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Enabling mmWave spectrum for new uses

Annexes 16-18: coexistence analysis

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Contents

Annex

A16. Coexistence

Introduction

A16.1 In this annex we explain the technical coexistence analysis we have carried out to establish the extent to which new users of mmWave spectrum can coexist with each other and the extent to which existing users (including fixed links) can coexist with new users. This analysis builds upon the modelling work we set out in annex 6 of the May 2022 Consultation. In this annex we update our previous analysis and extend it to the other services in the 26 and 40 GHz bands.

A16.2 This annex is structured as follows:

- **coordination between new users**: we calculate the minimum separation distances for mobile base stations to ensure coexistence between them. This analysis informs our proposed approach to coordination between new users in section 10;
- **increasing realism in our coexistence analysis**: we present an update on our proposed “worst case reduction factor” which we use to increase realism in our coexistence studies between new users and other services including fixed links. This uses new evidence we have gathered through technical measurements of fixed link receiver resilience presented in annex 17;
- **building entry loss for indoor low power base stations**: we explain our reasons for proposing to adopt a building entry loss value of 14 dB for coordination of 26 GHz Shared Access indoor low power base stations;
- **method for identifying fixed links around high density areas that are unlikely to coexist with mobile deployments in high density areas**: we present our proposed method for identifying fixed links which operate near high density areas which are unlikely to coexist with mobile base stations in high density areas. This informs the lists of fixed links we consider are unlikely to coexist with new mobile users and which will therefore be subject to the revocation process that we have decided to start. (See sections 5 and 7 and annex 18); and
- **mobile base station coexistence with radio astronomy at 40 GHz**: we present the method we propose to use to determine the area within which mobile base station deployments could risk causing interference to the Cambridge radio astronomy site. We also discuss the options that licensees may have to engineer their base stations to enable deployments which could coexist with the Cambridge radioastronomy site. This analysis informs our proposals to coordinate new users within 50km of the Cambridge radio astronomy site as set out in section 10.

Coordination between new users

A16.3 As set out in section 10, we propose:

a) to coordinate new low power Shared Access licensees in the 26 GHz band with each other using separation distances; and

b) to use a technical assignment process to coordinate medium power base stations with low and medium power base stations.

A16.4 This subsection outlines the reasoning behind these proposals.

Calculation of the separation distance required between base stations

A16.5 When coordinating Shared Access licensees, we propose to determine the appropriate separation distances between different 5G deployments using Equation A16.1. This equation uses a similar I/N approach to the one we used for assessing coexistence between mobile base stations and fixed links in the May 2022 consultation,[1] but we have adjusted it to be appropriate for mobile base station to mobile base station coexistence.

A16.6 We have rearranged Equation A16.1A16. to give Equation A16.2 which we use to calculate the isolation that is required between two mobile users, *Lp*. We will use this value of *Lp* later in this part of the annex to calculate the equivalent separation distance.

Equation A16.1

$$\boldsymbol{\frac{I}{N} = P_t + G_t + G_r - L_b - L_p - L_{bel} - N + A_{MI} + A_{BW}}$$

Equation A16.2

$$L_p = P_t + G_t + G_r - L_b - \frac{I}{N} - L_{bel} - N + A_{MI} + A_{BW}$$

where,

$\frac{I}{N}$ is the interference to-noise ratio at the victim receiver in dB. $\frac{I}{N} = 0\ dB$ for assessing coexistence between mobile base stations because this is the interference-to-noise ratio that we use for synchronised medium power base stations in our Shared Access framework.[2] We consider that this is appropriate because in our coordination proposals we have said that licensees will need to synchronise when necessary to prevent harmful interference.

P_t is the transmit power of the interfering system in dBm / (BW in MHz)

G_t is the gain of the interfering system towards the victim receiver in dBi

G_r is the gain of the victim receiver towards the interfering system in dBi

L_b is the loss due to body proximity in dB

L_p is the path loss (also called "isolation") between the interfering system and the victim receiver in dB

N is the victim receiver system noise in dBm / (BW in MHz), which is calculated as the sum of the thermal noise floor and noise figure, i.e., $10\log_{10}(kT_0b) + NF$,

[1] May 2022 Consultation, paragraphs A6.33 – 6.41.
[2] Ofcom's Technical Frequency Assignment Criteria "OfW 590 Technical Frequency Assignment Criteria for Shared Access Radio Services v1.2", published 20 September 2022, paragraph 3.5.

where k is Boltzmann's constant, T_0 is the temperature in Kelvin and b is the operating bandwidth of the receiver in Hz. NF = 10 dB because this is the noise figure we use for medium power base stations in our Shared Access framework.[3]

L_{bel} is the building entry loss in dB. For outdoor to outdoor studies, $L_{bel} = 0$ dB

A_{BW} is the bandwidth adjustment factor in dB, given by the ratio $10\log_{10}\frac{overlapping\ BW}{interferer\ BW}$. $A_{BW} = 0$ dB for coexistence between mobile base stations because we have assumed that the transmitter and receiver bandwidths are the same with the same center frequency and so fully overlap.

