Ofcom
making communications work
for everyone

Enabling wireless innovation through local licensing

Annexes 1 to 5 – Supporting information

STATEMENT:

Publication Date: 25 July 2019

Contents

Annex

A1. Summary of consultation responses

A1.1 This annex provides a summary of comments received from stakeholders in response to our consultation, published on 18 December 2018, along with our responses to these comments and/or a reference to where our response is contained in the main section of this document. A total of 69 responses were received to the consultation.

A1.2 Where stakeholders have made the same, or very similar, comments to multiple questions in their response we have included the comment only once under the question to which the comment has greatest relevance.

A1.3 Organisations that submitted responses are listed below:

Advanced Wireless Technology Group (AWTG)
Aviation Spectrum Resources, Inc. (ASRI)
BT
Cisco
Disruptive Analysis
Energy Networks Association
Facebook
FMS Solutions
Huawei
Intelsat
The Joint Radio Company (JRC)
Motorola
Nokia
Ruckus Wireless
Simon Pike
Telefónica
Three
Urban Connected Communities (UCC)
Westica Communications
Angetech Consultants
Avanti
The Civil Aviation Authority (CAA)
Dense Air
DTG
Ericsson
Fairspectrum
Google
IEEE LAN/MAN Standards Committee
ip.access
Kazalia
National Farmers' Union (NFU)
Nominet
SES
TalkTalk
Telet Research
UKWISPA & INCA
Vodafone
Arqiva
BBC
CBNL
Digital Colony Partners
Dynamic Spectrum Alliance
EMEA Satellite Operators' Association (ESOA)
Federated Wireless
Heathrow Airport
IET & 5G Further Faster (5GFF)
iWireless Solutions
Kent County Council
Neutral Wireless
The Radio Society of Great Britain (RSGB)
Shyam Telecom
techUK
Telint
University of Strathclyde
Western Power Distribution

A1.4 In addition, we received 14 responses from stakeholders who requested that their name, or their entire response, be kept confidential ([✂]).

Question 1 - Do you agree with our proposal for a single authorisation approach for new users to access the three shared access bands and that this will be coordinated by Ofcom and authorised through individual licensing on a per location, first come first served basis? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Most respondents agreed with our proposal. Some respondents who agreed with our approach commented that it was simple, fair and open for SMEs to access spectrum for a range of different uses. Others appreciated that the Ofcom-managed approach would mean records of users in the band would be kept accurate, and others thought that in the absence of immediate DSA what we proposed seemed like an effective approach. A small number of respondents expressly disagreed with our proposal.	Noted.
Telet Research argued that while we had identified the three shared access bands well, the approach we had outlined for assignment of licences seemed to be too simplistic and not sufficiently flexible, and the levying of an annual licence fee was onerous and inefficient both for Ofcom and for users.	Our aim is to make spectrum available for new users under a simple process and common approach that is easy to understand. We consider that our proposals will achieve this. On the potential burden to Ofcom, the approach we have outlined is similar to the authorisation process in other Ofcom-managed bands; we have considerable experience managing spectrum in this way and regularly keep the process under review as appropriate.
Telint also suggested our proposal for 3.8-4.2 GHz was flawed as we would not be able to cope with the volume of licence applications we could receive without using DSA.	We remain of the view that our approach offers the quickest way to make spectrum available to the users. We further discuss issues relating to DSA in Question 4 below.
Three disagreed with our proposed approach because they felt that our proposal for 3.8-4.2 GHz dilutes their own spectrum rights in this band	We disagree that our proposal dilutes Three's rights to access spectrum under the UK Broadband licence. We note that the existing terms of the

(under their UK Broadband spectrum holding). They cite the existing practice of prioritising UK Broadband deployments in this spectrum, as laid out in OfW 188,[1] and therefore argue that it is not correct for us to claim that existing users are not having their rights to access spectrum changed.	UK Broadband licence require it to share with other users, which it can be notified of by Ofcom from time to time.
Alternative authorisation approach for FWA in 3.8-4.2 GHz Huawei argued that demand for 3.8-4.2 GHz from sharing users is unproven and we should only make a portion of the band available for per-location shared access licences until demand has been sufficiently demonstrated. The rest of the band should be made available through national licences with per-location coordination, to support proven demand for FWA. Making the band available in this way would encourage investment, as users would have greater assurance that the required spectrum would be available everywhere.	Our proposals aim to enable innovation and ensure that access to spectrum is not a barrier to the development of wireless equipment and connectivity solutions. We consider that the 3.8-4.2 GHz band could meet demands for spectrum for localised private networks and note that compatible chipsets already exist, as discussed below. Current access to the 3.8-4.2 GHz band is on the basis of per-location coordination independent of whether the licence is a national or local licence. Therefore, we disagree that the shared access licence approach would cause greater uncertainty to an FWA operator than a national licence with similar per-location coordination. We consider that our approach would also have the added benefit that users would only pay for the number of locations they deploy, compared to a national licence fee.
Ruckus Wireless suggested that licensing approach for 5.8 GHz FWA would be suitable for medium power and that future DSA approach could account for building entry losses in the different rural and urban environments.	The existing authorisation in 5.8 GHz is based on uncoordinated access which would not be suitable in the 3.8-4.2 GHz band, given that existing users' access to the spectrum is based on coordinated managed access. Our current coordination methodology takes account of building entry losses and we will refine this as we gain experience.

[1] Ofcom, *OfW 188: Co-ordination of licensed services in the band 3605 to 3689 MHz paired with 3925 to 4009 MHz*, 28 January 2008, https://www.ofcom.org.uk/__data/assets/pdf_file/0027/85086/coordination_processes.pdf

<u>Availability of 3.8-4.2 GHz equipment</u> Dense Air, Digital Colony Partners, IET & 5GFF, iWireless Solutions, Nominet, Ruckus Wireless, Simon Pike, TalkTalk and one confidential respondent ([✂]) were doubtful that equipment in this band would be readily available. On the other hand, another confidential respondent ([✂]) said that equipment was available right now, while Nokia and Motorola both said it will develop quickly.	As discussed in more detail in Question 4 below, we remain of the view that regulatory clarity on access to the band will be the first step to enable the rapid development of a suitable equipment ecosystem. We further note that compatible chipsets are already available which support the entire 3.3-4.2 GHz band, and which cater to the different availability of spectrum in different countries.
<u>Sharing below 3.8 GHz</u> Cisco, Dense Air, Federated Wireless, Google, IET & 5GFF, Nominet, Simon Pike, TalkTalk, Telint, UKWISPA and the University of Strathclyde all suggested we enable shared access below 3.8 GHz (some referred to 3.4-3.8 GHz while others only suggested 3.6-3.8 GHz) in some form, either through DSA or through the proposal we have outlined for 3.8-4.2 GHz. Telint suggested that DCMS' Statement of Strategic Priorities, which was published after our consultation, obliged us to do this.[2]	We outlined in the December consultation on the auction of spectrum at 700 MHz and 3.6-3.8 GHz,[3] that we considered national licences were the most appropriate way to make these bands available, as they are particularly well-suited to mobile broadband use, for which we expect there to be national demand. We considered that awarding this spectrum in other ways would have a higher opportunity cost than awarding national licences by auction. Users wishing to access awarded mobile spectrum bands on a localised basis could do so under our Local Access Licence approach outlined in Section 4 if the deployment does not impact on MNOs' planned use. This approach would apply to the 700MHz and 3.6-3.8 GHz bands if we decide to award them. Our proposal to award these bands is currently the subject of a separate consultation. The decisions we have taken in this statement are aligned with, and in some places go beyond, a number of the objectives set out in the SSP.

[2] DCMS, *Statement of Strategic Priorities for telecommunications, the management of radio spectrum and postal services*, 15 February 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/779226/SSP_Consultation_-_Publication_Version__2_.pdf (accessed 11 July 2019)

[3] Ofcom, *Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands*, 18 December 2018, Annex 5 (https://www.ofcom.org.uk/consultations-and-statements/category-1/award-700mhz-3.6-3.8ghz-spectrum)

<u>Small available bandwidths in 1800 MHz and 2300 MHz shared spectrum</u> Dense Air, Digital Colony Partners, Google, IET & 5GFF, iWireless Solutions, Nominet, the University of Strathclyde and one confidential respondent ([✂]) suggested that the usefulness of making the 1800 MHz and 2300 MHz shared spectrum available was limited due to the small bandwidths of these bands. On the other hand, AWTG, Telet Research and Motorola suggested that NB-IoT devices would be well served by the 1800 MHz shared spectrum.	We consider that the 1800 MHz and 2300 MHz shared spectrum could be suitable for a number of applications, including for IoT devices and other users looking to deploy GSM or possibly LTE, for voice or text as well as low data rate applications. A number of stakeholders responded supporting this view. We also note that the 1800 MHz shared spectrum could be coupled with licence exempt LTE in the 5150-5925 MHz band (3GPP Band 46) to provide additional channels to support higher capacity applications.
Shyam Telecom suggested the longer-term goal should be to increase the bandwidth of the 1800 MHz shared spectrum to 2 x 5 MHz to accommodate 5G services.	This has been considered previously, and when we consulted on this no respondents to the consultation supported this proposal. There is no vacant adjacent spectrum that could be assigned to make 5 MHz channels. Creating the required additional bandwidth could only come from the spectrum currently assigned to mobile operators and it is felt that the time (i.e. notice period), resource and costs required to re-distribute the spectrum make this option impractical.
Federated Wireless suggested that the small bandwidths would deter manufacturers from developing new equipment.	We disagree, as the bands are already supported by an existing equipment ecosystem.
Westica Communications and Neutral Wireless argued that the proposals for the 1800 MHz and 2300 MHz shared spectrum do not adequately support NB-IoT devices as there is no option for the small channel sizes which would be used for this.	As indicated in Question 11 below, we do not propose to coordinate smaller channel sizes as we do not consider that there would be further spectrum efficiency gain arising from this. However, this does not prevent licensees from deploying smaller channels in these bands.

<u>Other users in 1800 MHz</u> A confidential respondent ([✂]) highlighted that the 1800 MHz shared spectrum does have an assignment for earth station operations (Earth-space) on a secondary basis, though they do not think this will cause a problem. Another confidential respondent ([✂]) also highlighted this, but suggested that the impact would not be severe outside a handful of local areas, where existing agreements are in place to avoid interference.	As outlined in paragraph 3.24 of the Statement, prospective licensees should be aware that deployments using the 1800 MHz shared spectrum operating near the sites outlined in footnote UK90A to the UK Frequency Allocation Table could be subject to interference from use of the band by earth stations used by MOD.[4] However, we consider that the risk of interference from these deployments to new users to be very low.
<u>2300 MHz shared spectrum</u> Cisco and the IEEE LAN/MAN Standards Committee argued that we should put our plans for the 2300 MHz shared spectrum on hold pending further study.	As outlined in Annex 2, we continue to be of the view that the possibility of interference from indoor low power use to adjacent users such as Wi-Fi will be very small.
The RSGB said that it fully supports the position stated by Ofcom in the consultation proposing no changes to incumbent users' existing and future rights to deploy. RSGB holds the view that amateur usage is unlikely to pose a threat to the potential commercial use cases described in the consultation document, although some commercial installations could disrupt amateur activities.	We will allow continued use of the 2300 MHz shared spectrum by the Radio Amateur Service. We believe that, due to the low numbers of amateur users in the band, the intermittent nature of their transmissions and careful operation by users, the band can be shared with limited risk. We note that current amateur use of the band is on the basis of not causing harmful interference to other users of the radio spectrum[5] and should this arise, the licence provides that we may vary the Amateur Radio licence to remove the 2390-2400 MHz band for reasons related to interference management (after first giving reasonable notice of three months).[6] We consider that the potential for interference from radio amateur use of the 2300 MHz shared spectrum is small, and that we have

[4] Ofcom, "UK Frequency Allocation Table (UKFAT)", http://static.ofcom.org.uk/static/spectrum/fat.html
[5] Information on licences that we issue will be available in the Spectrum Information Portal. https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal
[6] Clause 4(6) of the Amateur Radio Licence

	the necessary mechanisms in place to deal with interference should it arise.
Dense Air proposed a time-sharing coordination approach with MOD.	We are not considering a time-sharing coordination approach with the MOD at the current time.
Federated Wireless said that at least 20 MHz should be available and multiples of 20 MHz where geographic location suggests sharing with MOD. Dense Air suggested that the bandwidth of the 2300 MHz shared spectrum could be expanded for indoor deployment where isolation from airborne MOD systems is significantly increased.	We are not planning to make any further shared spectrum available in the 2300 MHz band at the current time. However, we continue to work with MOD to identify any additional spectrum that could be released in the future which might then be added to our sharing framework.
<u>Satellite earth stations in 3.8-4.2 GHz</u> Several satellite stakeholders, namely Avanti, BBC, BT, ESOA, Intelsat, Vodafone and two confidential respondents ([✂]) insisted on the importance of protecting existing users in the band. Some emphasised the satellite industry's need for regulatory certainty, citing various reasons including the importance of C-band for reach and resilience; the need to protect large sunk investments; and the fact that earth station operators generally have no choice over the frequencies they use.	As set out in paragraphs 3.11-3.12 of our December consultation and paragraph 3.15 of the Statement, existing and future PES/ROES will continue to be able to access the band under existing site by site coordination. We appreciate that regulatory certainty is important to enable earth station users to make investment decisions. However, we also note there are growing and competing demands on the spectrum used by earth stations from other services which can also deliver a range of benefits. We consider that spectrum sharing could allow a broader range of services to operate to support growth in both areas. Earth stations currently access the band on a first come first served basis and this will continue to be the case when new users access the band.
The BBC, ESOA, Intelsat, SES, Vodafone and two confidential respondents ([✂]) said that growth of the sector could be expected at existing earth station sites and particularly to accommodate migrated traffic from 3.6-3.8 GHz clearance. Avanti, BBC, ESOA, Intelsat, SES, Vodafone and one	We have not seen evidence to indicate any considerable growth by earth stations in this band. Our licence records show a reduction of earth station frequency assignments in this band over the last few years. Earth station users already share this band on a first come, first served basis

confidential respondent ([✂]) suggested that Ofcom should put in place measures (e.g. reservation of spectrum) to safeguard future growth. A confidential respondent ([✂]) doubted that satellite earth stations could remain commercially viable if Ofcom licensed other users in the 3.8-4.2 GHz band.	with fixed link users so the existing nature of access to this band means that accommodating future growth is not guaranteed. In October 2017, we confirmed our intention to stop taking into account registered earth station use in 3.6-3.8 GHz, with effect from June 2020.[7] We expect that those earth station operators wishing to migrate traffic into 3.8-4.2 GHz would already be firming up their plans and will now be in a much better position to apply for the relevant frequency assignments by varying their existing PES licences or grants of RSA.
Avanti, ESOA, Intelsat and two confidential respondents ([✂]) also suggested that the 3.8-4.2 GHz band could be valuable for future satellite use, including satellite 5G; the development of non-geostationary orbit satellite constellations; and potentially satellite broadband as part of the solution for universal broadband coverage in the UK.	Ofcom notes these comments. Our proposals for coordinated shared access in 3.8-4.2 GHz does not change the way in which Earth station users can continue to access the band on a first come, first served basis.
Some stakeholders (SES, [✂] and [✂]) said that allowing primary and secondary users in the same band on an equal basis is wrong, because secondary users should protect both existing and future use. Also, primary users should receive a greater level of protection from secondary services than from other primary services.	The primary or secondary status of services is defined in the ITU Radio Regulations, which governs the relationship between different radio users internationally. At a national level, countries have the sovereign right to plan spectrum use within their own territories, and we are not introducing a hierarchy in this band; all new applications will be dealt with equally, on a first come, first served basis.
Cisco suggested that satellite downlinks should be repacked or moved to a certain portion of the band. This will ensure that terrestrial use is removed spectrally from satellite receive stations and reduce the risk of interference.	Ofcom notes this comment. At this point in time, we believe that shared access to the whole 3.8-4.2 GHz band will lead to more efficient use of spectrum, especially where localised access by users is required. It is also important to note that unlike some other types of radio users, earth station operators apply for the specific frequencies they require in a given

[7] Ofcom, *Improving consumer access to mobile services at 3.6 GHz to 3.8 GHz: Statement*, 26 October 2017, https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz

	frequency band and Ofcom coordinates and licenses them as appropriate. Ofcom does not assign specific frequencies to satellite earth stations and therefore is not able to pack frequencies into certain portions of the band.
Question 2 - Are there other potential uses in the three shared access bands that we have not identified?	
Issue raised	**Ofcom response**
Temporary solutions [✂]. Telet Research also said there had been no mention of the sort of temporary mobile/nomadic use which could be used to cover a temporary event or an emergency incident. A confidential respondent ([✂]) said the current licence allocation and pricing does not cover short term events (of a few days or weeks) such as the Commonwealth Games.	We will allow short-term licences in the shared access bands, as discussed in more detail in paragraphs 3.169 and 3.204 of the Statement.
National mobile Ericsson and a confidential respondent ([✂]) suggested that a more valuable use of the 3.8-4-2 GHz band might be to assign it for national mobile services. Ericsson suggested we make 200-300 MHz of 3.8-4.2 GHz available for national mobile (ideally the bottom end of the band), and only make 100 MHz available for shared access until demand from new sharers for more spectrum than this is demonstrated. Telefónica wanted us to clear the 2300 MHz shared spectrum and make it available for national mobile use.	In the case of the 3.8-4.2 GHz band, existing users in the band will continue to need access to this spectrum, including some use which will have been transferred from the adjacent 3.6-3.8 GHz band. We outlined both in 2015[8] and 2017[9] that making the 3.6-4.2 GHz band available for national mobile services without withdrawing incumbent users' rights to access spectrum would not be possible without leaving large areas of the UK unserved, and this is one of the key reasons we have adopted a different approach in 3.6-3.8 GHz and 3.8-4.2 GHz. With regards to the 2300 MHz shared spectrum, our proposals for shared access licences aim

[8] Transfinite Systems, *Geographic Sharing in C-band: Final Report*, 31 May 2015, https://www.ofcom.org.uk/research-and-data/technology/radio-spectrum/c-band-sharing
[9] Ofcom, *Improving consumer access to mobile services at 3.6 to 3.8 GHz: Consultation*, 6 October 2016, https://www.ofcom.org.uk/__data/assets/pdf_file/0035/91997/3-6-3-8ghz-consultation.pdf

	to ensure that existing use of the band and adjacent band will continue to be able to operate without harmful interference.
Mobile coverage Motorola, Ruckus Wireless, Shyam Telecom and a confidential respondent ([✂]) suggested that 3.8-4.2 GHz could also be suitable for mobile coverage, and Fairspectrum suggested the shared access bands could be useful for mobile network *capacity* as well as just coverage.	Our objective in the 3.8-4.2 GHz band is to enable deployment of local private networks in various sectors including industrial networks and fixed wireless access in rural areas. We are proposing to make the 3.6-3.8 GHz band available for national mobile broadband.
Neutral Host Disruptive Analysis and one confidential respondent ([✂]) suggested that neutral host operators could be interested in the shared access bands. TalkTalk however suggested we should make some clear provisions for regulated neutral host interconnection to support this, and another confidential respondent ([✂]) said that there was more to be done before neutral host options would become an effective solution to the UK's connectivity problems.	We discuss this in Other under Question 3.
Other Disruptive Analysis suggested our proposed approach could enable "un-roaming", for example for international travellers or overseas companies with UK sites, as well as for business FWA.	Noted.
Nokia suggested that PMSE and e-health applications could be accommodated by our proposal.	Noted.
FMS Solutions said the 3.8-4.2 GHz band lends itself to wideband short-range radio systems that might adopt non-cellular technologies.	Noted.
Simon Pike said the provision of LTE within railway carriages as a compliment to Wi-Fi would be precluded as shared access licences are	Noted

limited to specific geographic areas, but could co-exist because of the high shielding of railway carriages. This application would use the 1800 MHz or 2300 MHz shared spectrum.	
The IET said the definition of the word "innovation" means that other potential uses that cannot be identified now will emerge. [✂].	Noted.
Question 3 - Do you have any other comments on our authorisation proposal for the three shared access bands?	
Issue raised	**Ofcom response**
Process of issuing licences BT, FMS Solutions and techUK said that it would be important for Ofcom to ensure licence applications could be processed quickly, to make sure applicants received access to spectrum quickly enough. BT also said that assignment timescales would need to be managed to meet their customer deployment requirements. Telint, Three and Vodafone all expressed concern about the potential risk of Ofcom being overwhelmed by a large volume of licence applications.	The WT Act sets out that Ofcom will process licence applications within six weeks for all licences set out in the UK Plan for Frequency Allocation[10] (unless international coordination is required),[11] in practice the majority of licence applications are dealt with much more quickly than this, where we have the necessary information to assess the application. Applicants can help us to ensure that their applications are dealt with promptly by ensuring they submit accurate, fully completed applications and that payment is made quickly on receipt of the invoice.

[10] Ofcom, "Spectrum information portal", https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal
[11] WT Act, Schedule 1, para. 2(1)(a): https://www.legislation.gov.uk/ukpga/2006/36/schedule/1

Economic benefits A confidential respondent ([✂]) argued we are being driven by the citizen-consumer agenda and are omitting the industrial or economic benefits. Along with Avanti, Intelsat and another confidential respondent ([✂]), they also said that the proposals would undermine the UK's influence in the global satellite sector.	In fulfilling our statutory duties to further the interests of citizens and consumers in relation to communications matters, Ofcom has considered the costs and benefits to the UK as a whole in making these policy decisions.
Hoarding 16 stakeholders raised concerns about the prospect of new users hoarding spectrum, especially considering the first come, first served licensing process we have outlined. Federated Wireless, FMS Solutions, Motorola, Vodafone and two confidential respondents ([✂]) suggested implementing a use-it-or-lose-it clause in the licence, or a cap on the amount of spectrum any single user can hold in a given location, or reducing the maximum licence period.	The use of a cap may restrict some use cases, particularly at the 40 MHz suggested by one respondent, which might reduce the benefits of shared access. We consider our pricing approach strikes the correct balance of reducing incentives to hoard without creating significant barriers to entry. As outlined in Section 3, we are adding licence conditions that require licensees to commence transmission within 6 months of obtaining a licence and remain operational thereafter. We expect this will further reduce the risk of hoarding.
Other The NFU indicated that farmers require fair recompense for providing site access, in order to fulfil the ambition of high quality mobile coverage being available in rural areas. Disputes with MNOs on site valuation/rights are disincentivising further MNO rollout.	Noted.
FMS Solutions commented that attempts to establish localised roaming arrangements with UK MNOs was very challenging as they are against national roaming, and outlined the ways in which it felt provision of additional localised coverage by third parties was a benefit to the MNOs and their customers, rather than a threat to the MNOs. It also described two additional barriers even if MNOs were minded to support third party roaming, namely call charges for consumers (i.e. if urban and rural	We note these comments and hope that our plans for both the Shared Access and Local Access licences open up new opportunities for this sort of collaboration between MNOs and local providers.

customers are to be charged the same, the third party provider makes money from transiting traffic onto the local network so the MNO has to pay) and interconnect testing. FMS solutions suggested the latter costs several hundred thousand pounds per MNO.	
Question 4 - *What is your view on the status of equipment availability that could support DSA and how should DSA be implemented?*	
Issue raised	**Ofcom response**
DSA approach Most respondents agreed with our aim to work towards DSA although there were varying views on the timing for this.	Noted and discussed below.
Two confidential respondents ([✂]) considered that DSA is an essential part of efficient spectrum sharing, particularly in the case of multi-tenancy buildings which may require control to achieve the best user experience. Another confidential respondent ([✂]) indicated the approach proposed could be described as coordinated database assisted use of spectrum.	We consider DSA as a concept whereby access to spectrum is only authorised when equipment is transmitting, and spectrum becomes available to others when it is no longer required by the previous users. This will facilitate flexible and efficient spectrum management. Specifically, when equipment is not transmitting, the frequencies would be available to other users.
Dense Air, Dynamic Spectrum Alliance, Facebook, Federated Wireless, Google, Neutral Wireless, Nominet and the University of Strathclyde would like a DSA approach to be adopted at the outset, given that database technology is available today. The BBC suggested we wait until DSA is implemented before opening up the band, to prevent any disincentive for users to move to DSA at a later date. BT agreed with transitioning to DSA as a long-term possibility. Vodafone considered that transitioning to fully automated DSA should balance costs and the need for licences to be issued promptly. Nokia said that DSA could be introduced at a later stage when the need arises to automate due to a high volume of applications. [✂]. Simon Pike recommended	Our priority is to make spectrum available for new users as quickly as possible, and we continue to believe this is best achieved through our proposed approach. We also agree that it is important to be clear that the current approach is an interim measure and to signal that we intend to consider a move towards a fully automated database approach in due course if this can add further benefits. In order to support any future transition and to achieve the most efficient use of the band, we consider it necessary to embed the DSA concept in our Shared Access licences from the outset. We outline this in paragraph 3.187 of the Statement.

caution with mandating DSA, given the present unclear demand in 3.8-4.2 GHz, and Angetech Consultants wondered whether complex systems would be required to automate our existing proposal.	
[✂]. Heathrow Airport indicated that the DSA concept, whilst useful, is not suitable for operational or safety critical use cases. Ericsson indicated that DSA is not suitable for industrial processes requiring guaranteed bandwidth and would make bilateral discussion with neighbour impossible. A confidential respondent ([✂]) suggested that DSA is not compatible with satellite use, and SES indicated that sensing will not be effective to protect weak signals received from space.	We also consider that the ability to perform bilateral discussions would not be affected by a transition to DSA, provided that any such agreement could be communicated to the spectrum assignment database. We will consider in the development of the specification for DSA equipment whether sensing is appropriate and could provide useful information on the interference environment.
<u>Bands to introduce DSA</u> BT suggested DSA should be confined to the three shared access bands.	We plan to assess whether it would be appropriate in the future to transition towards an automated spectrum assignment in the bands outlined under our spectrum sharing framework.
Dense Air, Dynamic Spectrum Alliance, Federated Wireless, Google, Nominet, Telet Research and Telint said we should prioritise 3.6-3.8 GHz (the University of Strathclyde and IET & 5GFF suggested 3.4-3.8 GHz) as this leverages the existing CBRS equipment ecosystem. Nominet and University of Strathclyde suggested we should also include 700 MHz. The Dynamic Spectrum Alliance, Federated Wireless, Google, IET & 5GFF and the University of Strathclyde considered that an automated dynamic assignment would be more efficient than the current manual approach proposed to access awarded mobile spectrum. Federated Wireless and Google suggested MNOs having priority rights would better incentivise sharing.	We are proposing to award national licences for the 700 MHz and 3.6-3.8 GHz band. Under our Local Access licence (see Section 4), new users will be able to access any frequency bands covered by the Mobile Trading Regulations where the incumbent licensee does not reasonably object. As new bands are added to the Mobile Trading Regulations, we will also include these in the list of frequency bands which could be covered by the licence. However, we would not expect access to these newly awarded bands to be possible straight away (and possibly not for some considerable time), as the licensees will need time to decide where they intend to use the frequencies themselves.

Federated Wireless suggested adopting a tiered access model similar to the CBRS, and to also consider opportunistic access in the lower portion of the 2300 MHz band used by the MOD. Telet Research proposed a similar approach to the General Authorised Access (GAA) tier of the US CBRS system, which does not require a licence.	In transitioning to a fully automated database approach in the shared access bands, our intention is to maintain the first come, first served approach for users already operating in the band. This is in line with our objective to provide spectrum certainty to support infrastructure investment. The lower portion of the 2300 MHz band is subject to our ongoing work with MOD to determine how much spectrum could be shared and how. We are aware of approaches adopted elsewhere such as CBRS and will take this into account when considering if and how more spectrum in the lower 2300 MHz band can be made available.
<u>Equipment supporting DSA</u> AWTG, Dynamic Spectrum Alliance, Fairspectrum, Neutral Wireless, Shyam Telecom and the University of Strathclyde noted that equipment already supports this approach. AWTG, Motorola and UCC indicated that additional modifications to enable communication between equipment and the database would be essentially software issues, which can be performed at higher network control layers. Fairspectrum, Simon Pike and the University of Strathclyde cautioned against specifying DSA functionality as part of the device regulation, as this could limit future adaptability, and AWTG indicated additional technical requirements such as sensing would be burdensome on equipment manufacturers. A confidential respondent ([✂]) noted the need for further cross vendor firmware development to support communication with the database. Motorola expects the 5G ecosystem in 3.3-4.2 GHz to develop rapidly and to become commercially available soon. Ruckus Wireless indicated its existing DSA-enabled base station could support DSA access in 3.4-3.8	Ofcom notes that there are different views on the availability of equipment in the 3.8-4.2 GHz band. We remain of the view that regulatory clarity on access to the band would be the first step to enable rapid development of a suitable equipment ecosystem. We noted that chipsets are already available to support the entire 3.3-4.2 GHz band, catering to different spectrum availability in different countries. Moreover, given we are embedding DSA concept in the licence, equipment should have the ability to tune across the entire 3.8-4.2 GHz band. We also noted different views on additional equipment capability to support automated communication with the spectrum assignment database. We consider that such a specification is best developed together with industry to ensure it is proportionate while still achieving our aim to ensure the efficient use of spectrum. Therefore, we would like to engage with interested parties to assist us in defining an appropriate regulatory framework that specifies the appropriate interface between DSA equipment and our spectrum assignment database.

GHz but will a new generation of equipment will be needed to support DSA in the 3.8-4.2 GHz band. Both Ruckus Wireless and the IET & 5GFF expected it would take 5 years for a suitable equipment ecosystem to develop in the 3.8-4.2 GHz band. Ericsson and Vodafone indicated that DSA will increase costs for equipment. A confidential respondent ([✂]) considered we are a few years away from commercial off the shelf equipment that would be appropriate for 5G innovation. techUK and Huawei noted Ofcom already implement database assisted approach in some situations, such as PMSE licensing, and did not consider additional functionality would be required in the radio equipment to support this.	
<u>Support industry group</u> DTG, Digital Colony Partners, Fairspectrum, Google, SES and three confidential respondents ([✂]) welcomed the opportunity to participate in an industry group, with DTG suggesting this could be facilitated by the DTG's Spectrum Access Forum.	Noted.
<u>Implementation of database</u> ip.access indicated issues in having multiple database providers in CRBS and suggested Ofcom being the sole database provider would alleviate this. Similarly, Nominet suggested an open competitive tender for a single database provider.	Noted.
Federated Wireless and a confidential respondent ([✂]) suggested Ofcom should allow third parties to coordinate access to the shared access bands with Ofcom defining the overall rules of access. Facebook indicated that they supported an industry-led DSA solution.	Noted.

