward concerning the 3.6GHz to 3.8GHz band in the October consultation. In particular:
- Coexistence between mobile and the satellite earth stations and fixed links users based on our current coordination approach would be very challenging, and could significantly impact and constrain mobile deployments across large parts of the UK as a result of the large separation distances which would be required to maintain existing users' benchmark spectrum quality.
 - The impact of the required separation distances to maintain current levels of benchmark spectrum quality would vary across regions. There are many areas of the UK in which mobile deployment would be relatively unconstrained. However, owing to the location of current registered users, mobile deployment would be significantly constrained in some densely populated areas including greater London, where we would expect there to be particularly strong demand for new mobile services including 5G.
 - Overall, our simulations indicate that when both fixed links and satellite earth stations are considered, around a quarter of mobile sectors in the UK could be

⁶⁴ Where "the south of England" is defined as the European Parliament constituencies "Eastern", "London", "South East" and "South West".

⁶⁵ "Greater London" is defined as the European Parliament constituency "London".

affected in this band if benchmark spectrum quality for existing users were maintained. This figure rises to over half in greater London.

- Current coordination procedures are burdensome and would slow mobile roll out.
- 6.27 Taking account of the above, we have concluded that nationwide deployment of future mobile services including 5G cannot coexist with the coordination approach and current benchmark spectrum quality provided to registered users of this band.
- 6.28 However, as set out in paragraph 6.17, the degree of expected interference from future mobile services would vary according to a range of site specific factors including local topology, proximity to major urban centres, availability of shielding at the earth station, and earth station antenna type and direction. Whilst our analysis found that mobile deployment would be expected to degrade spectrum quality to a level below the current benchmark, it may be the case that a number of satellite earth station sites might be able to continue to receive using this band on a licence exempt basis without experiencing service-impacting levels of interference. In some cases this might be for a limited period of time, before full mobile deployment takes place, but in other cases longer term coexistence may be possible. We discuss this further in section 7 and 8.

Section 7

Proposed approach to making the band available for mobile services

- 7.1 In this section we explain our proposed approach to existing registered users of the band, following the decision to make the remaining 116 MHz in the 3.6GHz to 3.8GHz band available for mobile. This takes account of:
- the two policy options we set out in the October consultation;
 - stakeholder submissions regarding these options and alternative approaches; and
 - our assessment of these options, considering the likely impacts on realising the benefits of future mobile services including 5G in this band, and the impacts on services currently delivered using this band. This analysis outlines our assessment of the likely impact of each option.
- 7.2 We are consulting on our proposed approach. Stakeholders are invited to submit any comments by 22 September 2017.

Proposed policy options

- 7.3 In section 9 of our October consultation, we set out two policy options for current users of the 3.6GHz to 3.8GHz band:
- a) **Option A: Retain** existing users' current authorisations under the WT Act within the 3.6GHz to 3.8GHz band to (i) transmit for fixed links, and (ii) receive for satellite earth stations registered under grants of RSA for ROES and PES licences.
 - b) **Option B: Remove** existing users' authorisation to transmit for fixed links and no longer take satellite earth stations with a receiver component in the 3.6GHz to 3.8GHz band into account for frequency management purposes.
- 7.4 Under option A, we proposed to:
- continue to take satellite earth stations with a registered receiver component in the 3.6GHz to 3.8GHz band into account for frequency management purposes;
 - include in any new mobile licence terms and conditions aimed at preventing undue interference into licensed fixed links and registered satellite earth station receivers under PES licences or grants of RSA for ROES;
 - review fees for existing users, in line with our pricing framework,⁶⁶ to take account of the extent to which mobile deployments would have been denied access to the band; and

⁶⁶ SRSP: *The revised Framework for Spectrum Pricing: Our policy and practice of setting AIP spectrum fees*, Statement, December 2010, https://ofcom-build.squiz.co.uk/_data/assets/pdf_file/0024/42909/srsp-statement.pdf

- combine our approach with policies to eventually allow for more extensive use of mobile by incrementally reducing use by fixed links and satellite earth stations.

7.5 Under option B, we proposed that:

- a period of appropriate notice would be given to licensees and grant holders, before licence revocations/variations took effect;
- satellite users operating under a grant of RSA for ROES or PES licence would still be able to receive signals in the band on a licence exempt basis but would have to adjust to an expectation of lower spectrum quality;
- while satellite earth stations operators using the band would no longer be able to rely on a given benchmark spectrum quality, some, located away from urban areas, might be able to continue receiving in the band without suffering service-impacting levels of interference from future mobile services. However, it would be left to the satellite earth station operator to determine whether a particular earth station is sufficiently protected from interference, for example by natural or artificial shielding, or by reaching agreement with the relevant mobile licensees; and
- any new mobile licences awarded in the interim period (i.e. during the period of appropriate notice) could include interim terms and conditions aimed at preventing interference to current licensed or recognised receivers until the end of the notice period.

7.6 Our approach compared the advantages and disadvantages of each option at a high level, without stating a preference. Specifically, we observed at paragraph 9.20 that:

“Broadly speaking, policy option A, which minimises the disruption to current users, is likely to result in the least extensive availability of spectrum for 5G / mobile services at 3.6GHz to 3.8GHz. By contrast, option B is likely to be the most effective policy to enable spectrum availability for 5G / mobile services in the band, but is also likely to generate the most disruption for current users.”

7.7 We invited stakeholders to provide their views on our proposed options and to offer any alternatives for enabling mobile including 5G deployment in the band. We sought relevant evidence to support our decision making and our understanding of the costs and benefits, where available. We asked stakeholders:

- Question 6: Do you have a view on any of the two options we identified?
- Question 7: Do you have any quantitative evidence on the costs and benefits associated with the options? This include costs for existing users and/or consumers of existing services associated with potential changes, and benefits to UK consumers in gaining access to mobile services in this band
- Question 8: Do you have any other suggestions that would allow widespread 5G availability using the 3.6GHz to 3.8GHz band across the UK while allowing certainty for at least some existing users to continue to provide the benefits currently provided by use of the 3.6GHz to 3.8GHz band?
- Question 9: Do you have any comments in relation to these proposals?

Stakeholder responses

- 7.8 In general, mobile industry respondents, other than those with satellite interests, were strongly in favour of option B. The satellite sector tended to favour option A, although not any associated fee increases, or other approaches which would maintain current benchmark spectrum quality. A number of respondents put forward potential alternative solutions to support continued operation of some existing services in the band, in particular for satellite earth stations.
- 7.9 A full summary of stakeholder responses is provided at annex 6.

Overall comments on options A and B

- 7.10 Respondents supporting option A focused on the value and citizen and consumer benefits of services currently delivered using these frequencies and C-band (3.6GHz to 4.2GHz) more widely. The BBC and MOD set out specific public policy grounds for requiring continued access to 3.6GHz to 3.8GHz.
- 7.11 Satellite stakeholders were not in favour of changes to how we coordinate the band which might reduce the level of benchmark spectrum quality, although it was noted that there might be circumstances in which an individual site might decide this was acceptable.
- 7.12 Satellite stakeholders in general did not support our proposal (under option A) to review fees for existing users, in line with our pricing framework, to reflect the opportunity cost of spectrum access denied to mobile services. Some argued that increased fees would lead to operators no longer using these frequencies, and so would be equivalent to option B in practice.
- 7.13 The majority of mobile stakeholders, including two MNOs and manufacturers of mobile equipment, were strongly in support of option B. Vodafone and BT/EE, who also operate satellite earth stations, suggested only partial clearance of existing users might be needed (see 7.16).
- 7.14 Several mobile stakeholders argued that maintaining current levels of benchmark spectrum quality for incumbent services would be likely to lead to areas where mobile deployment, including 5G deployment, would be materially constrained, including in some key population centres. H3G argued that only option B would guarantee that the benefits for consumers of intensive use of the spectrum would be realised with high certainty. Telefonica noted that the prevention of mobile deployment in key population areas could also have consequences for competition. Vodafone suggested that option A would significantly devalue the spectrum for mobile purposes, potentially to the point of it having no value. BT/EE and Vodafone cautioned against significant restrictions being placed on mobile network roll out such as only small cells being permitted.

Alternative approaches

- 7.15 A number of stakeholders supported the principle of solutions involving partial clearance of existing services. Several respondents suggested a differentiated approach could be taken, to avoid impacting existing users of the band if this would be unlikely to constrain mobile roll out. These proposals reflected a number of stakeholder assumptions, including that there could be limited nationwide demand

for additional mobile capacity, and that existing use of the band could not always be migrated to alternative frequencies or technologies.

7.16 Suggestions for how some existing services could remain and share the band alongside future mobile services included:

- Vodafone suggested affording satellite and terrestrial links in rural areas with protection through exclusion/coordination zones for mobile put around the sites, while those in more urban areas would have protection withdrawn after a suitable notice period;
- UK Broadband suggested differentiating between areas of high population density or high data demand and other areas;
- the BBC suggested it may be possible to identify locations for earth stations in areas unlikely to attract roll out of 5G;
- Vodafone also suggested an option whereby there would be no interference protection for satellite and terrestrial links, but licences awarded to the new mobile users would require them to negotiate in good faith to allow coexistence;
- BT/EE suggested a 'reverse auction' would be a suitable mechanism to understand the value of the 3.6GHz to 3.8GHz band to existing users and to provide incentives for existing users to vacate the spectrum where their use is not the most efficient;
- several respondents advocated dynamic sharing approaches, with multi-tiered and database driven access systems;
- some stakeholders suggested using low power small cell solutions for mobile deployment to address coexistence challenges in some areas. The UK Space Agency suggested that effort should be put into developing 5G services that can share easily with satellite earth stations, such as low power or WiFi-like technologies;
- stakeholders with an interest in providing FWA services suggested that use of the band be shared between mobile in some busy areas and FWA elsewhere.

7.17 Whilst several stakeholders suggested that fixed links users could be migrated to other frequencies or replaced with fibre, Arqiva said that making such changes for fixed links would present specific challenges.

Stakeholder views on potential impacts, including costs

7.18 Mobile stakeholders highlighted the value of mobile services including future 5G services, noting that these benefits would likely be increased through making the 3.6GHz to 3.8GHz band fully available for 5G mobile. These arguments are set out above at paragraph 5.10. Furthermore, BT/EE and Vodafone cautioned against significant restrictions being placed on mobile network roll out such as only small cells being permitted, with BT/EE noting the cost avoidance potential associated with being able to deploy high power mobile services using existing macrocells.

7.19 Satellite sector stakeholders set out the importance of safeguarding the benefits from satellite earth station use, and highlighted the potential impact of implementing option B. For example, BT/EE said that if satellite operations at Madley were not

protected, this would affect high value contracts running to millions or tens of millions of pounds per annum. The UK Space Agency cautioned that Ofcom was likely to have underestimated the potential impact of its proposals given licence exempt use.

- 7.20 In the October consultation we observed that satellite earth station operators are generally able to provide the same service by using the same frequencies from a different location, by adopting technical mitigations against interference (such as shielding), and sometimes by using different frequencies.⁶⁷ Many respondents provided views on this.
- 7.21 In consultation responses and bilateral meetings, satellite stakeholders recognised that the majority of services provided in the 3.6GHz to 3.8GHz band could be provided using alternative frequencies, in particular 3.8GHz to 4.2GHz which use the same equipment. However, we were made aware of a small number of exceptions to this. Stakeholders expressed caution about the feasibility of technical mitigations such as shielding or site relocation for some operations, citing costs and technical considerations.
- 7.22 In consultation responses and meetings stakeholders raised a number of points regarding the adjacent 3.8GHz to 4.2 GHz band. Satellite stakeholders:
- stressed the continued importance of the 3.8GHz to 4.2 GHz band within C band for the satellite sector, and asked for greater certainty on the future use of these frequencies;
 - raised concerns about the potential for capacity constraints in 3.8GHz to 4.2GHz and other alternative bands, and the potential for this to lead to higher prices; and
 - cautioned that increased mobile activity in 3.6GHz to 3.8GHz could give rise to operational challenges for some satellite receivers using 3.8GHz to 4.2GHz as a result of out of band emissions and potential issues tracking satellite beacons if these are only available below 3.8GHz.
- 7.23 In contrast, Huawei cautioned that consideration should be given to the potential social and economic benefits that the upper part of the C-band could have for 5G in the future.
- 7.24 A number of stakeholders suggested there might be a case for funding to be provided to mitigate the costs of any changes to existing users' operations. Arqiva called on Ofcom to also provide regulatory certainty to underpin necessary investments and allow sufficient time for industry to respond to changes in policy.