A_{MI} is a factor that modifies the out of band emissions relative to the in band emissions. $A_{MI} = 0$ dB for co-channel operation and $A_{MI} = -ACLR$ in dB for operation in the first adjacent channel.

A16.7 We calculated values of isolation needed between mobile users, L_P, for the scenarios shown in Table A16.1 and Table A16.2 using Equation A16.2 and inputting the same values for mobile base stations as we presented in the May 2022 Consultation.[4] We then used these values of L_p to calculate the separation distances required between base stations for each scenario.

A16.8 We calculated the required separation distances using the P.1411-11[5] and free space path loss ("**FSPL**") propagation models[6]. We have used P.1411-11 because it is recommended for short-range outdoor radio systems between 300 MHz and 100 GHz and many urban mobile base station deployments are likely to be short range, especially low power deployments. We have used FSPL when the separation distance calculated from ITU P.1411-11 is beyond 2km and when both ends of the interference link are above rooftop height. This is because P.1411-11 is not suitable for these longer path lengths and FSPL is more suitable because there is likely to be line of sight between base stations when both of them are above rooftop height.

A16.9 In our modelling we have considered that the dominant interference scenarios are:

i) when synchronised: from a base station to a user terminal of a different network; and

ii) when unsynchronised: between base stations of different networks.

This is because, when base stations are synchronised, there is no time period when one base station is receiving whilst a nearby base station is transmitting. These dominant

[3] OfW 590, paragraph 3.5.
[4] Paragraph A6.11.
[5] ITU, "Recommendation ITU-R P.1411-11: 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 ", approved September 2019.
[6] ITU, "Recommendation ITU-R P.525-4: Calculation of free-space attenuation", approved August 2019.

interference scenarios for synchronised and unsynchronised 26 GHz TDD networks are the same as those identified in ECC Report 307.[7]

Results

A16.10 The calculated minimum separation distances for coexistence between unsynchronised base stations and synchronised base stations and terminals are presented in Table A16.1 and Table A16.2 respectively.

Table A16.1: minimum separation distances between mobile base stations that are unsynchronised

Scenario	Co-channel LoS (m)	Co-channel NLoS (m)	Adjacent channel LoS (m)	Adjacent channel NLoS (m)
Low power to low power	1430	110	70	20
Low power to medium power	2000	250	120	60
Medium power to low power	4700 [FSPL]	330	200	80
Medium power to medium power	7000 [FSPL]	Not applicable[8]	250	90

Table A16.2: minimum separation distances between mobile base stations and the terminals of other networks when synchronised

Scenario	Co-channel LoS (m)	Co-channel NLoS (m)	Adjacent channel LoS (m)	Adjacent channel NLoS (m)
Low power to user equipment	310	50	15	10
Low power to customer premise equipment	1990 [9]	140	95	30
Medium power to user equipment	670	140	50	40

[7] ECC, "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", published 6 March 2020, Figure 1.
[8] Assumptions about the local clutter and the height of the radio equipment lead to a particularly large variation in the results for this scenario so we have omitted these results to avoid drawing conclusions from a single separation distance value which might not be valid for all typical cases.
[9] The minimum separation distance between low power base stations and customer premise equipment (CPE) is larger than for low power base stations to user equipment (UE) because we have modelled the CPE with a higher antenna gain than the UE and we have also factored in a body proximity loss for the UE.

Scenario	Co-channel LoS (m)	Co-channel NLoS (m)	Adjacent channel LoS (m)	Adjacent channel NLoS (m)
Medium power to customer premise equipment	7000 [FSPL]	Not applicable[8]	220	80

Conclusions

A16.11 We have taken the synchronised results into consideration when assessing our coordination approach. This is because, as set out in “Synchronisation” in section 11, even if we do not mandate synchronisation in the technical licence conditions of the Shared Access licences and award licences, we would still require licensees to agree appropriate measures to mitigate the interference between their networks, if harmful interference occurred. Synchronisation is an example of an appropriate interference mitigation option when networks are deployed in the same area or near each other.

A16.12 Table A16.1 shows that there is a risk of interference between co-channel unsynchronised base stations which are within a few kilometers of each other when in line of sight but that this risk quickly falls to a few hundreds of metres when the base stations are not line of sight. We have provided these unsynchronised results to give potential licensees an idea of the separation distances between users which might allow for unsynchronised operation without harmful interference. However, as noted above, we consider only the synchronised values to be relevant when setting our approach to coordination.