Question 5 - Do you agree with our proposal for the low power and medium power licence? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Many stakeholders expressed agreement with our low/medium power licence proposal. No respondents specifically opposed our approach of issuing both low and medium power licences, though some suggested the implementation of DSA would remove the need for this distinction.	Noted.
<u>Low power proposal</u> AWTG and JRC argued that a circle with radius 50 metre was too small and that this would limit the possible deployment scenarios. Heathrow Airport suggested that while it will be possible to licence large sites using a large number of low power licence areas, this will not be very efficient and Motorola suggested we made larger area options available for the low power licence product.	We consider the proposal we have laid out strikes the right balance between something which is easy for applicants and which will suit the needs of a wide range of users. We don't think that adding different options for different-sized areas will make a big difference to users, but this could make the licensing process more complex and therefore could increase Ofcom's costs, and as a result increase the cost of the new licence. Although larger sites may need to apply for multiple licences, we do not expect that the effort needed to do this to be any greater than what would be required for the radio planning that licensees would need to undertake anyway. We would also clarify that the 50 metre-radius of the licence area does not limit the deployment to this area alone; it authorises all base stations within the 50 metre-radius circle, giving users the flexibility to place or move their base stations within this area, but allows terminals connected to authorised base stations to move outside the area. We discuss this in more detail paragraphss 3.44 to 3.51 of the Statement.
Nokia suggested we consider increasing the size of the low power licence area for outdoor deployments due to the further propagation of an	Having considered these suggestions, we've concluded that we should continue with our proposal. Changing to square areas for the low power

outdoor installation. Google argued that we should use a shape that can be tessellated without any gaps, instead of a 50 metre-radius circle which would always have either gaps or areas of overlap. It suggested using a 100m x 100m square. Ericsson suggested allowing users to define the shape of the area to be served, and defining radio conditions on the border of this area to prevent interference.	licence would make our licensing and coordination process more complex, which could in turn drive up the cost of the licence product. For example, we would need to define the orientation of the square, and decide how to coordinate for base stations that could be as little as 50 metre away from the centre point of the area (in the middle of the square's sides), or as much as ~70 metre (at the corners). This same problem, of increased complexity and therefore increased associated costs, also exists for the bespoke area licensing approach suggested by Ericsson. We also note that defining radio conditions on the border of the area to be served could restrict licensees' ability to deploy close to the edge of the area in order to meet the radio conditions.
Both Ericsson and Disruptive Analysis questioned if the 50 metre-radius licence area would have a third dimension, as this could be relevant to multi-storey buildings or any application with a height-specific element.	Outdoor antenna systems deployed under the low power shared access licence are limited to 10 metre above ground. For an indoor deployment, such as in a multi-storey building, the area licence would permit deployment in the entire building as long as this is within 50 metre horizontal distance from the requested location.
Google suggested that there should be an indoor-only licence option, as this would have a shorter reuse distance and encourage greater spectral efficiency.	Users can apply for an indoor-only licence and will need to ensure that all base stations and fixed/installed terminals are deployed indoor. It will be a breach of licence conditions if an indoor licence is used for outdoor deployment.
<u>Medium power proposal</u> Huawei wanted to know if fixed terminals in the 1800 MHz shared access band would be licence exempt like mobile terminals. It also asked for clarification on how terminal stations will or won't be coordinated for, and clarification on whether nomadic terminal stations were authorised under the licence or licence exempt.	The licence authorises all the terminals connected to the licenced base stations, both fixed/installed and mobile/nomadic. Additionally, mobile/nomadic terminals connected to licenced base stations in the 1800 MHz and 2300 MHz shared spectrum are also licence exempt.

	We do not coordinate terminals because we assume a base station with an omnidirectional antenna pattern, which also accounts for terminal interference.
The JRC said that our proposal was not suitable for energy sector use, and would like 50 x 50km areas for WAN for this sector instead.	Our proposal is intended to facilitate localised use of spectrum in locations where this does not impact on existing users in the band. Users looking for wide area deployment should consider alternative spectrum options.
<u>Mobile terminals for 3.8-4.2 GHz medium power</u> Motorola and Simon Pike both suggested that there could be interest from industry, particularly larger sites such as ports, railyards and larger factories, in using mobile terminals with medium power base stations in 3.8-4.2 GHz. On the other hand, Vodafone insisted it would be problematic for incumbents if medium power users in 3.8-4.2 GHz were allowed to use mobile terminals.	To enable users to deploy in a way which meets their needs, we have decided to allow mobile terminals at medium power in the 3.8-4.2 GHz band, provided that these terminals are confined only to the user's site. We are not permitting this band to be used to provide national mobile broadband, where we are proposing to make available national licences in the 3.6-3.8 GHz band for that purpose. For mobile terminals deployed in the 3.8-4.2 GHz band for both the low and medium power licences, licensees will be required to keep an accurate record of the mobile terminals and the address of the site or building they are limited to operate within.
Dense Air, Simon Pike and a confidential respondent ([✂]) all raised the idea of using 3.8-4.2 GHz on transport corridors but argued that the fixed terminal restriction for medium power makes this impossible. Simon Pike also suggested that our proposal as outlined did not make allowances for deploying LTE in rail carriages, which could be done using the 1800 MHz and 2300 MHz shared spectrum, on a neutral host basis to complement on-train Wi-Fi.	Users aiming to use the Shared Access licence to provide connectivity along transport corridors would need to carefully consider whether this is the most appropriate spectrum solution, given that there is no guarantee that spectrum will be available along the entire route. We do not currently have any plans to make blanket exceptions to our proposed licensing approach to allow for a different method of authorisation on transport routes. We believe there are other spectrum options which are more suitable for this purpose.

Question 6 - Are there potential uses that may not be enabled by our proposals? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Responses to this question included issues around transport corridors, terminal power limits for FWA, FWA in urban areas and exceptions to the rural restriction for medium power in 3.8-4.2 GHz.	We have addressed the points raised in response to this in Question 5.
The Energy Networks Association, JRC and Western Power Distribution indicated that the spectrum offered does not support needs of the energy sector, which required regional or national access with wide area and high power deployments.	Our proposal is designed to ensure that as many users as possible could benefit from access to spectrum on a localised basis. We recognise given the nature of shared access, this may not be suited for applications requiring regional/national access.
Question 7 - Do you agree with our proposal to limit the locations in which medium power licences are available? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
A number of stakeholders broadly agreed with our proposal to limit the medium power licence to rural areas only, however roughly the same number disagreed with this proposal or expressed reservations about it.	Noted.
<u>Principle of the restriction</u> Arqiva and the BBC said it didn't make sense to restrict medium power users to rural areas because this is where earth stations tended to be located, in part to ensure interference-free access to spectrum. Motorola said that medium power should be allowed anywhere if it doesn't cause harmful interference, and Nokia did not think that allowing medium power in urban areas would materially restrict other deployments. Google would like us to aim to allow medium power across the whole of the UK eventually. A confidential respondent ([✂]) also	In proposing the medium power urban restriction, we consider that if we allow medium power users to deploy in urban areas, with their higher power and increased range, this would risk low power users suffering from limited or no availability of spectrum. All uses will be coordinated to ensure that interference is not caused to/suffer from other uses. We also want to strike the right balance between securing optimal use of spectrum and encouraging new uses. If applicants wish to deploy in

suggested we should study what the effects would be of allowing medium power in urban areas.	urban, but believe their use is still consistent with our policy objectives, they can approach Ofcom for us to consider their individual case.
Huawei suggested making most of the 3.8-4.2 GHz band available through national licences with per-location coordination and no urban restriction, and only allocating a portion of the band to localised Shared Access licences.	As outlined in our responses to issues raised under Question 1 above, we do not believe that making spectrum in this band available under national licences with per-location coordination would be a viable solution for smaller users, who may not be able to afford a national licence.
<u>Definition of the restricted areas</u> UKWISPA & INCA suggested that Ofcom has set the classification of "urban" areas too low, and this will exclude FWA in a range of locations which would reasonably be considered to be rural. Simon Pike also doubted whether sufficient demand for the band would extend to the rural areas as defined in our consultation.	We have reconsidered the dividing line we use to differentiate between "urban" and "rural" areas and now consider settlements of 10,000 population or more to be an urban area, based on rural-urban classification systems used by the ONS, Scottish Government and Northern Ireland Statistics and Research Agency. See paragraphs 3.59 to 3.63 of the Statement for more details.
Simon Pike suggested that the irregular shape of ONS Census Output Areas could lead to some bizarre exceptions.	In line with our approach of considering applications for medium power base stations in urban areas on a case-by-case basis, as outlined in paragraph 3.62, we would encourage users with problems of this nature to discuss their licence application with us.
<u>Uses which could be prevented due to this restriction</u> Disruptive Analysis, Ericsson, Fairspectrum and Ruckus Wireless suggested that larger industrial sites such as large factories, ports and railyards, which could be in urban areas, may be interested in deploying using medium power as the increased power would, for example, allow them greater range. AWTG also suggested some IoT applications might be prevented from deploying due to the rural restriction for medium power. Heathrow Airport said it was concerned by this restriction and wanted to better understand the exceptions we might make.	As explained in paragraph 3.62, we may consider exceptions to allow medium power in urban areas (subject to passing coordination). For example, the applicant may need to demonstrate that the higher power limit is crucial to the proper functioning of their deployment and that this could not be accomplished by the low power licence.

Dense Air and a confidential respondent ([✂]) questioned how this restriction could interact with providing connectivity along transport corridors.	Users aiming to use the shared access licence for transport corridors would need to carefully consider whether this is the most appropriate spectrum solution, given that there is no guarantee that spectrum will be available along the entire route.
Ericsson, Huawei, ip.access and Three suggested that there was a market for urban and suburban FWA, and that what we proposed would not permit urban FWA.	Our proposals have been developed to enable the rollout of solutions which could provide better options for rural connectivity. Consumers in urban areas are more likely than those in rural areas to have alternative solutions available to them.
Question 8 - Do you have other comments on our proposed new licence for the three shared access bands?	
Issue raised	**Ofcom response**
<u>Eligibility to apply for licence</u> Ericsson and two confidential respondents ([✂]) questioned who would be eligible for a Shared Access licence, and asked if it would only be service providers getting the licences or if landlords of properties could also do this. Telet Research suggested we should differentiate between use cases where public access is permitted, i.e. a Multi-Operator Neutral Host model (MONeH), as opposed to private access only. In scenarios where there is demand from both MONeH and private use cases, public MONeH should be prioritised.	At present we have no plans to provide priority access to the spectrum for any user, nor to impose restrictions on who can apply. All applicants will be dealt with on a first come, first served basis.

Provision of information Google suggested that Shared Access licensees across both the low and medium power products should be required to disclose what frequencies they use, in order to enable opportunistic access.	Frequencies of licences granted by Ofcom are made public through the Wireless Telegraphy Act Register[12] and Ofcom's Spectrum Information Portal.[13]
Regular review of proposals Shyam Telecom suggested we review our proposals on a regular basis, such as every four years. Vodafone also suggested regularly reviewing the licence conditions, and techUK suggested that we regularly review the fees to ensure they were set at an appropriate level not to deter new users.	We regularly review our policies, and we take action or make changes as we deem appropriate.
Other A confidential respondent ([✂]) suggested a "per small licence area" approach, rather than Ofcom's proposal for per base station coordination, which they argued would make transition to DSA difficult.	There is no specific proposal on the detail of area-based coordination. Ofcom's coordination proposal for the low power area licence is based on using a proxy base station to represent the coverage area that could be served by base stations located anywhere within the area.
Telint suggested that public health concerns relating to wireless transmission could disrupt the deployment of new innovative services, and that Ofcom should provide guidance to deal with consumers' concerns in this area.	Ofcom regulates the operation of mobile networks in relation to their use of radio frequencies, but does not have any duties in relation to exposure to emissions from electromagnetic fields (EMF emissions). These duties rest with other public bodies. For example, Public Health England (PHE) is responsible for advising the UK Government on EMF exposure. A summary of PHE advice on radio waves can be accessed on the PHE website.[14] PHE's view is that no negative effects on public health are anticipated with 5G and that the higher frequencies being considered for

[12] http://static.ofcom.org.uk/static/radiolicensing/html/register/WTR.csv
[13] Ofcom, "Spectrum information portal", https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal
[14] Public Health England, "Electromagnetic fields", published 9 July 2013, https://www.gov.uk/government/collections/electromagnetic-fields#radio-waves (accessed 11 July 2019)

	5G use (e.g. mmWave frequencies) are already covered by current exposure guidelines. PHE's main advice about radio waves from base stations is that the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) should be adopted for limiting exposures.[15] The ICNIRP guidelines apply to frequencies up to 300 GHz and cover exposures arising from new 5G base stations as well as from older technologies. Mobile operators are required to ensure their mobile phone base stations comply with the ICNIRP guidelines. These guidelines already apply to all radio equipment including frequencies that will be used for 5G.
Question 9 - Do you agree that our standard approach to non-technical licence conditions is appropriate? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Overall most respondents did not have any comments on the proposed non-technical licence conditions. The comments that were received are set out below.	Discussed below.
<u>Licence duration</u> The Energy Networks Association, JRC and Western Power Distribution were concerned that the licences Ofcom is proposing to offer would have a duration of only three years.	This is incorrect; the three-year licence term refers to the Local Access licence, for which this is the normal maximum licence duration. The Shared Access licence will be issued for an indefinite duration, subject to continuous use of the licensed deployment and the payment of annual licence fees.

[15] Guidelines for limiting EMF exposure that will provide protection against known adverse health effects are published by ICNIRP, which is formally recognised by the World Health Organization (WHO). The current set of guidelines is available at the following link: https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf

Nominet and two confidential respondents ([✂]) suggested that Ofcom provide the option for shorter duration licences. This was argued as being necessary in order to support national and other temporary events where the spectrum may be needed for a short period of time.	We agree and will allow licences for shorter durations. These licences will follow our standard short-term licensing process. Licensees will be charged a pro-rota fee[16] subject to a minimum fee of £32 per licence.
Avanti, ESOA and Intelsat all stated that the licences should be time-limited similar to the proposed three-year Local Access licences. They argued that the satellite industry needs long-term regulatory certainty. Google also proposed that the licences should not be for an indefinite duration and instead proposed to have either a five- or ten-year licence which can be renewed for the same term.	Local Access licences are issued for a time-limited period as the spectrum usage rights have already been granted for the UK. In the shared access bands, licences are granted on a first come, first served basis. Users are able to deploy as long as their licensed deployment remains operational and upon payment of an annual licence fee.
<u>Trading</u> Advance Wireless Technology Group, Fairspectrum and Motorola proposed that trading should be allowed in the three bands. Motorola supported the idea as it would allow the transfer of licences, and concurrent transfer to multiple parties, as well as possibly transferring a 3.8-4.2 GHz licence in blocks of 10 MHz. Ericsson suggested that licence rights should not be transferable, sub-licensing disallowed and that spectrum should go only to those who can deploy.	We will permit total trades, either outright or concurrent. This will help facilitate the transfer of assets when a business is taken over and ensure that access to the spectrum will continue. Additionally, concurrent trading would provide a mechanism to allow several users at the same location to jointly hold a licence. However, we will not permit partial trading of frequencies as the licence does not provide any ongoing spectrum usage rights if users are no longer operational. This will ensure that licensees only request the amount of spectrum they require as no commercial benefits would be gained from selling off the excess spectrum.
<u>Revocation period</u> Energy Networks Association, Heathrow Airport and a confidential respondent ([✂]) all advised that a five-year notice to revoke was too	We set out our approach to revocation period in paragraph 3.206 of the Statement.

[16] This represents one-twelfth of the prescribed sum multiplied by the number of complete and part-complete months.

short, particularly for certain use cases that require secure, long-term access to spectrum. ip.access and Ericsson agreed with the five-year revocation period. Fairspectrum suggested that a one-year notice period should be included for adapting to DSA. Vodafone suggested including use-it-or-lose-it provisions in the licence and that consequently, revocation should be on a shorter term than five years. Similarly, Cisco suggested a five-year revocation period is excessive for licensees who have not deployed.	
<u>Information provision</u> [✂]. Dense Air suggested the requirement to provide information to Ofcom could necessitate the registration of thousands of small cells.	Information collected under Ofcom's powers is subject to provisions on disclosure set out in statute. The provisions set out in paragraph 3 schedule 1 of the licences are intended to allow Ofcom to request information regarding the use of the spectrum by the licensee. We would expect that licensees would be keeping records of their deployed equipment. We set this out in paragraphs 3.210-3.213 of the Statement.
<u>Geographical extent</u> Fairspectrum requested that the proposals be extended to consider off-shore use on oil rigs and marine vessels.	Any equipment installed on board a UK-registered vessel would be covered by a Ship licence. For off-shore use, outside the 12nm limit, Ofcom already has a licence product set up that allows access to a number of mobile frequency bands.[17] The shared access bands will be added to the list of available frequencies on this licence.

[17] This is the Spectrum Access Offshore Mobile licence, which you can find out more about here: https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences

Simon Pike highlighted that Ofcom had advised that the Shared Access licence would also be available in the UK's territorial seas, but the data defining rural and urban areas applies to the UK landmass only.	We can confirm that we will consider any area not covered by the rural-urban classifications outlined in paragraph 3.60 of the Statement but included within the UK's territorial sea limit to be a rural area. More information on this limit can be found through the UK Government website.[18]
Other [✂].	As DfT is a Crown Body, it does not legally require authorisation from Ofcom. However, to do this would require agreement that the most efficient use of this spectrum would be for rail use. Ofcom has already provided Government with advice on rail connectivity and as part of that work considered the 3.8-4.2 GHz band.[19] In our assessment we noted that it would conflict with this policy of enabling sharing by new fixed and mobile applications in this band. We also indicated that there may also be significant lengths of rail track in the approaches to London and in a number of other areas where use for rail connectivity (which might operate at relatively high powers) would be restricted to protect satellite earth stations, meaning that this band could not support a single solution across the whole rail network. We have also provided advice on other bands which may be more suitable.
JRC was concerned about our statement that "licences issued by Ofcom are not exclusive". It asked what could happen to the spectrum in other bands for which JRC pays a premium fee to secure exclusive access.	As we have stated, licences issued by Ofcom do not grant exclusive rights over the frequencies covered by the licenses. Ofcom, as the authorising body, reserves the right to grant licences in any frequency. In doing so, Ofcom will take into account the needs of any incumbent operator and

[18] UK Hydrographic Office, "UK, UK Overseas Territories and UK Crown Dependencies Maritime Limits and Law of the Sea", updated 10 July 2019, https://www.gov.uk/guidance/uk-maritime-limits-and-law-of-the-sea (accessed 11 July 2019)

[19] Ofcom, *Advice to Government on improving rail passenger access to data services*, August 2018, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/123657/Rail-connectivity-advice-DCMS.pdf

	ensure that any new authorisation does not cause undue interference to existing users. This means that in some cases use may in practice be exclusive, but exclusivity is not a right conferred by the licence.
Question 10 - Are you aware of any issues regarding numbering resources and Mobile Network Codes raised by our proposals which we have not considered here?	
Issue raised	**Ofcom response**
13 respondents provided comments on numbering resources and Mobile Network Codes (MNCs): Angetech Consultants, Dense Air, Digital Colony Partners, Disruptive Analysis, Ericsson, Motorola, Nokia, Ruckus Wireless, Shyam Telecom, Telet Research, Urban Connected Communities, Vodafone and one confidential respondent ([✂]). Responses to the consultation confirmed that forecasting likely demand for mobile numbers and MNCs remained difficult, with some respondents agreeing it should be manageable, while others identified potential use cases that could result in a significant increase. The remainder of the respondents either did not believe that there were any issues and provided no further comment, or did not answer this question.	See below.
<u>Potential demand for numbering resources</u> Dense Air strongly believed that Neutral Host small cells should not require additional numbering resources. Instead they should use the numbers allocated to retail service providers to ensure transparency to end users. Dense Air also believed that MNCs should be reused across different geographic domains and industry sectors. Existing allocations would therefore be appropriate for service providers utilising the proposed shared spectrum.	We agree with these comments that models exist that provide for the effective use of current resources. We will continue to encourage efficient use of existing mobile numbers and MNCs and work with providers to find alternative solutions. We agree that MNCs should be used across different industries and geographic locations wherever possible.

[✂]. Vodafone did not foresee an issue with demand for numbering and MNC resources, as both could be obtained from existing mobile network operator stocks. However, if Vodafone's expectations were incorrect and a core-core interconnect model does develop, then Ofcom would be faced with a difficult situation to meet demand given the limited available resource.	
Digital Colony Partners argued that a vital part of supporting shared spectrum access and collaboration with the wider mobile market successfully was to secure an MNC from Ofcom.	We note the comments from Digital Colony Partners that allocation of an MNC is vital to support shared spectrum access and collaboration with the wider mobile market successfully. While this might not be necessary in all cases we acknowledge the role of MNCs in identifying public networks. We welcome the comments received on potential use cases for MNCs. These are useful in Ofcom's ongoing work to ensure we can support opportunities for innovation with appropriate access to numbering resource. We will monitor demand closely and plan to look in more depth at the examples provided in responses to understand scenarios were demand is likely to arise.
Disruptive Analysis considered that some potential use cases (e.g. for enterprise private communications, blending private mobile and voice/unified communications as a service (UCaaS) propositions) could require substantial numbering resources for the largest employers. In particular, MNCs could be requested by a significant number of new providers, especially if automation was involved, with potential for some very innovative models for multinational businesses or software companies.	With reference to private networks, our policy is not to allocate an exclusive MNC (see below for comment on shared MNCs). MNCs are used in accordance with ITU-T Recommendation E.212, which provides the international identification plan for public networks and subscriptions (Rec. E.212).[20] According to Annex B of Rec. E.212, MNCs are to be assigned to applicants and used by assignees for public networks offering public telecommunication services. Although Rec. E.212 provides for MNCs to be assigned to other applicants (e.g. for GSM-R networks), such

[20] ITU, "Recommendation E.212 (2016) Amendment 1 (07/18)", https://www.itu.int/rec/T-REC-E.212-201807-I!Amd1/en (accessed 11 July 2019)

	assignments are to be made according to procedure and criteria established by the national numbering plan administrator. In the UK, our procedure does not include allocation of an MNC for private networks. In accordance with Rec. E.212, as part of the application process, we request that the applicant complies with interworking requirements among public networks.
Angetech Consultants thought that Ofcom could receive applications from many possible operators such as landlords, mall and stadium owners. However, it questioned the validity of allocating an MNC to an operator of perhaps one/a group of base stations at a fixed location. Motorola anticipated potential growth in private and localised licensees wanting to operate their own MNCs. [✂].	In terms of allocation of MNCs for use in local public networks, we are mindful of the statement in Rec E.212 that the assignment of MNCs to small geographic areas within a country is not recommended because it is not an efficient or effective use of the MNC resource.
<u>Potential demand for other resources</u> In addition to phone numbers and MNCs, Angetech Consultants also expressed concern about the administration of other resources, including Base Station Identity Codes (BSIC), Cell ID (CI), National and International Signalling Point Codes (NSPC and ISPC) and Issuer Identifier Numbers (IIN). It recognised that some resources are managed by the regulator, while others can be operator managed.	In response to Angetech Consultants' comments on the administration of other resources, Ofcom does not plan to change the way that these are managed. We allocate NSPCs and ISPCs to communications providers meeting the eligibility criteria. We also administer the IINs in collaboration with the ITU. We are not aware of any issues regarding the management of these resources.
Nokia also noted that additional identifiers might be needed for managing deployment of private LTE networks.	We welcome stakeholder suggestions for how Ofcom might manage significant increased demand for numbering resources, should that situation arise. As explained in the consultation document, mobile numbers and MNCs are a valuable and limited resource.

Managing demand: Requirement for an agreement with an MNO Digital Colony Partners considered that access to numbering resources could be managed by making it a requirement for an agreement be in place with an incumbent mobile operator to collaborate on deploying new network or to have short-term plans to deploy owned infrastructure and improve coverage.	In answer to Digital Colony Partners' comment that an agreement with an MNO should be in place to be eligible for number allocation, we confirm that we have established certain eligibility criteria that a provider must satisfy if it wants to apply for the direct allocation of numbers from Ofcom. Elements of the criteria are specific to number types and are designed to demonstrate an operational need for the numbers. For mobile numbers, amongst other things, we request evidence of the network being provided (or intended to be provided/accessed within six months of the application). For those providers without a network, the relevant documentation that we request might include an interconnection agreement, hosting agreement or MVNE/MVNO agreement.
Managing demand: Allocation of smaller number blocks Angetech Consultants and Motorola suggested allocating smaller blocks of numbers. Angetech Consultants argued that the standard block size of 100,000 numbers was a significant undertaking and that it might be sensible to consider allocation of smaller blocks of 10,000 or even 1,000 numbers. Motorola suggested blocks of 5,000 or 10,000 numbers for private mobile systems, with the 100,000-number block remaining applicable for commercially operating MNOs and MVNOs.	In terms of block size, numbers are allocated to providers in large blocks of 100,000 numbers. An isolated exception has been made in the Isle of Man to accommodate the availability of 07624 Mobile Numbers across providers offering services on the island. However, this exception aside, Ofcom's discussions with MNOs have concluded that allocation of mobile numbers in blocks smaller than the standard 100,000 numbers creates problems for routing of calls, particularly when roaming, and for respecting the Mobile Global Title. This is acknowledged in Vodafone's response and is an international issue. Given the significant impacts likely to arise from allocation of mobile numbers in smaller blocks, Ofcom does not have plans currently to make changes to the standard block size for allocation.

Managing demand: Increase the supply of MNCs Motorola suggested that Ofcom might consider requesting an additional Mobile Country Code (MCC) from the International Telecommunication Union (ITU).	The ITU allocates MCCs to countries. The UK has two MCCs (234 and 235). We have allocated 60 MNCs from our stock of 200. We need to ensure best use of this limited resource. In terms of applying for an additional MCC from the ITU as suggested by Motorola, Annex C of Rec. E.212 states that a national numbering plan administrator may apply to the ITU for a subsequent MCC when an existing MCC is approaching exhaustion. Exhaustion is defined as having less than 20% of the MNC resource available within an MCC. An additional assignment would be based on confirmation that the existing resource is being used in an efficient and effective manner. The UK currently has 70% of its MNC resource available and is not therefore approaching exhaustion.
Motorola and Shyam Telecom suggested that one solution to managing demand might be to expand MNCs from two to three digits. However, Vodafone acknowledged that there was no easy mechanism to extend the supply of MNCs.	Motorola and Shyam Telecom suggested expanding the digit length of MNCs. According to Rec. E.212, an MNC under a geographic MCC is two or three digits in length and the length of the MNC is a national matter. A two-digit configuration provides 100 MNCs (00-99) while a three-digit configuration provides for 1000 MNCs (000-999). Most countries, including the UK, have opted for a two-digit MNC configuration for historical reasons. Managing demand and maximising MNC resource has become an issue for many countries. This was looked at in ECC Report 212 on Evolution in the use of E.212 Mobile Network Codes published in April 2014.[21] In the Report, the ECC looked at the possibility of mixing two- and three-digit MNCs in the same geographic MCC and migrating from two- to three-digit

[21] CEPT ECC, *ECC Report 212*, 9 April 2014, https://www.ecodocdb.dk/download/8b9d79d3-ab26/ECCREP212.PDF (accessed 11 July 2019)

	MNCs. However, these options did not appear to be straightforward and operators may have to modify IMSI numbering analyses and translation tables in their network elements to recognise three-digit MNCs. Nevertheless, these options for increasing the stock of MNCs may benefit from further study, as well as analysis of any measures undertaken by other regulators or bodies on moving from two- to three-digit MNCs.
<u>Managing demand: Making MNCs available for shared use</u> Urban Connected Communities suggested that Ofcom could make one/a few shared MNCs available for use by new entrants with private networks. Nokia and Ruckus Wireless referred Ofcom to solutions employed in the USA to support large numbers of private LTE networks in the CBRS shared spectrum band. Nokia noted that the CBRS Alliance worked with ATIS IMSI Oversight Council (IOC) to reserve a shared Home Network Identity (HNI) for CBRS networks. Ruckus suggested that we investigate whether any of the principles applied in the USA might also apply in the UK. Shyam Telecom referred to the initiative taken in Sweden to allocate a few "open" MNCs to support innovation and microbusiness, as well as making MNCs available for emergency purposes, testing and demos.	Some respondents referred to different methods of sharing MNCs between multiple users. Sharing the resource between providers is a valuable means of making efficient use of the limited supply of MNCs. We plan to study the different methods of sharing MNCs from the UK's MCCs, for instance the potential dedication of an MNC for shared use, with networks identified via the leading digits of the Mobile Subscription Identification Number (MSIN) and dedicating an MNC for private network use without application to Ofcom. We will look to international examples of such measures to inform our study, including those in USA and Sweden as highlighted in the consultation responses.

Managing demand: Use of shared ITU-T E.212 mobile country code (MCC) 999 Ericsson referred to the shared MCC 999 made available by the ITU for internal use within a private network. MNCs under this MCC are not subject to assignment and therefore may not be globally unique. No interaction with the ITU (or Ofcom) is required to use an MNC under this MCC as the code only has significance within the private network. Ericsson mentioned that specification of solutions for MCC 999 was ongoing in 3GPP and suggested that Ofcom regulations support its use for private networks, in accordance with ITU-T Recommendation E.212 Appendix III. Nokia also referred to the shared MCC 999. However, Nokia raised concerns that due to no guarantee of uniqueness, there may be issues if devices using an MNC from MCC 999 roamed or moved into the coverage area of other networks using the same HNI. It noted that cellular networks must broadcast an HNI consisting of a MCC and MNC in order to be identified. This is traditionally managed on a per-country basis and limited to those with exclusive use licensed spectrum for providing public networks.	We will continue to promote awareness of the ITU's MNCs that are available for global or private network use. For networks and services to be provided in more than one country (excluding mobile roaming services), applicants are encouraged to apply to the ITU for the assignment of an MNC under a shared MCC. For internal use within a private network, we will encourage the use of an MNC from the MCC 999, as referred to in the Ericsson and Nokia responses.
Question 11 - Do you agree with the proposed technical licence conditions for the three shared access bands? Please give reasons supported by evidence for your views	
Issue raised	**Ofcom response**
General comments Cisco called for the final adoption of the approach for 3.8-4.2 GHz to be as technology neutral as possible. It said that the technical rules in the consultation are quite 3GPP-centric, regarding channel widths, frame structure, synchronous behaviour etc, and these may exclude certain	We have decided to remove the requirement for a specific frame structure from our technical licence conditions in the 3.8-4.2 GHz band. We consider that this is likely to address some of the concerns raised by

technologies or future evolutions of technologies. It suggested that, at a minimum, alternative technologies should be allowed provided they do not cause harmful interference to geographically adjacent licensees.	Cisco. We discuss specific comments on authorised channel bandwidths and synchronisation later in this Annex.
Avanti, ESOA and Intelsat did not agree with the conclusions we had drawn from the ECC Decision regarding licence conditions for the three shared access bands. With regard to the 3.8-4.2 GHz band, they noted that the protocols for accessing shared spectrum mentioned in Ofcom's spectrum sharing framework would not apply to terrestrial services wishing to operate in bands used by the satellite service, and that it would not be practical for other devices to detect a signal from a GSO satellite or to determine where it is being received.	We do not require that equipment deployed by new users should have the capability to detect satellite signals. Ofcom will perform the coordination calculations for all the new services, maintaining existing protection criteria of satellite earth stations in the band.
Telint agreed with our proposals subject to health concerns being addressed and RF screening considerations.	We respond to this point under Question 8.
For the 1800 MHz shared spectrum, Nokia encouraged Ofcom to align our regulatory framework to the future ECC Decision (06)13, if required.	Ofcom has been actively involved with work on this ECC Decision. We note that the current version refers to harmonised standards that have not yet been published and it is therefore not possible at this stage to fully assess the impact of aligning our technical conditions for the 1800 MHz shared spectrum with this decision. We will continue to engage with this work and consider at a future date whether amendments to the technical licence conditions are necessary and/or appropriate.