Our assessment

- 7.25 In section 5 we identified a number of benefits of making the 3.6GHz to 3.8GHz band available for mobile, including:
- Providing additional capacity to enable mobile networks to meet growth in demand for mobile data services across the UK.

⁶⁷ *Improving consumer access to mobile services at 3.6 to 3.8 GHz, Consultation, October 2016*, https://www.ofcom.org.uk/_data/assets/pdf_file/0035/91997/3-6-3-8ghz-consultation.pdf, paragraph 9.15.

- Enabling new and improved mobile services, including 5G, with an improved quality of service.
 - Ensuring optimal use of the spectrum in the 3.6GHz to 3.8GHz band and the delivery of increased benefits from the use of these frequencies across the UK.
- 7.26 As we noted in paragraphs 5.60-5.61, we consider that these benefits would be maximised if we made the spectrum available for mobile services as soon as practicable and in as many areas as possible.
- 7.27 When assessing options A and B and stakeholders' suggestions we have sought to determine the approach which would achieve the greatest overall benefits for UK citizens and consumers. In relation to each option we have considered:
- the extent to which they would permit the benefits of future mobile services to be realised; and
 - the impact on existing users of the band and the benefits delivered through the services offered by those users.
- 7.28 As set out in section 6 there are many areas of the UK where, given the geographic distribution of existing services in the 3.6GHz to 3.8GHz band, the approach we take towards existing authorisations in the band is unlikely to have a material impact on mobile roll out. This includes most of the north of England, southern Scotland, Northern Ireland and Wales. In considering options A and B, and alternatives put forward by stakeholders, our assessment has therefore focused on the areas in which mobile roll out would potentially be affected, which reflects the location of existing services and anticipated separation distances which would be required to maintain benchmark spectrum quality.

Consideration of option A

Impact on benefits available from future mobile services

- 7.29 It is clear from our updated coexistence analysis set out in section 6 above that maintaining the current authorisation and coordination approach to the band (i.e. Option A) would act as a material constraint on the nationwide deployment of mobile services including 5G using this band. Our analysis shows that this could affect around one quarter of mobile base station sectors across the UK (see paragraph 6.22).
- 7.30 Option A would, in particular, be expected to result in extensive restrictions on mobile deployment using 3.6GHz to 3.8GHz across densely populated areas in the south of England and West Midlands, including greater London, where we would expect there to be particularly strong demand for additional mobile data capacity and future services including 5G. This arises from the location of the existing registered users, and the high proportion of mobile sectors in this area.
- 7.31 Our analysis suggests that two fifths of mobile sectors could be affected in the south of England, and over half of the sectors in Greater London. As a result, there would be material constraints on use of the additional spectrum for mobile services including 5G in areas amongst those likely to have the highest demand for mobile data services.

- 7.32 Option A would also be expected to reduce the availability of spectrum for 5G / mobile services at 3.6GHz to 3.8GHz in a number of rural and suburban areas including parts of Kent, the West Midlands, East Anglia and Cornwall.
- 7.33 This level of constraint would make mobile deployment extremely challenging. We acknowledge that in some areas careful network design and site engineering, including the use of small cells, could reduce the impact of existing services on mobile roll out. However, this would increase costs and make deployment more complicated, compared to a macrocell deployment. This could undermine the economic case for deployment in some areas and lead to slower roll out in others, leading to a worse outcome for consumers.
- 7.34 Furthermore, as set out in paragraphs 6.24 and 6.25, under option A planning mobile roll out would be complex due to the need to comply with coordination procedures, which currently require an application for each new transmitter in the band to assess its impact on existing users. This is particularly the case in areas where interference would need to be avoided towards multiple directions owing to the location of relevant registered users. This would also be likely to delay the roll out of mobile services in some affected areas.
- 7.35 We therefore consider that option A would in practice deny citizens and consumers in large parts of the UK access to many of the benefits expected to be achieved through the deployment of mobile services in this band, including new 5G services and applications. This effect would be particularly strong in some densely populated areas where we expect there to be the greatest demand for future mobile services including 5G, including greater London, but we also expect there to be impacts in some less densely populated areas.

Impact on existing services

- 7.36 In principle, Option A would minimise the disruption to current users of the 3.6GHz to 3.8GHz band. In particular, the benefits of current registered use could be maintained without any operational changes, with current benchmark spectrum quality levels maintained. There might also be scope for these activities to grow, although as set out in section 5 above we have not identified 3.6GHz to 3.8GHz as a key growth band for the satellite earth station sector.
- 7.37 However, in the October consultation we said that in line with our pricing framework we would be likely to review fees for existing users under option A, to take into account the extent to which mobile deployments would have been denied access to the band. Stakeholders' responses highlighted that this could impact existing use of this band following a fees review, with some likely to cease use of the band. We would not expect this to result in the loss of the benefits currently delivered through the band, given the possibility of delivering these services using alternative frequencies or technologies as set out in paragraph 7.48 below. However, there could be some associated costs for existing users (see paragraph 7.50 below).

Overall assessment of option A

- 7.38 Whilst option A minimises disruption to current registered users, it would prevent or impede future mobile services including new 5G services from being made available using the 3.6GHz to 3.8GHz band across large parts of the UK. Our coexistence analysis indicates that around a quarter of the mobile sectors across the UK could be impacted and around two fifths across the south of England, with

greater London particularly affected. Given this impact on mobile deployment we consider that the costs of this option would outweigh the benefits.

Consideration of option B

Impact on benefits available from future mobile services

- 7.39 Option B would remove the constraints on mobile which currently exist, and would continue to exist under option A (as set out in section 6 and summarised above). This would enable nationwide deployment of mobile services including 5G using the 3.6GHz to 3.8GHz band, and thereby deliver the greatest benefits from making this band available for mobile services.
- 7.40 Compared to option A, this approach would enable more citizens and consumers, across the UK to access future mobile services including 5G. Additional spectrum and increased capacity would be made available in a number of densely populated areas, as well as certain rural and suburban areas, which would otherwise face material constraints.

Impact on existing services

- 7.41 This approach would have an impact on existing services currently delivered using the band. These are set out in section 4 and include distribution of international broadcasting content to the UK, connections to broadcasting sites within the UK and data communications. In particular:
- Users of fixed links currently licensed to use these frequencies would no longer be permitted to do so once the relevant licence had been revoked.
 - Satellite earth station operators currently receiving in the 3.6GHz to 3.8GHz band under a PES licence or grant of RSA for ROES would no longer be guaranteed benchmark quality spectrum. These operators would remain authorised to receive in the 3.6GHz to 3.8GHz band on a licence exempt basis, but the extent to which each site would be able to continue operating using frequencies in the band in practice would depend on the level of interference from mobile in the band. This would be determined by a range of factors including location, terrain, dish specification and mobile deployment pattern.
- 7.42 Taking account of the information provided to us through consultation responses, meetings and other submissions, we have concluded that most, if not all, of the benefits currently delivered using this band could continue to be achieved under option B, as explained below.

Fixed links

- 7.43 It is our assessment that the services currently delivered using fixed links in the 3.6GHz to 3.8GHz band could be delivered using other frequencies or technologies. This was confirmed by the fixed links licensees that we spoke to.

Satellite earth stations

- 7.44 In relation to satellite earth stations, the position would vary according to site characteristics and nature of current use of the band.

- 7.45 Satellite earth station sites currently operating under a PES licence or grant of RSA for ROES would, over time, have to adjust to an expectation of lower spectrum quality as a result of mobile use in the band.
- 7.46 However, we believe that some satellite earth stations located away from densely populated areas might be able to continue operating using the 3.6GHz to 3.8GHz band on a licence exempt basis without marked degradation of spectrum quality. Operators may also be able to implement technical mitigations such as shielding (e.g. terrain or walls) to reduce interference from mobile services.
- 7.47 We set out in section 8 that we are also minded to consider applying localised restrictions in future mobile licences to facilitate continued operation of satellite services in the band under option B, where this would not have a material impact on mobile deployment (see paragraphs 8.15-8.21).
- 7.48 For those satellite earth station which were not able to continue operating on a licence exempt basis there would be three broad options available:
- **Migrating services to other frequencies.** Many services currently received by satellite earth stations using the 3.6GHz to 3.8GHz band could be received using other frequencies, including using 3.8GHz to 4.2GHz. It is our understanding that there is available C-band satellite capacity above 3.8GHz.
 - **Using alternative technologies.** In some cases, delivery of services using non-satellite technologies (e.g. fibre connections) may also be possible.
 - **Using alternative sites.** Finally, it may be possible to relocate receive functions to sites whose location enabled them to continue to receive using 3.6GHz to 3.8GHz on a licence exempt basis, including by making arrangements with providers who already operate at such sites.
- 7.49 As a result, we consider that it should be feasible for most, if not all, of the services currently delivered using the 3.6GHz to 3.8GHz band, and the associated benefits, to continue to be delivered under option B. As a result, we do not consider that option B would be expected to lead to the loss of the value of these benefits and services. However, the impact of option B on each existing registered user would vary according to a range of factors. In some cases, temporary disruption to existing services might occur, or operators might incur additional costs. We consider these in the next part of this section.

Costs

- 7.50 Under option B some of the registered fixed link and satellite earth stations operators, and their clients (including any based overseas), would be likely to incur some costs as a result of the need to make operational changes in order to continue delivering/receiving existing services. These costs would vary in each case but might include:
- investment to mitigate against mobile interference, such as protective site engineering measures or commercial arrangements with mobile operators;
 - costs associated with contract changes, including any price changes relating to using different satellite frequencies, costs arising from outsourcing services currently delivered in-house, or loss of business;

- retuning or other adaptations to equipment in the UK and overseas, potentially also affecting uplink operations in cases of fixed frequency pairings;
- equipment related costs such as purchasing and installing new equipment suitable for use with different frequencies, and loss of use of current equipment still within its expected working life; and
- relocation costs.

7.51 In general stakeholders provided limited information on the likely scale of these costs in response to the October consultation, although some illustrative costs were provided. For example, Orange suggested that migrating a satellite earth station service from C-band to Ku band could cost less than £500,000 for a large dish. We do not consider it feasible to estimate the total costs that would be incurred as these would vary according to decisions taken by the operators at each site.

7.52 We expect that providing a reasonable time period for ceasing use of these frequencies, or transitioning to alternative delivery approaches, should assist affected stakeholders to minimise any costs and disruptions. This is considered further in section 8 below.

7.53 Our assessment of alternative delivery mechanisms and potential costs also applies to any users which currently access the 3.6GHz to 3.8GHz band to receive satellite transmissions on a licence exempt basis, i.e. without a PES licence or grant of RSA for ROES. However, as set out in paragraph 4.22 above we have not been made aware of anything to suggest that there is extensive licence exempt use of the band. We also note that these users are not currently taken into account for the purposes of Ofcom's frequency assignment criteria.

3.8GHz to 4.2GHz

7.54 In forming this assessment, we have recognised that there is likely to be continued demand for UK satellite earth stations to provide services using C-band, given its particular characteristics. Under option B, we anticipate that many users may consider moving services currently delivered using 3.6GHz to 3.8GHz to the higher 3.8GHz to 4.2GHz frequencies within C-band.

Future band access

7.55 Given the type and location of use in the 3.8GHz to 4.2GHz band, we think this band has potential for shared access between existing and future users based on geographically defined authorisations and are minded to develop proposals to facilitate this, including further consideration of database solutions for dynamic spectrum access. Further detail of our considerations is provided in our April 2016 Call for Input on sharing spectrum at 3.8GHz to 4.2GHz,⁶⁸ and the short Update published in August 2016.⁶⁹ This approach is in line with the UK Government's 5G

⁶⁸ *3.8 GHz to 4.2 GHz band: Opportunities for Innovation*, Call for Input, April 2016, https://www.ofcom.org.uk/data/assets/pdf_file/0031/79564/3.8-GHz-to-4.2-GHz-band-Opportunities-for-Innovation.pdf

⁶⁹ *3.8 GHz to 4.2 GHz band: Opportunities for Innovation*, Update, August 2016, <https://www.ofcom.org.uk/consultations-and-statements/category-2/opportunities-for-spectrum-sharing-innovation>

Strategy, which set out that the Government will work with Ofcom to assess the feasibility of 5G sharing in the 3.8GHz to 4.2GHz band.