General comments on EIRP limits AWTG questioned the disparity between the powers of the two types of new licence class. They said that more justification should be given as to why these values were chosen but did not suggest alternative values. Huawei and Dense Air also asked us to clarify the rationale behind the proposed limits.	We respond to this point as part of our response to specific comments on the low and medium power licence EIRPs below.
BT suggested that, as the term carrier is not defined, it should be clarified further with "carrier per antenna" to cover the case of multiple antennas for one carrier.	We note BT's comment. In our technical licence conditions, the maximum mean power in band is specified as spectral density (dBm/MHz) per sector, irrespective of the number of transmit antennas. This means that antennas having overlapping beams towards a specific direction should not, in aggregate, exceed the specified max spectral density levels in that direction.
ip.access asked whether, given the TDD nature of band 40 and 3.8-4.2 GHz, the power levels are defined as peak values or averaged over the TDD frame (assuming all sub-frames are carrying full buffer traffic).	We define power levels as maximum mean power, measured as EIRP (or TRP) irrespective of the number of antennas. Here we define EIRP as the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain), measured during the "on" part of the transmission.
Simon Pike suggested the definition of maximum mean EIRP density could be simplified to "Pmax - X"	We agree with this change and have reflected this in the final version of the EIRP limit tables in Table 3.5–3.7 of our statement.
EIRP for low power base stations Dense Air and Google said that the proposed limit of 24 dBm for low power base stations was too low. Dense Air said that enterprise grade indoor base stations are capable of higher powers and suggested setting a	Our proposal for 24 dBm EIRP for low power base stations was based on the rated output power limit at the antenna connector for a Local Area Base Station, as defined in 3GPP, TS 38.104.[22] This, combined with an

[22] 3GPP, *TS 38.104 V15.5.0: Technical specification Group Radio Access Network; NR; Base Station radio transmission and reception*, https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3202 (accessed 11 July 2019)

limit of 4W EIRP (i.e. 36 dBm). Google said that this power limit is almost 8 times less powerful than the lowest-power 3.5 GHz CBRS device, and 16 times less powerful than 2.4 GHz Wi-Fi. It added that the base station is only 1dB more powerful than the mobile, even though it will typically transmit several times as many resource blocks. Huawei said that the proposed in-block EIRP limit for the low power licence would restrict coverage of their low power pico-cell base stations for channel bandwidths of 40 MHz or lower. Motorola said it would prefer to see maximum EIRP levels increased to 30 dBm/10 MHz (per sector) for low power systems.	assumption that base stations use an omnidirectional antenna with 0 dBi gain, provides an EIRP of 24 dBm per carrier for carriers ≤ 20 MHz. Our proposed low power limit was designed to enable access to spectrum for as many users as possible. In addition, we note that the proposal for a 50 metre-radius authorisation area means that new sharers will be able to use as many base stations as they feel are necessary to provide coverage for their services, subject to managing interference in their networks.
BT said that, for the 1800 MHz shared spectrum, licences have an in-block power limit expressed as 0 dBm/kHz EIRP. The new proposed low power base stations are expressed as 24 dBm per carrier per sector. BT suggested that for wide carriers, such as LTE, this substantially reduces permitted power compared to the 35 dBm under the existing licence.	Whilst we acknowledge that our proposal means that operation above 24 dBm can only be deployed in rural areas under the medium power licence, we note that there are no existing deployments operating above this power.
EIRP for medium power base stations Motorola said it would prefer to see maximum EIRP levels increased to 43 dBm/10 MHz (per sector) for medium power systems (slightly higher than our proposal). UKWISPA & INCA and Google said that there are circumstances where the EIRP for the base station will need to be higher than 42 dBm (e.g. in certain remote rural locations or for rural broadband coverage).	The EIRP value of 42 dBm for medium power base stations aligns with the existing DECT guard band licences (30 dBm/200kHz or 42 dBm/3.3MHz). We consider that the proposed power level is also appropriate for the provision of rural broadband in 3.8-4.2 GHz, noting that in the 5.8 GHz band, the regulatory limit for FWA services is 36 dBm,[23] which is lower than our medium power proposal.

[23] Ofcom, *Improving access to 5.8 GHz spectrum for broadband fixed wireless access*, 27 November 2017, https://www.ofcom.org.uk/consultations-and-statements/category-2/improving-access-5.8-ghz-broadband-fixed-wireless-access

Huawei said that the proposed in-block EIRP limit for the medium power licence would restrict the coverage of their medium power micro-cell base stations for channel bandwidths of 40 MHz or lower. They said that the proposed EIRP limit is lower than the 53dBm/MHz specified for UKB and is not suitable for efficient deployment of FWA in the 3.8-4.2 GHz band.	UKB has a national licence that allows it to transmit with an EIRP of 53dBm/MHz in 84 MHz of spectrum in the 3925-4009 MHz band.[24] This licence was issued at a time when there was a different market environment. We believe that the proposed EIRP for medium power base stations in the 3.8-4.2 GHz shared band is sufficient to provide FWA services in rural areas and we have not seen any technical evidence in consultation responses to suggest otherwise. We note that the band is still open for fixed link point-to-point applications with 50 dBW maximum EIRP.[25]
ip.access said that, for small numbers of terminals, the EIRP limits for medium power base stations would lead to an unbalanced link. They asked if it was Ofcom's intention to rule out point-to-point links as a potential application for this spectrum.	Our EIRP proposal for medium power base stations is designed to enable last mile point-to-multipoint applications. New users that wish to deploy fixed point-to-point links can continue to apply for a fixed link licence in the 3.8-4.2 GHz band where the EIRP limit is 50 dBW.
EIRP for terminals Several respondents disagreed with limiting fixed terminal station EIRP to 23 dBm. Google said that the US FCC is working to authorize 3.5 GHz CPE that can transmit at 47 dBm back to the 47 dBm base station, as those are the power levels that the rural operators have determined are needed for effective service. It said that 23 dBm EIRP is likely not sufficient as a CPE power level. Kazalia noted that, in the 5.8 GHz band, both base and terminal stations are permitted to operate up to 36 dBm EIRP. They challenged our argument for limiting the power of terminal stations on a number of	We note that the revised EC Decision on the technical conditions in the 3.4-3.8 GHz band specifies a maximum terminal power of 28 dBm TRP. We have therefore decided to increase the maximum power for mobile terminals associated with both the low and medium power licences in the 3.8-4.2 GHz band from 25 dBm to 28 dBm TRP to align with the EC Decision. This also aligns with the limit for Class 2 equipment for band n77 in 3GPP standard TS 38.101. For fixed/installed terminal stations we agree that it would be beneficial, particularly for rural broadband scenarios, to allow the use of higher gain

[24] Spectrum Access 3.6 GHz licence granted to UK Broadband Limited, 25 June 2019, https://www.ofcom.org.uk/__data/assets/pdf_file/0019/83800/SA-3.6-GHz-LICENCE-UK-Broadband-0823615.pdf

[25] Ofcom, *OfW 446: Technical Frequency Assignment Criteria for Fixed Point-to-Point Radio Services with Digital Modulation*, July 2018, https://www.ofcom.org.uk/__data/assets/pdf_file/0017/92204/ofw446.pdf

grounds (limited number of fixed links licensed in the UK, relative geometries of terminal stations, base stations and fixed links, terminal station antenna height, unlikely to be a shortage of spectrum in rural areas). UKWISPA said that the proposed 23 dBm EIRP limit was an extremely low power for terminal devices used in FWA applications. It noted that 36 dBm EIRP is allowed in the 5.8 GHz band and said this was demonstrably necessary. It suggested that a condition could be included whereby terminals pointing at the base station (within a defined azimuth) could transmit at a higher power. Motorola recommended a higher power class be allowed for fixed customer premises equipment, utilising high gain, highly directional antennas. ip.access also said that the proposed EIRP limits for medium power fixed access applications were too low in the uplink. They said that the SINR at the terminal receiver would be roughly 19 dB higher than at the base station meaning that the system would be uplink limited, and at 23 dBm EIRP, its useful range would be constrained.	directional antennas pointing towards medium power base stations. We will therefore set both an EIRP and TRP limit for fixed/installed terminals: a maximum EIRP of 35 dBm / 5 MHz and a maximum TRP of 28 dBm. This should enable use of higher gain directional antennas for the medium power licence while aligning with the limits set in the EC Decision. For terminal stations in the 1800 MHz and 2300 MHz shared spectrum we confirm that the maximum permitted powers will be 23 dBm and 25 dBm, respectively. This is a TRP limit for mobile or nomadic terminals and an EIRP limit for fixed or installed terminals.
<u>Authorised bandwidth in the 1800 MHz band</u> Telet Research proposed the allocation of narrow channel licences (which could be 200 kHz channels), rather than issuing one single paired 3.3 MHz channel.	We continue to consider that authorising 3.3 MHz channels is more consistent with a technology neutral approach than an approach based on 200 kHz channel bandwidths. Our proposed approach will still allow applicants to utilise 200 kHz channels if they wish to do so and will also simplify applications for new sharer networks which require multiple channels. We note that applicants for 200 kHz channels may still be able to share spectrum with other narrowband users in the same area by applying for a concurrent trade.

Authorised bandwidth in the 2390-2400 MHz band Simon Pike suggested that this band should be configured as 2 x 5 MHz channels rather than a single 10 MHz channel, to allow more than one user in any given location. Telet Research thought that both 5 and 10 MHz bandwidths could be used, noting that it may be better configured as 2 x 5 MHz LTE-TDD channels in scenarios where multiple users require access to spectrum. Digital Colony Partners and Federated Wireless called for Ofcom to enable access to more spectrum around 2300 MHz, e.g. by enabling opportunistic access to MOD spectrum.	We accept that the use of 5 MHz instead of 10 MHz channel bandwidths would allow more than one user in any given location. However, as with the 1800 MHz shared spectrum, we need to make a trade-off. Smaller channel bandwidths potentially allow a greater number of users in an area but can make it more difficult to obtain access to wider bandwidths (e.g. because a licensee using a narrower bandwidth is already operating in the area). On the other hand, larger channel bandwidths still allow users of smaller bandwidths to gain access to spectrum, and concurrent trading allows this spectrum to be shared with other users. We also note that, in general, we are seeing a move towards greater demand for larger bandwidths as licensees look to increase speed and data throughput and use spectrum for a wider variety of applications. This is reflected in the calls from some respondents for access to more spectrum around 2300 MHz (although we note that we do not have agreement from MOD to enable opportunistic access to more spectrum at this point in time).
Authorised bandwidth in the 3.8-4.2 GHz band AWTG said that it was unnecessary to limit bandwidth in the 3.8-4.2 GHz band to 100 MHz, noting that upcoming (e.g. 5G) communication systems will use channel bandwidths of 200 MHz or more.	Our proposal to offer different size bandwidths up to 100 MHz is in line with the 3GPP standard for Base Station transmission and reception (for New Radio operating band n77).[26] Applicants requiring higher bandwidth may wish to consider the 26 GHz band (see Section 5) which we are also making available for indoor shared access.

[26] 3GPP, *TS 38.104 V15.5.0: Technical specification Group Radio Access Network; NR; Base Station radio transmission and reception*, https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3202 (accessed 11 July 2019)

Antenna height Heathrow Airport hoped that it would be possible for Ofcom to consider deployment of low power base stations with higher antenna heights on a case by case basis. Shyam Telecom, commenting on the 10m antenna height limitation for the 1800 MHz and 2300 MHz shared spectrum, noted that rural IoT applications might need higher antenna heights. Motorola supported our proposal not to restrict the height limit for medium power base stations and indoor equipment, but said it would prefer to see the outdoor low power base station antenna height limit raised to 15m above ground level, noting that signals at these high frequencies (in the 3.8-4.2 GHz band) are greatly attenuated by terrain and clutter features.	Our proposal was designed to ensure that we could accommodate as many uses as possible. Increasing outdoor antenna height has the effect of increasing the interference range which may limit others' ability to deploy. We consider that our proposed outdoor antenna height limit is appropriate for a low power licence and represents typical small cell deployment. However, we note that certain deployments in rural areas may be precluded by the 10m antenna height in the 1800 MHz and 2300 MHz shared spectrum. We may consider exceptions to this on a case by case basis taking into account sterilisation of spectrum for other users. We note that there is no antenna height restriction for medium power licences in the 3.8-4.2 GHz band.
SES on the other hand were concerned that the lack of a maximum specified height for the FWA stations could contribute to significant deployment constraints for new satellite services.	We note that the absence of a maximum antenna height limit is consistent with the approach that is already in place for fixed links in the 3.8-4.2 GHz band. While increased use of the band will inevitably result in some risk of additional constraints for new deployments, including satellite earth stations, we need to balance this risk against the risk of unnecessarily constraining the flexibility of new spectrum users. In addition we note that we have not seen evidence to indicate any considerable growth by earth stations in this band. Our licence records show a reduction of earth station frequency assignments in this band over the last few years.
Synchronisation requirements in the 2300 MHz spectrum and 3.8-4.2 GHz band A number of mobile equipment manufacturers agreed with our proposed frame structure requirements while suggesting that additional flexibility could be allowed in some cases. Other respondents disagreed with the	For the 2390-2400 MHz band, we have decided to proceed with the proposed approach we consulted on. We provide more detail on this in paragraphs 3.96-3.100 of our statement.

proposals saying that these were not technology neutral or would preclude certain technologies. Huawei said that it was essential for outdoor deployments in 3.8-4.2 GHz to be synchronised with each other, and with services below 3.8 GHz, in order to avoid base-to-base and terminal-to-terminal interference. It suggested that unsynchronised use could be allowed for indoor deployments if these applied radio engineering measures to mitigate interference to outdoor deployments. Nokia and a confidential respondent ([✂]) suggested that additional flexibility could be introduced in line with the suggestions in ECC Report 296. Nokia noted that the business models of verticals could be different from those of commercial networks and might result in different UL/DL ratios. The University of Strathclyde highlighted that there are some specific use-cases, particularly in rural communities, where higher uplink speeds are required and noted that this is often achieved by using more UL sub-frames. It suggested that consideration be given as to how to permit such usage where it is not detrimental to other users. Motorola supported frame alignment of TDD technologies but said frame structure restrictions were unnecessary, noting that other means (such as sub-frame conflict aware scheduling) were available to alleviate interference issues. Cisco said that the proposed technical rules, including the proposed frame structure, were quite 3GPP centric and that this may exclude certain technologies or future evolutions of technology. Kazalia said that a range of different technology platforms may be suited to offer cost effective fixed wireless access in rural areas, not just LTE based solutions and said there was non-LTE equipment from at least two	For the 3.8-4.2 GHz band, we recognise that our proposed frame structure may not be optimal for some future uses, including those that require low latency. Several respondents said that the proposed frame structure A and alternative frame structure B might not be optimal for all services. No alternative frame structures were put to us as part of the consultation process, although we recognise that there may not be a single preferred solution. After careful consideration and taking into account our policy objective to enable opportunities for innovation, including use of the spectrum for 5G technologies, we have decided not to mandate synchronisation in the 3.8-4.2 GHz band. We provide further details on this decision in paragraphs 3.101-3.111 of our statement.

wireless vendors already on the market that covered this frequency band and that could be used for such deployments. A number of respondents thought that the frame structure proposals would preclude, or be incompatible with, certain technologies: • AWTG said that very-narrow bandwidth applications such as sensor networks, and perhaps "smart-X" and some forms of IoT would be less compatible with the proposed technical conditions, including the frame structure requirement; • Motorola said that TDD frame configuration flexibility was especially important for certain use cases that may need higher uplink capability, such as in systems deploying remote video links (e.g. as used in remote robotics and security applications); • Dense Air said that using a legacy 4G frame structure would preclude 5G New Radio technologies; • Simon Pike said that many potential applications of 5G require low latency but that the frame structure proposal was incompatible with this. He suggested there should be no restriction on frame structure in part of the 3.8-4.2 GHz band, e.g. the upper 100 MHz; • UKWISPA & INCA thought that the 3:1 frame structure would be unduly limiting and unnecessary in the case of long range FWA. It thought that FWA would normally be well separated from mobile users, and that it was unclear that it was necessary to specify the TDD cycle to be used. Dense Air suggested that spectrum holders should work together to agree the best frame structure for 4G and 5G and said this should not be a matter for Ofcom to mandate.	

Heathrow Airport hoped that it would be possible for the licensee to select the appropriate frame structure in order to optimise the uplink/downlink data rate split according to business requirements.	
Simon Pike said if Ofcom wishes networks to be synchronised, it may need to define an absolute time reference that all networks must synchronise to, for example based on UTC.	UTC should be used as the common reference time to enable new users to synchronise with Telefónica's network in the 2350-2390 MHz band. A new frame should start at the start of the UTC 1 second boundary.
Shyam Telecom said synchronisation requirements should be stated in more technical detail (e.g. +1.5ms).	We are not licensing a specific synchronisation timing accuracy but note that we do require that a suitable accuracy is chosen to avoid undue interference. Further information on a suitable accuracy will be provided in a future update to the guidance document (published alongside this statement) to help new users to synchronise with Telefónica's deployments.
Ericsson thought it was unnecessary to mandate 1ms timeslot length for NR. It said the 1ms should only apply to subframe duration in the LTE configuration. Ericsson asked for confirmation that we do not mandate specific timeslots for NR.	We note the comments from Ericsson. As indicated above, we have decided not to mandate synchronisation in the 3.8-4.2 GHz band.
Ericsson said synchronisation should be expressed as low/high rather than up/down to allow UL slots to be used for DL if using low power. It proposed those limits should be set at the border of the licence area, giving industries even higher flexibility from the choice of adding shielding.	Due to our methodology for co-ordinating base stations, we have decided to keep our current definition of uplink and downlink, and not move to change the definitions to low and high power.
<u>Sharing with Wi-Fi above 2400 MHz</u> BT, Cisco and DTG raised concerns about possible interference to Wi-Fi. BT said there was the potential of interference to Wi-Fi hubs from 2300 MHz shared spectrum mobile handsets. They referred to a CEPT study that suggests interference effects are 15 dB greater in the absence	As set out in Annex 2, we continue to consider that the probability of interference to Wi-Fi and other Short Range Devices (Zigbee, Bluetooth etc.) in the adjacent band remains low and we are not minded to commission any further measurement studies at this time. The 2390-2400

of a guard band and recommended that we commission further measurements. Cisco urged Ofcom to put its plan to open 2390-2400 MHz to mobile use on hold, pending further study. It noted three reasons for doing so: i) the studies cited in our consultation did not consider new Wi-Fi technology coming to market, such as Wi-Fi 6 (802.11ax) which it said uses broader channels, makes greater use of multi user MIMO, and has signals that travel farther than previous generations; ii) probability of interference to channel 1 (2412 MHz) - it said that a 24 dBm base station located indoors could substantially degrade Wi-Fi operations on Channel 1 at up to 3m; iii) Ofcom cannot rely on non-existent user standards. It also pointed out that Listen Before Talk (LBT) is predominantly for managing transmissions with other LBT devices, not for other types of system.	MHz band is intended for communications networks with a limited geographic footprint, rather than for the provision of national mobile networks. We consider that, unless a combination of factors occurs simultaneously (weak Wi-Fi signal, inadequate filtering, mobile handsets operate with full power and close to the Wi-Fi receiver) then the probability of interference is low. We also consider that the introduction of new Wi-Fi technology should improve the ability to share with adjacent users, rather than making sharing more difficult. Although standards for licence exempt receivers may not be finalised, we would not expect wideband Wi-Fi receivers to have selectivity performance that increases their vulnerability to services in adjacent bands. Finally, we note that the use of multi user MIMO should allow greater flexibility in shaping antenna sidelobes, cancelling signal reception from the direction of a potential interferer.
<u>Sharing with ALDs above 2400 MHz</u> DTG noted that previous studies showed that 2.3 GHz LTE operating at 2390-2400 MHz could cause interference to ALDs operating in 2.4 GHz but that this wasn't an issue at the time as this spectrum was not used for LTE. It said that this could now become an issue for ALD users if licences are awarded in the 2390-2400 MHz band.	As noted above, we continue to consider that the probability of interference to Short Range Devices in the adjacent band remains low. The 2390-2400 MHz band is intended for communications networks with a limited geographic footprint, rather than for the provision of national mobile networks. We discussed additional measures we are planning to take in paragraphs 3.144 to 3.146 of the statement.
<u>Sharing with mobile services below 2300 MHz shared spectrum</u> [✂].	Our proposed technical conditions require new users in the 2390-2400 MHz band to synchronise with users below the band to ensure that both services can coexist.

Question 12 - Are there other uses that these bands could enable which could not be facilitated by the proposed technical licence conditions? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Approximately 19 respondents provided comments on other uses of the bands that they considered were not facilitated by our proposed technical licence conditions.	We have addressed most comments on other uses of the bands in our responses under Questions 2 and 6. Comments which are relevant to the decisions on technical licence conditions are covered under question 11.
A confidential respondent ([✂]) asked whether our proposals cater for a neutral host type architecture where an active DAS system is used to provide coverage in an underground station or tunnel. A number of low or medium power base stations would be connected via fibre to high power remote units typically broadcasting 43 dBm composite power (needed for transmission over a radiating cable).	The maximum power we allow for medium power base stations is 42 dBm and generally in rural areas only. Please refer to paragraph 3.246 of the statement and the guidance we have published which sets out the approach Ofcom generally expects to take.
Question 13 - Do you agree with our proposed coordination parameters and methodology? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
<u>General comments on coordination parameters</u> Google noted that Ofcom proposed simplifying assumptions, such as proxy base stations, that may not reflect actual conditions. It asked whether parties (either new entrants or incumbent users) would have an opportunity to challenge the interference assumptions as either too conservative or insufficiently protective for their particular case.	Our coordination assumptions aim to strike a balance between reflecting typical uses and preventing the coordination process from being too onerous, which could delay licence processing. We consider that an approach where we change interference assumptions to cater for individual cases would result in the coordination process becoming overly onerous, complex and time consuming. We will review our coordination assumptions as we gain more experience of demand and the patterns of use.

The BBC and BT asked for more clarity on the existing coordination assumptions, criteria and methodology. The BBC agreed with our proposal to maintain existing defined protection criteria for earth stations and expects that technical licence conditions for new users maintains the levels afforded by RSAs. The BBC noted that we said current assumptions would be maintained for existing earth stations with respect to propagation losses, but pointed out that these assumptions were not referenced in the Consultation.	The existing coordination process assesses coexistence between the new service and co-channel and adjacent channel fixed links, satellite earth stations and UK Broadband deployments. To model propagation, our coordination tool uses ITU-R P.452-10 with clutter for different percentages of time depending on the interfering and the victim service. The interference criterion is I/N and the levels depend on the victim service. A summary of the coordination criteria, including the criteria for protecting incumbent users, is presented in Annex 4.
SES noted that the Mobile Service is a secondary service in the 3.8-4.2 GHz band while FSS is a primary service and said this should be reflected in the protection criteria used during any modified coordination process.	We note SES's comment. As highlighted above, new satellite earth station applications will be coordinated using the same criteria as are used for existing earth stations. However, we note that the primary and secondary service distinctions, as defined in the ITU Radio Regulations, are relevant to interference disputes between countries, but not ordinarily between users within the UK. As such, these distinctions do not constrain national spectrum management decisions.
Nokia said that more dynamic scenarios should be allowed in the medium term and that the tools to cope with those scenarios should be decided after adaptation to each considered frequency band.	We address this point in Question 4.
<u>Propagation model and losses</u> Google said that clutter, such as buildings and foliage, is a particularly critical factor. It argued that some standard propagation models, including those that incorporate clutter loss on a statistical basis such as ITU-R P.452, can underpredict losses on shorter paths by tens of dB. It said Ofcom should encourage industry to develop refined propagation models that utilise the best available clutter data, and such models should be used for all spectrum sharing scenarios. Simon Pike said ITU-R P.452 should be treated carefully as it is intended for distances measured in	We continue to believe that our implementation of ITU-R P.452 is an appropriate model as it accounts for terrain and clutter losses along the propagation path. ITU-R P.452 will be used for all coordination scenarios, so the separation distances may vary from a few hundred meters to tens of km, distances which are in line with the range specified in the model's scope.

kilometres. He added that Ofcom should consider using other techniques such as a planning tool for mobile networks and should use the most recent version of ITU Recommendations (P.452-16, dated 2015). Motorola supported the use of a propagation model with 50 metre terrain resolution and suggested that actual antenna heights should be utilised wherever possible.	Regarding the use of antenna heights, for coordination purposes we note that we will use the actual antenna heights for medium power and low power outdoors services, and for medium power indoor services.
The IET & 5GFF said the better the RF screening a building has, the greater the flexibility Ofcom should permit. Motorola generally agreed with our approach but suggested a higher median building penetration loss of 15dB (especially above 2.3 GHz).	Our proposal for 12dB wall loss was derived from Recommendation ITU-R P.2109 under the assumption of a 70/30 ratio of traditional/energy efficient buildings, which we consider represents an average building entry loss.[27]
Antenna parameters Huawei suggested that we should account for directional antennas and real antenna heights in the coordination process. The CAA said that limits needed to be placed on the antenna pattern. AWTG said that emissions modelling, especially at frequencies such as 3 GHz and above, should consider multi-antenna-element solutions. They also said antenna orientation and gain pattern should be considered when modelling interference. Simon Pike noted that we referenced Recommendation ITU-R F.1336 for an omnidirectional antenna pattern, but said this Recommendation only defines the radiation pattern in elevation, and it appears from the consultation that none of the co-existence scenarios described will need to take the radiation pattern in elevation into account.	We remain of the view that assuming an omnidirectional antenna for the purposes of coordination is appropriate. Considering a more directional antenna pattern on a case by case basis could present an interference risk due to e.g. steering beams from base stations. In addition, the omnidirectional assumption for the antenna pattern allows us to include the impact of terminal stations without requiring additional coordination for each terminal station, which would be burdensome for us and the users. Real antenna heights are considered in all services except low power indoors. We note Simon Pike's comments. Our coordination tool will assume an omnidirectional antenna pattern where the EIRP has the same levels in all directions in azimuth and elevation.

[27] ITU, *Recommendation ITU-R P.2109-0: Prediction of building entry loss*, June 2017, https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.2109-0-201706-I!!PDF-E.pdf (accessed 11 July 2019)

Indoor antenna height Simon Pike said that assuming an indoor base station height of 5m is not appropriate for coexistence with incumbents. He said that, for a tall building, the floor on which an indoor system is deployed could make the difference between an obstructed path and line-of-sight to the incumbent system.	We are aware of the risk that Simon Pike highlights. However, as noted in our consultation, we consider that, while indoor use in high-rise buildings may be above local clutter, these buildings are likely to benefit from increased building entry losses compared to traditional buildings.
Proxy base station EIRP Avanti, ESOA, Intelsat said that our proposal for an additional 2 dB to compensate for multiple base stations may be adequate when considering traditional mobile applications but that 5G consists of a variety of use cases where a high density of base stations may be required. Avanti, ESOA and SES urged Ofcom to impose a maximum EIRP of +2 dB per license area defined (as a total EIRP envelope) to compensate for the effect of multiple BSs. Huawei asked for more details on how the +2 dB proxy EIRP was arrived at.	The additional 2 dB was included with the aim of taking into account the possibility that interfering and victim low power base stations may be located anywhere within their respective 50 metre-radius areas and that the separation distance between them may therefore be less than if they were assumed to be located at the centre of the 50 metre area. This assumption is based on a scenario where the 50 metre areas are very close together; the additional 2 dB will be more than is required for scenarios where the 50 metre areas are further apart and is therefore a conservative assumption for the majority of cases. We also consider that the probability of multiple low power base stations within a 50 metre area producing an aggregate interference impact towards nearby satellite earth stations that exceeds the levels assumed in our coordination approach (24 dBm EIRP + additional 2 dB) will be very low in practice. We therefore continue to consider that the assumption of an additional 2 dB for the purposes of coordination between low power base stations and other uses is a proportionate response to the interference risk. We also note that we have powers to require licensed users to modify their radio equipment in the event that harmful interference occurs.

<u>General comments on coordination methodology</u> AWTG suggested that, rather than rejecting an application because it breached coordination levels, e.g. by 2dB, a lower power limit could be offered. Huawei suggested it would be more helpful if Ofcom could provide more granular feedback than a simple pass or fail. Two confidential respondents ([✂]) asked what would happen in a scenario where a user requested 40 MHz bandwidth but part of the requested allocation could only be assigned by interfering with another service; they asked whether this would result in Ofcom offering a reduced bandwidth allocation, a lower power option or imposing the use of DSA/Cognitive Radio.	We agree that it would be useful to provide additional feedback to applicants as part of the coordination process. For example, in cases where an application fails the interference tests, we can provide new sharers with information where appropriate on the margins by which they failed the coordination thresholds. Applicants for medium power licences will be able to use this information to inform any adjustments to its requested power and deployment location (and bandwidth in the case of the 3.8-4.2 GHz band). Applicants for low power licences will be able to use this information to inform any adjustments to its requested location (and bandwidth in the case of the 3.8-4.2 GHz band) and not the licensed power. In a scenario where a new sharer requests a channel bandwidth which overlaps with the bandwidth of an existing low/medium power user, and where the coordination assessment indicates that interference would be caused to other users, Ofcom would inform the applicant that the application had failed coordination and, in the same way as described above, provide the applicant with information on the margins by which they failed the coordination thresholds. The applicant could then decide whether to resubmit the application with different parameters.
Telet Research recommended managing interference using Inter-Cell Interference Coordination (ICIC) or eICIC from release 10 onwards. It also suggested that eNodeBs have the ability to scan the entire available bandwidth and report channel use and said this could be helpful in identifying real time spectrum use and would allow dynamic updates to central spectrum databases. It would like to see the inclusion of a method	We note the comments from Telet. However we are making the shared access bands available on a technology neutral basis whereas using ICIC or eICIC is only relevant to mobile technologies. Managing interference using ICIC or eICIC is something that licensees could consider implementing if they so wish. We are not considering the use of third party UE tools to report spectrum use at the present time.

for third party reporting of spectrum use using UE tools (like Network Signal Guru and Network Cell Info).	
UKWISPA & INCA noted that Ofcom did not propose to consider other base stations of the same licensee, considering that the licensee is best placed to manage interference in its own network. It said this would mean that the applicant would need to ask for a frequency which did not clash with its own frequency reuse plan but that it was not clear how this would be allowed for.	Applicants for new licences or additional assignments could indicate preferred frequencies in their application however, there is no guarantee that this will be available. Applicants should also be aware that as part of the licence conditions, Ofcom may notify requirement to change frequency within the permitted band from time to time for spectrum planning purposes.
Huawei said it was not immediately clear whether fixed/installed terminals would be subject to the same coordination process as base stations.	We can confirm that fixed terminals will not be subject to the coordination process. As noted above, one of the benefits of assuming an omnidirectional antenna for base stations in the coordination process is that it avoids the need to undertake additional coordination for terminal stations.
Telet requested clarification on how multi-storey coordination would be managed.	Indoor propagation requires detailed site-specific parameters to model accurately in a coordination tool and we are not currently considering supporting this at this time. However, we will continue to review demand and may consider this in the future. We note that concurrent spectrum trading allows multiple licensees to agree to use the same channel in the same geographic area. We also note that we are making 390 MHz of spectrum available in the 3.8-4.2 GHz band with a range of bandwidth options, which we believe should be sufficient to accommodate spectrum demand in multi-storey buildings.
<u>Action in cases of interference</u> Arqiva said that Ofcom did not explicitly refer to its enforcement duties in the consultation and asked for further clarity on how Ofcom would deal with interference issues as and when they arise. It opined that, where	Generally speaking, in such situations we would look to amend the licence of the new user to prevent any further interference, however we would assess any case based on the specific circumstances involved. The

both parties are operating lawfully and in compliance with their licence, Ofcom should focus its enforcement action on the new user. Avanti, ESOA and Intelsat said that licence conditions must ensure that stations of the Fixed Satellite Service operating above 3800 MHz are protected from undue interference.	terms and conditions of the Shared Access licence, outlined in Section 3 and included in Annexes 6 and 7, include provisions that enable Ofcom to inspect licensees' equipment and force closedown of users' equipment if this is causing interference. As we outline above and in Section 3, earth stations will be protected from interference using the same coordination procedure that is currently used.
Question 14 - What is your view on the potential use of equipment with adaptive antenna technology (AAS) in the 3.8-4.2 GHz band? What additional considerations would we need to take into account in the technical conditions and coordination methodology to support this technology and to ensure that incumbent users remain protected?	
Issue raised	**Ofcom response**
Approximately 30 respondents provided comments on the use of active antenna systems (AAS) and additional considerations we may need to take into account to ensure incumbent users remain protected. Ericsson, Huawei, Nokia, Urban Connected Community and one confidential respondent ([✂]) were supportive of including technical conditions for AAS. Huawei and Nokia suggested that Ofcom consider the regulatory limits specified in ECC Decision (11)06 (as revised in October 2018) to account for AAS base stations in the 3.8-4.2 GHz band. Ericsson suggested that regulations must allow choice of measurement methodology, with EIRP or TRP as equivalent choices. Avanti, ESOA, Intelsat and SES were not in favour of allowing AAS, saying that it would make coordination more difficult and complex, increasing interference risks to incumbent users. SES said that, even with an enforceable total EIRP envelope, the use of AAS technology would make monitoring, compliance and enforcement of such a cap very difficult. [✂].	Licensees can deploy AAS in the 3.8-4.2 GHz band provided they comply with our technical licence conditions. We are of the view that further engagement with stakeholders is needed before we consider any amendments to these technical conditions to further facilitate AAS in the 3.8-4.2 GHz band. We need to better understand the availability of commercial equipment, the implications for co-existence and how best to define the technical licence conditions to support AAS technology while ensuring incumbent users remain protected. We will continue to monitor developments in AAS technology and review at a later date.

Other respondents were more neutral in their response, while providing comments and suggestions on how AAS could be taken into account. The BBC said it agreed with Ofcom's proposal as long as current protection levels afforded by grants of RSA were maintained. The CAA and a confidential respondent ([✂MOD]) highlighted the need to ensure that radio altimeters in the adjacent band were protected. DTG thought that further considerations would be needed regarding additional protection criteria to avoid interference, and noted that power levels should be expressed in TRP. Dense Air suggested that low EIRP levels be considered in order to encourage a deployment model that enables network densification. ip.access on the other hand suggested a coordination method that increases the allowed EIRP in the case of AAS, but with the capability of raising an alarm where an accidental alignment of base stations and terminals in adjacent allocations creates interference – and noted that such an alarm would be most usefully generated in the context of DSA. The University of Strathclyde also thought that a DSA-based approach would provide a framework that would allow flexibility to adapt to new technologies as and when they become available. Simon Pike thought that the technical licence conditions for 3.8-4.2 GHz provided an incentive for the deployment of AAS technology for point-to-multipoint or mobile systems. He added that the impact on incumbent users depended on several factors but was unlikely to be sufficient to warrant the added complexity in modelling AAS in coexistence analysis. Telet Research suggested that the operating parameters of these systems would have to be taken into account in order to minimise potential interference but that, as commercially viable equipment in this band is	

still some way off, this work would not be required in the first iterations of the shared spectrum management system. Vodafone said that further industry engagement would be required on the usage of AAS. Two confidential respondents ([✂]) also suggested that engagement with equipment manufacturers would be important.	
Question 15 - Do you agree with our proposal not to assign spectrum to new users in the 3800-3805 MHz band and the 4195-4200 MHz band?	
Issue raised	**Ofcom response**
A confidential respondent ([✂]) said that it did not believe that new satellite use would cause issues for services below 3.8 GHz and above 4.2 GHz and thought that a blanket ban on use in these bands was unnecessary.	The whole 400 MHz in the band will still be available for satellite earth stations. We are not authorising new shared use in the two 5 MHz blocks at the top and bottom of the 3.8-4.2 GHz band.
SES urged Ofcom to look at adjacent band effects from IMT stations below 3.8 GHz into FSS receivers above 3.8 GHz.	The adjacent band effects from IMT stations below 3.8 GHz into FSS receivers above 3.8 GHz were analysed and discussed in Ofcom's consultation in December 2018, *Award of the 700 MHz and 3.6-3.8 GHz spectrum bands*.[28]
Vodafone agreed with our proposal but added that it believed that, in order to make most efficient usage of spectrum, and allow flexibility to change licensing arrangements should there be a global evolution to high power usage in the 3.8-4.2 GHz band, it may be best to manage the band such that shared usage is clustered towards the top wherever possible.	We agree that it is important that spectrum is utilised in the most efficient way. Our proposed approach was designed to allow greater flexibility and greater shared use of the band and we will manage the band in a way that is consistent with this approach.
The BBC said they welcomed the guard band at 3800-3805 MHz but sought assurance from Ofcom that protection of monitoring services at 3.8 GHz would be retained.	We will maintain current protection levels afforded to existing users.

[28] Ofcom, *Award of the 700 MHz and 3.6-3.8 GHz spectrum bands*, 18 December 2018, https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf

Nokia expressed support for our proposed approach but pointed out that, especially for AAS systems, the RF filter has to be implemented from the beginning and cannot be changed. It said Ofcom should carefully consider the characteristics of the guard band above 3.8 GHz. It added that harmonisation, at least at a regional level, would be necessary as it would be impossible to develop requirements for different countries.	Noted.
ASRI raised concerns over interference to radio altimeters above 4.2 GHz. It pointed out that the ICAO paper cited in Annex 5 of our consultation was just a working paper from one author that provided a preliminary assessment and said that further studies would be needed. It noted that the study did not include possible multipath effects or aggregate power from multiple BSs or UEs situated at different points around the approach path or airport. It also said that there was ongoing testing of the performance of radio altimeters to better understand its performance in the presence of adjacent band OFDM signals, which it expected to be published in approximately Q2 2019, and recommended that this is considered by Ofcom before implementing changes below 4.2 GHz. It also recommended that Ofcom seek guidance from the UK CAA on separation distances between aircraft and potential new services in the 3.8-4.2 GHz band. The CAA asked for regulatory assurance that there would be no interference to radio altimeters or Wireless Avionics Intra-Communications (WAIC) systems operating in the frequency band 4.2-4.4 GHz. A confidential respondent ([✂]) said that it supported our proposals not to allocate spectrum in the 4195-4200 MHz band but noted a US DOD	We presented our analysis of potential interference from new shared use of 3.8-4.2 GHz spectrum to radio altimeters above 4.2 GHz in annex 5 of the consultation. Respondents did not indicate that they disagreed with our analysis and did not provide any technical evidence that indicated that our analysis was wrong. However, we note the points made about ongoing testing of the performance of radio altimeters. If additional evidence presented to us indicates that there are new unforeseen risks of interference, we have the flexibility to build additional safeguards into our coordination and assignment process as required.

report which it said indicated that exclusion zones around military airfields and guard bands may be needed to protect radio altimeters.	
Telet Research said that it did not see any obvious issues with the use of these guard bands. It said that systems are likely to use wideband spread spectrum waveforms and AAS which reduces the likelihood of interference at band edges and suggested we consider low power medium bandwidth use cases for the guard bands in the short term. Simon Pike said Ofcom should allow assignments in 3800-3805 MHz for low power indoor base stations.	We consider that the remaining degree of uncertainty around radio altimeters as highlighted above supports our view that we should take a cautious approach and, in the immediate term, not permit use in the 4195-4200 MHz spectrum. We also note that, as mentioned in our consultation, the inclusion of this guard band does not materially reduce spectrum availability given that we are assigning spectrum with minimum bandwidth of 10 MHz.
Question 16 - Do you agree with our fee proposal for the new shared access licence? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Avanti, ESOA, Intelsat, SES, Vodafone and one confidential respondent ([✂]) argued that it is inconsistent and unfair to charge cost-based licence fees for new sharers when incumbent users pay higher, AIP-based fees. Federated Wireless argued that the price of spectrum should reflect the underlying market conditions.	We believe the difference in fees is justified given that an earth station sterilises a much larger geographic area than a new user would. For example, a Permanent Earth Station is more sensitive to interference and thus requires a low level of protection coupled with the assessment of short-term propagation conditions. As explained in our consultation, we consider it unlikely that demand for new users will lead to excess demand. We may reassess this position once new licences have been rolled out and evidence of their actual demand and use is available, but there is currently insufficient evidence to suggest that a market-based price is required.
Several stakeholders (FMS Solutions, Google, Heathrow Airport, Nokia, Simon Pike, and Urban Connected Communities) suggested that the pricing structure does not work for some use cases, e.g. femtocell or large-scale deployment. Other stakeholders consider the fees to be too	We consider cost-based fees to be at an affordable level whilst ensuring the recovery of costs incurred from the introduction of these licences. Although total fees vary depending on the number of licences require to larger scale deployments, we would also expect the gains from such a

expensive. Two confidential respondents ([✂]) suggested that the fees should be lower, whilst Telet Research and Telint argued that the fees should be zero.	deployment to be relatively large. We note that most stakeholders either did not comment on or agreed with our fee proposals. Stakeholders who disagreed with the fee suggested both higher and lower fees.
Advanced Wireless Technology Group, Vodafone, Three and Telefónica were concerned about excess demand and the potential for hoarding. Motorola suggested a 40 MHz cap in high demand areas.	No stakeholders suggested a change to our proposed fees to address the risk of hoarding. We consider our approach strikes the right balance of mitigating the risk of hoarding whilst encouraging new and innovative use of the spectrum.
Some stakeholders have suggested alternative structuring of the cost-based fees. Two confidential respondents ([✂]) found the fee structure to be affordable but suggested scaling the license fees to be consistent with the CPE cost culture. Fairspectrum suggested pricing based on population density as it considered this to be correlated with demand. BT and Neutral Wireless argued for lower fees if a licence uses narrower channels.	We consider it appropriate to have a simple pricing structure that is affordable and provides the opportunity for efficient use of spectrum. We do not consider structuring the fees to scale with CPE costs or population density or narrower channel size is consistent with our cost-based approach, nor is it clear that doing so would result in a more efficient use of spectrum.
Nominet and two confidential respondents ([✂]) suggested that Ofcom provide the option for shorter duration licences to support temporary events where the spectrum may be needed for a short period of time. [✂].	As discussed in Question 9, we will create an option for short-term licences and pro rata prices to account for the shorter duration of these licences. We consider it appropriate to set prices for short-term licences in this way as it will likely result in greater use of the spectrum. Furthermore, we consider this pricing approach to be aligned with our goal of moving towards a DSA system.
Avanti, ESOA, Intelsat and one confidential respondent ([✂]) raised concerns about the impact on PES fees, specifically that new users should pay any additional costs incurred by Ofcom.	We do not expect to make any changes to PES fees as a result of the additional costs incurred by the new licences. New users will pay fees that not only recover the costs directly incurred by the shared access licences but also some of the fixed and common costs associated with coordinating, enforcing, and distributing licences more generally.

Question 17 - Do you agree with our proposal to change the approach to authorising existing CSA licensees in the 1800 MHz shared spectrum? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
BT said that publishing of assignments could infringe customer confidentiality.	We already publish information on the licenses we issued in the Wireless Telegraphy Act Register (WTR), so that applicants can have a clear view of availability of spectrum in a desired area.[29] Many spectrum authorities worldwide publish detailed assignment data and there are several policy and legal drivers for Ofcom to make more information progressively available.
FMS said the proposal was effectively a "revocation" of their rights (requiring a 5-year notice period).	Licensees will be able to access the same spectrum; existing assignments will be migrated to the new licensing platform. All licensees will still have the ability to make new assignments, just under conditions aimed to facilitate wider and more effective use of the spectrum than has been evident since the initial award. Ofcom does not agree therefore that any access to spectrum has been revoked.
BT and FMS Solutions were concerned that the new licensing and fees structure might be incompatible with their business model.	The original concept for the band was one of shared use. It was clear in the 2006 Award that licences would become eligible for annual fees after the initial period and, during the development and consultation on future policy, licences have remained charge-free for an additional period of more than 3 years. Ofcom believes that the fees and assignment proposals are fair and appropriate, however we will continue to work with affected stakeholders to understand and address any transitional issues.

[29] Ofcom, "Wireless Telegraphy Act Register", 4 June 2014, https://www.ofcom.org.uk/spectrum/information/spectrum-info-faq/wtr

A number of current licensees have notified that they have no current deployments in the spectrum. Vodafone noted the need for an audit of use in the band, not relying on the previous database.	It will not be possible to migrate a CSA licensee with no existing deployments to the new licensing platform. Licensees for whom this is the case will be invited to surrender their CSA licence, but all licensees will be able to apply for Shared Access licences at any time, so none will lose their rights to use spectrum in the future.
FMS solutions wanted consideration for a maximum 3 dBm femtocell.	There are no current plans to authorise a 3 dBm femtocell, however this might be considered in future, were that position to change.
Questions 18 and 19 - Do you agree with our proposal for the Local Access licence? Please give reasons supported by evidence for your views. Do you have any other comments on our proposal?	
Issue raised	**Ofcom response**
Many respondents (were in favour of the general approach for providing access to already allocated spectrum and saw this as a positive step by Ofcom. Westica Communications suggested a similar approach could apply for the 1.4 GHz fixed links band which has recently been closed for new applications. Disruptive Analysis in their response set out that this was a good compromise and could become an example internationally if it works. Angetech Consultants, Arqiva, DTG, IET & 5GFF, Simon Pike, Telint, UKWISPA & INCA, Vodafone and two confidential respondents ([✂]) agreed with the concept but highlighted a number of concerns/flaws in the proposal. Dense Air commented that it was hard to determine how this proposal could be effective as economics typically determine when MNOs stops network coverage because of a poor business case.	We note these comments and address specific points raised below.

A number of respondents suggested that Ofcom move towards a DSA approach straight away. Nominet requested that Ofcom set out a roadmap for moving this to a DSA approach. BT, Telefónica, Vodafone and a confidential respondent ([✂]) were supportive of Ofcom's general aims to ensure spectrum is used efficiently, however they were not supportive of the proposals as set out in the document. They all suggested alternative approaches to that proposed by Ofcom.	
<u>Move away from market-based mechanisms</u> BT and Three stated that the proposed approach represents a move away from spectrum being deployed based on market-based mechanisms to a more prescriptive approach reminiscent of the earlier "command and control" approach to spectrum management.	As we set out in our Spectrum Management Strategy in 2013, our key objective when managing spectrum is to deliver its optimal use, meaning the use that delivers the greatest value to UK citizens and consumers.[30] We stated that we would continue to rely on market mechanisms where possible and effective, but also take regulatory action where necessary. We advised that we would proactively explore how regulatory support for new forms of sharing could enable new spectrum uses without unduly constraining incumbent users. Our approach is in line with this policy.
Both BT and Three believed that such a prescriptive approach is only necessary in situations of market failure. As there is no obvious market failure that needs correcting Ofcom should not intervene in this way.	As we noted in our consultation document, for gaining access to spectrum already allocated the market mechanisms such as transfer or leasing have a number of risks associated with them. We believe that these act as disincentives and are not the most effective way to enable access to spectrum for localised use.
<u>Undermines the principal of ALF</u> BT went on to state that our proposed approach undermined the reasoning behind Annual Licence Fees (ALFs). ALFs were introduced to	We do not think that the Local Access licences will reduce incentives to transfer spectrum under the spectrum trading regime, nor should they

[30] Ofcom, *Spectrum management strategy*, 30 April 2014, https://www.ofcom.org.uk/__data/assets/pdf_file/0021/71436/statement.pdf

provide the correct incentives to use spectrum efficiently by operators paying the market value of spectrum. This is so that operators have incentives to invest efficiently in mobile networks. By paying the market value of spectrum through ALFs, MNOs would base their investment decisions on the true cost of the spectrum input and where necessary spur trading. By allowing overlay licences this would reduce the market value of the MNOs' spectrum. Ofcom's current ALF fee does not account for this situation.	impact ALFs. Users of a shared access licence will pay a fee below AIP but will also face less certainty regarding the long-term availability of the licence. Therefore, some users may prefer a traded licence, e.g. those facing a long payback period for their investments, whilst others may prefer a Local Access licence. We also do not expect shared access to undermine the private value of spectrum or the incentive to invest since access will only be granted where the incumbent licensee has no foreseeable plans to deploy.
<u>Undermines investment</u> BT and AWTG warned that Ofcom's "use-it-or-share-it" policy could undermine these incentives to invest because spectrum could be valued differently by new operators compared to existing licensees.	We are not proposing to amend existing licences to include a use-it-or-share-it provision. Our aim is to bring parties together so that they can reach an agreement to enable spectrum to be used in areas that MNOs have no current plans to deploy in the near future.
Telefónica stated that Ofcom must not dilute the rights of spectrum licensees by adopting a local access sharing regime. This would hand deployment rights to parties on an uncontrolled basis, in a misguided attempt to facilitate an as-yet-unknown demand which has not been quantified, nor has been properly assessed through undertaking a robust cost-benefit analysis. Three stated that at best these proposals would dilute their rights, and at worst would involve signing them away for a period of time, with no prospect of compensation.	Incumbent users' rights to deploy services will not be diluted by our proposals. Ofcom's approach is to allow spectrum that is not going to be used in the foreseeable future to be put to use. Where operators are currently using the spectrum in that area or have plans to do so within three years, they are able to raise an objection to the application. If we consider those objections are reasonable we would not grant a Local Access licence. Where Ofcom has granted a licence, all parties will be required to cooperate and not cause interference to each other's networks as this is a condition included in both parties' licences.

<u>Reduces incentives for spectrum trading</u> BT advised that Ofcom's proposals could also reduce the incentive to trade spectrum. Under Ofcom's proposals, new operators would only have to pay an admin cost-based licence fee for any unused spectrum.	We recognise that it is already possible for people to gain access to currently licensed mobile spectrum through the spectrum trading process which is based on a commercial agreement between the parties with very little Ofcom involvement. However, our experience shows that this process is used mainly to enable the transfer of rights to spectrum from one user to another rather than to share access rights. Furthermore, although spectrum trading can be effective in facilitating such outright transfers of spectrum rights, we note that even here it is only likely to happen where there is sufficient return to make the effort worthwhile. Where the transaction costs are too high, because it takes too much effort to organise a transaction or where there is too much perceived risk, it is not likely to happen. Sharing spectrum in a particular location is both complex in terms of the transaction and less likely to realise a significant return. Given this evidence, it is difficult to see how our proposals would significantly reduce incentives to trade. Trading involves the transfer of the existing spectrum rights and obligation granted to the MNO for a perpetual period whereas our proposals are for a maximum of three years (longer periods are only permitted where the MNO has consented to this). Our proposal may reduce demand where a licensee only wished to access spectrum for a period of up to three years but for longer durations it should have no impact on the incentives to trade.
<u>Lack of incentives for incumbent licensees</u> Dense Air and Arqiva questioned why the existing licensee would agree to Local Licence applications. They encouraged Ofcom to consider an incentive for existing license holders to cooperate in this process.	We note that incentives could play an important role in this process and our proposals would not prevent parties from entering into such arrangements. In our December 2018 consultation on coverage

One confidential respondent ([✂]) was supportive but did not believe the that the proposals were bold enough as they believed that receiving buy in from the MNOs was going to be challenging. Ruckus Wireless and IET & 5GFF also highlighted the need for the incumbent licensees to be incentivised. IET & 5GFF suggested an approach whereby the lending MNO would have the right of free access some of the cell capacity for their own customers to use. Ruckus Wireless suggested that the new user's operations be counted towards the overall coverage figures for the original licence holder. AWTG suggested that a mutually agreeable plan and revenue-sharing model between the incumbent and new entrant may provide incentives to encourage further sharing.	obligations for the 700 MHz and 3.6-3.8 GHz spectrum award,[31] we set out our thoughts on this issue. In the document we said that good quality coverage delivered through third party roaming could count towards delivering the obligation and set out what we would consider when deciding if a proposal could count towards it. We stated that since the purpose of the coverage obligations was to secure the provision of good quality voice and data services, we were minded to include the effect of roaming only so long as we were satisfied that this provides a meaningful good quality service and seamless transition as customers move from the operator's network to the roaming network and vice versa. We would expect operators to demonstrate that a seamless roaming service had been implemented and that qualifying coverage would be equivalent to that provided over their own network. We considered seamless roaming to mean a seamless transition between the coverage of two (or more) operators, i.e. no additional disruption at the time of transition between the home and the visited networks. This includes maintaining calls or data sessions that are in progress at the time of a transition.
<u>Alternative proposals: spectrum leasing</u> MNOs, Ericsson and techUK suggested that an alternative should be that Ofcom allows spectrum leasing in these bands. Three advised that spectrum leasing can promote sharing without the need for further intervention. techUK advised that the process of spectrum sharing was not helped by the current Ofcom prohibition on MNOs leasing any of their spectrum.	Although there was some support for the idea from the MNOs and some others, most respondents agreed with our proposed approach rather than adopting spectrum leasing. As we set out in the December consultation, leasing would remove some of the complexities associated with providing access via spectrum trading. We would consider extending leasing if we thought that there were likely to be net benefits, including

[31] Ofcom, *Consultation: Coverage obligations in the 700 MHz and 3.6-3.8 GHz spectrum award - Ofcom's approach to verifying compliance*, 31 January 2019, paras. 1.7, 4.33, 4.166, https://www.ofcom.org.uk/consultations-and-statements/category-2/coverage-obligations-in-the-700-mhz-and-3.6-3.8-ghz-spectrum-award

Vodafone stated that it had long argued for the possibility to voluntarily lease their spectrum, where it is not in use and is unlikely to be in use for the foreseeable future. Vodafone welcomed Ofcom's proposals, which effectively provide a mechanism to sub-let spectrum, but using a different licensing model. However, this was subject to a series of caveats. BT outlined that the spectrum leasing model could work well in the mobile bands. It advised that this would enable MNOs to recover the opportunity costs associated with offering access to a portion of their spectrum in a specific geographic location, whilst also being able to engage directly with the new user to agree the duration of the agreement.	sufficient demand to lease spectrum. We will continue to review this position in light of any new circumstances. However, we believe our proposed local licensing approach would achieve the same outcomes as leasing but is more likely to be successful in encouraging an agreement between parties since it does not place responsibility for the third party on the incumbent licensee. None of the responses received have led us to believe that this is still not the case, especially where access is only needed for a period up to 3 years. However, we note that for those parties wishing to have security of tenure for over three years this will only be permitted with the agreement of the MNO. Our proposals do not rule out agreements being reached for periods shorter than this. For long-term access, our proposals give MNOs the ability to enter into commercial agreements (if they wish to do so) whilst minimising the risks to the incumbent licensee if the third party were to breach the terms of the licence.
Three highlighted that Ofcom's proposals are inconsistent with requests by Government for Ofcom to clarify that spectrum leasing is not prohibited under the Mobile Trading Regulations.	We are aware of the Government's proposals in the SSP consultation and share with them the aims of providing access to unused mobile spectrum. However, as discussed above we believe that the current leasing proposals raise a number of risks and competition issues. Our approach achieves the same outcome whilst minimising these risks. We will keep this under review.
<u>Alternative proposals: DSA</u> IET & 5GFF, Telint, University of Strathclyde and one confidential respondent ([✂]) all suggested moving to a DSA approach.	Our position on a DSA approach for these bands is set out in our response to Question 4.
<u>Alternative proposals: certification/commercial agreement</u> BT, Telefónica and Vodafone proposed similar alternative solutions. BT in its response recommended a process whereby the MNO would issue a	Our proposals would not prevent incumbent users from reaching a commercial agreement with new sharers if this was needed to underpin

certificate to the third party once an agreement was made between the two parties. Upon receipt of this certificate Ofcom could then proceed to issue the licence.	significant effort required to secure longer term access to mobile spectrum. As explained above our Local Access licensing approach provides for a range of circumstances where a commercial agreement may or may not be needed. All applications for access to mobile spectrum will be discussed and agreed with the incumbent licensee – some may be simple and require little effort; others may be more complicated and require a commercial agreement between the parties. In all cases Ofcom will seek to facilitate agreement and be responsible for authorising access to spectrum by the new user.
Telefónica and Vodafone said they would expect that any agreement by Ofcom to over-license MNOs' spectrum would be accompanied by a commercial agreement between them and the prospective sharer. Vodafone argued this was required to protect both parties, in that Vodafone would be able to factor in the application to its network planning tools, and the prospective sharer would have greater certainty of access.	We note these comments and agree that certainty of access, especially for periods over three years, can only be achieved it the incumbent licensee does not raise a reasonable objection.
Telefónica stated that this was a more appropriate and fair way to incentivise existing licence holders to facilitate spectrum sharing. Ofcom should ensure that there are no barriers to commercial arrangements and that operators are suitably compensated for providing access and foregoing rollout in specific areas. They also added that existing licence holders should also have the ability to recover the costs they are likely to incur as a result of dealing with sharing requests, commercial and legal management, technical co-ordination, synchronisation and interference prevention and management process and associated agreements.	We hope to minimise the burden of the new process on the incumbent operators by requesting a degree of due diligence in advance, and by Ofcom conducting an initial check of applications in order to avoid purely speculative requests being sent to the MNOs. We would expect that as part of any application, the applicant will provide evidence as to why they considered that the requested spectrum is unused in an area. MNOs could also look to decrease costs by also providing more information about coverage and potential sharing opportunities. As noted in the submission from Ruckus, there could be a role for third parties to help encourage and support this process. We would like to encourage all parties to work together to provide guidance on sharing opportunities.

	This may include what emission limits may be acceptable or codes of practice. However, we note that the responses to this consultation from MNOs highlight concerns with making available detailed technical information.
Alternative proposals: concurrent licence Three suggested that an alternative approach was to issue a concurrent licence with the third party and the incumbent licensee both being on the licence.	This proposal is already possible and not impacted by the approach we have outlined.
Alternative proposals: set parameters outside which everything else is permitted IET & 5GFF suggested that Ofcom set the parameters that would protect the incumbent users' deployments and that everything outside of that can be used.	We note that this would provide clear information concerning what spectrum may be available and is something that we may wish to develop in the future. We would welcome parties to begin to discuss such ideas to see if this concept can be developed further. However, we note that this would require detailed assessment of sharing conditions and may take time to agree. Given this, we believe that our proposed approach is a good starting position and is something that can be deployed quickly. Although we do note that with such a system caution may be needed as the modelling required may not be able to take into account the deployment of different technologies or other factors such as local conditions or mitigations that could be put in place.
Alternative proposals: encourage marketplaces or brokerages to advertise opportunities Ruckus Wireless proposed that Ofcom encourage the formation of one or more licence "marketplaces" or "brokerages". In these, existing licensees could register used and unused areas along with operational characteristics. New users could register their need for spectrum in a	Third parties providing supplementary services could be set up now. We note this was anticipated once spectrum trading was permitted, but we note that none have been established since spectrum trading was introduced in 2004.

certain location/area and their relevant technical characteristics. Such a service would greatly ease the administrative burden on Ofcom, the existing license holders, and the new users.	
<u>Alternative proposals: require "use or share" provision in MNO licences</u> Facebook and DTG advised that without provisions to compel incumbent licensee to share they will refuse all applications. Facebook suggested that their licences should be varied to include a "use or share" provision. This, they argued, would put more of the onus on them to share rather than letting them refuse applications.	On mandating "use it or share it" conditions in the MNO licences, our view is that it is difficult to make workable in practice for licences that are awarded for the whole of the UK, as we set out fully in our response to DCMS on the issue. In this, we explained that it is difficult to define what constitutes "use" in order to trigger an enforced trade or revocation. There could be legitimate reasons why the spectrum may not be in use as the licensee is holding it back until they see a suitable commercial opportunity or until the technology they wish to use is ready to use. Finally, we consider that imposing such an obligation here could potentially distort competition and/or chill the incentives to invest in the spectrum.
<u>General approach to the authorising use</u> We received a number of comments concerning the proposed licensing process. Telint, University of Strathclyde and a confidential respondent ([✂]) all suggested that the licence process needed to be automated. Telint commented that the DCMS SSP makes it clear that DSA should be progressed in the short term and that it believed Ofcom has simply made a mistake and had not factored in the SSP when making these proposals.	Our position on DSA is set out in response to Question 4. The SSP consultation asks that Ofcom identify the opportunities for spectrum sharing in the mobile bands and the extent to which spectrum sharing policies are increasing the utilisation of spectrum. The provisions in the SSP do not stipulate the method of sharing to be taken forward.
IET & 5GFF, iWireless Solutions and techUK had concerns over the approach. iWireless Solutions stated that the process was acceptable, but slow, and was unlikely to facilitate widespread usage by third parties. techUK had concerns about Ofcom's ability to scale up the proposed	We consider our proposed approach will enable us to respond appropriately to initial requests for access to mobile spectrum and to assess the level and nature of demand. Our licensing model is based on the existing licensing process that Ofcom operates for those companies

labour-intensive approach if responding to many applications for Local Access licences.	wishing to obtain an Innovation and Trial licence. This has been running successfully for a number of years.
[✂]. FMS Solutions raised concerns about the technical competency of potential applicants, and suggested that some kind of technical requirement is placed in the process, such as evidence to support the application as a demonstration of competence.	We note that the process as originally defined may pass on some burden to the MNOs for them to demonstrate that the spectrum is in use. Therefore, we expect that as part of the application process applicants will provide their reasoning as to why they believe that the spectrum they are seeking access to is currently not being used. We discuss, in response to question 20, that some information on spectrum use is already in the public domain and that this can be used to assist with the application. However, we are not proposing to carry out a vetting procedure in regard to who can and cannot apply for a licence based on a competency test.
Simon Pike explained that the process as defined by Ofcom would require MNOs to provide information on their future deployment plans, which are very commercially sensitive. There is a risk that this information could leak into the public domain or be used for other purposes due to legislative provisions such as the Environmental Impact Regulations (EIR). Simon Pike suggested that it was difficult to see why an applicant would need spectrum within a particular part of a mobile band for technical reasons. In cases where an applicant has not obtained the support of an MNO, it should be sufficient for the application to state the frequency band that is being requested. Ofcom could then contact the MNOs with spectrum in that band. This would increase the change of a successful assignment and also reduce the "leakage" of commercially sensitive information on future deployments.	Ofcom regularly deals with commercially sensitive information as part of regulating the communications industry and is subject to various statutory restrictions on its disclosure. We note the concerns raised regarding the sensitivity of rollout plans and will liaise with the incumbent licensees regarding the level of information that will be shared with us and made available to third parties. However, we are aware that for a number of years operators have been providing local councils with potential rollout locations of their networks for the upcoming 12 months. We understand that the government encourages councils to publish a register of existing telecommunications installations within their area so that both the public and the operators are aware of the current range of sites where equipment has been installed.

Keep under Review Digital Colony Partners urged Ofcom to continually review this process as, in the event of no agreements, Ofcom must enforce underutilised spectrum to be accessed by third parties.	We will keep this process under review and will monitor the cases where objections from the MNOs were received. In these cases, we may follow up with the MNOs to see how their deployment plans are going. We would expect that the information provided on future use should be broadly accurate. If this is found not to be the case we will consider further changes to the process.
Agreed timescales for the process Angetech Consultants, Energy Networks Association, Telet Research and Western Power Distribution all had concerns that the process had no agreed timescales and suggested that Ofcom should set defined time limits for each step of the process. Energy Networks Association asked how Ofcom would ensure timely engagement by MNOs.	Given the ad-hoc nature of these requests, the uncertainty over the level of demand and the discussions that may need to take place to achieve agreement, we do not believe a one-size-fits-all mandatory time limit would be appropriate in terms of a timescale for responses from MNOs. However, we would like to work with both incumbent licensees and potential applicants to come to a working agreement on timescales that would balance the needs of the applicant for a response whilst acknowledging the impact on incumbent licensees' resources.
Incumbents' right to deploy ip.access was concerned about incumbents' right to overbuild in the area that they deployed, and suggested that new users be given the opportunity or the obligation to extend the mobile network's coverage on their behalf.	Incumbent users' rights to deploy services will not be diluted by our proposals. Ofcom's approach is to allow access to spectrum that is not going to be used in the foreseeable future. Where operators are currently using the spectrum in that area or have plans to do so within three years, they are able to raise an objection to the application. If we consider those objections are reasonable we would not grant a Local Access licence. Where Ofcom has granted a licence, all parties will be required to cooperate and not cause interference to each other's networks as this is a condition included in both parties' licences.