Coexistence

- 7.56 We have taken account of stakeholder comments on potential coexistence issues with the 3.8GHz to 4.2GHz band, which would be expected to have more impact under option B compared to option A owing to more widespread mobile deployment. The October consultation noted that the Transfinite study included preliminary studies into out-of-band interference, and we have also held initial conversations with stakeholders to consider potential impacts on services in the 3.8GHz to 4.2GHz band.
- 7.57 In general, we would expect the impact of interference from mobile services at 3.6GHz to 3.8GHz on the adjacent band to be much less than the impact of interference arising in band, although the risk of interference is likely to be greater for those adjacent services that are using the frequencies closest to the 3.8 GHz boundary. In recent stakeholder discussions, we have also been made aware that there may be a very small number of satellites accessed by registered stakeholders in the UK which do not have a tracking beacon using frequencies above 3.8GHz. This might result in some earth stations based in areas of high 3.6GHz to 3.8GHz mobile activity needing to adopt alternative tracking mechanisms for these satellites.
- 7.58 Overall, we believe that any additional coexistence impacts with operations in the 3.8GHz to 4.2GHz band as a result of future mobile deployment at 3.6GHz to 3.8GHz under option B will be limited compared to the additional benefits which option B would deliver.
- 7.59 We will undertake further technical analysis in the coming months to examine potential coexistence issues in greater detail. This will consider out of band emissions above 3.8GHz. We are not currently minded to introduce restrictions on future 3.6GHz to 3.8GHz mobile use which would materially constrain mobile operations using these frequencies to protect users of the 3.8GHz to 4.2GHz band. However, we will consider in due course whether there are appropriate restrictions which would provide a degree of protection to 3.8GHz to 4.2GHz band users without materially affecting mobile deployments.

Overall assessment of option B

- 7.60 Option B would enable the roll out of mobile services including 5G across all of the UK, including densely populated areas such as greater London where there is likely to be high demand. This option would create disruption to current users of the band, although we judge that most or all of the benefits currently delivered using these frequencies could continue to be delivered using alternative frequencies or technologies.
- 7.61 By enabling the use of these frequencies for future mobile services including 5G across wider areas of the country, including areas of high demand such as greater London, this option is most likely to support the early development and adoption of new and innovative mobile services, including 5G applications to the benefits of citizen and consumers across the UK. This option is also more likely to facilitate competition in the provision of consumer mobile services including 5G than option A, under which there would be material constraints on mobile deployment in many parts of the country.

- 7.62 Overall, we consider that the benefits of option B would outweigh the costs. This provisional conclusion is explained more fully at paragraphs 7.74 to 7.85 below, where we set out our proposal to follow option B in making the 3.6GHz to 3.8GHz band available for mobile.

Stakeholder proposals for sharing of 3.6GHz to 3.8GHz band

- 7.63 We have also considered the various proposals put forward by respondents to enable shared use of the band between future mobile services and existing users, in particular fixed satellite services.
- 7.64 In principle, we agree with stakeholders that it should remain possible for some existing users to continue to use the 3.6GHz to 3.8GHz band in certain areas alongside future mobile services. In particular, we recognise that enabling shared use in a way that would not materially affect the roll out of mobile services is more likely to deliver an optimal spectrum outcome. However, we judge that this would only be feasible for satellite earth stations, as they only use the 3.6GHz to 3.8GHz band to receive (and so would not create interference to mobile).
- 7.65 Some stakeholders suggested benchmark spectrum quality could be maintained for satellite earth stations located in rural areas only. However, our coexistence analysis found that maintaining benchmark spectrum quality for some satellite earth stations based in rural locations could result in material constraints on mobile over wide areas, particularly for sites operating under a PES licence owing to the consideration of short term interference.⁷⁰ Furthermore, as set out at paragraph 6.24, under current coordination mechanisms each new transmitter would require Ofcom confirmation that it would not be expected to undermine benchmark spectrum quality for existing registered user over a large radius. As a result, maintaining current coordination mechanisms for all satellite earth stations situated in rural locations could create a significant constraint on mobile roll out, including in more densely-populated areas.
- 7.66 Nonetheless, as stated in paragraph 7.46 we believe that some satellite earth stations located away from populated areas may be able to continue to receive on a licence exempt basis without experiencing service-impacting levels of interference under option B.
- 7.67 Vodafone proposed that requirements could be placed in future mobile licences to oblige mobile licensees to negotiate with any satellite earth stations continuing to use the band, subject to Ofcom determination where no agreement is reached. We consider that this approach could be complex to administer in practice, and risks providing insufficient certainty to both parties. However, we consider that specific mobile licence provisions to facilitate continued operation of satellite earth stations could offer an alternative approach to provide greater certainty to both satellite earth station operators and mobile operators. We consider this possibility further in section 8 below.
- 7.68 We do not plan to adopt BT/EE's proposal to hold a 'reverse auction', which we expect would be complex to deliver and likely to undermine our objective to enable the deployment of mobile services in a timely way across the UK.

⁷⁰ *Improving consumer access to mobile services at 3.6 to 3.8 GHz*, Consultation, October 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0035/91997/3-6-3-8ghz-consultation.pdf. Table 3, page 46

- 7.69 We recognise that dynamic sharing approaches offer new opportunities for spectrum management and have considered the proposals put forward. Overall, we do not consider that such an approach would deliver the same benefits as enabling mobile services in the 3.6GHz to 3.8GHz band on a nationwide basis. However, as set out at paragraph 7.55 we are minded to develop proposals to enable shared access on a geographic basis in the neighbouring 3.8GHz to 4.2GHz band, building on our experience in using dynamic database solutions.
- 7.70 Some existing users of the band, in addition to FWA respondents, suggested that small cell based deployment would better support coexistence between satellite earth stations and mobile, and we recognise that small cell based deployment is more likely to be able to coexist with satellite earth stations. However, constraining future mobile deployment so as to only permit low power services or deployment using small cells in wide areas would be likely to significantly increase the cost and complexity of mobile deployments on a UK wide basis. This would be likely to reduce the benefits that would be delivered to UK citizens and consumers by slowing or removing the case for mobile roll out using these frequencies in some areas. Furthermore, as set out in the October consultation, previous studies have shown that coexistence with some registered users would remain challenging with a small cell based mobile deployment.

Overall assessment of stakeholder sharing proposals

- 7.71 We welcome stakeholder proposals to deliver optimal use of the spectrum in the 3.6GHz to 3.8GHz band and have fully considered the implications of these.
- 7.72 We are not minded to pursue the specific proposals put forward. In particular, in accordance with our duty to further the interest of consumers and have regard to the desirability of encouraging the availability and use of high speed data transfer services throughout the UK, we are not minded to maintain material restrictions on mobile deployments using this band in some parts of the country. We also wish to make the spectrum available as soon as is practicable and provide operational clarity to existing and future band users.
- 7.73 However, we have taken account of the suggestions put forward in our proposal to examine potential future mobile restriction zones around satellite earth stations, which is discussed in paragraphs 8.15-8.20 below.

Provisional conclusion and proposed approach

- 7.74 To give effect to our decision to make the rest of the band available for mobile data use and facilitate future mobile services in the band, we have formed a preference for adopting policy option B, i.e. to remove existing authorisations for the transmitting fixed links in the 3.6GHz to 3.8GHz band and no longer take registered receiving satellite earth stations into account for frequency management purposes.
- 7.75 Option B would facilitate mobile deployment using this spectrum across the country, by removing constraints which would be imposed on mobile roll out under current coordination procedures. This would allow for the greatest benefits from making the band available for mobile, set out in section 5 above. In particular, we expect this approach to achieve:
- **Wider availability and unconstrained access to the 3.6GHz to 3.8GHz band for mobile services across the UK** providing additional capacity to support higher data rates for large numbers of connected devices. This includes in

densely populated areas in the south of England and West Midlands, including greater London where there is likely to be the highest demand for new and improved future mobile services including 5G. However, it also applies to a number of rural and suburban areas where the roll out of mobile services using this spectrum would be constrained under current arrangements. This is particularly the case given the ability to use existing macrocells for deployment of mobile services in the band, which we expect to support wider roll out.

- **Wider availability of new and improved services, including 5G.** As set out in section 5, this band has been identified as a primary 5G band. Option B will enable new services and applications to be available on a more widespread basis, affording the benefits of innovation to more citizens and consumers across the UK.
- 7.76 As a result, we consider that option B is likely to deliver optimal use of spectrum and increased benefits from the use of these frequencies across the UK. In particular, we noted in section 5 that the general estimates for the value of future 5G services are very significant, building on the high value associated with existing improvements to mobile data services, such as through 4G. The Government has set out its ambition that the UK should be a global leader in 5G, with high quality 5G coverage where people live, work and travel to support the delivery of productivity and growth benefits, as well as enhanced lifestyles.
- 7.77 New spectrum will be needed to realise these benefits and support quick deployment of 5G networks. The 3.4GHz to 3.8GHz band has been identified in the EU and UK as one of the key three spectrum bands which will be important for this, in particular because it offers the large bandwidths needed to support higher data capacity and speeds needed for future 5G applications. It can also be easily deployed using macrocells, which would be expected to help early deployment and availability of new and improved services including 5G.
- 7.78 Making the remaining 116 MHz of the 3.6GHz to 3.8GHz band is an important step to realising these benefits, by ensuring that spectrum is not a barrier to their delivery. This band is particularly suited to delivering some of the anticipated future benefits of 5G, and new and improved mobile data services more generally.
- 7.79 Under option A, these benefits could be realised in many areas of the country. But in many areas they would either not be available at all, or face constraints which would make it less likely that consumers would be offered these new and improved services fully and quickly, if at all. Given that the worst affected areas include a number of densely populated areas with high demand including greater London, option A would be expected to constrain the UK's ability to realise the very significant potential economic and wider benefits of new and improved mobile services, including future 5G services.
- 7.80 Under option B, those constraints would be removed, meaning that the additional spectrum would be made available across the UK to support delivery of these anticipated benefits, including in areas expected to be amongst those with the greatest levels of demand. This will result in greater economic, competition and innovation benefits, with consumers across the country more likely to have access to new and improved mobile data services including 5G.
- 7.81 We recognise that a number of services and associated benefits are currently delivered by existing users of the 3.6GHz to 3.8GHz band. In assessing the impact of option B, we have taken account of our conclusion that most, if not all, of the

benefits currently delivered through this band can be delivered using alternative frequencies, locations or technologies, albeit with additional costs in some cases.

7.82 We also believe that some satellite earth stations, located in less densely populated areas, would continue to be able to operate in the band alongside future mobile services and we are minded to explore how this could be facilitated without materially impacting mobile deployment. We explore this further in section 8 below.

7.83 We recognise that option B is likely to lead to some disruption and/or additional costs for existing users in moving to alternative arrangements for delivery of existing services. However, in considering these impacts we have taken into account:

- The relatively small number of existing users of the 3.6GHz to 3.8GHz band which would be affected by our decision.
- Our proposal, explained more fully in section 8 below, to provide notice periods of several years to existing licensees and grant holders before we implement our proposals for existing fixed links licences, PES licences and grants of RSA for ROES. We believe that this will assist existing users to minimise the impact of our proposed approach.
- That some costs to existing users would be likely to apply even if we maintained existing authorisations. As set out above, under option A we would be likely to review existing users' fees to take account of the extent to which mobile deployment would have been denied access to the band. A number of these users suggested that they would not be able and/or willing to pay revised fees and that they would therefore cease using the 3.6GHz to 3.8GHz band. This indicates that some existing users would incur the costs of moving to alternative arrangements under either option A or option B, whilst those that remained in the band under option A would be likely to face higher spectrum fees.

7.84 Taking into account the discussion above, we believe that the additional benefits of enabling future mobile services in the band on a more widespread basis across the UK, including in areas of high demand such as greater London, would outweigh the impacts on existing users.

7.85 We therefore believe that removing existing authorisations for the transmitting fixed links in the 3.6GHz to 3.8GHz band and no longer taking registered receiving satellite earth stations into account for frequency management purposes – following an appropriate period of notice – would achieve the greatest net benefits for citizens and consumers. We also believe that enabling the use of this spectrum for the delivery of future mobile services including 5G across the UK would ensure the optimal use of spectrum and give effect to our duties regarding the promotion of competition and innovation.

7.86 We explain our proposed approach to implementing option B in the following section.

Question 1: Do you agree with our proposed approach towards registered fixed link and satellite earth stations users of the 3.6GHz to 3.8GHz band?

Question 2: Do you have any comments on our assessment of the likely costs and benefits of our proposed approach?

Section 8

Proposed implementation approach

- 8.1 In section 7 above we set out our preference to follow policy option B set out in the October consultation, i.e. to remove existing users' authorisation to transmit for fixed links and no longer take registered satellite earth stations with a receiver component in the 3.6GHz to 3.8GHz band into account for frequency management purposes.
- 8.2 In this section, we:
- explain our proposed implementation approach under option B, and how this would affect existing users of the 3.6GHz to 3.8GHz band;
 - set out our policy on applications for new authorisations for fixed links and satellite services (under PES licences or grants of RSA for ROES) in the 3.6GHz to 3.8GHz band, which follows from our decision to make the remaining 116 MHz in the band available for mobile services; and
 - explain our intended approach to the UK Broadband licence in the band.