Telefónica stated that existing licensees must be protected from harmful interference and any sub-licensing of sharers should include robust measures to monitor and address interference with the primary user, should it arise. This, they argued, was vitally important in order not to effectively dilute the property rights that primary licensees have purchased from the Government. They asked that Ofcom provide more detail and clarity about rights to deploy and, where a Local Access licence has been issued, the incumbent licence holder's rights to deploy in the future, in the area where the Local Access licence holder has deployed. Telefónica went on to state that they will not provide any commitment not to deploy outside of the locations identified in its submissions to Ofcom at a given time. That would undermine the rights it currently enjoys. Should incoming licensees require greater certainty than this, then they would need to reach a commercial agreement with Telefónica.	MNO and Local Access licences include provisions for Ofcom to require the modification, restriction or shutdown of equipment if it is causing harmful interference to the use of authorised radio equipment. This provision applies to both parties.
<u>Ofcom liability in cases where harmful interference is caused</u> Telefónica asked that given that causing harmful interference is a criminal act, and Ofcom is going to be responsible for co-ordination and issuing licences, where does Ofcom stand in relation to its potential liability for causing any harmful interference to existing licence holders services, were such a situation to arise.	As part of the process, MNOs will be given the opportunity to assess the risk of interference to their network and can explain why they think the proposed deployment would cause a problem. Ofcom will consider this in deciding whether to issue a licence. In cases where Ofcom does not agree with an MNO's objection we will discuss this further with all parties before making a final decision.

MNOs' ability to reasonably object Most comments received regarding the process were on our proposal to allow the incumbent licensee an opportunity to object to the application if they had reasonable course to do so. Neutral Wireless, Nominet, Ruckus Wireless, ip.access, Telet Research, DTG, Telint, Google, UKWISPA & INCA and BT all commented that the proposals needed further clarification.	We purposely did not seek to define what we consider constitutes a reasonable objection, as each case will be evaluated on the specific circumstances of the application. We believe that this approach will provide more opportunities for sharing, compared to setting out a list of defined criteria. However, for an incumbent licensee to raise an objection, this should be based on a technical assessment that shows that either the spectrum is already in use in that area; there is planned future use within the next three years; or the proposed third-party transmission site would cause interference to their existing deployments in the local area. As described in the process, the final decision on licensing rests with Ofcom and incumbent licensees have no right of veto. However, our aim for this process is to facilitate discussions between the applicant and incumbent licensee to be able to reach an agreement rather than to impose a decision.
Google set out that giving MNOs a veto threatens to nullify this concept. They stated that MNOs tend to be sceptical of the idea that other providers can use portions of their spectrum without impairing the MNOs' own current or future operations. In the USA, where spectrum leasing is generally allowed, nearly 90% of secondary market transactions have involved purchases of spectrum by the largest national carriers to consolidate their holdings, instead of transfers of rights to smaller operators that would use them more intensively.	We note the experience of users in the USA.
Future rollout Ruckus Wireless was concerned that rejections could be due to administrative burden, loss of future options or inhibiting competition. The approach we had outlined seemed very easy for the MNO to raise	We understand the concerns raised and will monitor the process. If we see that all applications are being rejected on the basis of future deployment we will follow these up and see if they have deployed in the

enough of an objection to deter investment and prevent deployment, while not actually being obliged to deploy themselves.	timescales they suggested. If it was found that deployments were not being rolled out on a systematic basis we would need to consider changes to the proposed approach.
UKWISPA & INCA supported the proposed licensing process but were concerned about the potential lack of teeth in the process when an incumbent says they are using the spectrum but in reality are not using it. Telint urged Ofcom to use far stronger language or be accused of being "soft" at the expense of citizens and consumers. Facebook suggested that applications for local access should be granted unless the incumbent licensee can demonstrate that it is committed to serve that area within a short period of time, such as six months. BT and a confidential respondent ([✂]) advised that the process assumes that MNOs will know with sufficient certainty where they plan to deploy within three years' time, which is not always the case.	Our proposals also need to take into account the reasonable expectations of MNOs to be able to deploy future services. Given some of the complexity surrounding mast deployments and contractual negotiations we do not believe that such a provision would be of benefit. For newly awarded bands we think it is reasonable to allow a period of time for MNOs to consider their network deployment plans. If an operator does not have sufficient certainty over deployment plans in a particular area, to confidently respond positively to an application, they can say so. We would not expect this to be the case in every area.
<u>Technical criteria</u> Telet Research explained that if the selection criteria are too tight to the extent that it becomes very difficult to get an application through the process, then uptake will be severely limited. [✂].	We agree and for this reason we are not proposing to set any mandatory criteria at this moment in time. In regard to interference, we would expect any assessment to be based on internationally recognised criteria and propagation models. We would welcome discussions with industry about developing a set of technical proposals that everyone agrees with and could form the basis of analysis. However, we also note that this needs to be considered on a case by case basis as there may be local considerations to take into account e.g. use in an underground location such as a mine.
<u>Appeal process and monitoring</u> Angetech Consultants advised that there needed to be a mechanism that would allow MNOs' objections to an application to be appealed.	The process as we set out in the December Consultation did not include an appeals process step. As discussed previously, our aim is to try to

Three stated that Ofcom had not explained, for example, the procedure if a new user chooses to challenge the decision of the MNO, or how such disagreements will be resolved. It said that this would be of critical importance, as it would be wholly unacceptable for the MNO to be compelled to share any commercially sensitive detailed rollout plans with Ofcom or third parties. Ruckus Wireless argued that Ofcom will need to monitor rollout of networks in areas where an MNO refused a Local Access application due to reasons of future deployment.	facilitate parties reaching an agreement. However, this may not always be possible, so Ofcom will need to make a decision in relation to the application. In such cases we would make our provisional decision known to the concerned parties and allow them to make representations before we come to a final decision. Where possible we would like to share the nature of the objection with the third party so that they can assess their proposal in light of this evidence and either modify their application to mitigate any concerns or provide technical evidence as to why the assessment is incorrect. We note that in regard to future deployments this may be difficult, but we would expect that the information provided by the MNOs in these cases to be sufficiently detailed. If agreement can still not be reached, we will assess the evidence provided and make a decision.
<u>Competition concerns and anti-competitive behaviour</u> BT stated that MNOs may have the greatest interest in accessing one another's spectrum where it is not yet deployed. They suggested that Ofcom might wish to consider how it is able to address any competition issues that arise in this instance prior to granting licences for shared use. It will be important that it has the necessary statutory powers to perform ex-ante competition checks and where necessary decline to issue licences for shared spectrum. MNOs could game the system to expand their holdings. Existing licensees are not prevented from applying for each other's spectrum under Ofcom's proposals. Existing MNOs could therefore apply for licenses simply to prevent their competitors from deploying spectrum in future for uses they cannot envisage today.	An MNO could apply for a Local Access licence but, as with all other applications, a licence will only be granted in areas where the spectrum is not being used or is not planned for use in the foreseeable future as agreed with the incumbent licensee.

<u>Access for to non-mobile supported bands</u> CBNL requested that this concept be extended to other block assigned frequency bands such as 10, 28, 32 and 40 GHz. JRC raised concerns that if Ofcom was intending to introduce a general policy of licensing additional users within existing exclusively licensed spectrum then Critical National Infrastructure uses should be excluded from this.	We are not proposing to extend these proposals to other bands at this time. Our approach focusses on meeting demand for access to spectrum suitable for mobile use. The frequency bands that CBNL requested the process to be extended to by CBNL are mainly for Fixed Links or FWA. There are already licence products available through that meets these needs.
<u>Not restricting incumbents' deployments in case of emergency</u> AWTG, Motorola and a confidential respondent ([✂]) urged Ofcom to ensure that the MNOs' rights for rapid deployment into unused licenced spectrum in the case of emergencies and natural disasters be carefully protected.	Shutdown provisions are already included in the Local Access licence (Clause 13).
<u>Other non-spectrum factors may need to be considered</u> A confidential respondent ([✂]) advised that access to spectrum is just one matter that will need addressing. We should also consider roaming arrangements and ensure that number ranges for these micro carriers are not blocked or restricted. Simon Pike highlighted that in addition to the spectrum requirements there may be a need for agreement between the MNO and Local Access licensee that go beyond what is normally contained in a WT Act licence for example conditions for site sharing. These could be included in a separate agreement between the two parties.	We address issues on roaming in Question 3 and issues on numbering in Question 10. The approach we have outlined is compatible with MNOs and third parties making separate agreements with each other.
<u>Other issues - awards</u> Arqiva argued that this policy contrasted with its own experience of trying to facilitate sharing arrangements in the 700 MHz duplex gap. This is to enable valued DTT services to operate in spectrum which will likely not be immediately used by the new mobile licensees. In its recent consultation	We think it is more appropriate to consider comments on the bands proposed for award, as part of that consultation and have forwarded these comments to Ofcom's awards team.

document on the 700 MHz and 3.6 GHz award, Ofcom has proposed a comparatively "hands off" approach and, to date, has not offered similar offices to come to an outcome that suits all stakeholders. Again, to be consistent and equitable to all end consumers, Ofcom should take this more proactive approach to sharing in the 700 MHz duplex gap. Telint suggested that all spectrum in remote "deep rural" areas should be carved out the upcoming auctions. The rationale is that appears to be no plan at all to serve them anyway, therefore, on what lawful basis could such a request be reasonably refused. Outside these remote areas if someone is able to use the MNOs spectrum for free then they should be willing to surrender up to 10% of any capacity to the MNO for its own use – to benefit some of its own customers too that it cannot currently adequately serve.	
Question 20 - What information should Ofcom consider providing for potential applicants in the future and why would this be of use?	
Issue raised	**Ofcom response**
Ericsson advised that it was difficult for third parties to identify sharing opportunities. A confidential respondent ([✂]) suggested that most community-led applications for spectrum would lack the skills and formalities of an industry hardened applicant and will therefore require guidance.	We acknowledge that finding detailed information in the public domain on spectrum use may be difficult. Current information on coverage provided by Ofcom[32] and MNOs focuses on overall coverage, but this is not broken down into specific bands. We would suggest that potential applicants wanting to know further information about spectrum availability discuss their requirements with Ofcom and the incumbent licensees and begin a dialogue. We will work with the MNOs and ask that they provide contact information so that these requests can be directed to the relevant area in their organisation.

[32] Ofcom's mobile coverage maps can be found on our website at: https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/advice/ofcom-checker

[✂].	We note this point.
Dense Air advised that there are lots of sources of spectrum usage data available. During the application process, the onus should be placed on the applicant to provide evidence that the spectrum is not utilised in that area.	We do note that there are some sources of information available. We also agree that if applicants are able to provide some evidence to show that the spectrum is not being used, this may help their application. The exact nature of what would be suitable would likely depend on the applicant's request.
Most respondents identified the locations of masts, their technical characteristics and operator coverage as the most important information that should be made available. Google explained that the location, maximum EIRP, antenna characteristics, centre frequency, and channel bandwidth were all required. AWTG added that the incumbent's coverage maps, received power level estimations, current incumbent deployment locations, propagation/loss maps and/or models, any information on expected future deployments or plans of the incumbent, and monitoring information on spectrum use in terms of interference and security would all be helpful.	We are aware that some of the requested information is sensitive both for commercial and potentially national security reasons, and may be difficult to make available directly and in full to applicants. However, information is already in the public domain. Information on current and future mast deployments can be found through contacting local council planning departments. We are aware of websites that gather information using crowd sourced information and mobile applications that provide information on the signal strength and other technical information of a mast. Finally, those applicants with access to monitoring equipment should be able to carry out their own site surveys to monitor if the spectrum is in use in that area.
Energy Networks Association wanted a detailed and up-to-date list of all spectrum deployments and "assets", both current and planned.	We are aware that such information may be available via local councils. MNOs also provide lists of planned deployment sites for the upcoming 12 months as part of the planning process.
BT, Telefónica, Three and Vodafone advised that only basic information about MNO deployments should be supplied and that applicants should be directed to the relevant MNO to discuss further. Vodafone advised that anonymised information on availability could be acceptable but went on to say that anything more detailed is confidential and they cannot	We will work with the MNOs and ask that they provide contact information so that these requests can be directed to the relevant area in their organisation if appropriate.

support Ofcom publishing details of deployments and specific spectrum bands.	
Three was very concerned about the prospect of sharing commercially sensitive information with Ofcom or third parties. Simon Pike commented that it was difficult to see what useful information could be provided to third parties that would not compromise the confidentiality of MNOs' future business plans.	We understand that sharing commercial information with third parties is not welcomed and for this reason our proposed approach aims to reduce this. Ofcom has processes in place and statutory limitations covering the information that we hold. However, we note that for a number of years the MNOs have been providing local councils with their proposed upcoming 12-month rollout plans.
Coverage and capacity maps IET & 5GFF, Fairspectrum and Telet Research all suggested that Ofcom should produce maps of geographic coverage. Fairspectrum advised that these should be band-specific. Angetech Consultants suggested that UK operators should be encouraged to publish "deemed consent" frequency maps.	Ofcom does provide coverage maps but these are not band specific. We will continue to look at making more information available and will take these comments into consideration.
Telet Research explained that these maps needed to be much more detailed showing coverage and capacity information. These should indicate gaps in each operator's service. This was also raised by a confidential respondent ([✂]) who wished for information on "Not Spots" or poorly served areas.	Although we understand the need to know where spectrum is not being used we are unsure as to why information regarding the cell capacity would be necessary for this process.
Telet Research and Telint both expressed concerns over the current coverage tools and models used by Ofcom. Telet Research stated that current Ofcom mobile coverage prediction tools have proved to be largely inaccurate. It would like to see capacity and network availability included in any future coverage obligations associated with spectrum licences. This should be coupled with actual spectrum use data (showing	The coverage checker map uses signal level predictions provided by the four UK MNOs. Ofcom has tested actual coverage in various locations around the UK, and uses the results to set the thresholds for voice calls used on the map. We continue to conduct testing, work with the mobile operators and analyse consumer feedback with a view to improving the accuracy of the map.

waveform/power/location/capacity) as an overlay on the existing coverage maps.	
Telint stated that it believes Ofcom's coverage prediction model is not able to function at mmWave. However, it suggested that there could be an opportunity to build upon the work carried out by Ordnance Survey and the University of Surrey's 5G Innovation Centre (5GIC) in this space. The simple act of further refining models to be fit for the 5G era itself will make possible more efficient use of spectrum.	As noted, mmWave spectrum will likely be used for small cell rather than macro deployments and therefore predicting such coverage may be more difficult.
<u>Up-to-date information</u> Neutral Wireless and Ericsson highlighted the importance of access to accurate and up-to date coverage information and spectrum utilisation information on a localised basis. Federated Wireless and Google also advised that up-to-date information on assignments would also be crucial for any future DSA approach. Google advised that information on deployments and use can be held in a public or confidential database depending on the incumbent user.	We agree that up-to-date information is valuable and will try to ensure that any information provided by Ofcom is kept up to date.
<u>Register of previous applications</u> Fairspectrum and three confidential respondents ([✂]) all requested that Ofcom provide an online register of previous applications similar to a local authority's register of planning applications. Fairspectrum also advised that as part of this, feedback on denied Local Access licence applications would also help.	At present it is not clear to us the value of such a tool but we will monitor the situation. If we believe such a tool would bring benefit then we may consider this point further.

Question 21 - Do you agree with our proposal to have a defined licence period and do you have any comments on the proposed licence term of three years?	
Issue raised	**Ofcom response**
Arqiva, Fairspectrum, Motorola, Neutral Wireless, Nominet, UCC and a confidential respondent ([✂]) all agreed that the three-year period was reasonable. Others also agreed but also requested that Ofcom allow for periods shorter than three years. Disruptive Analysis advised that a three-year timescale provided an easy way of holding MNOs to account if they reject an application with the intention to build.	We note these responses.
17 respondents requested access for periods longer than three years.	We address this point below.
[✂]. DTG was concerned about how we would ensure applicants had sufficient security of tenure to justify a business case.	We believe that the proposed three-year licence duration will provide a suitable timeframe for MNOs to understand their rollout plans and give the third party enough time to deploy and run its services, where this is not the case a longer period can be requested but this may require a commercial agreement with the MNO.
<u>Should allow licences to be issued for periods of less than 3 years</u> Google, Neutral Wireless, Nominet, Simon Pike, University of Strathclyde, Vodafone and a confidential respondent ([✂]) all stated that Ofcom should consider periods shorter than three years to address temporary use cases.	We note the comments received and agree that licences should be available for periods shorter than three years if requested. However, the default period will remain at three years.
<u>Three-year licence is too short</u> AWTG, JRC, Nokia, Telet Research and two confidential respondents ([✂]) stated that the proposed minimum term was inadequate to stimulate the market and be enough time to get a return on investment.	We believe that the three-year period is a reasonable time frame over which an MNO will have sufficient certainty about their deployment plans to respond quickly to the request. It also provides new users with a

Dense Air stated that three years is too short to underpin a credible business case. Telet Research said they expected the normal period for ROI to be five or more years in order to encourage investment in local infrastructure by non-MNOs. Nokia said we needed to strike a fair balance between an MNO's needs with their planning horizons and the need of allowing for return on investment for private local licence owners (as equipment depreciation periods are in the range of 7-10 years). AWTG, Ericsson, CBNL, DTG, Shyam Telecom and two confidential respondents ([✂]) all stated that a three-year licence was not long enough and that Ofcom should consider granting access for five years. Kent County Council explained that a five-year licence for community-led mobile extension schemes would allow local and national funders to gain support and investment. A shorter period may result in a reluctance to support and invest in the associated infrastructure where there appears to be a relatively short time-limited benefit. ip.access was concerned that the three-year licence period was too short. It explained that in the US, the CBRS Priority Access Licence (PAL) duration was debated heavily, and was extended from three years (with no right of renewal) to ten years. JRC stated that a defined licence period was important, but the proposed minimum term was inadequate to stimulate the market developments being encouraged by Ofcom as it would not afford sufficient security of access for new operating models to become established. Shyam Telecom expressed the view that three years is in general a short period, in view of providing an installation and a service.	substantial time period over which they can expect to use the spectrum. When developing our proposal, we needed to balance the needs of potential applicants and the reasonable expectations of the MNOs to deploy services in the long term. Applicants that wish to have a longer duration licence are able to do so, but this may require a commercial agreement with the MNO. We have placed no restrictions on the length of any such agreement. Alternatively, applicants can apply for a low or medium power sharing licence in one or more of the three proposed shared access bands.

<u>Indefinite duration</u> IET & 5GFF, Telint and Ruckus Wireless all stated a preference for an indefinite licence duration. IET & 5GFF and Telint suggested that this could work if MNOs were able to give 12 months' notice for the return of the spectrum through a revocation clause.	We do not consider that an indefinite licence with a 12-month notice period or less would be likely to be a workable solution in practice. A licensing approach where the licensee has little or no control over when and under what circumstances its rights could be withdrawn would undermine their business case. It is preferable when making an investment decision, that certainty of access is provided upfront. If an indefinite licensing approach was adopted, it could also impact on the incumbent MNO. If an MNO did decide to deploy within an area, any existing customers' service may be lost and the MNO might be blamed for service being lost early, despite being within their rights to deploy. For these reasons we think that having a defined licence term provides a clear indication of the period that the new user has access to spectrum for, so they can make their investment decisions based on this and can provide clear messaging to their customers as to the likely duration of their service.
<u>Licence duration should be flexible</u> Angetech Consultants, Dense Air, FMS Solutions, techUK and a confidential respondent ([✂]) suggested that a one-size-fits-all approach would not work. All proposed that the licence period should be considered on a per application basis. Dense Air asked for Ofcom's view on the maximum licence period that could be considered. Angetech Consultants did not think a one-size-fits-all approach would work. They highlighted that they did not anticipate that in urban areas spectrum would be available for long durations but in rural areas, especially for higher frequency spectrum bands, multi-year licences could be available.	We agree and each application will be dealt with on a case by case basis. We have tried to keep the process flexible to allow a variety of application proposals. As discussed previously, we are to amend our original proposals and allow for licence periods shorter than three years on request. Periods over three years we will also accept providing this can be agreed between the applicant and MNO.

Licence duration should be defined by commercial agreement Three stated that the licence term should be based on a commercial agreement with the provider. Vodafone also argued that for longer term access, a commercial agreement would give the sharer the confidence that Vodafone would support renewal of the licence.	This could be the case for any licences issued for periods over three years. For periods less than three years it may still be advantageous for the third party to have an agreement in place but there is no requirement to do so.
Licence renewal process Heathrow Airport, UKWISPA & INCA and a confidential respondent ([✂]) all commented that when applying to renew the licence the process should be efficient and if possible automatic. The licensee should expect to be able to have access again at the end of the three-year licence period if no notice has been received from MNO that the status of regarding their deployments has changed.	Our aim is to keep the process as simple as possible and minimise the burden on all parties. However, MNOs must be given the opportunity to reassess the application for a further duration to allow them to consider any changes to their deployment plans.
Question 22 - Do you have any other comments on the proposed Local Access licence terms and conditions?	
Issue raised	**Ofcom response**
Trading Vodafone and a confidential respondent ([✂]) did not support our proposals that the licence should be tradable. The confidential respondent advised that in their view, shared spectrum should not be tradable as this will hinder coordination agreements. Vodafone did not agree that licence should be tradable as it removes certainty around the competence of the sharer. They advised that given that the MNO has agreed to relinquish access to spectrum, any spectrum trade should	Although we note the concerns raised over making these licences transferable, Ofcom is required to do so under the new European Electronics Communications Code (EECC), which came into force in December 2018.[33] This is currently in the process of being transposed into UK law. Article 51 of the EECC requires Member States to allow all licensees[34] to trade rights of use. Given this, we will permit concurrent and outright total transfer of these licences.

[33] European Commission, *Directive (EU) 2018/1972*, 11 December 2018, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=EN (accessed 11 July 2019)
[34] Subject to a minor exception for those licences for broadcasting or those issued free of charge.

require its consent (there could be a condition that this consent should not be unreasonably withheld).	The rights of use which could be transferred would be the existing licence terms and conditions (including duration, transmitter locations and other technical parameters) as initially agreed when the licence was first issued. Therefore, we do not expect that allowing transfers of the same terms would have any impact on the incumbent licensee.
Revocation period BT wanted a much shorter licence revocation notice if we proceeded with our proposal.	The five-year revocation period on the grounds of spectrum management will only apply to those licences with a duration of five years or more. This clause mirrors the same provision in the MNO licence. The licence already allows Ofcom to revoke or restrict use in cases where a breach of licence has occurred. This is set out in Schedule 1 of the WT Act.
IET & 5GFF, Telint and UKWISPA & INCA suggested that a revocation clause could be added to the licence. UKWISPA & INCA advised that the MNO should be required to ask for the spectrum back, ideally with a notice period of two years. IET & 5GFF and Telint suggested one year, but this was based on having an indefinite licence duration.	We do not believe that providing a 12-month revocation clause provides sufficient security of tenure for third parties. The defined licence period provides clarity to users on which they can build their business case.
Shutdown provision AWTG, Motorola and a confidential respondent ([✂]) all proposed a provision that would allow the shutdown of these licences if the incumbent licensee needed to use the spectrum due to an emergency. [✂].	This is already included in Clause 13 of the licence and is a standard provision in most Ofcom licences.
Should include UIOLI condition Facebook, IET & 5GFF and Motorola all put forward proposals that the Local Access licence should include a UIOLI condition that set out timescales that the spectrum should be put to use. Facebook suggested that this must be to deploy a service within the first year and should be	At this time we are not proposing to include such a provision in the licences. However, as we have stated, the licences that Ofcom issue are non-exclusive. If the Local Access licence is not being used then Ofcom retains the right to authorise another user of the spectrum in that area.

required to return the licence if service is not operational for six months or longer. IET & 5GFF suggested that licences should be revoked immediately if found not transmitting.	
Include capacity sharing condition IET & 5GFF proposed inserting a condition that would require any Local Access licensee to allow the incumbent MNO to use a determined percentage of the new cells' capacity to service their own customers. This, they argued, would provide MNOs with an incentive to share access to spectrum.	The Local Access licensee and MNO can come to some arrangements on sharing capacity and this would fall outside of provisions set out in the licence. However, we do not believe that imposing such a condition on all licensees would be appropriate as compliance would depend on the type of service being offered and technology being used.
All transmitter locations need to be registered Telefónica wanted to make sure all new base station locations are registered (and terminals, unless these are licence exempt) and changes to this are expressly prohibited.	All transmitters will either be licensed individually or within a defined area. These will be agreed on a case by case basis with discussions between the parties.
Must be synchronised with MNO Vodafone advised that the technical provisions should not allow the use of a restrictive emissions mask. Instead they advised that the synchronised frame structure should always be used. They explained that the MNO using the adjacent spectrum should be made aware when another MNO has agreed to a Local Access licence request.	This will depend on the technology being deployed. If access can only be secured via synchronisation to minimise interference then we would include such a provision in the licence. We will work with all parties to come to an agreement.
Commercial protection Telet Research said that they would like to see some kind of commercial protection for small Local Access licence holders where the incumbent wishes to activate a service in the same area at the end of the licence period. They would like to see some kind of special provision made to protect infrastructure that is deployed within buildings and on private property. Without some clearly defined commercial protection for Local	These issues fall outside of Ofcom's power set out in the Wireless Telegraphy Act. MNOs continue to have rights to deploy in the band so are free to deploy services in all areas providing they do not interfere. The Local Access licence provides for no guarantees of continued access to spectrum after the licence period has ended. If longer term access is

Access licence holders the uptake on these licences is likely to be severely constrained.	required then we would advise that parties seek to gain agreement with MNOs.
Question 23 - Do you agree with our fee proposal for the new Local Access licence? Please give reasons supported by evidence for your views.	
Issue raised	**Ofcom response**
Most respondents agreed that the proposed fees were proportionate. Digital Colony Partners, Google and Western Power Distribution all urged Ofcom to keep the fees as low as possible to encourage productive uses of otherwise vacant frequencies. Telint disagreed with the proposed fee, suggesting that in deep rural areas even £1 could be deemed too much. A confidential respondent ([✂]) explained that the fees were too high and should be similar to the 5.8 GHz fees [*these are a £50 annual licence with a registration cost of an additional £1 per transmitter after the first 50 transmitters*]. Urban Connected Community advised that the proposed fees would be fine for small scale, but for large sites these could become prohibitive.	We have set these fees in order to reflect the cost to Ofcom in processing the requests. The fee is not subject to the same area constraints that the Shared Access licences are. Deployments can be for a single base station or for an area.
ip.access stated that they were in favour of a flat one-off fee and agreed that the fee seems reasonable. Angetech Consultants suggested that the fee should be a one-off and not paid on an annual basis.	The proposed fee covers the costs of Ofcom carrying out the assessment. We can confirm that the £950 fee we proposed is one-off, not an annual fee. Our aim is to keep the fee as low as possible.
Nominet, Neutral Wireless, Telint and the University of Strathclyde stressed that costs may be reduced by automating the process.	Although we acknowledge that the individual transactional costs of an automated process compared to a manual approach may be lower, this does not account for the costs associated with setting up such a process. Where transactional volumes are high this would reduce the per licence cost for an automated process but demand for these licences is uncertain. If demand is low then this would significantly increase the cost of the licence given the costs of building and maintaining an automated authorisation platform.

techUK and Telefónica both advised that the fees should be set at a level where MNOs are able to recover their costs through commercial arrangements. However, Three warned that the relatively low fee will encourage many applications and potentially lead to great administrative burden for MNOs.	The fees reflect Ofcom's costs and will not be passed onto MNOs. Our process allows for commercial agreements to be entered into but does not preclude access if these are not in place for a period up to three years.
A confidential respondent ([✂]) was concerned that as the fee is modest Ofcom should have clear rules to avoid a land grab and should ensure that the applicant is bona-fide and the motivation behind the application is legitimate.	As we have stated, the licences that Ofcom issues are non-exclusive. If the Local Access licence is not being used then Ofcom retains the right to authorise another user of the spectrum in that area.
Simon Pike advised that to minimise the risk of bogus applications, fees should be paid on application.	Ofcom does not charge for licence fees upfront. Ofcom is only able to charge for the licences it issues and not for processing an application. We note though that purely speculative applications received without supporting evidence will not be considered.
Vodafone suggested that the fee should be on a per operator basis; if an applicant applies for spectrum that covers multiple incumbent MNOs then the cost should be based on the number of operators contacted.	Our current proposal is to charge on a per application basis. At present we see no justification to base Ofcom's costs on a per incumbent licensee basis.
Kent County Council asked that Ofcom differentiate between commercial applications and community-led ventures.	Given this is a cost-based fee, we will treat all applicants the same in regards to the fees that they pay.
<u>Licence renewal costs</u> FMS Solutions and Shyam Telecom both raised concerns over the fees when applying to renew the licence. FMS Solutions urged that if additional tenure periods are added then the fee should be proportional. Shyam Telecom stated that in the case of extension after three years, the fee should correspond to the proposal for the Shared Access licences.	Ofcom will try to ensure costs are kept down. However, at the end of the licence any renewal application will be run through the same process and incur a similar cost. Therefore, at this time any future renewals will be charged the same fee.

A2. 2300 MHz shared spectrum coexistence with 2400 MHz licence exempt services

A2.1 The 2300 MHz shared spectrum sits between the 2350-2390 MHz spectrum ("the 2.3 GHz award") recently awarded to Telefónica and the 2400 MHz band used by Wi-Fi, Zigbee, Bluetooth and Bluetooth-like technologies (such as assistive listening devices (ALDs)) on a licence exempt basis.

A2.2 In this annex, we present the qualitative analysis on the possible risks of interference from new users in the 2300 MHz shared spectrum to uses in the 2400 MHz band. We focus on Wi-Fi as one of the most widely used technologies in that band and ALDs as some stakeholders raised a particular concern regarding ALDs during the preparations of the 2.3 GHz award. However, we consider that our conclusions are also applicable to other licence exempt technologies such as Zigbee, which can be found in devices such as smart meters, building automation and smart home technology.

- This annex is structured as follows:

Existing Studies	We review the relevant findings from our coexistence analysis undertaken for the 2.3 GHz award,[35] [36] [37] as well as some independent studies undertaken by the European Commission's Joint Research Centre (JRC) which focused particularly on the 2300 MHz shared spectrum.[38] [39]
Assessment of interference risk from new uses in 2300 MHz shared spectrum	We consider the factors contributing to interference in realistic use cases as well as additional mitigations that might reduce the risk of certain sets of circumstances occurring where the risk of interference is the highest.
Summary of our previous position	We summarise our previous assessment of the risk of interference from low power and medium power 2.3 GHz base stations to licence exempt services.

[35] Ofcom, *Public Sector Spectrum Release (PSSR): Technical coexistence issues for the 2.3 and 3.4 GHz award*, https://www.ofcom.org.uk/consultations-and-statements/category-1/pssr-2014

[36] Ofcom, *Technical coexistence issues for the 2.3 and 3.4 GHz award: Annexes 7-13*, 19 February 2014, https://www.ofcom.org.uk/__data/assets/pdf_file/0034/46699/annexes_7-13.pdf

[37] Ofcom, *Compatibility of 2.3 GHz 4G mobile with Assistive Listening Devices, 11 May 2017*, https://www.ofcom.org.uk/research-and-data/technology/radio-spectrum/compatibility-of-2.3-ghz-4g-mobile-with-assistive-listening-devices

[38] European Commission Joint Research Centre, *JRC Study on Coexistence between 2.3 GHz TD-LTE and 2.4 GHz Wi-Fi: Preliminary findings*, 24 June 2016, https://www.cept.org/Documents/wg-se/32511/se-16-info024_tdd-lte-and-Wi-Fi-at-24-ghz

[39] European Commission Radio Spectrum Committee, *Presentation of the study on Assistive Listening Devices (ALDs) in the 2.3-2.4 GHz band by the JRC: Working Document (RSCOM17-17)*, 9 March 2017, https://circabc.europa.eu/d/d/workspace/SpacesStore/e47fae70-e491-450d-ba18-46e58647d639/RSCOM17-17%20JRC_study_on_ALDs.pdf

Stakeholder responses and our updated final position	We summarise the stakeholder responses to the December 2018 consultation in relation to coexistence and address each of the issues raised.

Existing Studies

Wi-Fi

A2.3 Wi-Fi operates using the 2400 MHz band on a licence exempt basis, with the lower edge of channel 1 at approximately 2402 MHz.

A2.4 Our previous Wi-Fi assessment[37] [38] consisted of:

a) lab based measurements of Wi-Fi devices to quantify their vulnerability to 4G signals from both base stations and mobile handsets;

b) field trials to validate the effects predicted in real world environments; and

c) quantitative analysis, using measurement results, to extrapolate the potential scale of interference between large scale 4G networks and Wi-Fi deployments, based on a 10% reduction in throughput.

A2.5 Based on these laboratory measurements and field trials (including measuring the performance impact in a congested environment at London Victoria Station), we concluded that the overall impact of potential interference from 4G operating in 2350-2390 MHz was small and likely to affect only a very limited number of Wi-Fi users. As a result, no intervention in the market was necessary to protect Wi-Fi from potential interference.

A2.6 Nevertheless, we recognised at the time that the risk could be reduced further for Wi-Fi devices if they had improved receiver performance.

A2.7 In 2016, JRC also carried out a study on coexistence between 4G in the 2300 MHz shared spectrum and Wi-Fi in the adjacent 2400 MHz band. Measurement of performance degradation was undertaken on a selection of Wi-Fi devices using simulated and recorded 4G signals considering both base station and handset signal configurations. The testing demonstrated that some Wi-Fi equipment suffered from what they termed minor to significant throughput loss depending on the frequency offset and separation distance from the 4G interference sources.

A2.8 We recognise that the results in the existing studies suggest that there could be a risk of some degradation to the performance of Wi-Fi when a combination of circumstances occur at the same time. In particular, if:

a) the Wi-Fi signal is very weak, operating at its minimum signal levels; and

b) the Wi-Fi equipment does not have sufficiently good filters to reject signals from the adjacent mobile band; and

c) mobile handsets use the 2300 MHz shared spectrum; and

d) mobile handsets transmit at near full power of +23 dBm; and

e) the mobile handset is particularly close to the Wi-Fi receiver, i.e. less than one metre away.

Assistive Listening Devices

A2.9 ALDs operate using the 2400 MHz band on a licence exempt basis. As part of the 2.3 GHz award and in response to stakeholder concerns, we carried out a comprehensive and real-life based test programme[37] to investigate the risk of 4G mobile handsets[40] in the 2350-2390 MHz spectrum causing interference to ALDs above 2400 MHz. The test programme included comprehensive testing of 46 equipment combinations provided by thirteen ALD manufacturers. We found in that study that no ALDs suffered from any kind of link failure, or complete audio drop out, the risk of which concerned some ALD stakeholders the most. Furthermore, there was no other obvious interference effects like audio delay when a smartphone was close to an ALD. Although some minor degradation was observed, we demonstrated that this did not result directly from 4G interference.

A2.10 When undertaking additional tests on a small sample of ALD devices with 4G operating in the 2300 MHz shared spectrum, two devices were potentially affected by interference from a mobile handset transmitting close to maximum power,[41] and within 0.5 metres of the ALD. On one occasion, nearly one second of audio was lost at the beginning of an ALD transmission. However, the underlying adaptive algorithm of the ALD radio technology then worked as it should do and the ALD link recovered and worked well afterwards.

A2.11 We did not investigate further at the time as the 2300 MHz shared spectrum was not part of the award spectrum. However, we did not believe that there was sufficient consistency in the results of the additional tests to determine an underlying cause of the interference.

A2.12 In contrast, JRC's work[38] focused on testing with 4G use in the 2300 MHz shared spectrum. However, they used a more laboratory focused methodology compared to our user scenario focused approach. Rather than using real handsets as the interferer, two signal generators were set up to replay signals recorded from handsets on a previous occasion. The JRC setup used a range of wanted signal levels for the ALD link, including a weaker level than would be expected from a system operating at its maximum practical distance.

A2.13 Despite these pessimistic operating conditions, the JRC report concluded that ALDs were very robust to interference when configured in line with typical operational conditions, so that the frequency hopping mechanism of the underlying technology worked effectively to combat aggressive interference. They did note, however, that at very weak ALD signal strengths, some devices exhibited audio performance degradation, which they classified as ranging between minor and severe.[42] However, in our view, this was a more susceptible configuration than the way ALDs would be used in practice.

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[40] Our previous analysis had demonstrated that the greatest risk of interference would be from handsets in close proximity rather than from base stations which, although output higher power, would be further away.
[41] Measured mean power of +20 dBm
[42] The JRC studies defines a "severe" degradation as a "temporary or permanent loss of signal, more than two glitches or short dropouts, strong wobbling or other distortions reducing speech intelligibility, strong increase in background noise"

A2.14 We note that when an ALD link was established with a very low wanted signal strength, representing a very large separation between the ALD transmitter and receiver, some performance degradation would be exhibited even before any interference is introduced. Moreover, during our previous engagements with manufacturers and users, they indicated that ALDs utilising Bluetooth or Bluetooth-like technologies were not designed for long-range use.

A2.15 In summary, although the previous coexistence studies suggest that ALDs are quite robust to 4G interference in most real-life scenarios, they also indicated that, when a combination of circumstances occurs in parallel, there could be a risk of interference leading to a severe audio degradation. In particular if:

a) the ALD system is working at or beyond its normal maximum range and therefore has a very weak signal; and

b) the mobile handset transmits at near full power of +23 dBm; and

c) the mobile handset is located particularly close to the ALD receiver, i.e. less than one metre away.

Assessment of interference risk from new uses in 2300 MHz shared spectrum

A2.16 Whilst we considered the risk of interference from base stations when preparing for the 2.3 GHz award, the maximum base station powers are much lower in 2300 MHz shared spectrum compared with that award band. We therefore consider that any risk of interference will be from handsets in the 2300 MHz shared spectrum.

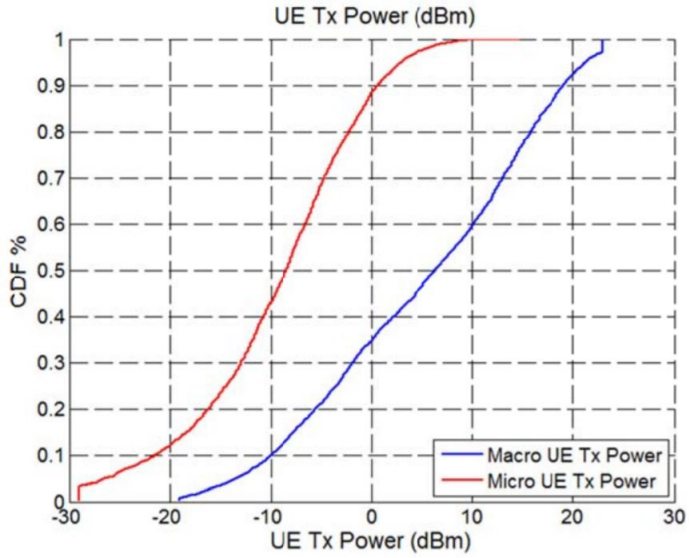
A2.17 As indicated above, there could be a risk of interference to Wi-Fi and ALDs if a number of circumstances were to combine. In practice, we consider that there is a low likelihood that these circumstances will occur individually and a much lower likelihood that they will occur simultaneously. We set out the reasons for this below.

Moderate handset transmit power

A2.18 We consider the likelihood of mobile handsets transmitting at near full power to be low. Mobile handsets are designed to optimise the performance of the communication link and to minimise power consumption to extend battery life. They operate under power control from the base station and typically only operate at full power when they are far from the serving base station or the signal is blocked by obstacles such as trees, buildings, etc. Figure A2.1 below (taken from ECC report 203)[43] illustrates that a mobile handset – also known as user equipment (UE) – would transmit much less power (rarely above 10 dBm) when connected to a medium power micro base station than when connected to a high power macro base station (which would be above 10 dBm for 40% of the time).

[43] ECC, *ECC Report 203*, 14 March 2014, https://www.ecodocdb.dk/download/f5cd8793-5692/ECCREP203.PDF

Figure A2.1: Comparison of transmit power profiles of handsets. Macro UE refers to a handset connecting to a macro base station while Micro UE refers to a handset connecting to a micro base station



Source: ECC Report 203

A2.19 Indoor base stations are similarly likely to lead to much lower handset powers as indoor coverage solutions are designed to provide strong coverage across the area. However, when an indoor mobile handset is connected to an outdoor base station, there are additional building entry losses that degrade the signal and lead to a requirement for the handset to transmit at a higher power.

Operating in close proximity

A2.20 There are two potential interference scenarios where mobile handsets could operate in close proximity with ALDs and Wi-Fi devices.

A2.21 In the first scenario, if a user was to hold a handset directly next to their ALD or Wi-Fi receiver, this would create a circumstance with almost no separation between the two devices.

A2.22 In the second scenario, disruption or reduced quality could occur as a result of some circumstances created by another party and the user is unaware.

A2.23 Similar to the 2.3 GHz award analysis, we are not concerned about the use of 2300 MHz and Wi-Fi or ALD technology within the same device as we expect the manufacturer to ensure that both systems would work together in the device.

A2.24 We noted that if indoor base stations were located very close to Wi-Fi access points that the static nature of both devices could lead to performance reduction of both systems. However, we further noted that where these are installed in close proximity, the installation would be under the control of the licensee.

A2.25 In general, we are less concerned about a small risk of interference when it is likely to be transient and under the influence of the affected party. Therefore, we would be more concerned with a risk that the second scenario above would occur. In addition, handsets operating in an indoor environment may be more static than those outdoors where the users are moving around more. So, of more concern is the situation where handsets are indoors (and therefore more static) but using higher power (as a consequence of being connected to an outdoor base station).

Victim receiver operating in weak signal

A2.26 For ALDs, normal day-to-day use of ALD systems does not typically involve operating with very weak wanted signals at the ALD receivers, meaning that they are more robust to interference in practice than the JRC report suggested. We also understand that information on the distance range of the link, or how reducing the range can have a positive impact in mitigating any interference, is often provided as part of the ALD equipment specification. We believe that these extremely weak signals will not occur very often.

A2.27 For Wi-Fi that has been designed to provide good coverage throughout an area such as an office block or warehouse, the wanted power levels will also remain high in order to maximise the performance of the network.

What we are doing already to reduce the risk

A2.28 In the unlikely event that interference was to occur in practice it would be possible for either the 2300 MHz shared spectrum user or the ALD or Wi-Fi user to adjust their location slightly in order to increase the separation distance between the two devices or to improve the radio conditions.

A2.29 Whilst we showed in our analysis for the 2.3 GHz auction that interference was unlikely, we also noted that improvements to the receiver performance of Wi-Fi devices would be beneficial in reducing the risk of interference.

A2.30 The Radio Equipment Directive (RED)[44] was introduced in 2014 and came into full effect in 2016. Amongst other things, this directive added a requirement for radio equipment to have appropriate receiver performance. Since 2015, we have been working with industry and ETSI[45] to ensure that harmonised equipment standards for the 2400 MHz band include requirements for improved receiver performance. These new standards will lead to a reduction in the risk of interference for new equipment.

A2.31 As part of our previous work on ALDs, we worked closely with different charities involved with those who use ALDs. As part of this we contributed to some guidance information for ALD users to help them understand the possible impacts of using a mobile handset in very

[44] European Commission, *Radio Equipment Directive (RED)*, https://ec.europa.eu/growth/sectors/electrical-engineering/red-directive_en
[45] European Telecommunication Standards Institute, https://www.etsi.org/

close proximity to their ALD and therefore to help them avoid those circumstances with very low physical separation between the mobile handset and the ALD receiver.

Further approaches to reducing risk

A2.32 In the December 2018 consultation we said that we did not consider that interference is likely to occur, however, we recognised that the existing information on which we base our qualitative assessment was not specifically developed for the particular deployment scenarios and frequencies that we proposed. In the context of widescale use of Wi-Fi and the more vulnerable nature of users of ALD systems, albeit operating on a non-interference non-protection licence exempt basis, we believed it would appropriate to take a cautious approach, at first, for the introduction of new users in the 2300 MHz shared spectrum.

A2.33 We proposed three additional measures.

a) Firstly, we recognised that the risk of interference with fixed infrastructure may be mitigated with careful deployment and use of the 2300 MHz shared spectrum system. For example, we intended to provide guidance to users saying that the risk of interference to Wi-Fi can be reduced by creating physical separation between the new low power base stations and Wi-Fi access points (or other devices operating in the 2400 MHz band). We said that the improvement will depend on the actual performance of the base station; the filtering available within the Wi-Fi access point and that greater separation in space may be necessary when using the lowest Wi-Fi channels;

b) Secondly, we said that we would provide guidance advising that licensees should consider carefully whether there is a risk of mobile handsets using the 2300 MHz shared spectrum operating near those ALD receivers that are operating over an increased range (such as in the school classroom scenario that we studied in our previous work as one of the worst-case scenarios). In those circumstances, the users may wish to consider whether one of the alternative Shared spectrum frequency bands is more appropriate for their uses; and

c) Finally, through our technically assigned coordination approach, we said that we could consider whether specific proposed deployments are likely to cause a higher than expected risk of interference to other users. We therefore expected that, initially, spectrum is likely to be widely available for indoor low power uses but outdoor and medium power base stations may be available in select locations only. We expected the availability of outdoor and medium power base stations to increase over time as we gained more knowledge of real-world coexistence.

Summary of our previous position

Low power use

A2.34 Overall, we considered the risk of interference from low power deployments in 2300 MHz shared spectrum to co-channel MOD uses and ALDs/Wi-Fi in the adjacent 2400 MHz band

to be low. There remain some sets of circumstances which, although are very unlikely to occur in real life, could lead to interference. We said that we would make applicants aware that careful base station deployment should be considered in locations close to Wi-Fi access points and in environments where long-range ALD systems are more likely. We said that we would consider on a case by case basis whether outdoor base stations can be authorised when taking the various other uses and risks into account at those locations.

Medium power use

A2.35 We said that medium power base stations are more likely to be outdoors and this will increase the handset power for handsets located in an indoor environment because the handset would need to increase its power when compared to a handset communicating with a base station in the same building. We said that we would take a precautionary approach and expected that medium power will be available in selected rural locations only if we consider that interference to other users is minimal.

A2.36 We expected the availability of outdoor and medium power uses to be more generally available once we gained more knowledge of real-world coexistence.

Stakeholder responses and our decision

Summary of responses

A2.37 BT was particularly concerned that Wi-Fi coverage could be reduced citing the CEPT report we had referenced[46] which stated that interference effects from mobile operating in 2390-2400 MHz were 15 dB greater than mobile operating below 2390 MHz.

A2.38 Cisco challenged our coexistence analysis on several points:

a) **Previous studies considered a previous generation of Wi-Fi technology and not the most recent generation going on the market this year**. Cisco argued that Wi-Fi 6 is substantially different to the previous generation of 2.4 GHz Wi-Fi devices (IEEE 802.11n). It said that Wi-Fi 6 uses broader channels, makes greater use of multi-user MIMO antenna technology and has a greater range.

[46] European Commission Joint Research Centre, *JRC Study on Coexistence between 2.3 GHz TD-LTE and 2.4 GHz Wi-Fi: Preliminary findings*, 24 June 2016, https://www.cept.org/Documents/wg-se/32511/se-16-info024_tdd-lte-and-Wi-Fi-at-24-ghz

b) **There are realistic scenarios where a 2.3 GHz base station could be installed within 3 meters of Wi-Fi users including residential and commercial scenarios and the evidence shows an increased risk of Wi-Fi degradation at this range**. Cisco argued that our consultation suggested that the Wi-Fi energy detection threshold[47] would be triggered on Wi-Fi channel 1[48] when an indoor LTE base station operating at 24 dBm was within 3 m of the Wi-Fi device and that this would degrade Wi-Fi operation. Cisco said that Wi-Fi devices could be that close to 2390-2400 MHz base stations in typical residential or commercial scenarios. Cisco considered that coordination could reduce the risk of interference from medium power base stations to installed Wi-Fi access points, however coordination would not be possible with Wi-Fi terminals, for example, when a mobile phone is being used as a Wi-Fi hotspot for tethering a laptop.

c) **Ofcom cannot rely on improved Wi-Fi receiver standards because these have not been agreed in Europe yet and these would only improve coexistence for new devices, not the very large number of Wi-Fi devices in use today**. Cisco observed that even if new receiver standards were brought in 2019, it would take a long time for these improved devices to represent a significant proportion of the Wi-Fi devices in use.

d) **The "additional measures" proposed by Ofcom in the consultation are insufficient to overcome the risks.** Cisco argued that advising users to separate low power base stations and Wi-Fi access point might work with for enterprises with IT professionals but would not help in other deployment scenarios. Cisco gave the example of someone using their mobile phone as a personal hot spot to tether another device such as a laptop or tablet and it said that coordination could not prevent this sort of hot spot being set up close to a 2.3 GHz indoor base station.

e) **The IEEE LAN/MAN Standards Committee said that we should have also taken into account IEEE 802.15.4 technologies**. These technologies including Zigbee (as used in many home automation radio systems including smart energy meters) and Wi-Sun.

Our response

We do not consider Wi-Fi 6 devices to present a materially worse coexistence challenge when compared to IEEE 802.11n devices.

A2.39 Both technologies support up to 40 MHz bandwidth at 2400 MHz: IEEE 802.11n uses channel bonding to combine two 20 MHz carriers whilst Wi-Fi 6 supports this bandwidth natively and we do not consider that this difference materially changes the coexistence challenge.

A2.40 Wi-Fi 6 adds multi-user MIMO to 2400 MHz but it also adds other multiple-antenna techniques to 2400 MHz including standards-based sounding and beamforming[49] and these

[47] The IEEE 802.11n Wi-Fi energy detection threshold is -62 dBm / 20 MHz.
[48] Wi-Fi channel 1 is centred on 2412 MHz and has a bandwidth of 22 MHz.
[49] Cisco, *The Cisco Wi-Fi 6 White Paper*, p. 1, accessed 12 July 2019, https://www.cisco.com/c/dam/en/us/products/collateral/wireless/white-paper-c11-740788.pdf

can help to increase the robustness of Wi-Fi connections. Wi-Fi beamforming can reduce the risk of interference from other sources, including 2.3 GHz mobile, by increasing the wanted signal and creating a "null" in the direction of other signals when those other sources are spatially separated from the Wi-Fi access point, the client and the propagation channel between the two.

A2.41 The range enhancements in Wi-Fi 6 comes from two main sources: beamforming (as we have discussed in the previous paragraph); and OFDMA[50] used in conjunction with lower data rate modes. OFDMA allows for clients to connect to an access point using a subset of the available OFDM subcarriers which can be used in conjunction with low data rate coding and modulation to increase the sensitivity of Wi-Fi by up to 8 dB.[51] However, operation in this mode is intended for IoT applications rather than conventional consumer applications and we do not consider that this would significantly increase the vulnerability of Wi-Fi 6 to interference.

A2.42 Taken together, we consider that the new technologies in Wi-Fi 6 will make future devices more robust to interference and not less robust. We are, therefore, not concerned that our previous analysis did not include Wi-Fi 6 devices.

We do not consider that our decision to authorise 2.3 GHz base stations and terminals will significantly degrade Wi-Fi services

A2.43 We consider that the way we proposed to authorise this band remains appropriate for managing coexistence with adjacent licence exempt services. We acknowledge BT's observation that the interference risk could be 15 dB higher from devices in 2390-2400 MHz than device operating below 2390 MHz, however, the low and medium power base station licences (24 and 42 dBm per carrier EIRP respectively) are more than 15 dB lower power than the base station power limits in the 2350-2390 MHz licences (61 dBm / 5 MHz EIRP per cell). For these medium and low power scenarios is likely that interference would only occur when the Sharer and the 2400 MHz Wi-Fi user are close together, perhaps under control of the same organisation.

A2.44 We acknowledge that the risk of interference, whilst still small, could be higher for the medium power licences and outdoor licences. For this reason, we continue to consider that it is appropriate for us to authorise Sharers in this band for low power licence in indoor locations only, at first, and expect to make low power outdoor and medium power licences available as we gain more knowledge of real-world coexistence.

A2.45 We acknowledge that Wi-Fi to Wi-Fi coexistence will be ameliorated in dense environments in Wi-Fi 6 using OBSS & BSS colouring which dynamically adjusts the energy detection thresholds and that this will not help coexistence with adjacent LTE. However, we still consider that Wi-Fi coexistence with LTE in 2390-2400 MHz will not be significantly more difficult than coexistence with other Wi-Fi devices in 2400-2483.5 MHz.

[50] OFDMA: Orthogonal frequency division multiple access.
[51] *The Cisco Wi-Fi 6 White Paper*, para. 3.4

We expected that improved receiver standards could improve coexistence in the future, but did not rely on this in our previous analysis.

A2.46 Our previous analysis was not based on the assumption of improved receiver standards but devices on the market at the time. However, we still consider that improved receiver standards could improve coexistence for many future devices. Improved receiver standards were agreed in ETSI on the 1 July 2019 which means that new devices based on these standards can be expected to enter the market in 2021 and will replace existing Wi-Fi devices at a rate which will depend on the replacement rate for the specific device that the Wi-Fi radio is embedded into.

We consider that our previous analysis took all licence exempt services into account.

A2.47 We consider that the coexistence analysis discussed above for Wi-Fi also applies to other licence exempt services including those based on IEEE 802.14.5. These technologies include Zigbee (as used in many home automation radio systems including smart energy meters) and Wi-Sun.

A3. Coexistence in the 26 GHz band

A3.1 This annex contains the technical information and analysis when assessing potential interference from an indoor 5G (IMT-2020) system to the existing services and future co-channel outdoor 5G system in the 24.25-26.5 GHz band.

Existing services considered in the analysis

A3.2 The 24.25-26.5 GHz band is the lower part of the 26 GHz band,[52] which is the European pioneer[53] millimetre wave band for 5G recently harmonised[54] across Europe with a requirement to make spectrum in this frequency range available in the 2020 timeframe.[55]

A3.3 In the UK the lower part of the 26 GHz band, or parts thereof, is used for fixed links, satellite receiving Earth stations for the Earth Exploration Satellite Service (EESS), Programme Making and Special Events (PMSE) equipment and Short Range Devices (SRDs).

A3.4 Adjacent services in the 23.6-24 GHz frequency band such as the radio astronomy earth stations and the EESS passive sensing satellites could also be affected by the introduction of 5G indoor services.

Modelling of 5G indoor system

5G indoor system characteristics

A3.5 The indoor 5G system is modelled based on the parameters provided by ITU-R WP5D in Attachment 2 of document ITU-R 5-1/36.[56] These parameters are used together with the beamforming antenna model taken from Recommendation ITU-R M.2101-0.[57]

A3.6 Every Base Station (BS) is modelled with an "8 x 8" beamforming antenna array with a 23 dBm/200 MHz Total Radiated Power (TRP) level.

A3.7 The indoor terminal stations (referred to as User Equipment, UE, in some related documents) are modelled with a "4 x 4" beamforming antenna array.

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[52] The 'full' 26 GHz Band is 24.25-27.5 GHz

[53] Radio Spectrum Policy Group (RSPG) opinion 16-032: http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

[54] European Commission (EC) Decision (EU)2019/784: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019D0784&from=EN

[55] European Electronic Communications (EECC) Code - Directive 2018/1972: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=EN

[56] Attachment 2 of *ITU-R 5-1/36: Characteristics of terrestrial IMT systems for frequency sharing/interference analyses in the frequency range between 24.25 GHz and 86 GHz*.

[57] ITU-R, *Recommendation M.2101: Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies*, February 2017, https://www.itu.int/rec/R-REC-M.2101/en

5G indoor deployment model

A3.8 The indoor 5G Base Station (BS) deployment model used in the studies is adapted from the generic indoor deployment model described in parameters document[56] and the analysis is based on a deployment of three ceiling-mounted BSs evenly spaced in a 1,800 m^2 floor area.

A3.9 The indoor terminal stations are modelled at 1.5m above a 3m standard floor height. These terminals are uniformly distributed across the floor of the building and beamforms to their nearest BS less than 15m away. Due to this proximity the indoor terminals will transmit well below their maximum power for most of the time, and the interference from these terminals is significantly lower than the BSs and is therefore not taken into account in the technical analysis.

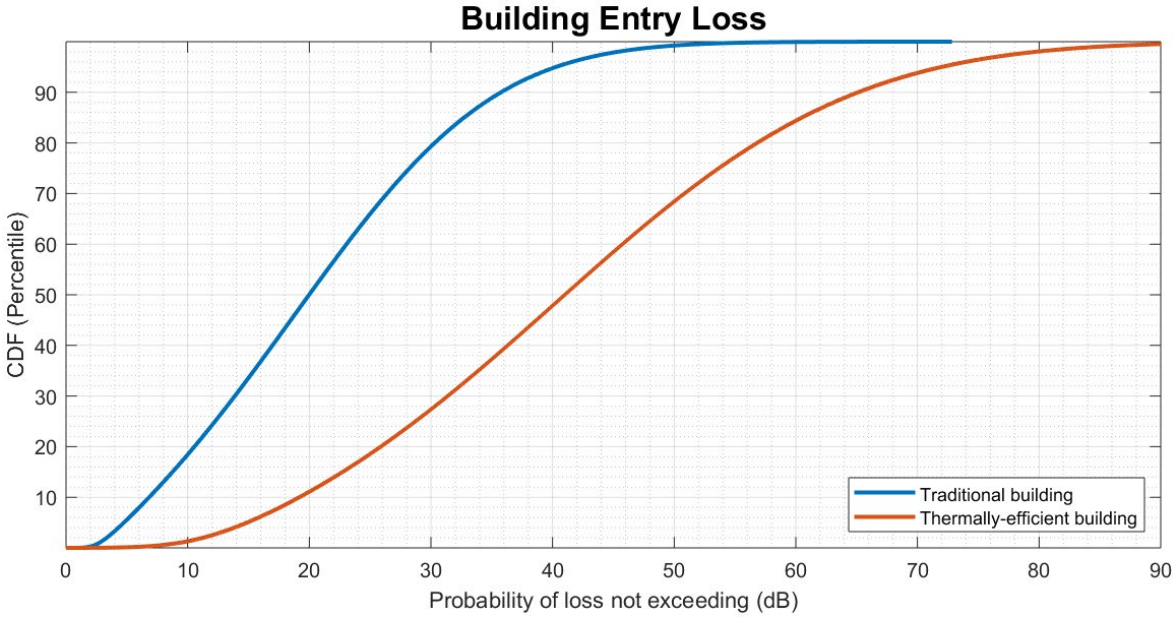
Building penetration loss

A3.10 The building penetration loss is modelled according to Recommendation ITU-R P.2109-0[58] which defines building entry loss for traditional and thermally-efficient buildings. This Recommendation shows a strong correlation to the measurement data collected on building penetration loss in the UK for this frequency band (26GHz).[59]

A3.11 The cumulative distribution function (CDF) on the building penetration loss according to the Recommendation is shown in Figure A3.1. At 50th percentile, the thermally-efficient buildings will have about 21 dB more loss than traditional buildings.

[58] ITU-R, *Recommendation P.2109-0: Prediction of building entry loss*, June 2017, https://www.itu.int/rec/R-REC-P.2109/en
[59] ITU-R, *WP3J Contribution 110: Building entry loss - Measurements covering 25 to 73 GHz frequency range* (United Kingdom), 15 March 2017, https://www.itu.int/md/R15-WP3J-C-0110/en

Figure A3.1: Building entry loss for both traditional and thermally-efficient building



Coexistence analysis with fixed links

A3.12 These are point-to-point wireless links that carry a mixture of low, medium to high capacity data traffic between specific geographic locations. They are individually assigned and licensed on a first come first served basis and used for a variety of applications such as; backhaul for mobile network operators, fixed networks, utilities, emergency service traffic, TV broadcast distribution, and by several other private and public entities. Fixed links are the main use of the 24.5-26.5 GHz band with around 1,800 licences currently on issue across the whole of the UK.

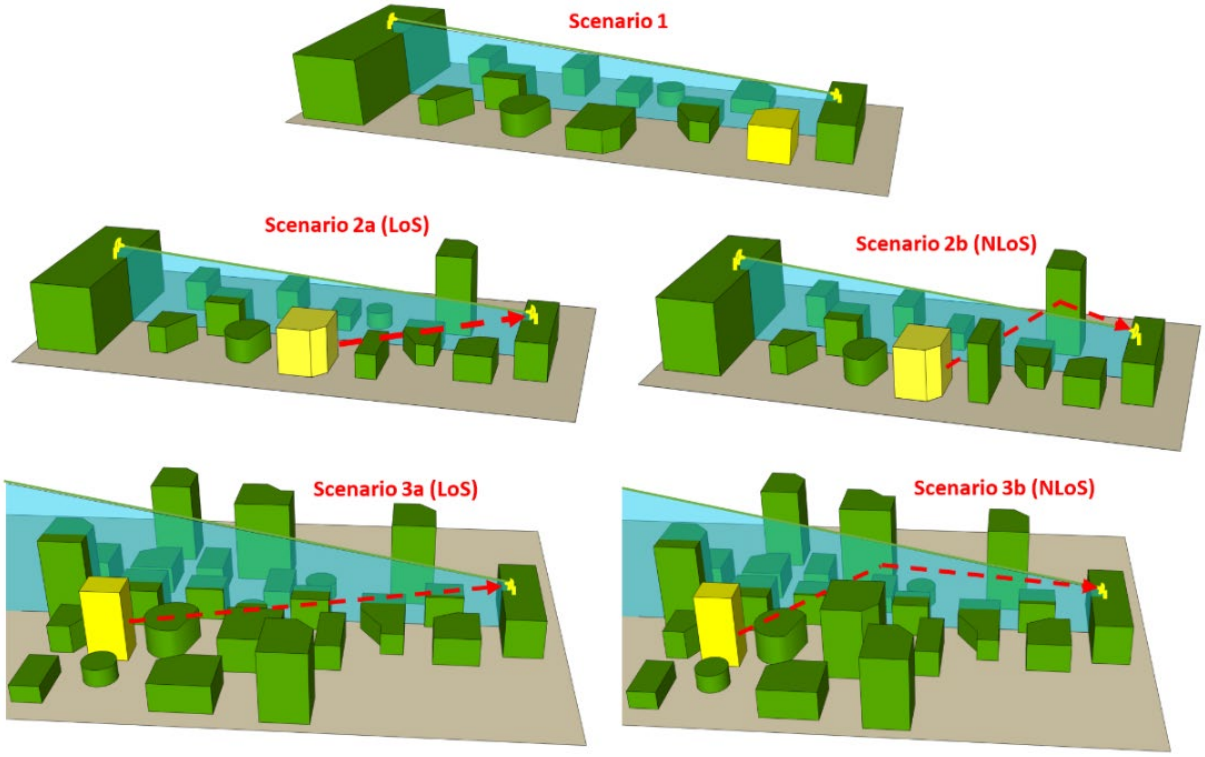
A3.13 The technical analysis is based on the fixed links deployments in London; which is one of the few cities in the UK with high number of fixed links.

Fixed link interference scenarios

A3.14 At the time of the analysis there were about 137 bi-directional fixed links in the frequency range 24.5-26.5 GHz around London. After reviewing all the links, the situations where interference to fixed links is most likely can be generalised into 3 different interference scenarios.

A3.15 Figure A3.2 below shows the 3 difference interference scenarios considered for the fixed links study.

Figure A3.2: Generalisation of interference scenario for fixed links study



A3.16 **Scenario 1:** Fixed link receiver high above clutter

i) This scenario represents about 85% of fixed link receivers in the case study.

ii) Direct interference path is through the roof where attenuation of the interference signal to the fixed link receiver will be extremely high and any signal diffracted from indoor 5G to the fixed link receiver will be very small. Therefore, interference based on this scenario is negligible.