Option B: Proposed approach to existing licences and grants of RSA

Fixed links

- 8.3 We will shortly write to holders of licences for fixed links authorised to transmit using frequencies in the 3.6GHz to 3.8GHz band to set out that, if we decide to follow option B, we would propose to revoke these licences after an appropriate period of notice.
- 8.4 The terms of fixed links licences typically require us to give the licensee at least five years' notice when revoking the licence for spectrum management purposes.
- 8.5 However, as set out in paragraph 7.43 we believe it should be possible for all fixed links licensees currently using 3.6GHz to 3.8GHz to deliver these services using other frequencies and/or technologies over time. In order to ensure the benefits of making this band available for future mobile services can be realised as soon as practicable, we would aim for these fixed links operations to migrate to alternative frequencies by 1 June 2020 where possible, and engage with licensees to explore whether suitable alternative spectrum is available. In some cases, alternative technologies may also be appropriate means for delivering these solutions.
- 8.6 We will take account of any representations made by affected stakeholders on the proposed revocation of their licence(s) before reaching a decision on our proposed approach. If we decide to follow option B we would subsequently send the licensees formal notice of our proposal to revoke their licences in accordance with the provisions of the WT Act before implementing our decision.

Satellite earth stations

- 8.7 We will shortly write to licensees and grant holders in the band setting out how we would propose to vary existing authorisations for receiving satellite earth stations operating under PES licences and grants for RSA for ROES such that, after an appropriate period of notice, we would no longer take satellite earth stations with a receiver component in the 3.6GHz to 3.8GHz band into account for frequency management purposes.
- 8.8 Under our proposed approach these variations would take effect by 1 June 2020. We believe that this is a reasonable and appropriate period of notice for licensees and grant holders to make any necessary adjustments to their operations. This is because we think it provides a suitable balance between minimising disruptions for satellite earth station operators and ensuring the benefits of making this band available for future mobile services can be realised as soon as practicable, having regard to the potential mitigations we identified at paragraph 7.48.
- 8.9 The effect of the proposed variations would be to remove any receive frequencies in the 3.6GHz to 3.8GHz band from the relevant schedule to the PES licences and grants for RSA for ROES, with effect from the end of the notice period. The proposed variations would not affect the remainder of the licences / grants which would continue to authorise the use of other frequencies (outside the 3.6GHz to 3.8GHz band) as relevant in each case. Receiving satellite earth stations would also remain authorised to receive in the 3.6GHz to 3.8GHz band on a licence exempt basis.
- 8.10 We will take account of any representations made by affected stakeholders on the proposed changes to their licence or grant, before reaching a decision on our proposed approach. If we decide to follow option B we would subsequently send the licensees and grant holders formal notice of our proposal to vary their licences / grants in accordance with the provisions of the WT Act before implementing our decision.

Transitional arrangements

- 8.11 Under our proposed approach, we would continue to maintain appropriate protections for registered band users until the notice period had lapsed. If we award this band for future mobile services in the interim period before all notice periods have lapsed, we would therefore include time-limited interim restrictions in new mobile licences.

Fees

- 8.12 Under option B we would not currently propose to review WT Act licence and grant fees paid by users of the 3.6GHz to 3.8GHz band given our proposal to vary licences and grants for satellite earth stations and revoke fixed link licences.
- 8.13 As set out in the October consultation, in the event that we were to decide to pursue option A, we would expect to review fees for WT Act licences and grants in line with our pricing framework.

Funding

- 8.14 A number of stakeholders argued that existing users should be compensated for any impacts on them as a result of our proposal to make the band available for

mobile. Given that we are proposing reasonable notice periods in accordance with the terms of the respective licences/grants we do not currently see a case for funding being made available.

Option B: potential mobile restriction zones around satellite earth stations

- 8.15 Our proposal to pursue option B is intended to remove constraints on mobile roll out arising from existing coordination requirements which maintain benchmark spectrum quality.
- 8.16 Following the end of the notice periods, satellite earth station operators could choose to continue to operate in the 3.6GHz to 3.8GHz band on a licence exempt basis, although in practice their ability to continue to receive without service-impacting interference could vary according to site characteristics (including location, terrain, dish specification) and the speed and characteristics of mobile roll out.
- 8.17 We expect that some satellite earth station sites (such as those located away from urban centres, or those with sufficient shielding) might be able to continue receiving in this band without suffering service impacting levels of interference from future mobile services. In some cases this may be for a limited period of time, before full mobile deployment takes place, but in other cases longer term coexistence may be possible. In general, satellite earth stations located near densely populated areas would be less likely to be able to continue receiving in the 3.6GHz to 3.8GHz band.
- 8.18 It would be up to each satellite earth station operator to determine whether the spectrum quality level for a specific site was sufficient to continue using these frequencies on a licence exempt basis. They might also choose to take action to decrease the risk of interference, for example by using an earth station at a different location or using new shielding (such as terrain or walls).
- 8.19 From our discussions with satellite earth station operators, it was clear that a number of them believe interference issues are likely to be greatest where mobile services are deployed in the immediate vicinity of earth stations, and that they may be able to continue to receive using these frequencies if mobile base stations are not deployed near to their existing sites. To facilitate continued operation of satellite services in the band where possible (if, following consideration of responses to this consultation, we decide to follow option B), we therefore intend to explore applying localised restrictions in future mobile licences, where these would not have a material impact on mobile deployment.
- 8.20 Such conditions would place technical restrictions on a mobile network operator deploying base stations in the immediate vicinity of satellite earth station sites. For example, this might require MNOs to take steps to mitigate interference when deploying base station sectors in the direct line of sight of a receiving dish within a specified area or to reduce transmit power. In general, we would expect any such arrangements to apply to relatively small areas, such as within a radius of 1-3km. However, we will consider larger areas if these would not have a material impact on mobile deployment.
- 8.21 We will engage stakeholders in developing this approach, taking account of the following considerations:

- our objective to ensure consumers right across the UK can benefit from new mobile services including 5G;
- that any constraints to mobile deployment should be kept to a minimum, and should not prevent MNOs from offering mobile services in the area affected;
- that any proposals should take account of local site and topology characteristics; and
- ensuring MNOs are able to meet demand across the UK by deploying mobile services using this spectrum on existing macrocells.

Policy on new applications in the band

- 8.22 As a result of our decision to make the 3.6GHz to 3.8GHz band available for mobile services, we will be closing the frequency range 3.6GHz to 3.8GHz (channels 1-7) to new applications for fixed link licences, with effect from the date of this statement.
- 8.23 We will also be closing the band to new applications for PES licences and grants of RSA for ROES for satellite earth stations with a receiver component in the 3.6GHz to 3.8GHz band using these frequencies, with effect from the date of this statement. In addition, we do not expect to approve any variations to existing PES licences or grants of RSA for ROES which would add additional frequencies (including associated emissions) within the 3.6GHz to 3.8GHz band. We note that satellite earth station operators which wish to use the band could choose to receive on a licence-exempt basis, although interference may increase following the start of mobile deployment.
- 8.24 Non-operational licences for testing and development purposes will continue to be available in the period before an award.

UK Broadband

- 8.25 As set out in section 4, UK Broadband is already licensed to provide electronic communications services, including mobile services, in 84 MHz of the 3.6GHz to 3.8GHz band (3605MHz to 3689MHz). In the October consultation, we said that, if we proceeded with our proposal to make the remainder of the band available for future mobile services, we would consider the implications for the UK Broadband licence at an appropriate time.
- 8.26 In particular, we said that we would consider reflecting the opportunity cost of mobile use in the licence fee that UK Broadband pays for this spectrum, as well as harmonising its licence coordination requirements with any obligations associated with potential future mobile network operators in this band.
- 8.27 Since the October consultation UK Broadband has been acquired by H3G. H3G announced it had reached agreement to acquire UK Broadband Limited, including its spectrum holdings, on 6 February 2017. The agreement was cleared by the Competition and Mergers Authority on 3 May 2017⁷¹ and was completed on 31 May

⁷¹ Competition and Markets Authority, *Hutchison 3G UK / Transvision Investments merger inquiry*, <https://www.gov.uk/cma-cases/hutchison-3g-uk-transvision-investments-merger-inquiry>

2017.⁷² UK Broadband is now a wholly owned subsidiary of H3G, but remains the holder of the licence within the 3.6GHz to 3.8GHz band.

- 8.28 We intend to consider the issues relating to the UK Broadband licence in this band further and will consult on proposals at a later date if necessary. In doing so we will take account of responses received to the October consultation.

⁷² Three, "Three UK completes acquisition of UK Broadband Limited", <http://www.threemediacentre.co.uk/news/2017/ukb-completion.aspx>

Section 9

Conclusions and next steps

Summary of decisions and proposals

Making the 3.6GHz to 3.8GHz band available for mobile services

- 9.1 Having considered the responses to the October consultation, we have decided to make the remaining 116 MHz of spectrum in the 3.6GHz to 3.8GHz band not currently assigned for electronic communications services available for mobile services through a future award.
- 9.2 We expect that the benefits resulting from our decision will be greater the sooner the spectrum can be used for mobile services. Our objective is therefore to make the band available as soon as practicable.
- 9.3 As a result of this decision we are closing the frequency range 3.6GHz to 3.8GHz to new applications for fixed link licences, PES licences and grants of RSA for ROES, with effect from the date of this statement.
- 9.4 As a result of the geographic concentration of existing users, there are areas in which these frequencies could be used from today, for trials and pre-commercial deployments. Ofcom can make spectrum available to facilitate trials and pre-commercial deployments, including 5G, to support innovation in the UK.

Proposed approach for existing satellite earth station and fixed links users

- 9.5 To facilitate the deployment of future mobile services in the band in as wide an area as possible across the UK, we are minded to remove current authorisations for fixed links and no longer take registered satellite earth stations with a receive component in the 3.6GHz to 3.8GHz band into account for frequency management purposes – option B in the October consultation – as soon as practicable.
- 9.6 We will shortly write to existing licensees and grant holders in the band setting out details of how we would propose to implement option B (if, following consideration of responses to this consultation, we decide to adopt it) by (i) varying existing authorisations for satellite earth stations operating under PES licences and grants of RSA for ROES and (ii) revoking licences for fixed links.
- 9.7 The effect of our proposed approach would be to enable future mobile services in the 3.6GHz to 3.8GHz band to be deployed in many areas from around 2020, but not necessarily nationwide before 2022.
- 9.8 We are consulting on our proposed approach, and will take account of comments received and representations from affected licensees and grant holders before reaching a decision.

Our approach to the UK Broadband licence

- 9.9 We have noted the recent acquisition of UK Broadband by H3G. We intend to consider issues relating to the UK Broadband licence at 3605MHz to 3689MHz further, and consult on proposals at a later date if necessary.

Next steps

- 9.10 Once we have considered responses to this consultation, we will publish a further statement in due course setting out our decision on our approach to existing authorisations and providing an update on how we expect to make the band available for mobile services
- 9.11 As a result of our decisions, we also intend to:
- conduct further technical analysis on coexistence issues;
 - consult on a draft statutory instrument to remove the option to have a grant of RSA for ROES issued in the 3.6GHz to 3.8GHz band;
 - update the UK Frequency Allocation Table and Technical Frequency Assignment Criteria to reflect the future use of the band.

Further technical analysis

- 9.12 If we decide to follow option B, to facilitate continuing operation of satellite services in the 3.6GHz to 3.8GHz band where possible we will explore applying localised restrictions in future mobile licences, where these would not have a material impact on mobile deployment. Such conditions would place technical restrictions on a mobile network operator deploying base stations in the immediate vicinity of satellite earth station sites. In general, we would expect these arrangements to apply to relatively small areas. However, we will consider larger areas if these would not have a material impact on mobile deployment.
- 9.13 We will begin work to determine the technical conditions for the future mobile licences. This will include details of any conditions required to ensure that new systems will not cause undue interference to one another, existing mobile networks or any specific locations that we determine need to be protected. We will work with the Ministry of Defence to identify appropriate restrictions for future mobile licences to ensure that Defence capabilities are not unduly affected.
- 9.14 We will work with neighbouring National Regulatory Authorities to identify any future same or adjacent band coordination requirements.

Preparing for the future award

- 9.15 Subject to the outcome of future consultations, we are minded to deliver a future combined award in 2019 of:
- the remaining 116 MHz being made available in the 3.6GHz to 3.8GHz band; and
 - the 700MHz spectrum which is expected to become available by mid 2020.
- 9.16 Given our decision to make this band available for mobile services, we intend to bring the 3.6GHz to 3.8GHz band under the Mobile Trading Regulations prior to a future spectrum award. We published a separate consultation on proposals to bring

the band under the Mobile Trading Regulations in December 2016⁷³ and will publish a statement in due course.

⁷³ *Proposed changes to spectrum trading regulations: Statutory notices of proposals to make regulations under section 122 of the Wireless Telegraphy Act 2006*, Consultation, December 2016, <https://www.ofcom.org.uk/consultations-and-statements/category-3/changes-to-spectrum-trading-regulations>.

Annex 1

Responding to this consultation

How to respond

- A1.1 We would like to receive views and comments on the issues set out for consultation in section 7, **by 5pm on Tuesday 22 September 2017**.
- A1.2 We strongly prefer to receive responses via the online form at https://www.ofcom.org.uk/data/assets/rtf_file/0008/105200/consultation-form.rtf
- A1.3 We also provide a cover sheet (see Annex 3 or <http://stakeholders.ofcom.org.uk/consultations/consultation-response-coversheet/>) for responses sent by email or post; please fill this in, as it helps us to maintain your confidentiality, and speeds up our work. You do not need to do this if you respond using the online form.
- A1.4 If your response is a large file, has supporting charts, tables or other data, please email it to 3.6-3.8.GHz.mobile@ofcom.org.uk, as an attachment in Microsoft Word format, together with the cover sheet found at the link above or in Annex 3. You can also use this email address to submit your response in an alternative format (e.g. a video or audio file).
- A1.5 Responses may alternatively be posted to the address below, marked with the title of the consultation.
- Nina Percival
Ofcom Riverside House
2A Southwark Bridge Road
London SE1 9HA
- A1.6 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt if your response is submitted via the online web form, but not otherwise.
- A1.7 We welcome joint responses.
- A1.8 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed at Annex 3. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.
- A1.9 If you want to discuss the issues and questions raised in this consultation, please contact Nina Percival on 020 7981 3338, or by email to 3.6-3.8.GHz.mobile@ofcom.org.uk.

Confidentiality

- A1.10 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other

respondents' views, we usually publish all responses on our website, www.ofcom.org.uk, as soon as we receive them.

- A1.11 If you think your response should be kept confidential, please specify which part(s) this applies to, and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.
- A1.12 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.
- A1.13 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further at <http://www.ofcom.org.uk/terms-of-use/>

Next steps

- A1.14 Following this consultation period, Ofcom plans to publish a further Statement in due course.
- A1.15 If you wish, you can register to receive mail updates alerting you to new Ofcom publications; for more details please see <http://www.ofcom.org.uk/email-updates/>

Ofcom's consultation processes

- A1.16 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in Annex 3.
- A1.17 If you have any comments or suggestions on how we manage our consultations, please call our consultation helpdesk on 020 7981 3003 or email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.

If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact Steve Gettings, Ofcom's consultation champion:

Steve Gettings
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601
Email steve.gettings@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has seven principles that **it follows for every public written consultation:**

Before the consultation

A2.2 Wherever possible, we will hold informal talks with people and organisations before announcing a big consultation, to find out whether we are thinking along the right lines. 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 whom 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 for people to give us a written response. If the consultation is complicated, we may provide a short Plain English / Cymraeg Clir guide, to help smaller organisations or individuals who would not otherwise be able to spare the time to share their views.

A2.5 We will consult for up to ten 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 aim to reach the largest possible number of people and organisations who may be interested in the outcome of our decisions. Ofcom's Consultation Champion is the main person to contact if you have views on the way we run our consultations.

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

After the consultation

A2.8 We think it is important that everyone who is interested in an issue can see other people's views, so we usually publish all the responses on our website as soon as we receive them. After the consultation, we will make our decisions and publish a statement explaining what we are going to do, and why, showing how respondents' views helped to shape these decisions.

Annex 3

Consultation response cover sheet

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

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

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

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

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

DECLARATION

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

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

Name

Signed (if hard copy)

Annex 4

Consultation questions

Question 1: Do you agree with our proposed approach towards registered fixed link and satellite earth stations users of the 3.6GHz to 3.8GHz band?

Question 2: Do you have any comments on our assessment of the likely costs and benefits of our proposed approach?

Annex 5

Coexistence analysis

- A5.1 This annex provides additional detail about the assumptions of our updated coexistence studies.
- A5.2 As outlined in section 6, we have updated our coexistence studies to take into account updated technical information and assumptions about potential future deployment of mobile services including 5G in this band. We modelled a realistic simulated future UK-wide 5G macrocell deployment, based on an updated understanding of the likely characteristics of potential 5G networks at 3.6GHz to 3.8GHz. In order to make our simulation as realistic as possible, we have made use of commercially sensitive information which we are unable to publish.

Satellite earth station sites

- A5.3 We used the same interference thresholds for satellite earth stations that we use when considering the granting of new fixed links and UK Broadband deployments in the 3.6GHz to 3.8GHz band. Current coordination mechanisms provide benchmark spectrum quality by ensuring that I/N levels do not exceed -10 dB for more than 20% of the time⁷⁴ for registered receiver components under PES licences and grants of RSA for ROES and 0dB during anomalous propagation conditions (0.005% of the time) for registered receiver components under PES licences.⁷⁵
- A5.4 In Table 2 we show the main differences between the October consultation and updated 2017 assumptions.

⁷⁴ This is known as long-term interference and refers to 20% propagation time in propagation models ITU-R P452 and ITU-R P1812. In our studies we used propagation models P452-16 and P1812-4.

⁷⁵ This is known as short-term interference, and refers to when the interference to a receiver is enhanced for a short period of time, occurring when weather conditions lead to anomalous propagation. During current coordination, we use 0.005% propagation time in propagation model ITU-R P452-10, although in our studies we used model ITU-R P452-16.

Table 2: Comparison of simulation assumptions between our October consultation and latest 2017 studies for satellite earth stations

	October 2016 consultation assumptions	Updated 2017 assumptions
Base Station (BS) position and BS deployment	Based on a realistic network deployment covering greater London within the M25	Based on a simulated network as described in A5.2, covering an area centred on each satellite earth station with a radius of 140km ⁷⁶
EIRP	61dBm/MHz	Values extracted from simulation model
BS antenna	Single antenna based on SL 12436A	ITU recommendation M.2101, with 8 vertical elements (separated by 0.9λ) and 4 horizontal elements (separated by 0.5λ). Sensitivity analysis available for 2 and 8 horizontal elements
Number of sectors per site	3	Values extracted from simulation model
Sector pointing	Fixed: 0°, 120°, 240°	
Antenna tilt	Fixed: 2°	
Antenna height	Fixed: 34 m	
BS downlink activity factor	1	0.5
TDD downlink/ uplink ratio	-	80/20
Shielding around satellite earth stations	Chalfont (<u>35 dB</u>) towards London	Chalfont (35 dB), Bedford (30 dB towards Milton Keynes) ⁷⁷
Propagation model	ITU-R P.452-16 (long-term and short-term) and ITU-R P.1812 (long-term)	ITU-R P.452-16 (short-term) and ITU-R P.1812 (long-term)
Terrain and Land Use Data	Ofcom 50 m terrain and land use databases. When applicable, the effect of local clutter at the BS and the ES and clutter across the path have been considered.	Ofcom 50 m terrain and land use databases. When applicable, the effect of local clutter at the BS and the ES and clutter across the path have been considered.
ESs modelled	Chalfont, Bedford, Crawley Court, Crowsley Park, Brookmans Park, Madley	Registered satellite earth station sites at 3.6GHz to 3.8GHz in UK ⁷⁸

⁷⁶ We have not published the full set of assumptions owing to the use of commercially sensitive information to inform our assumptions.

⁷⁷ Based on local knowledge and coordination measurements completed by Ofcom and the Radiocommunications Agency.

⁷⁸ We considered all registered satellite earth sites in the band with the exception of the Met Office site at Exeter. This is because the Met Office indicated in its consultation response that it did not use the 3.6GHz to 3.8GHz band.

Fixed links

A5.5 In Table 3 we show the main differences between the analysis summarised in the October consultation (based on the 2015 Transfinite study) and updated 2017 assumptions on fixed links.

Table 3: Comparison of simulation assumptions between our October consultation and latest 2017 studies for fixed links

	October 2016 consultation assumptions	Updated 2017 assumptions
Base Stations modelled	Single and multiple small cell BSs	Based on a simulated network, as described in A5.2, covering an area centred on each fixed link with a radius of 250km
EIRP	22 dBm/MHz	Based on values extracted from simulation model
BS antenna	ITU-R F.1336 Omni	ITU recommendation M.2101, with 8 vertical elements (separated by 0.9λ) and 4 horizontal elements (separated by 0.5λ). Sensitivity analysis available for 2 and 8 horizontal elements
Number of sectors per site	1	Values extracted from simulation model
Sector pointing	Various cases considered	
Antenna tilt	N/A	
Antenna height	6 m (outdoor) and 3 m (indoor)	
BS downlink activity factor	0.5	0.5
TDD downlink/ uplink ratio	-	80/20
Propagation model	Various cases considered	ITU-R P.452 (short-term) and ITU-R P.1812 (long-term)
Terrain and Land Use Data	Ofcom 50 m terrain and land use databases. When applicable, the effect of local clutter at the BS and the fixed link and clutter across the path have been considered.	Ofcom 50 m terrain and land use databases. When applicable, the effect of local clutter at the BS and the fixed link and clutter across the path have been considered.
Fixed links modelled	BT Tower in London	All mainland fixed links; one fixed link to the Isle of Wight; a selection of fixed links in Shetlands and Hebrides

Annex 6

Summary of October consultation responses

- A6.1 This annex summarises the 36 submissions we received from stakeholders in response to the October 2016 consultation, together with our response to their submissions. Four respondents submitted confidential responses. All non-confidential responses are published on our website.⁷⁹
- A6.2 All responses have been considered and taken into account in the preparation of this statement and consultation. The summary follows the structure of the nine questions we asked in the consultation. Where stakeholders have answered on similar topics in response to different questions, we reflect these only under the question to which they have the greatest relevance.

Question 1: Do you have any comments on the use of the 3.6GHz to 3.8GHz band by existing services?

Stakeholder comments	Ofcom response
Access Technologies, BT/EE (with respect to fixed links), Ericsson, ip.access, Microsoft, Orange, Telefonica, Three, and a confidential respondent agreed with our observations about the geographically limited nature of current use of the band.	<p>We welcome the additional information respondents provided, and have updated our understanding of the band based on the information received.</p> <p>As set out under question 4 below, we intend to consider issues relating to the UK Broadband licence further in light of the recent acquisition of UK Broadband by H3G.</p>
Arqiva, BBC Monitoring, BT/EE, Intelsat, ESOA, techUK, Global VSAT Forum, and a confidential respondent discussed the importance of this band for broadcasting.	
The Met Office, Intelsat, ESOA, techUK, Arqiva, BT/EE, and Vodafone discussed the importance of this band for satellite data communications. Examples given included the exchange of meteorological data in tropical areas and connectivity for the Galileo and EGNOS projects.	
The Ministry of Defence said that it has additional use of the band in Bude, Cornwall.	
The BBC provided additional information about their BBC Monitoring service.	

⁷⁹ <https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz>

ESOA, Global VSAT Forum, and techUK noted that the band is used for telemetry, telecommand, and control.	
UK Broadband provided further information about its use of the band (see [4.13-4.14]). Cambium Networks and a confidential respondent criticised the extent of UK Broadband's use.	
The UK Space Agency and techUK responded that fixed satellite use was possibly more substantial than our assessment, as we did not take into account licence exempt use of the band.	See 4.22. We recognise that there is licence exempt use in the band, but have not been made aware of anything that suggests there is extensive licence exempt use.
Intelsat, ESOA, techUK and BT/EE said that C-band (3.6GHz to 4.2GHz) is sought after within the satellite industry due to its unique characteristics. Intelsat and ESOA said that satellite use of the 3.6GHz to 3.8GHz is growing whereas Ericsson said use of the band could be characterised as not growing.	See 4.21. While we recognise the importance of 3.6GHz to 4.2GHz to the satellite sector, we do not judge this to be a key growth band for satellite.

Question 2: Do you agree with our identification of a trend towards the use of mobile in the 3.6GHz to 3.8GHz band?