A3.17 **Scenario 2:** 5G indoor at same level as the fixed link receiver at a distance of 100m

i) Higher floors of the building (100m away) in direct view of the fixed link receiver.

ii) This scenario represents about 10% of fixed link receivers in the case study.

A3.18 **Scenario 3:** 5G indoor at same level as the fixed link receiver at medium distance (300m)

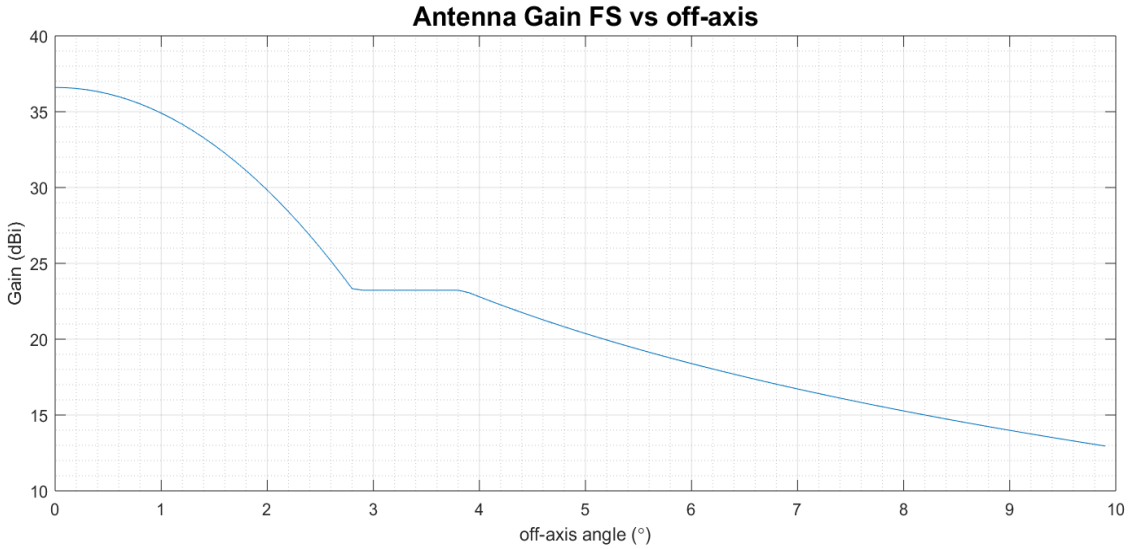
i) Higher floors of the building (300m away) in direct view of the fixed link receiver.

ii) This scenario represents about 5% of fixed link receivers in the case study.

Technical characteristics of fixed links

A3.19 The antenna gain pattern for the Fixed Service is based on Recommendation ITU-R F.699-8[60] and is shown in Figure A3.3. This is an envelope antenna radiation pattern where the gain in the sidelobes of real antennas is likely to be lower.

Figure A3.3: Fixed links antenna gain based on Rec. ITU-R F.699-8



A3.20 The single-entry level of -134.5 dBW/MHz is used to assess the risk of interference to fixed links. This is based on our fixed link national assignment criteria[61] (on the 137 links), where the level ranges from -134.5 dBW/MHz to -90.6 dBW/MHz.

Methodology in assessing the risk of interference to fixed links

A3.21 The 5G indoor BS are evenly-spaced across the floor and the indoor terminals are distributed uniformly inside the building. The propagation model used in the analysis is based on Section 4.2.1 of Recommendation ITU-R P.1411-9[62] where the transmitter is below the rooftop and the receiver is on top of the rooftop.

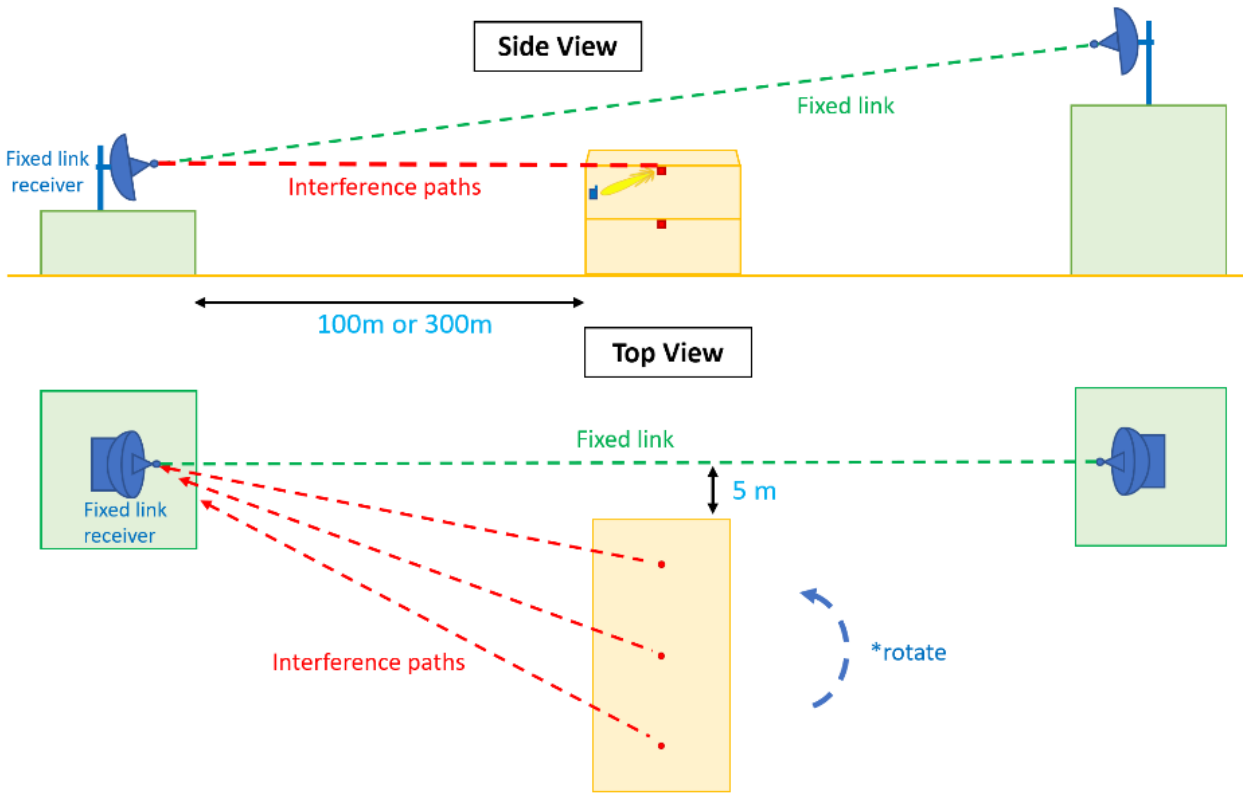
A3.22 The interference Scenarios 2 and 3 considered in the simulation is shown in Figure A3.4.

[60] Recommendation ITU-R F.699-8: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz

[61] This criterion takes into account the available fade margin on the fixed link and that the propagation mechanism will be correlated with the 5G interference path due to the short distance involved in this case.

[62] Recommendation ITU-R P.1411-9: Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz

Figure A3.4: Interference Scenarios 2 and 3



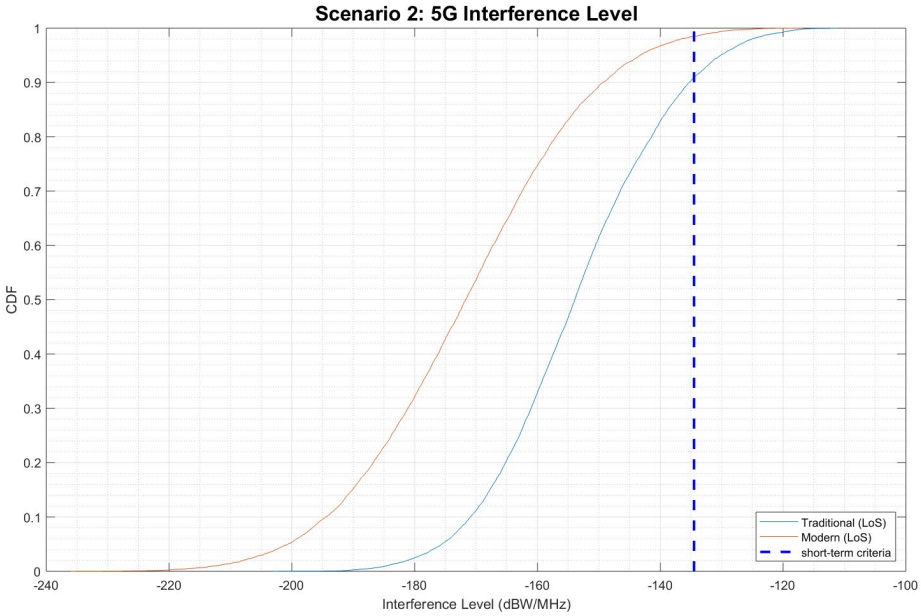
A3.23 The '5G indoor building' is modelled 5m away (perpendicular) from the fixed link assuming the link runs through the middle of a narrow two-lane street. This will create a situation where interference to the fixed link receiver is most likely.

A3.24 The simulation uses a Monte Carlo approach (with 10,000 snapshots) considering the variability of the 5G beamforming antenna gain, building penetration loss and the path loss. The risk of interference is then assessed against the most sensitive criteria level of -134.5 dBW/MHz.

Result of the fixed links analysis

A3.25 The result of the Monte Carlo analysis for Scenario 2 (100m) is shown in Figure A3.5.

Figure A3.5: CDF of 5G interference (Scenario 2)



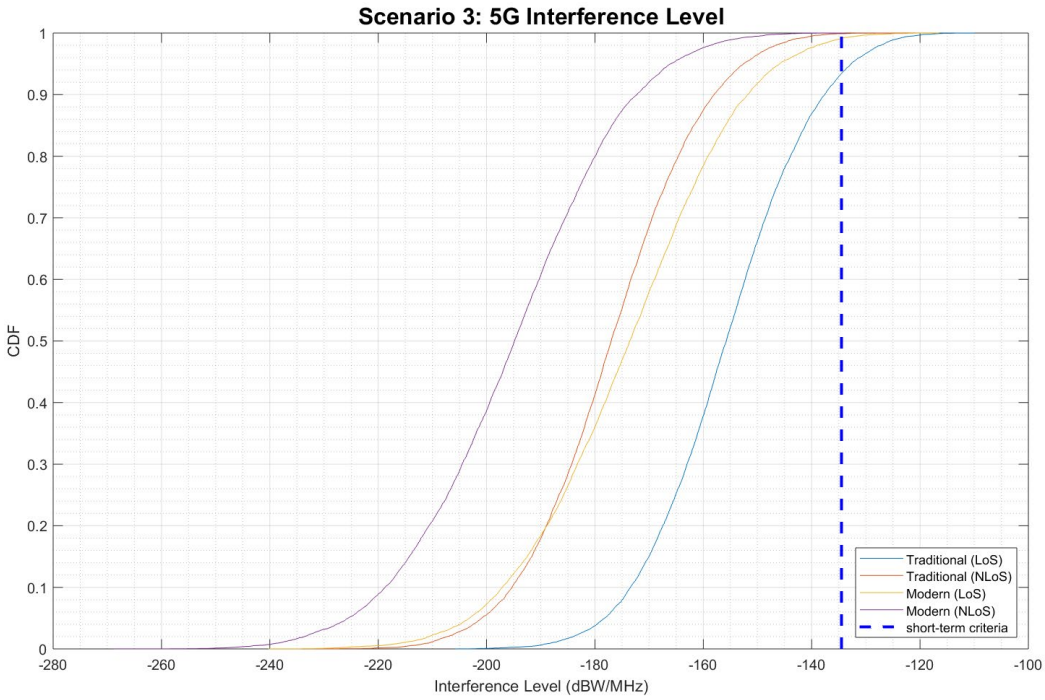
A3.26 The cumulative distribution function (CDF) shows the probability of not exceeding the interference level. It is assumed that there are no obstructions to the interference path at 100m away, therefore only line-of-sight (LoS) is considered.

Table A3.1: The cross-point in the CDF for Scenario 2

Building Type	Probability of interference less than -134.5 dBW/MHz
	LoS
Traditional	0.909
Thermally-efficient (Modern)	0.9849

A3.27 The result of the Monte Carlo analysis for Scenario 3 (300m) is shown in Figure A3.6.

Figure A3.6: CDF of 5G interference (Scenario 3)



A3.28 The CDF shows the probability of not exceeding the interference level. Both the line-of-sight (LoS) and non-line-of-sight (NLoS) path loss components were considered.

Table A3.2: The cross-point in the CDF for Scenario 3.

Building Type	Probability of interference less than -134.5 dBW/MHz	
	LoS	NLoS
Traditional	0.9345	0.991
Thermally-efficient (Modern)	0.999	0.9999

A3.29 The risk of interference can be calculated based on some assumptions and information from the 137 links studied:

i) The medium/high buildings in the London area is assumed to be 80% 'Modern' (thermally-efficient) and 20% "Traditional"

ii) Equal probability of line-of-sight and non-line-of-sight component with no strong justification favouring any.

iii) Scenario 2 represents 10% of the fixed link receivers in the London study area

iv) Scenario 3 represents 5% of the fixed link receivers in the London study area

v) Based on the most sensitive assignment threshold of -134.5 dBW/MHz.

A3.30 The percentage of cases that exceeds the single-interferer threshold of -134.5 dBW/MHz is 0.34%[63]. This is an upperbound as there are less sensitive threshold in the fixed links assigned.

Conclusion on fixed links study

A3.31 The analysis shows that with a large number of indoor 5G deployments, the percentage of cases that exceeds the single-interferer threshold of -134.5 dBW/MHz is 0.34%. This level is based on the most sensitive criteria found from the 137 links in London with indoor 5G deployments in medium to high-rise buildings, therefore it is an upperbound. This percentage will be even smaller when considering a more detailed analysis higher single-interference threshold levels.

A3.32 The risk of interference should not increase if it is to consider the aggregation effect of more than a single 5G indoor deployment within the vicinity of the fixed link receiver. The fixed link assignment technical policy[64] takes account of the aggregated-interferer situation where at 26 GHz the I/N threshold level is set at -2.3 dB taking into account a 2dB interference margin. This means 4 interferers with identical interference level to the fixed link receiver; which is unlikely for the 5G indoor deployment.

A3.33 The London case study used for the analysis represents a near worst-case due to the amount of fixed links assignment in a dense city environment. The study also assumes that the fixed link channel is overlapping (co-channel) with the channel used by the 5G indoor base station.

Earth Exploration Satellite Service (EESS) / Space Research Service (SRS) earth stations

A3.34 There is currently one receiving earth station (Harwell) in the 25.5-26.5 GHz band that is authorised under a grant of Recognised Spectrum Access for Receive-only Earth Stations (RSA for ROES). This earth station is used as part of the Earth Exploration Satellite Service (EESS) to collect data downlinked from an Earth observation satellite in geostationary orbit. This data contains information about the Earth and its environment, including Earth imagery and weather data.

A3.35 Our space spectrum strategy[65] indicated that we expect that only a small number of earth stations may be needed to realise the benefits from the EESS data as once downlinked to Earth, the data can be distributed to users using terrestrial (e.g. fibre) networks. Grants of RSA for ROES are also available in this band for receiving earth stations in the Space

[63] This is calculated by summing the following:
a) Scenario 2 : ((1-0.909)×20% + (1-0.9849)×80%)×10%
b) Scenario 3 (Traditional) : (((1-0.9345)×50% + (1-0.9910)×50%)×20%)×5%
c) Scenario 3 (Modern) : (((1-0.9990)×50% + (1-0.9999)×50%)×80%)×5%

[64] Ref to OFW446

[65] https://www.ofcom.org.uk/__data/assets/pdf_file/0030/96735/Statement-Space-Spectrum.pdf

Research Service (SRS). This would involve downlinking data from spacecraft, for example the International Space Station or deep space missions to Mars and other planets.

A3.36 Grants of RSA for ROES are currently available in the UK across 1 GHz of bandwidth in the 25.5-26.5 GHz band. These are issued primarily to provide a specified maximum interference level at the earth station receiver, not to be exceeded, which is then taken into account with respect to any future assignments in the band. There are no current plans to extend, in frequency terms, the 26 GHz RSA product further within the UK.

Technical characteristics of the EESS earth station

A3.37 The technical parameters used in the analysis for the Harwell EESS Earth station are shown in Table A3.3 below.

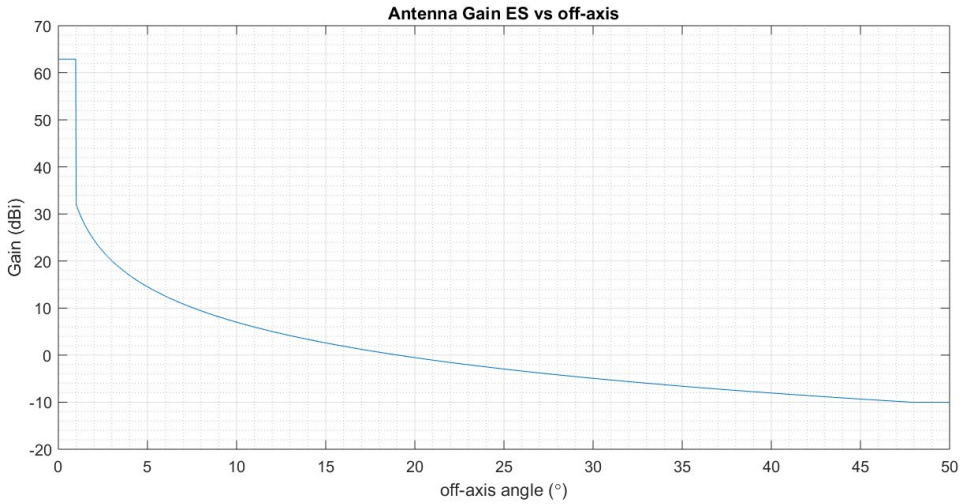
Table A3.3: Technical parameters of the EESS receiving Earth station

Parameter	Value
Frequency	25.5-26.5 GHz
Antenna diameter	6.8 m
Antenna centre height above ground	6 m
Antenna Gain	62.9 dBi
Antenna pattern	Rec ITU-R S.465
Earth station location	SU 48273 86772
Satellite GSO location	9^{o} East
I/N (20% of time)	-10 dB
System noise temperature	300 K
Receiver system noise	-143.8 dBW/MHz
Interference criteria (20% of time)	-153.8 dBW/MHz

A3.38 The EESS antenna gain according to Recommendation ITU-R S.465-6[66] is shown in Figure A3.7. This is an envelope antenna radiation pattern where the gain in the sidelobes of real antennas is likely to be lower.

[66] Recommendation ITU-R S.465-6: Reference radiation pattern for earth station antennas in the fixed-satellite service for use in coordination and interference assessment in the frequency range from 2 to 31 GHz.

Figure A3.7: EESS antenna gain according to ITU-R S.465-6



A3.39 The Harwell EESS Earth station is pointing towards a GSO satellite at 9° East, hence forming an elevation angle of 30.2° above the horizon. Therefore, reading from Figure A3.7, the maximum antenna gain at the horizon is -5 dBi. At about 45° off-axis angle, the antenna gain at the horizon drops to -10 dBi.

Methodology in calculating the separation distance for the EESS earth station

A3.40 The ECC Recommendation 19(01)[67] adapts the Time Variable Gain (TVG) methodology outlined in Appendix 7 of the Radio Regulation to take into account of the beamforming characteristics in the 5G system. The Recommendation specifies the minimum propagation loss to ensure protection to the EESS Earth station, and for this technical study Recommendation ITU-R P.525-3[68] (free-space attenuation) is used to calculate the propagation loss which then leads to determining the minimum separation distance. This Recommendation was used to calculate the propagation loss instead of Recommendation ITU-R P.452-16[69] because it speeds up the simulation and the difference to using the more accurate model in ITU-R P.452 is not significant for the distance being considered in the analysis.

A3.41 According to the ECC Recommendation, the required minimum propagation loss is then given by

$$L_{req}(p_v) = P_t + G_t(p_n) + G_r - I(p), \quad \text{where}$$

- Lreq is the required minimum propagation loss;
- Pt is the total transmitting power level (dBW) in the reference bandwidth of a transmitting 5G base station;

[67] The ECC Recommendation 19(01) - Technical toolkit to support the introduction of 5G while ensuring, in a proportionate way, the use of existing and planned EESS/SRS receiving earth stations in the 26 GHz band and the possibility for future deployment of these earth stations

[68] Recommendation ITU-R P.525-3: Calculation of free-space attenuation

[69] Recommendation ITU-R P.452-16: Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz

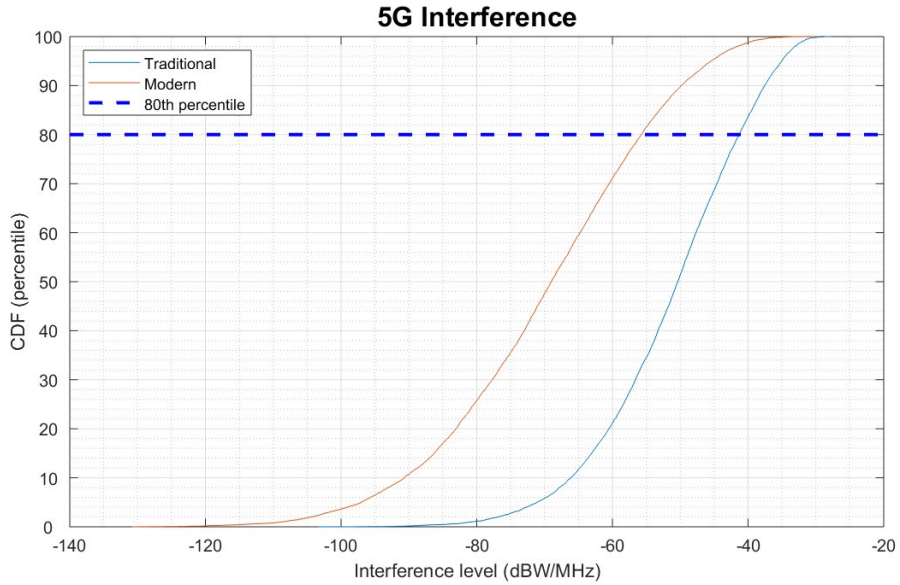
- $I(p)$ is the protection threshold (dBW) in the reference bandwidth to be exceeded for no more than $p\%$ of the time at the input of the antenna of the receiving EESS earth station that may be subject to interference;
- $Gt(pn)$ is the gain towards the horizon of the transmitting antenna (dBi) that is exceeded for $pn\%$ of the time on the azimuth under consideration;
- Gr is the gain towards the physical horizon for a given azimuth (dBi) of the EESS Earth station antenna;
- (pv) is the minimum required propagation loss (dB) for $pv\%$ of the time; this loss must be exceeded by the propagation path loss for all possible $pv\%$ values retrieved from the considered gain complementary cumulative distribution function. pv is the time percentage that approximates the convolution between the variable horizon gain and the propagation mode path loss.

A3.42 The Monte Carlo simulation used in the study takes into account of the statistical distribution of the 5G antenna gain and the building penetration loss. According to the recommendation, the time percentage interference criteria (i.e. 20% for EESS) equates to the percentage of snapshots of the combined antenna gain and building penetration loss distribution. Therefore for this analysis, the 5G interference level will be taken at 80th percentile on the CDF of the total interference before taking into account of the path loss. The separation distance can then be calculated from the minimum path loss required to satisfy the protection criteria of the EESS earth station.

Result of the EESS earth station analysis

A3.43 The CDF 5G interference curve from the Monte Carlo simulation is shown in Figure A3.8.

Figure A3.8: 5G indoor interference CDF



A3.44 The minimum path loss required to meet the protection criteria at the maximum EESS earth station antenna gain at the horizon is given as

$$\text{Traditional building} \quad : \quad L_{req}(p_v) = -41.2 - 5 - (-153.8) = 107.6 \text{ dB}$$

Modern building : $L_{req}(p_v) = -55.7 - 5 - (-153.8) = 93.1$ dB

A3.45 The minimum path loss required to meet the protection criteria at the minimum EESS earth station antenna gain at the horizon is given as

Traditional building : $L_{req}(p_v) = -41.2 - 10 - (-153.8) = 102.6$ dB

Modern building : $L_{req}(p_v) = -55.7 - 10 - (-153.8) = 88.1$ dB

A3.46 Using ITU-R P.525-3, the minimum separation distance calculated from the minimum path loss is summarised in the following Table.

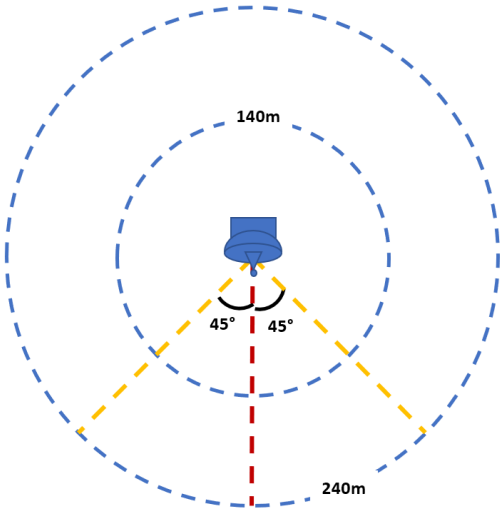
Table A3.4: Minimum separation distance to avoid interference, traditional and modern buildings

Building type	Minimum separation distance	
	Horizon boresight	>45° off-axis
Traditional	240m	140m
Modern (thermally-efficient)	50m	30m

Conclusion on EESS Earth station study

A3.47 Figure A3.9 shows the minimum separation distance assuming "Traditional" building for the penetration loss. Terrain and clutter were not considered in the calculation but it will have minimum effect to the separation distance.

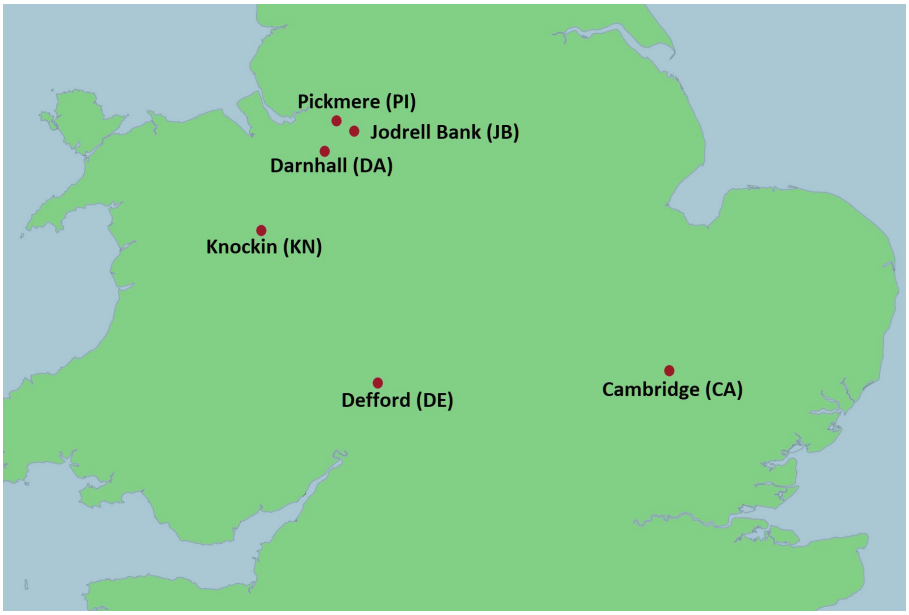
Figure A3.9: Separation distance based on "Traditional" building entry loss calculation



Radio Astronomy Service (RAS) in the adjacent frequency band 23.6-24 GHz

A3.48 There are several radio astronomy stations in the UK which are spread across six different radio astronomy sites, that are authorised under grants of RSA for the 23.6-24 GHz band.

Figure A3.10: Location of radio astronomy sites with grants of RSA for the 23.6-24 GHz band



Technical characteristics of radio astronomy stations

A3.49 The protection level for the radio astronomy stations located at the six sites are listed in Table A3.5

Table A3.5: The protection level according to the RSA grant in our database.

No	Observatory	Location	Spectrum quality benchmark level (SQB)
1	Cambridge (CA)	Cambridge	-210 dBW/250 kHz
2	Darnhall (DA)	Cheshire	-168 dBW/250 kHz
3	Defford (DE)	Worcestershire	-168 dBW/250 kHz
4	Jodrell Bank (JB)	Cheshire	-210 dBW/250 kHz
5	Knockin (KN)	Shropshire	-168 dBW/250 kHz
6	Pickmere (PI)	Tabley, Cheshire	-168 dBW/250 kHz

A3.50 The table shows that the stations at Jodrell Bank and Cambridge are the most sensitive with a protection level of -210 dBW/250 kHz (i.e. -204 dBW/MHz) while the rest are protected to a level of -168 dBW/250 kHz (i.e. -162 dBW/MHz).

A3.51 The antenna gain for the radio astronomy stations assumed in sharing studies is 0 dBi in all horizontal directions, in line with ITU-R Recommendation RA.769.[70]

A3.52 We have used the unwanted emission limit from 5G base station of -42 dBW/200 MHz (i.e. -65 dBW/MHz) in the 23.6-25 GHz band based on the EC Decision (EU)2019/784[71].

Methodology in calculating the separation distance for radio astronomy stations

A3.53 The methodology to calculate the separation distance is the same as in the EESS case using the Time Variable Gain (TVG) methodology outlined in ECC Recommendation 19(01). The Recommendation specifies the minimum propagation loss to ensure protection to the radio astronomy station, and for this technical study Recommendation ITU-R P.525-3[72] (free-space attenuation) is used to calculate the propagation loss which then leads to determining the minimum separation distance.

A3.54 The required minimum propagation loss given by

$$L_{req}(p_v) = P_t + G_t(p_n) + G_r - I(p), \quad \text{where}$$

- L_{req} is the required minimum propagation loss;
- P_t is the total transmitting power level (dBW) in the reference bandwidth of a transmitting 5G base station;
- $I(p)$ is the protection threshold (dBW) in the reference bandwidth to be exceeded for no more than p% of the time at the input of the antenna of the receiving RAS station that may be subject to interference;
- $G_t(p_n)$ is the gain towards the horizon of the transmitting antenna (dBi) that is exceeded for p_n% of the time on the azimuth under consideration;
- G_r is the gain towards the physical horizon for a given azimuth (dBi) of the radio astronomy station antenna, and in this case is 0 dB;
- (p_v) is the minimum required propagation loss (dB) for p_v% of the time; this loss must be exceeded by the propagation path loss for all possible pv% values retrieved from the considered gain complementary cumulative distribution function. p_v is the time percentage that approximates the convolution between the variable horizon gain and the propagation mode path loss.

Result of the radio astronomy analysis

A3.55 There are two protection levels to be considered for radio astronomy which is -210 dBW/250 kHz (or -204 dBW/MHz) and -168 dBW/250 kHz (or -162 dBW/MHz).

[70] ITU-R, *Recommendation RA.769: Protection criteria used for radio astronomical measurements*, May 2003, https://www.itu.int/rec/R-REC-RA.769/en

[71] European Commission, *Commission Implementing Decision (EU) 2019/784*, 14 May 2019, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019D0784&from=EN

[72] Recommendation ITU-R P.525-3: Calculation of free-space attenuation

A3.56 The minimum path loss required to meet the protection criteria of the radio astronomy station with a protection level of -210 dBW/250 kHz is

Traditional building : $L_{req}(p_v) = -85.4 - (-204) = 118.6$ dB

Modern building : $L_{req}(p_v) = -104 - (-204) = 100$ dB

A3.57 As an illustration, the minimum path loss required to meet the protection criteria of the radio astronomy station with a protection level of -168 dBW/250 kHz is

Traditional building : $L_{req}(p_v) = -85.4 - (-162) = 76.6$ dB

Modern building : $L_{req}(p_v) = -104 - (-162) = 58$ dB

A3.58 Using ITU-R P.525-3, the minimum separation distance calculated from the minimum propagation loss is summarised in Table A3.6.