Stakeholder comments	Ofcom response
Access Technologies, BT/EE, CONNECT, Federated Wireless, GSA, Huawei, IET, Qualcomm, techUK, and Telefonica highlighted the RSPG Opinion on spectrum related aspects for next-generation wireless systems (5G).	In section 5.40–5.50 we provide additional information with regards to the increasing international developments to make this band available for mobile, supported by the development of a device ecosystem, and the suitability of this spectrum, as a result of the wide bandwidth available, to deliver higher speed and capacity, and improved quality of service, whilst being deployed on existing macrocells.
Intel, GSA, Qualcomm and Access Technologies pointed out that ECC Decision (11)06 was being revised in PT1 to support technical conditions for 5G.	
Federated Wireless, Access Technologies, ip.access, BT/EE, Ordnance Survey, Ericsson, UK Broadband and Qualcomm gave information about plans to make portions of the band available for mobile in other countries outside the EU.	
Intel and GSA said manufacturers are already developing mobile equipment for this band.	

<p>The MOD, Access Technologies, and techUK argued Ofcom should consider the band as appropriate for a wider variety of 5G technologies, including backhaul, fronthaul and Mi-Fi, in addition to traditional mobile services.</p>	<p>Ofcom’s policy is to award spectrum licences in accordance with the principles of technology and service neutrality.</p>
<p>The UK Space Agency and two FWA stakeholders – Cambium Networks and a confidential respondent – disagreed with our identification of a trend towards mobile in this band.</p>	<p>This band has the potential to deliver significant benefits for UK consumers and citizens, including by providing additional capacity and enabling new and improved mobile services, including 5G, with an improved quality of service. This spectrum is part of the primary band for introducing 5G in Europe. This will contribute to the development of innovative mobile services as well as promoting competition in the mobile market.</p> <p>Making the band available for mobile, will therefore support the delivery of increased benefits from the use of these frequencies across the UK.</p> <p>Our assessment and decision making process to make this band available for mobile is provided in section 5.</p>
<p>Cambium Networks, a confidential respondent and ESOA said mobile operators should use existing spectrum more efficiently, rather than identifying new spectrum for mobile.</p>	
<p>UK Space Agency argued that we do not have demand study evidence, mobile parameters are not finalised, and that there is no global harmonisation in this band for mobile. They also said that making this band available cheaply to MNOs discourages innovation at mmWave.</p>	
<p>The MOD said it is first necessary for industry to confirm whether or not the band is the prime candidate for development of 5G.</p>	
<p>The UK Space Agency and ESOA pointed out that previous attempts to use this spectrum for terrestrial broadband have not been very successful.</p>	

Question 3: Do you agree with our high level proposal to make 116 MHz within the 3.6GHz to 3.8GHz band available for mobile and 5G services, bearing in mind our statutory duties and the high level trends we have identified?

Stakeholder comments	Ofcom response
<p><i>Overview:</i> 27 respondents supported our high level proposal. Four opposed, of which two (UK Space Agency and a confidential respondent) represent space interests and two (Cambium Networks and a confidential respondent) represent FWA interests.</p>	
<p>Some stakeholders’ agreement was conditional on how mobile would be implemented in the band. The BBC and a confidential satellite sector respondent supported the proposal</p>	<p>Our proposed approach for making the band available for mobile is discussed in Sections 7</p>

if fixed satellite services are protected from interference from mobile. Arqiva said they would need more information on available mitigations for existing uses.	and 8. Our proposals are to make this spectrum available as soon as practical to maximise the citizen and consumers' benefits identified in section 5.
Intelsat and ESOA said identification of the band for mobile should not preclude use by other applications, and noted that mobile does not have priority in the Radio Regulations.	
The UKSA opposed making the band available for mobile because solutions to allow mobile use while protecting space use have yet to emerge. They also said it would also be very difficult to introduce new ground stations if this required new constraints on deployed mobile networks.	
The IET, Arqiva, the BBC, Cambium Networks and two confidential respondents questioned whether this band would be used across the UK for mobile services including 5G, for example given its propagation limitations (and therefore deployment costs). Use is likely to be concentrated in busy areas.	As we set out in 5.36, emerging technologies will enable the 3.6GHz to 3.8GHz to be deployed using existing macrocells.
<i>Timing of availability:</i> Qualcomm argued the spectrum should be released in a 2017/18 timeframe to allow 5G trials ahead of commercial roll out before 2020. IET said Ofcom's timetable must allow research test-beds to function now.	Our objective is to make the band available as soon as practically possible. We are minded to deliver a future combined award by 2019 of this spectrum and spectrum in 700MHz band, see 9.15. Non-operational licences for testing and development purposes will continue to be available in the period before an award. ⁸⁰ As set out in section 6, there are many areas of the UK where mobile roll out would only be expected to be negligibly affected by maintaining existing authorisations, if at all. In other areas, under our current coordination procedures mobile roll out would be significantly constrained owing to the location of existing registered users. Under our proposed approach, set out in sections 7 and 8, future mobile services would be enabled in
BT/EE said that standardisation may be complete within the next 2 years and that 5G systems will be operational in the next 2 to 3 years.	
Arqiva commented that actual deployments would not necessarily be expected to be rolled out in 2020. They highlighted studies regarding the 700MHz band centre gap that suggested a time lag of 5 to 7 years between standardisation and significant handset penetration.	
Vodafone would prefer the band to be made available in a timescale that would allow it to be brought into service contemporaneously with the 3.4GHz to 3.6GHz band.	

⁸⁰ <https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences>

	many areas from around 2020, but not necessarily nationwide before 2022.
Ordnance Survey doubted the band could be made available to the Government's timescales and suggested focus on enabling nationwide use of a higher band, e.g. 26GHz.	We set out at 5.38 why we do not consider spectrum at high frequencies above 24GHz to be a substitute for spectrum at 3.6GHz to 3.8GHz.
<i>Bandwidth:</i> Intel and GSA expressed a preference for 400 MHz of contiguous spectrum (including 3.4GHz to 3.6GHz) to enable four, 100 MHz channels for 5G. Huawei proposed an 80-100 MHz target for the minimum amount of spectrum available to each operator, and said that larger bandwidths can be achieved by considering 3.8-4.2GHz.	We will address our approach to awarding the spectrum for mobile use in future publications.
Microsoft noted we did not propose a channelization plan or number of licences to issue.	
Which? and Arqiva urged Ofcom to consider the impact on existing users of the band and the value to consumers created by these services, as well as the impact and risks to consumers of these services suffering disruption or loss of service.	We consider the benefits of making the band available for mobile against the impact on existing users throughout sections 5 and 7.

Question 4: Do you agree with our general approach regarding spectrum currently licensed to UK Broadband?

Stakeholder comments	Ofcom response
Of those stakeholders who responded, only two said they opposed our general approach. Cambium Networks and a confidential respondent argued that UK Broadband should be penalised on the grounds of "use it or lose it", as their national coverage is low.	UK Broadband has recently been acquired by H3G.
Vodafone suggested that if UK Broadband's use is very limited, Ofcom could freeze the licence to cover areas currently deployed and award the spectrum across the rest of the UK.	As set out in paragraph 8.27 and below, we intend to consider the issues relating to the UK Broadband licence further in light of the recent acquisition.
<i>Harmonising the UK Broadband licence's coordination obligations with potential obligations associated with potential future MNOs in the band:</i> Mobile manufacturers particularly supported this proposal, ⁸¹ as well as Orange, Microsoft, and the Met Office.	Regarding BT/EE's proposal, we do not plan to hold a reverse auction, see 7.68.

⁸¹ Ericsson, Qualcomm, Intel, GSA

<p>The UK Space Agency and BBC were concerned about changes to UK Broadband's licence conditions. The BBC said that this would impact BBC Monitoring, and urged Ofcom to make changes only when they become necessary, e.g. immediately before the launch of new mobile services.</p>	
<p>BT/EE argued that if UK Broadband wants its licence conditions amended, this should take place within a reverse auction process. Absent a reverse auction, they recommend requiring UK Broadband to re-bid for the location of its existing spectrum if it enters an auction of the 3.6GHz to 3.8GHz band, to minimise the risk of fragmented assignments</p>	
<p><i>Altering UK Broadband's licensed frequencies:</i> Microsoft advocated shifting UK Broadband's licence down to 3600MHz to 3684MHz. Nominet also support a shift. i.p access would prefer to see UK Broadband's holdings moved above 3700MHz, so that emerging CBRS capable smartphones can access the maximum amount of spectrum.</p>	
<p><i>Reflecting opportunity cost of mobile use in UK Broadband's fees:</i> No stakeholders disagreed that UK Broadband's licence fees should be reviewed.</p>	
<p>UK Broadband argued there is currently no opportunity cost because coexistence issues mean the spectrum cannot be used in certain locations, and there is no device ecosystem yet for mobile handsets. techUK and Vodafone also said that new fees should apply once there is an ecosystem in the band, which could before the band is released for mobile.</p>	
<p>UK Broadband suggested the value of fees should be derived from the 3.6GHz to 3.8GHz band auction, which will probably be in 2018 or 2019, by which time the band is likely to be available in mass market handsets. techUK and Vodafone suggested fees could be based on a future auction of the 116 MHz in 3.6GHz, or the outcome of the 3.4GHz auction.</p>	
<p><i>Bringing the band under the Mobile Trading Regulations (MTR):</i> No stakeholders disagreed with this proposal. However, there was disagreement regarding timing.</p>	
<p>UK Broadband argued it would be premature to bring the band under the MTR until mobile handsets are widely available and some or all FSS co-existence issues have been resolved, as there is no possibility for a trade to distort the market. Three agreed it would be premature, and suggested inclusion in the run-up to a 3.6GHz auction, or at the same time as 700MHz if certainty had developed around use of 3.6GHz for mobile.</p>	<p>As we set out in 9.16, we intend to bring the band under the MTR prior to a future spectrum award. We published a separate consultation on proposals to bring the band under the MTR in December 2016, and will publish a statement in due course.</p>

<p>Vodafone argued it is necessary to immediately make the licence subject to MTR, because Ofcom has said that we have the option to address spectrum asymmetry issues via conditions in subsequent awards such as 700MHz and 3.6GHz. Therefore, in the event of a trade of spectrum in this band, it is only correct that Ofcom undertakes due diligence to ensure there are no adverse competitive consequences.</p>	
<p><i>Leasing:</i> UK Broadband and techUK argued that Ofcom should consider permitting spectrum leasing and other forms of capacity or network sharing in bands subject to the MTR. UK Broadband also said it might be necessary in view of the much wider channel bands required for 5G and mobile data.</p>	<p>This is outside the scope of the current consultation. We have previously set out a view on leasing within mobile bands in our Spectrum Sharing Framework.⁸²</p>

Question 5: Do you agree with our assumptions, methodology, and conclusions with regards to potential coexistence between mobile and existing fixed links and satellite earth stations?

Stakeholder comments	Ofcom response
<p>The Met Office, Microsoft, Ordnance Survey, Vodafone, Telefonica, Orange, Ericsson, Arqiva, BT/EE, Federated Wireless, and a confidential respondent in agreed in general with the assumptions, methodology, and conclusions of our analysis.</p>	<p>Coexistence between mobile and current users is discussed in Section 6.</p>
<p>Intel, GSA, and a confidential respondent highlighted the difficulties of coexistence between mobile and current users, which has been established in previous ITU-R studies.</p>	
<p>Ericsson and Telefonica argued that large separation distances raised questions about the feasibility of sharing between mobile and other services, particularly in London and south-east. The UK Space Agency said that interference to earth stations from mobile deployments 80km away would not be unexpected.</p>	
<p>IET, i.p. access, the Dynamic Spectrum Alliance, Access Technologies and UK Broadband argued that the coexistence studies were too conservative, and UK Broadband</p>	

⁸² A framework for spectrum sharing, Statement, April 2016, https://www.ofcom.org.uk/data/assets/pdf_file/0028/68239/statement.pdf, see paragraph 6.18.

emphasised the mitigations that are available. The IET pointed out that in general theoretical models tend to over-estimate the threat of harmful interference.	consider that they provide a reasonable guide to the potential scale of the challenge. See 6.12.
<p>Access Technologies said that our choice of scenarios was not representative of real deployments, e.g. that we did not take account of the shielding provided by the urban environment. They also said we did not take account of the full range of relevant use cases.</p> <p>They noted that more careful calculations undertaken in the context of the CBRS improved the availability of spectrum from 60% of the US population to 95%.</p>	<p>Our analysis has taken account of the shielding effect of local topology (trees, fences, buildings, etc.) and of the shielding effect along the path between macrocell and earth station. See 6.17. It did not assume additional filtering or site shielding for earth stations.</p> <p>As set out in 6.13, our updated analysis is based on an updated understanding of the likely characteristics of potential 5G networks at 3.6-3.8GHz. Further details are provided in annex 5.</p>
Access Technologies argued that our protection criteria for fixed satellite services do not adequately take into account the impact of clutter, and that their experience of propagation studies suggests that more realistic calculations could reduce the constraint on new users.	
The BBC expressed concern that the study assumed that filtering and site shielding could be used as a mitigation, and argued was not the case at its earth station sites.	
Ordnance Survey argued that calculating exclusion zones would require more precise datasets that Ordnance Survey may be able to assist with.	
Ericsson, techUK and a confidential respondent argued that it is impossible to carry out coexistence analysis accurately without knowing 5G specifications.	
UK Space Agency and techUK criticised a lack of detailed information about a range of factors, including assumed propagation assumptions and the density of small cells.	
Intelsat, techUK, Cambium Networks, UK Broadband, ESOA, and a confidential respondent, argued that the studies demonstrated that coexistence should involve the use of small cells in the vicinity of satellite earth stations.	As set out in 7.70, to only permit low power deployment using small cells would be likely to reduce the benefit to UK citizens and consumers.
Intelsat and ESOA said our studies could not be considered full and accurate across the UK as they only referred to London.	Our updated studies consider all satellite earth station sites in this band with a receiver component registered under PES licences or under grants of RSA for ROES, all mainland fixed links, a fixed to the Isle of Wight and a

	number of fixed links connecting mainland Scotland to Orkney.
The MOD, DSA, BBC and Intelsat said further technical analysis would be needed, including with respect to out-of-band emissions.	One of our next steps is to carry out further technical analysis on coexistence issues, see Section 9.