Table A3.6: Minimum separation distance to the radio astronomy stations

No	RAS station	Minimum path loss / separation distance	
		Traditional building	Modern building (thermally-efficient)
1	Cambridge (CA)	850m	100m
2	Darnhall (DA)	<10m	<10m
3	Defford (DE)	<10m	<10m
4	Jodrell Bank (JB)	850m	100m
5	Knockin (KN)	<10m	<10m
6	Pickmere (PI)	<10m	<10m

Conclusion on radio astronomy study

A3.59 Based on our existing criteria for the protection of radio astronomy, the separation distance required based on 'traditional' building penetration loss for both Cambridge and Jodrell Bank is around 850m but it will reduced to 100m based on 'thermally-efficient' buildings. The technical analysis shows that no separation distance is required for the remaining 4 radio astronomy stations.

A3.60 It is worth noting that terrain and clutter was not taken into account in the calculation and it could reduce the separation distance.

Programme Making and Special Events (PMSE)

A3.61 PMSE is allocated in the 24.25-24.5 GHz part of the band. Typical applications are temporary point-to-point and portable video links. The band has very low usage.

A3.62 Given the low PMSE usage in this band and the technical requirement of these links are similar to that of other fixed links, no coexistence issues have been identified with respect to indoor 5G.

Short Range Devices (SRDs)

A3.63 A number of licence exempt uses are possible on a non-protected basis as detailed in IR2030[73] along with the European Commission Decisions related to the harmonised use of 21.65-26.65 GHz for automotive radars, also known as short range radars or SRR. However, given the end date of 1 January 2022 for the 26 GHz SRR devices[74] these are expected to be gradually phased out.

A3.64 Therefore, given the general nature of SRD operation (operation on a non-protected basis) and the gradual phasing out of 26 GHz SRRs no co-existence issues have been identified with SRDs or automotive short-range radars.

Earth Exploration Satellite Service (Passive) in the adjacent frequency band 23.6 – 24 GHz

A3.65 The passive sensors equipped on the satellite using the frequency bands allocated to the Earth exploration-satellite service (EESS) (passive) are used for meteorology, climatology and other scientific purposes. These sensors are sensitive to emissions within their allocated frequency band and would need to differentiate the wanted signal from the interference signal.

A3.66 The EESS (passive) non-geostationary satellites (non-GSO) typically orbit the Earth at an altitude between 350 m and 1400 m, and some sensors make measurement at the same area on the Earth every day, while some repeat the measurement over a longer period.

A3.67 Some of the passive sensors are configured in a conical scan mode maintaining a constant ground incidence angle along the entire scan-lines. These scanners are used to monitor precipitation, near-surface wind speed, sea surface temperature, soil moisture, etc.

A3.68 Technical studies performed at ITU-R have shown that the 5G unwanted emission level of -42 dBW/200 MHz for the base station and -38 dBW/200 MHz for the terminal station provide adequate protection to the EESS (passive) service in the adjacent frequency band of 23.6-24.0 GHz. These levels have been included in the European Commission Implementing Decision (EU) 2019/784.

Future outdoor 5G Systems

A3.69 The 26 GHz band (24.25-27.5 GHz) is also intended for outdoor 5G systems and there are a number of existing co-existence studies performed to evaluate the interference between indoor and outdoor 5G systems. These studies are documented in the ECC Report 307[75]

[73] https://www.ofcom.org.uk/spectrum/radio-spectrum-and-the-law/licence-exempt-radio-use/licence-exempt-devices/short-range-devices-information

[74] European Commission, *Implementing Decision 2011/485/EU*: http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:198:0071:0072:EN:PDF

[75] Draft ECC Report 307 Toolbox for the most appropriate synchronisation regulatory framework including coexistence of MFCN in 24.25-27.5 GHz in unsynchronised and semi-synchronised mode https://cept.org/files/9522/Draft%20ECC%20Report%20307.docx

which looks at the synchronisation regulatory framework and was approved by the ECC for public consultation at the time of writing this Annex. Although most of the studies in the Report consider co-existence between adjacent channels, similar conclusions can be made if these systems are co-channel and includes building penetration loss. Drawing from the results and conclusions from this Report, the risk of interference from an indoor 5G system to an independent outdoor 5G system is considered low.

A3.70 The building penetration loss at 26 GHz is substantial and offers good isolation between indoor and outdoor 5G systems. With the current knowledge and assumption that the indoor 5G base station serving only indoor terminals, co-existence between these systems and future outdoor 5G systems is considered possible without the need for co-ordination.

A4. Coordination of new shared access licence applications

A4.1 In this annex, we present a summary of the coordination approach and parameters we will use as part of the assignment process for new shared access applications for low and medium power base stations in the 1800 MHz shared spectrum, 2300 MHz shared spectrum and 3.8-4.2 GHz.

A4.2 This updates the information presented in Section 5 of the December 2018 consultation.

A4.3 We discuss responses to our proposed coordination approach and parameters in Section 3 of the Statement.

Coordination approach

A4.4 We will coordinate new users with other licensed users in the same band. In line with our standard approach, we will not carry out coordination with other uses in adjacent bands.

A4.5 We will coordinate a potential assignment on the basis that it may both cause interference to other users within the shared spectrum as well as suffer interference from them.

A4.6 For shared access use in the 3.8-4.2 GHz band, we will coordinate proposed base stations with both existing and new users as follows:

a) other co-channel shared access low and medium power base stations in the band;

b) co-channel and adjacent channel fixed links – these will operate in channels 8 and 9 only (3815-3875 MHz paired with 4135-4195 MHz) following clearance of the 3.6-3.8 GHz band;

c) co-channel and adjacent channel UK Broadband (UKB) deployments in 3925-4009 MHz; and

d) co-channel and adjacent channel satellite earth stations (receive-only in this band);

e) the Crown use by MOD at Bude and Menwith Hill.

A4.7 For new shared access applications in the 1800 MHz shared spectrum, we will coordinate new base stations with other licensees' low and medium power base stations (including existing deployments by CSA licensees) in the band. As there is a single bandwidth available in this band, we will treat all base stations as co-channel assuming the carrier power is spread across a 3 MHz bandwidth, even if they are using only a portion of the available bandwidth.

A4.8 For new shared access applications in the 2300 MHz shared spectrum, we will coordinate new base stations with other licensees' low and medium power base stations in the band on a single 10 MHz co-channel basis.

A4.9 Finally, we will not take into account other base stations of the same licensee in our coordination approach as we consider that the licensee is better placed to manage interference in its own network(s).

Coordination parameters

A4.10 We will need relevant parameters of both new users and other services operating within the shared spectrum environment in order to undertake coordination. In some cases, these parameters will be provided as part of the licence application and enforced via the resulting licence, for example, the site location and EIRP. In other cases, we will use assumptions about equipment performance or deployment approaches, for example, assumptions about the transmit and receive antenna patterns.

A4.11 We present the list of parameters and assumptions we will use for coordination in Table A4.1 below. Parameters that are marked as 'user defined' will be taken from the details provided by the applicant.

Table A4.1: Coordination parameters

	Low power base station		Medium power base station	
	Indoor	**Outdoor**	**Indoor**	**Outdoor**
Tx Antenna pattern	Omnidirectional pattern with 0 dBi gain			
Rx Antenna pattern	Omnidirectional pattern with 0 dBi gain		Omnidirectional pattern with user defined gain	
Antenna height	5m[76]	User defined (up to max 10m)	User defined	User defined (up to max 10m for 1800 MHz and 2300 MHz)
Base station EIRP	26 dBm[77]/ carrier[78] 20 dBm[79]/5MHz for carriers greater than 20 MHz in 3.8-4.2 GHz band		User defined up to max 42 dBm/carrier[78] User defined up to max 36 dBm/5 MHz for carriers greater than 20 MHz in 3.8-4.2 GHz band	
Building penetration loss	12 dB	n/a	12 dB	n/a

[76] We will assume that low power indoor base stations are at a height of 5m irrespective of the actual height or floor they are deployed on
[77] 24 dBm + 2 dB proxy EIRP to account for area authorisation
[78] For carriers up to 20 MHz for 3.8-4.2 GHz band, 10MHz for 2300 MHz shared band and 3MHz for 1800 MHz shared band
[79] 18 dBm + 2 dB proxy EIRP to account for area authorisation

Channel size	*3.8-4.2 GHz*: User defined (10, 20, 30, 40, 50, 60, 80, 100 MHz) *1800 MHz*: 2 x 3.3 MHz *2300 MHz*: 10 MHz	
Interference to noise ratio ($I/N_{thermal}$)	*1800 MHz and 2300 MHz:* 1 dB *3.8-4.2 GHz:* -5 dB	*1800 MHz and 2300 MHz:* 0 dB *3.8-4.2 GHz:* -6 dB
Noise figure	13 dB	10 dB

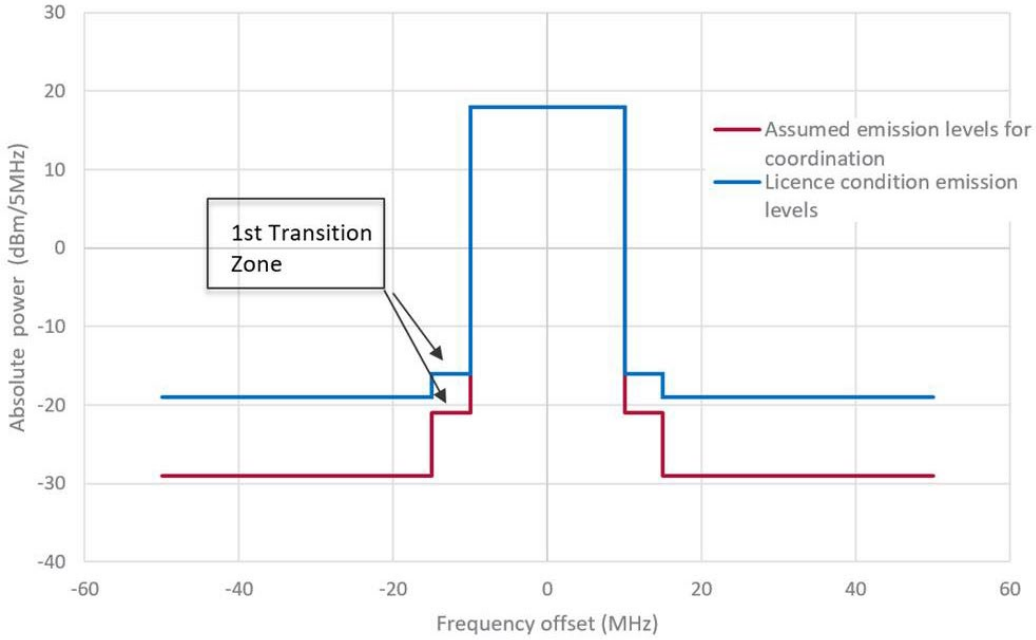
Specific considerations for the 3.8-4.2 GHz band

Out of block emissions

A4.12 We explained in our December 2018 consultation that, as noted in ECC Report 249, emissions are often better than the regulatory masks that have been set. We will take this into account in our coordination approach. Specifically, we will assume the emission levels are reduced by 5 dB in the adjacent 5 MHz and 10 dB thereafter.

A4.13 An example of the proposed emission levels for coordination for a low power base station operating in a 20 MHz channel is shown in Figure A4.1. For comparison, we present the out of block emissions required in the new shared licence conditions (which are based on those in CEPT Report 67).

Figure A4.1: Out of block emission assumptions for coordination in the 3.8-4.2 GHz band.



Protecting incumbent users in 3.8-4.2 GHz

A4.14 We have existing defined protection criteria for earth stations, fixed links and UKB deployments that are used to coordinate new deployments within the 3.8-4.2 GHz band and are shown in Table A4.2. We propose to maintain these protection levels for these services when coordinating with the new users in the band, so that there will be no change

to the current protection levels that these users are afforded. These protection criteria will also be applied to any new earth stations, fixed links and UKB deployments[80].

Table A4.2: Protection criteria for incumbent users in 3.8-4.2 GHz

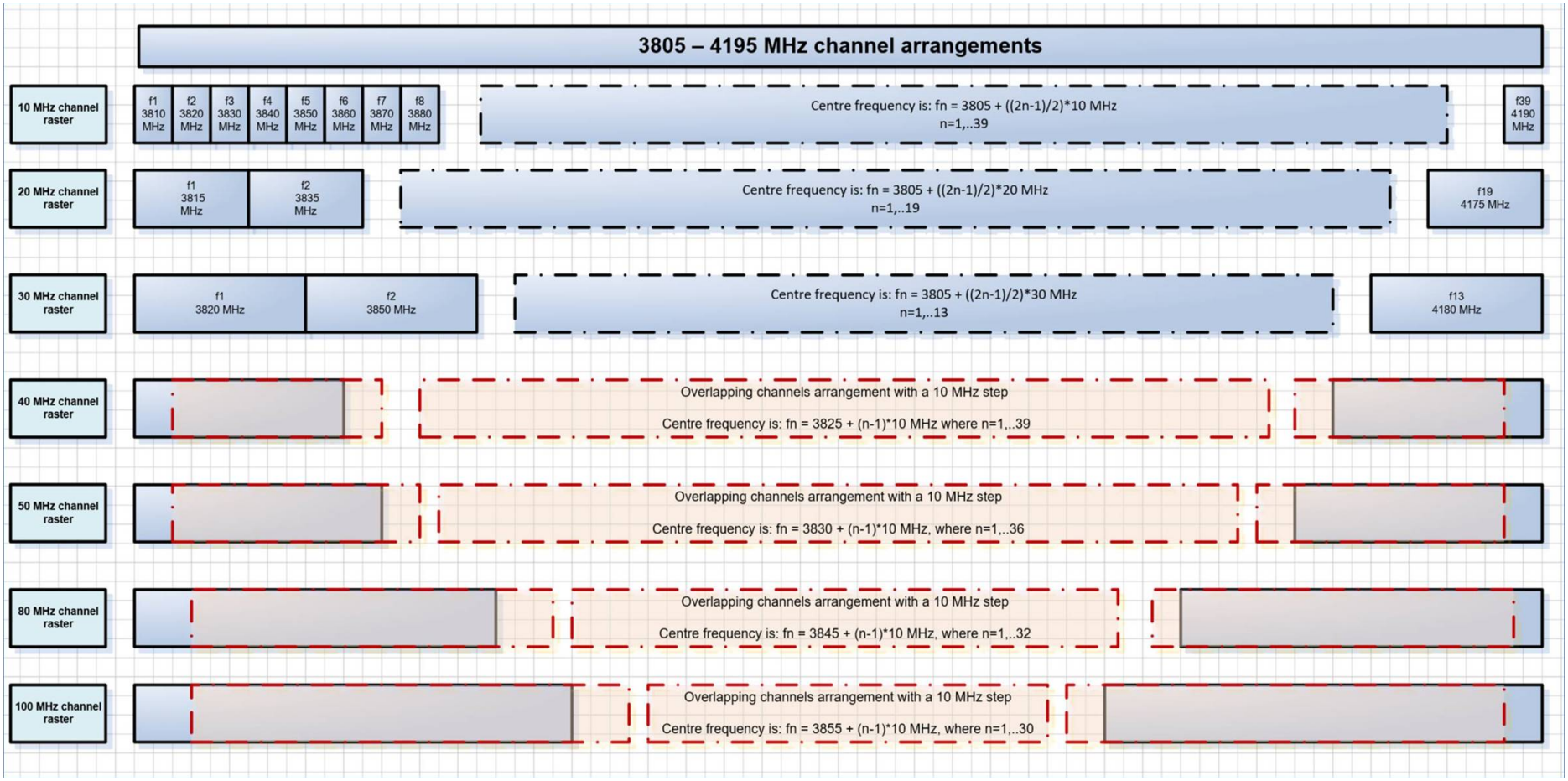
New application for Shared Access to:		
Fixed link(s)	**Permanent Earth Station (PES)** (*for RSA for ROES, we only apply test 2*)	**UK Broadband deployments**
Test 1[81]*:* Ensure the equipment specific W/U[82] ratio is met, assuming propagation for t=50% of time and the RSL[83] that is specified in the fixed links technical frequency assignment criteria document[84]. *Test 2:* Ensure the equipment specific W/U ratio is met, assuming propagation for t=(100-FL availability %)% of time, using the FL fade margin and the RSL that is specified in the fixed links technical frequency assignment criteria document	*Test 1:* I/N = 0dB propagation for t=0.005% of time *Test 2:* I/N = -10dB propagation for t=20% of time	*Test 1:* W/U = 27dB propagation for t=50% of time, assuming RSL = -75dBm *Test 2:* W/U = 6.5dB propagation for t=0.001% of time, assuming RSL = -75dBm

Channel plan for the 3.8-4.2 GHz band

A4.15 We show the channel plan in Figure A4.2 below. In the case of the larger channel bandwidths, channels will overlap with a 10 MHz offset. Whilst multiple overlapping channels will not be usable within the same area, this approach will give us the most flexibility when assigning frequencies to be able to avoid those frequencies used by earth stations, fixed links or existing UKB coordinated base stations within a given area. We will not allocate spectrum in the bottom and top 5 MHz blocks of the band.

[80] PES and RSA for ROES in the 3.8-4.2 GHz band are receive-only. Coordination of new applications for PES or RSA for ROES would involve checking whether the requested assignment is predicted to experience interference from co-channel or adjacent channel fixed links, UKB deployments or new sharers.
[81] Indicative levels of W/U ratio and RSL levels are presented in Ofcom's Technical Frequency Assignment Criteria based on specific modulation schemes.
[82] W/U = Wanted signal level / unwanted signal level
[83] Receiver sensitivity level
[84] OFW446: https://www.ofcom.org.uk/__data/assets/pdf_file/0017/92204/ofw446.pdf

Figure A4.2: Channel plan for the 3.8-4.2 GHz band



Coordination methodology

A4.16 Each requested base station (or authorised area in the case of low power licence requests) will be assessed to ensure that it does not cause interference to, or receive interference from, other co-channel users. In the case of the 3.8-4.2 GHz band, we will also undertake an adjacent channel assessment, taking into account the out of block emissions as shown in Figure A4.1.

A4.17 In some cases, the bandwidth of the new base station and that of the system being protected will be different or will have EIRP and protection levels which are defined against different reference bandwidths. In this case, we will also take a correction factor into account to align the parameters of the two systems.

A4.18 Our current coordination tool for coordinating new UKB deployments, earth stations and fixed links uses our own implementation of the ITU-R P.452[85] propagation model, with different percentages of time depending on the service being protected. We will maintain this approach for protection of existing satellite earth stations, fixed links and UKB base stations in the 3.8-4.2 GHz band.

A4.19 When considering protection of existing base stations in the three shared use bands from new base stations (including existing 1800 MHz shared spectrum deployments), we will also use the ITU-R P.452 propagation model, but with a percentage of time equal to 20%.

A4.20 We will use terrain and clutter maps of 50-metre resolution from Infoterra as part of the path loss model.

National and international coordination

A4.21 We will also need to carry out the following national and international coordination checks before assigning channels:

- National coordination:
  - *3.8-4.2 GHz band*: Low and medium power base station applications will need to be coordinated with MOD if the station falls within the 50km coordination zones at RAF Bude and RAF Menwith Hill. Applications which fall within a 5km radius of these sites will be rejected.
- International Coordination
  - *1800 MHz and 2300 MHz spectrum*: Medium power base station applications will be checked against limits contained in the memoranda of understanding (MoUs) that Ofcom has agreed with neighbouring administrations. Further details are available in the Shared Access Technical Frequency Assignment Criteria document which will be published on our website in autumn 2019.

[85] ITU-R, *Recommendation ITU-R P.452-10: Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz*, 2001, https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.452-10-200102-S!!PDF-E.pdf

Summary of coordination process

A4.22 The coordination processes that we will use for the three shared use bands are shown in Figures A4.3 and A4.4 below.

A4.23 As discussed in Section 3 of our statement, in the event that an application fails the coordination process and we are unable to assign a channel using the requested parameters, we will provide the applicant with information on the margins by which they failed the coordination thresholds to help inform their next steps.

Figure A4.3: Coordination approach in the 3.8-4.2 GHz band

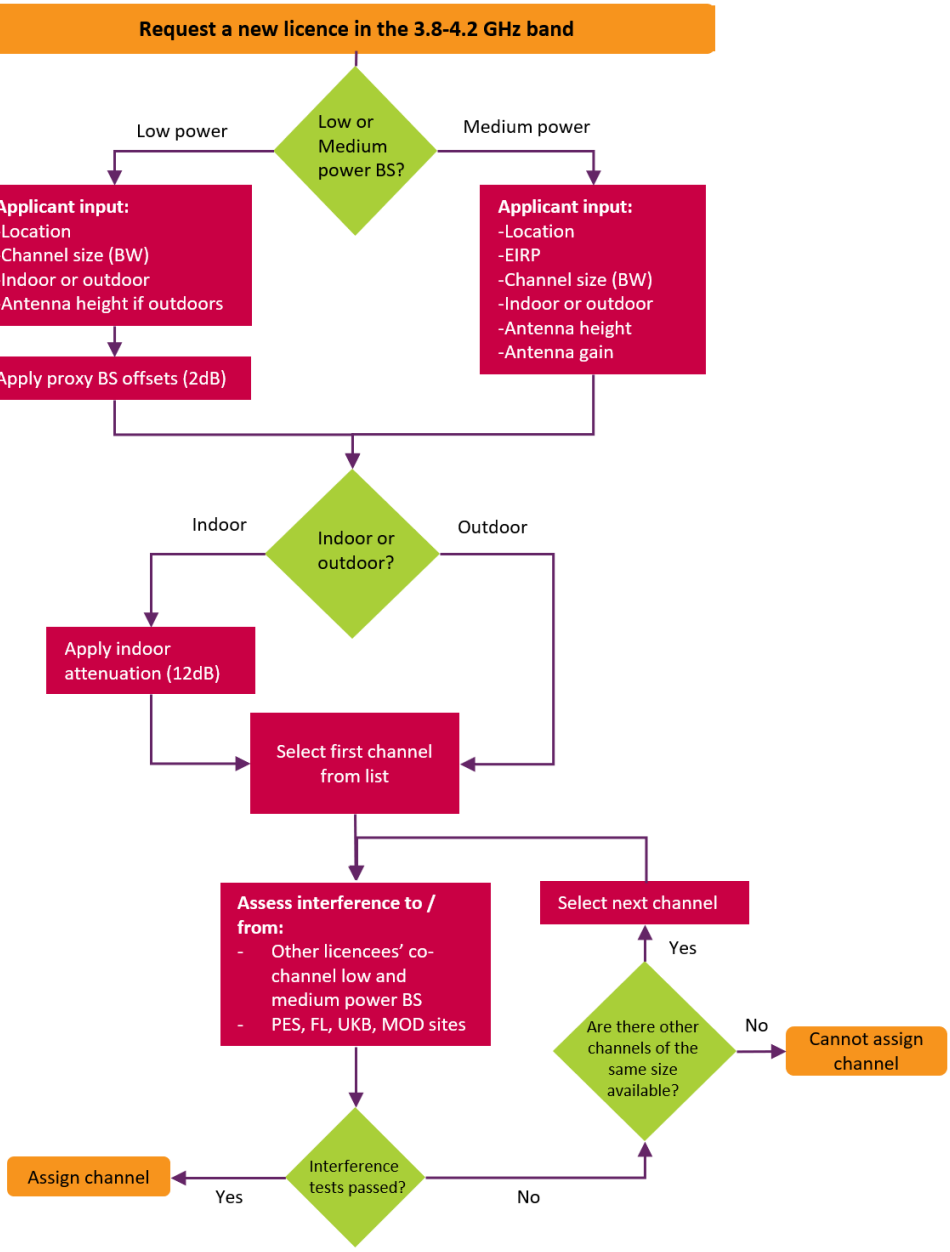
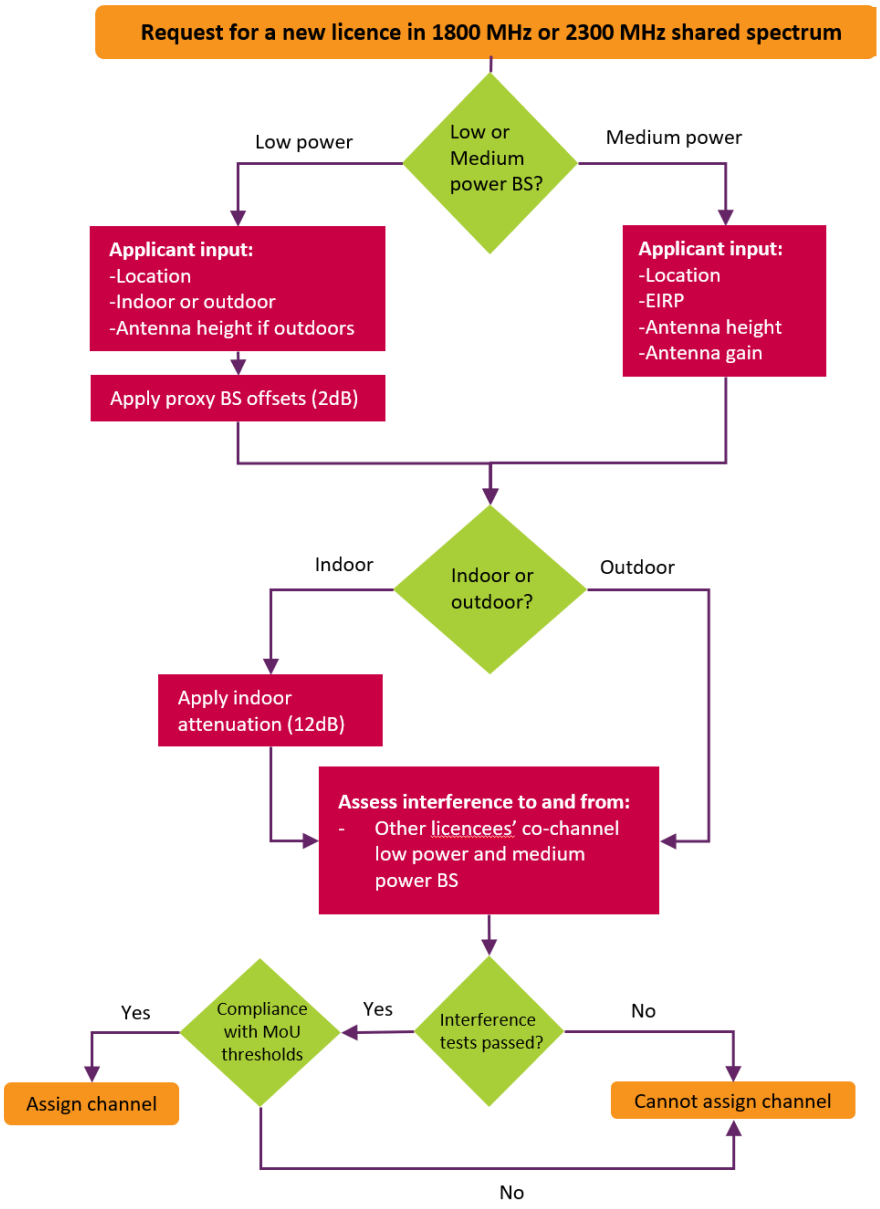


Figure A4.4: Coordination approach in 1800 MHz and 2300 MHz shared spectrum



A5. Glossary of terms used in this document

3GPP	3rd Generation Partnership Project (3GPP). A body that develops standards for mobile technology.
2G	Second generation mobile phone standards and technology
4G	Fourth generation mobile phone standards and technology
5G	Fifth generation mobile phone standards and technology
5G NR	5G New Radio. A new air interface developed for 5G.
AAS	Active Antenna Systems
AIP	Administered incentive pricing. A fee charged to users of the spectrum to encourage them to make economically efficient use of their spectrum.
ALD	Assistive Listening Device. Used by people with hearing impairments, often in conjunction with hearing aids or similar devices, to better distinguish speech from noise. An ALD often consists of a microphone used by the speaker and a receiver used by the listener.
BEM	Block edge mask. The emissions mask within a band of spectrum, but outside a licensee's specific block.
BS	Base station
CEPT	The European Conference of Postal and Telecommunications Administrations
CFI	Call for Input
Communications Act	The Communications Act 2003
CSA	Concurrent Spectrum Access
dB	Decibel. A notation for dealing with ratios that vary over several orders of magnitude by using logarithms.
dBm	Decibels relative to an isotropic radiator, measured in milliwatts.
dBW	Decibels relative to an isotropic radiator, measured in watts
DSA	Dynamic Spectrum Access. This is a technology for a variety of reconfigurable radio equipment allowing it to select the frequency on which it will operate at a given location and over a given period of time to optimise the use of available spectrum and avoid interference with other radios or other systems.

Earth station	A station located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for radio communication with one or more satellites or space stations.
EC	European Commission. Executive branch of the European Union.
ECC	Electronic Communications Committee. One of the three business committees of the European conference of Postal and Telecommunications.
EIRP	Equivalent Isotropically Radiated Power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency Division Duplex. A technology that deals with traffic asymmetry between uplink and downlink where separate frequency bands are used for send and receive operations.
FL	Fixed link. A terrestrial-based wireless system operating between two or more fixed points.
FWA	Fixed Wireless Access. Radio link to the home or the office from a cell site or base station, replacing the traditional local loop.
Hz	Hertz. Basic unit of frequency; one hertz is equivalent to one cycle per second. (kHz = 1000 Hz, MHz = 1000 kHz, GHz = 1000 MHz)
ICAO	The International Civil Aviation Organisation
IMT	International Mobile Telecommunications. The ITU term that encompasses 3G, 4G and 5G wireless broadband systems
I/N	Interference to noise ratio. An important figure in coexistence calculations between users of radio spectrum.
Interference	Unwanted disturbance caused in a radio receiver or other electrical circuit by electromagnetic radiation emitted from an external source.
IoT	Internet of things
IR	Interface requirement. These provide a link between the requirements of the Radio Equipment Directive (RED) and how spectrum is used nationally for radio equipment.
ITU	International Telecommunications Union. Part of the United Nations with a membership of 193 countries and over 800 private-sector entities and academic institutions.
ITU-R	International Telecommunications Union Radiocommunication Sector

Licence exemption	Exemption regulations made by Ofcom allow anyone to use specified radio equipment without the need to have a WT Act licence.
LTE	Long Term Evolution. Part of the development of 4G mobile systems that started with 2G and 3G networks. Aims to achieve an upgraded version of 3G services having up to 100 Mbps downlink speeds and 50 Mbps uplink speeds.
MNC	Mobile network codes
MNO	Mobile Network Operator
MOD	Ministry of Defence
NISRA	Northern Ireland Statistics and Research Agency
Ofcom	The Office of Communications
ONS	Office for National Statistics
PES	Permanent Earth station
RED	Radio Equipment Directive. The European regulatory framework for placing radio equipment on the single market.
RF	Radio frequency
ROES	Receive-Only Earth Station. A satellite earth station which receives radio signals but does not transmit.
RSA	Recognised Spectrum Access
RSPG	Radio Spectrum Policy Group. 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.
SRD	Short range devices
TDD	Time Division Duplex. A technology that deals with traffic asymmetry where the uplink is separated from the downlink by the allocation of different time slots in the same frequency band.
TRP	Total Radiated Power
UE	User Equipment
UL/DL	Uplink/Downlink
WAIC	Wireless Avionics Intra-Communication. Referring to radiocommunications between two or more points within a single aircraft.

Wi-Fi	Commonly used to refer to wireless local area network (WLAN) technology, specifically that conforming to the IEEE 802.11 family of standards.
WSD	White Space Devices. Devices which make use of transmission frequencies that are nominally allocated to other services but which are unused in the vicinity of the device.
WT Act	The Wireless Telegraphy Act 2006