Question 6: Do you have a view on any of the two options we identified?

Stakeholder comments	Ofcom response
<p><i>Overview:</i> Two satellite stakeholders - Global VSAT Forum and a confidential respondent - said that they supported Option A. Eleven stakeholders supported Option B. These were predominantly mobile equipment manufacturers, as well as Telefonica, Three, Microsoft, Orange and the IET. The majority of stakeholders preferred a solution somewhere between the two options.</p>	
<p>The MOD made the general point that the options identified by Ofcom are only assessed in terms of spectrum availability for 5G, rather than in terms of the benefits for UK citizens and consumers in general.</p>	<p>Our principal duty is to further the interests of citizens and consumers. As explained in sections 5 to 7, we believe that our decision to make the band available for mobile and our proposed approach to existing authorisations will achieve the greatest net benefits for citizens and consumers. We have also taken account of our other statutory duties as relevant.</p>
<p>Satellite stakeholders generally supported continued protections for their use (an element of Option A). The Met Office said there should be retention of at least some C-Band capacity.</p>	<p>Our overall view on option A is set out in Section 7, particularly 7.29-7.38.</p>
<p>Satellite stakeholders opposed the proposal within Option A to review fees in line with our pricing policy. Intelsat, ESOA, techUK, the BBC, Arqiva, BT/EE and a confidential respondent argued that a large increase would force incumbent earth stations out of the band (e.g. to other bands with lower fees, or out of the UK) and so have the same effect as Option B. The UK Space Agency said that any fee increase would be interpreted as an</p>	<p>We set out our proposed approach to 3.8GHz to 4.2GHz band at 7.55.</p>

attempt to price the space sector out of its allocations, and would undermine confidence in future investment in the UK.	
The UK Space Agency was concerned that Option A does not allow for growth through introduction of new earth stations, and that three-year licences are not compatible with investment in space sector infrastructure.	As discussed in 4.21, we do not judge this to be a key growth band for satellite.
techUK argued that Ofcom shouldn't authorise new fixed links or grants of RSA, as the intent behind coordination would be to protect existing users' investments. New earth station receiver components should only be taken account of where an urban or suburban earth station relocates to a rural area. BT/EE also supported a freeze on further fixed links.	We set out our policy on new applications in the band in 8.22–8.23.
On benchmark spectrum quality, ESOA and Intelsat said they would support a policy whereby earth stations could voluntarily accept lower benchmark spectrum quality, but would oppose this being mandated. Arqiva argued there is no real scope to accept lower benchmark spectrum quality, because industry already operates C-band at the lowest possible margins.	If we were to maintain current benchmark spectrum quality for satellite earth stations in this band there would be significant constraints on mobile deployment, see 7.29. We set out our proposed approach in Section 7 and 8.
Supporters of Option B emphasised the impact that allowing existing users to remain could have on availability of the band for mobile, particularly 5G deployments. Three argued that only Option B guarantees that the benefits for consumers of intensive use of the spectrum for mobile will be realised. Given the location of existing users and the restriction zones they would impose, prolonged existence of even a small sub-set of these users could have a substantial effect on mobile access. Uncertainty also creates the risk that spectrum may not be allocated to those with the best use cases, but to those with the most optimistic view of when existing users will vacate the band.	Our view on option B is set out in Section 7, particularly 7.39-7.62, including the impact that this approach would have on mobile deployment.
Telefonica argued that sharing the band would prevent mobile deployment in some key population centres, potentially meaning that a mobile operator would not be able to deploy 5G nationwide. This could restrict the scope for competition in provision of 5G services and lead to more fragmentation than is ideal for 5G, and uncertainty over sharing could artificially inflate the value of substitute spectrum (i.e. 3.4GHz and UK Broadband licence).	

<p>Intelsat and ESOA argued Option B would go against Ofcom’s statutory duties to protect incumbent services and encourage competition.</p> <p>A number of stakeholders including Intelsat, ESOA, techUK, and a confidential respondent said that a shared approach would be compatible with the EC decision, and BT/EE noted that other countries are making the band available for mobile on a shared basis.</p>	<p>We discuss the legal framework in section 3, and explain our proposal to follow Option B in the context of our statutory duties in section 7. As explained in that section we believe that under this approach most, if not all, of the benefits from services currently delivered by existing users could continue to be delivered. See in particular 7.49. We also explain that there would be scope for some satellite services to continue to use the band on a licence exempt basis.</p>
<p>Many stakeholders supported alternative solutions providing continued protection for some satellite earth stations, while providing some means to encourage release of more spectrum to mobile where this has a higher value. For example, Vodafone and BT/EE (with interests in both mobile and satellite) argued that protecting all incumbent services would significantly devalue the spectrum for mobile and reduce the benefits that could be released, but removing protections would not safeguard the benefits of existing high value services, and would mean installations with no real chance of affecting mobile roll out could be unnecessarily decommissioned.</p>	<p>Our views on the alternative solutions proposed by stakeholders are set out in Section 7, particularly 7.63-7.73.</p> <p>In principle, we agree that it should remain possible for some existing users to continue to use the 3.6 to 3.8GHz band alongside future mobile services in some areas. However, maintaining benchmark spectrum quality for some earth stations in rural locations could result in material constraints on mobile over wide areas of population, particularly for sites operating under a PES licence owing to the protections against short term interference. See 7.65.</p>
<p>We received several suggestions for partial clearance based on location:</p> <ul style="list-style-type: none"> • UK Broadband suggested removing only those earth stations affecting areas of high population density or high mobile data demand. • A confidential satellite respondent said that earth stations should be offered a choice to relocate to an area where the protection criteria and level of service can be ensured. • Vodafone’s preferred option was to differentiate between urban and rural earth stations. • The BBC suggested it may be possible to identify locations that fit operational requirements for earth stations and are in areas unlikely to attract roll out of 5G. • Ericsson also suggested that removing or relocating earth stations would be an effective method of avoiding interference in the longer term. 	

<ul style="list-style-type: none"> Microsoft suggested that, due to the low number of sites nationwide, there may be ways to apply different sharing strategies on a station-by-station basis to make the retain option practicable at some locations. 	
<p>BT/EE proposed a reverse auction mechanism. They argue that this would provide an opportunity to arrive at an efficient level of ongoing use from incumbent users, whilst also enabling Ofcom to assign licences for mobile use in this band without delay. Participation would be voluntary, prior to a forward auction awarding the band for mobile, subject to the restrictions necessary to protect existing users who had opted to stay. BT/EE suggested this may encourage earth stations to be consolidated at existing sites away from urban areas.</p>	<p>We respond to this proposal in 7.68.</p>
<p>Vodafone proposed another solution whereby incumbents would have no protection, but new mobile licensees would be required to negotiate in good faith to allow coexistence.</p>	<p>We respond to this proposal in 7.67.</p>
<p>FWA stakeholder Cambium Networks and a confidential respondent said that mobile should be able to use the spectrum in city centres and other crowded areas, with FWA allowed to use it in rural areas on a light licensed basis. The confidential respondent said this spectrum should be free to rural WISPs.</p>	<p>The European harmonised standards for this band could allow for FWA. However, we believe the greatest benefits in using this band can be delivered by ensuring that mobile can be deployed in many areas across the UK. We see greater potential for shared access in the 3.8-4.2GHz band, see 7.55.</p>
<p>i.p. access suggested clearing the lower half of the band (below 3700MHz) to support CBRS devices.</p>	<p>The EU has identified the 3.4GHz to 3.8GHz band as a 5G band and we note the emerging ecosystem. See Section 5.</p>
<p><i>Dynamic shared access:</i> Several stakeholders argued for sharing approaches featuring dynamic spectrum access.</p> <p>Federated Wireless suggests allowing commercial third parties to automate spectrum access decisions in near real time. Auctions of secondary rights would reflect the need for frequency agility by awarding rights to logical channels rather than specific frequencies.</p>	<p>As set out in 7.69, we recognise that database technology poses opportunities for new policy approaches to spectrum management in general, particularly in a shared spectrum environment. However, in respect of the 3.6GHz to 3.8GHz band, we understand that much of the satellite earth station use is on a continuous basis, meaning that there would be limited</p>
<p>Access Technologies recommended a multi-tier database-driven access system, facilitating both licensed and unlicensed access. They suggest this would enable a wide range of providers to meet both well-established use-cases for mobile broadband and new</p>	

<p>use cases for 5G systems. Nominet and techUK also recommended database-driven access.</p>	<p>opportunity for mobile services to access the band in some areas on a dynamic basis.</p> <p>We note however, that over longer timescales there may be potential for dynamic spectrum access to deliver benefits to UK citizens and consumers using the 3.8GHz to 4.2GHz band, as set out in paragraph 7.55.</p>
<p>i.p. access also proposed a tiered shared access model, but with a neutral host service provider as an essential part of the ecosystem.</p>	
<p>CONNECT said we need to move to much more extreme sharing scenarios than currently exist, e.g. pool all spectrum and dynamically allow different networks to access the pool on an as-needed basis, rather than assign spectrum to any one network. They suggest that Ofcom could draw on aspects of the CBRS in the 3550MHz to 3700 MHz band in the USA.</p>	
<p>Microsoft argued that a shared access approach to spectrum management, such as the CBRS in the US would not be appropriate for the 3.6GHz to 3.8GHz band due to the underlying rules prescribing high power TD-LTE in the band.</p>	
<p>The Dynamic Spectrum Alliance said Ofcom should lead on developing coexistence work in a similar fashion as it has for TVWS.</p>	
<p><i>Potential for mitigations for existing users:</i> Ericsson argued that existing uses have many spectrum alternatives, whereas 3.6GHz to 3.8GHz is particularly suited for mobile use with future 5G technologies, providing a good balance of non-line-of-sight propagation and relatively wide contiguous bandwidth. They suggested 6GHz as a suitable alternative band for fixed links.</p>	<p>The impacts of proposed options, including stakeholder comments about mitigations, are discussed in Section 8.</p> <p>As set out in [8.50], we will undertake further technical work to examine the potential for future mobile deployment to affect services provided using neighbouring bands.</p>
<p>Vodafone and two FWA stakeholders, Cambium Networks and a confidential respondent suggested that some fixed links users could be replaced with fibre connectivity.</p>	
<p>Arqiva argued that Ofcom policy towards fixed links should be in line with the general regulatory principles that it proposes for satellite earth stations. These include sufficient time for industry to respond to policy, mitigations should be accompanied long term by regulatory certainty, decisions on pricing should not undermine investment decisions and reflect that use of spectrum is already changing, and funding or other support for existing users to cover incremental costs related to migration measures.</p>	

<p>The BBC said that relocating earth station sites would require assurances around security of tenure and access to spectrum free from harmful interference over the (25+ year) investment period, and future fee levels.</p>	
<p>Satellite stakeholders including the UK Space Agency, Intelsat, ESOA, the BBC and a confidential respondent, plus techUK, argued that while it is sometimes true that earth station operators can relocate in location or frequency or otherwise protect themselves (at a cost), this is not always the case. MOD, BBC Monitoring, BT/EE, techUK and Ordnance Survey highlighted the limited control satellite earth station operators sometimes have over the frequencies required for reception. The size of the dishes can also create constraints on mitigations and relocations.</p>	
<p>Met Office said it is imperative that some capacity to transmit in C-band is retained, e.g. in 3.8 to 4.2GHz. Arqiva said industry would need some level of assurance that 3.8 to 4.2GHz would not be proposed, at an ITU level, as a future band for mobile in the longer term. UKSA said it is likely that the 3.8-4.2GHz CFI will be seen by industry as first stage in removing protected access to C-band as a whole.</p>	<p>In 7.54-7.55 we set out our approach to the 3.8GHz to 4.2GHz band with regard further shared access between new and existing users on a geographic basis.</p>
<p>Huawei said that the possibility of shifting users to 3.8GHz to 4.2GHz to clear the band should be carefully assessed, accounting for the potential social and economic benefits that 3.8GHz to 4.2GHz could have for 5G in the future.</p>	

Question 7: Do you have any quantitative evidence on the costs and benefits associated with the options? This includes costs for existing users and/or consumers of existing services associated with potential changes, and benefits to UK consumers in gaining access to mobile services in this band.

Stakeholder comments	Ofcom response
<p>Orange, Ericsson, Arqiva, IET, a confidential respondent, CONNECT and Telefonica highlighted the general value of mobile, and that this would likely increase for 5G.</p>	<p>Stakeholder responses indicate that there are likely to be very large benefits to be gained by making the band available for mobile, which we have taken into account in our assessment.</p>
<p>Telefonica noted an Analysys Mason report for the UK Government in 2012, which found that mobile services accounted for 58%, or £30.2 billion, of the total value of spectrum to the UK economy. They also cited a Capital Economics Research estimate that the roll out</p>	

<p>of 4G networks will provide a £75bn boost to the UK economy. Estimating the economic value of 5G services is difficult at this stage, but is likely to be very high.</p>	<p>However, it is difficult to make a full quantitative evaluation of these benefits as the evidence provided to us was often based on different methodologies and assumptions, and cannot be considered comparable.</p>
<p>CONNECT noted a 2016 study commissioned by the EU which studied the spectrum requirements needed to deliver future 5G services.⁸³</p>	
<p>Ericsson said that doubling the average speed of broadband can add 0.3 percentage points to GDP growth, so introducing faster speeds from 5G will have positive impact on GDP. Ericsson also said that future economic studies should take into account indirect benefits through connected products and services enabled by the internet of things.</p>	
<p>The IET estimated that 5G will be pivotal in sustaining a £28bn market for the next 10–15 years, even before accounting for any new services enhanced 5G networks will enable, based on the current annual value of UK mobile network at £15bn and fixed telecoms at £13bn per year.</p>	
<p>Telefonica and Orange stated that the benefits of mobile use would be higher than the benefits of any other user, or the cost of migration of current users, respectively.</p>	
<p>Ericsson cited a 2015 Plum Consulting report which estimated the benefit from avoided costs owing to early availability of 3.6-4.2GHz spectrum at EUR 1.4bn in 2018 NPV terms. However, Intelsat, ESOA and a confidential respondent said the Plum Consulting report was methodologically flawed.</p>	
<p>BT/EE stated that the difference in benefits between Options A and B is the difference in value for mobile of a national licence with, and a national licence without, exclusion zones. This may depend on factors such as location of earth stations, and the difference in cost of deployment for relevant areas between low power mobile and high power mobile.</p>	
<p>Vodafone argued that retaining current benchmark spectrum quality for all current users would reduce the value of the mobile spectrum, potentially to the point of having no value.</p>	
<p>Access Technologies said that spectrum sharing may enable co-investment and partnership models of network investment; vertical industries self-providing 4G/5G</p>	

⁸³ *Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe*, https://connectcentre.ie/wp-content/uploads/2016/10/EC-Study_5G-in-Europe.pdf

<p>infrastructure; shared multi-operator systems; and hybrid, flexible networks comprising a mix of mobile access, fixed access, and wireless backhaul and fronthaul.</p>	
<p>Orange argued the cost of migrating satellite earth station use from C-band to Ku-band would be fairly limited. The cost may be less than £500,000 for a large satellite dish.</p>	<p>Costs to existing services are discussed in section 7, see 7.50-7.53.</p>
<p>Arqiva listed a range of costs for geographical migration, including physically moving the earth station, securing planning permissions, ensuring service disruption is kept to a minimum, and increased connectivity and backhaul costs from moving to a more rural area. They also identified cost categories associated with a migration of services from the 3.6GHz to 3.8GHz band to the 3.8GHz to 4.2GHz band. These included the higher prices for satellite capacity that would arise from demand outstripping supply, filtering to minimise the effects of out of band emissions at the 3.8GHz band edge, and coordination and transaction costs associated with adapting to the new arrangements.</p>	
<p>We received confidential information about the increased costs that would be associated with certain mitigations that could be undertaken by satellite earth stations to overcome a higher interference level.</p>	
<p>ip.access estimated the economic value of making this spectrum available on a three-tiered basis could be above a billion pounds. There was likely to be benefit generated from using this band for geographical coverage too, assuming there would be tens of thousands of sites, and that these are five times more valuable than the vertical sites, leading to an economic value in the hundreds of millions</p>	<p>We have taken note of the potential benefits from alternative approaches but think it is unlikely that these approaches will deliver the same benefits as making the band available for mobile across the UK. However, we set out in 7.55 our view that the 3.8GHz to 4.2GHz band has potential for shared access.</p>
<p>Cambium Networks and a confidential respondent said there would be an opportunity cost if the band were made available to mobile and the benefits of FWA use were foregone.</p>	
<p>BT/EE argued there could be an impact on high value contracts for satellite operations at Madley, running to millions or even tens of millions of pounds per annum, thus removing a significant benefit that businesses, citizen-consumers, and Governments derive. Arqiva, techUK, BT/EE, ESOA, Intelsat and the UK Space Agency considered that the UK benefits economically from being a global hub of satellite communications, and we should recognise this in our policy. The UK Space Agency said that any evaluation must take into account the interest of UK industry and government, and not solely the benefits to UK citizens.</p>	<p>As set out in 5.51-5.54 we consider that under our proposed approach it should be possible for most of the benefits currently delivered using 3.6 to 3.8GHz band to continue to be delivered, see 7.49.</p>

	As we have set out previously, ⁸⁴ we can and do take account of wider UK public interests in our international representation work as we consider appropriate.
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Question 8: Do you have any other suggestions that would allow widespread 5G availability using the 3.6GHz to 3.8GHz band across the UK while allowing certainty for at least some existing users to continue to provide the benefits currently provided by use of the 3.6GHz to 3.8GHz band?

Stakeholder comments	Ofcom response
techUK said there may be a role for Ofcom to bring together central and local government, mobile operators, infrastructure providers, fibre providers and major landlords to address problems they identify with deploying urban cells such as planning issues and fibre availability.	Ofcom is willing to work with government, industry and other interested parties to consider whether more may be done to address potential challenges with urban cell deployment.
IET said that, for existing earth stations, there should be an emphasis on improving site shielding where feasible to reduce exclusion zones to the absolute minimum.	As set out in Section 8, we are minded to remove current authorisations for fixed links no longer take registered satellite earth stations with a receive component in the 3.6GHz to 3.8GHz band into account for frequency management purposes, after an appropriate period of notice. We also explain that if we award the band for future mobile services in the interim period before all notice periods have lapsed, we would consult on appropriate time-limited interim restrictions for new mobile licences, see 8.11.
Ordnance Survey more precise work on exclusion zones is required, not just for this band, but to enable improvements in all bands as part of a joined-up strategy.	

⁸⁴ *Space Spectrum*, Statement, January 2017, https://www.ofcom.org.uk/data/assets/pdf_file/0030/96735/Statement-Space-Spectrum.pdf, see paragraph 2.25

<p><i>Low power:</i> The UK Space Agency said that high power mobile is not suitable for sharing with satellite, and suggested that effort be put into developing 5G systems that can more easily shared with satellite earth stations such as low power or WiFi-like technologies.</p>	<p>As set out in 7.70, to only permit low power deployment using small cells would be likely to reduce the benefit to UK citizens and consumers.</p>
<p>A confidential respondent suggested allowing at least a portion of the spectrum to be accessible free of charge for neutral host small cells</p>	
<p><i>Funding:</i> Arqiva argued that incremental costs incurred as a result of a future migration should be met by public funding, in line with previous spectrum clearances where there is no benefit to existing users. Microsoft (regarding fixed links) and a confidential respondent said that if Option B were adopted then current users should be compensated.</p>	<p>See 8.14. Given that we will be proposing reasonable notice periods we do not currently see a case for funding being made available.</p>
<p>Ordnance Survey also supported the establishment of a spectrum efficiency fund.</p>	

Question 9: Do you have any comments in relation to these proposals?

Stakeholder comments	Ofcom response
<p>The IET suggested that Ofcom should think about what it can do after auctions to facilitate a re-ordering of the 3.4 – 3.8 GHz band so that there are wide contiguous blocks of spectrum.</p>	<p>We have set out our approach to the 3.4GHz to 3.6GHz spectrum auction in our 11 July Statement and accompanying documents. We will address our approach to awarding the 3.6GHz to 3.8GHz spectrum for mobile use when we consult on the award of the band.</p>
<p>A confidential respondent also said that it would like to know details of any guard band between mobile below 3.8 GHz and FSS above it.</p>	<p>As set out at paragraph 7.59, we will undertake further technical work to examine coexistence issues with operations in the 3.8GHz to 4.2GHz. We are not currently minded to introduce restrictions on future 3.6GHz to 3.8GHz mobile use which would materially constrain mobile operations using these frequencies to protect users of the 3.8GHz to 4.2GHz band. However, we will consider in due course whether there are appropriate restrictions which would provide a</p>

	degree of protection to 3.8GHz to 4.2GHz band users without materially affecting mobile deployments
The Ministry of Defence said that its use at Bude should be protected from interference.	We will work with the Ministry of Defence, to identify appropriate restrictions for future mobile licences to ensure that Defence capabilities are not unduly affected, see 9.13.
Ericsson advocated the use of long-duration spectrum licences so that licensees can justify investments in 5G deployment. They also said licences should be harmonised with global standards, and that network deployments would be faster and at lower cost if there are no country-specific requirements attached to the spectrum licences.	We will address our approach to awarding the spectrum for mobile use in future publications.
Telefonica expressed broader reservations about the asymmetry of mobile spectrum holdings, and the lack of a joined-up allocation and assignment policy in relation to the 3.4GHz to 3.8GHz band.	We consider asymmetries in spectrum holdings in Section 6 of our July 2017 Statement on the 2.3 and 3.4GHz auction. ⁸⁵

⁸⁵ *Award of the 2.3 and 3.4 GHz spectrum bands: Competition issues and Auction Regulations*, Statement, July 2017, https://www.ofcom.org.uk/data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf

Annex 7

Glossary

3GPP	The 3rd Generation Partnership Project (3GPP) is a body that develops standards for mobile technology
5G	5G is the term used to describe the next generation of wireless networks beyond 4G LTE mobile networks. 5G is expected to deliver faster data rates and better user experience. Technical standards are still under development and are likely to include both an evolution of existing and new radio technologies.
BT/EE	A UK mobile network operator
CEPT	The European Conference of Postal and Telecommunications Administrations
Communications Act	The Communications Act 2003
ECC	Electronic Communications Committee – One of the three business committees of the European conference of Postal and Telecommunications.
EU	European Union
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GHz	Gigahertz. A unit of frequency of one billion (10 ⁹) cycles per second
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.
LTE	Long Term Evolution. Part of the development of 4G mobile systems that started with 2G and 3G networks.
MHz	Megahertz. A unit of frequency of one million cycles per second.
MNO	Mobile Network Operator.
MTR	Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011
Ofcom	The Office of Communications
PES	A satellite Permanent Earth Station
ROES	Receive Only Earth Station. In satellite services, an earth station which does not transmit, but receives signal from a satellite.
RSA	Recognised Spectrum Access. RSA is a regulatory mechanism that provides formal recognition of receive-only radio stations by allowing Ofcom to take them into account when planning spectrum use and assigning frequencies to other radio users.
RSPG	Radio Spectrum Policy Group - European advisory body on spectrum issues.

TDD	Time Division Duplex – a technology that deals with traffic asymmetry where the uplink is separated from downlink by the allocation of different time slots in the same frequency band in unpaired spectrum.
TD-LTE	Time Division Long Term Evolution. Sometimes referred to as Long Term Evolution Time-Division Duplex.
WT Act	Wireless Telegraphy Act 2006
UK Broadband	A UK supplier of fixed wireless mobile services, now owned by H3G