A16.13 For adjacent channel operation we consider that synchronisation is likely to be effective at reducing the risk of harmful interference. We therefore propose to only coordinate co-channel mobile base stations and to require licensees to synchronise with one another when necessary to mitigate harmful interference when operating in adjacent frequency blocks.

Low power base stations

A16.14 Table A16.2 shows that the risk of interference between co-channel synchronised outdoor low power base stations and user equipment (“**UE**”) and consumer premises equipment (“**CPE**”) is highly variable, depending on whether the base station is in line of sight of the victim UE/CPE or not. In urban areas, an environment with a low probability of line of sight between outdoor low power base stations and the UE/CPE of another network might be an area with a lot of buildings. For contrast, an environment with a higher probability of line of sight between outdoor low power base stations and the UE/CPE of another network might be an urban park.

A16.15 Taking this variability into account, we have also considered other information to come to the provisional conclusion that a minimum separation distance of 200m is likely to be appropriate for coordination between the co-channel outdoor low power base stations:

a) at short distances our technical assignment tools may not accurately model coexistence because over these distances small changes in the local conditions can have a large impact on coexistence between networks, so technical assignment is unlikely to be an appropriate coordination approach; and

b) we note that a typical mmWave microcell might have a coverage radius of around 100m.[10] This means that a minimum separation distance of 200m between outdoor low power base stations would ensure that there is no overlapping coverage.

A16.16 Considering the separation distances given in Table A16.2 and a minimum separation distance of 200m between low power base stations, what this means for a mobile UEs is that there may be occasional interference when within a few hundreds of meters of a co-channel low power base station of a network that the mobile UE is not attached to. Any interference which might occur is likely to be transient and so may not significantly affect the service provided by the wanted signal, depending on the use case. For fixed CPEs the risk radius is larger, but an installer may be able to reduce this risk through careful installation taking the local radio environment into account.

Medium power base stations

A16.17 Table A16.2 shows that the risk of interference between co-channel synchronised medium power base stations and UEs and CPEs is highly variable, but that the risk area is significantly larger than for low power base stations. We also note that a medium power base station may be more likely to be in line of sight of UEs/CPEs than low power base stations because medium power base stations tend to be installed at a higher height than low power base stations. We therefore consider that technical assignment is appropriate for coordination between medium power base stations and all other co-channel base stations because over the long interference risk distances of medium power base stations our technical assignment tools are likely to accurately model coexistence. This is consistent with how we coordinate medium power base stations in the frequency bands already included in our Shared Access framework.

Increasing realism in our coexistence analysis

Background

A16.18 In the May 2022 Consultation, we observed that worst case assumptions about interference from mobile base stations to other users were unlikely to be representative of typical operating conditions[11] and might result in overly conservative coexistence results. We proposed to introduce a Worst Case Reduction Factor (“$\mathbf{F_{WCR}}$”) to reduce the conservatism of our results to make them more realistic. This F_{WCR} would be used to modify a worst case scenario considering a mobile base station using an active antenna system

[10] GSMA, “Vision 2030: mmWave Spectrum Needs”, published June 2022, Table A8.
[11] May 2022 Consultation, paragraph A6.42.

with maximum transmit power (P_t) and maximum single beam boresight gain (G_t) pointing directly towards a fixed link.

A16.19 We believed that F_{WCR} = 12 dB might be appropriate as a central case based on a combination of factors including:

a) **Time averaged beam patterns of beam steered antennas:**[12] for active antenna systems, our modelling showed that the mean antenna gain towards the horizon is approximately 12 dB lower than the maximum gain for both low and medium power deployment. We obtained this mean value by time averaging the antenna pattern for 10,000 random user equipment (UE) positions around the base station for both deployment scenarios. For low power deployments, we adopted an active antenna array size of 8 x 8 with the base station and UE heights of 6m and 1.5m above ground. With respect to medium power deployments, we used uniformly distributed UE heights of 3m, 6m and 9m, and the base station height set to 15m. For medium power UE heights, varying heights were used to model a deployment across a multistorey building.

b) **Multiple concurrent beams:**[13] for active antenna systems, we said that the array gain reduces as the number of beams increases. i.e., doubling the number of beams results in a 6 dB reduction in the peak boresight radiated power. For example, in a medium power deployment with 16 x 16 elements, the antenna gain can be 29 dBi for a single beam, 26 dBi for two beams or 23 dBi if four beams were generated from the 16 x 16 array.

c) **Base station duty cycle:**[14] we said that we do not expect any 5G base station to be transmitting continuously. We adopted a TDD DL/UL ratio of 4:1 in our study which implies that the base station will transmit 80% of the time. We consider that this assumption is realistic for mmWave deployments and we expect the duty cycle of the base station to reduce interference contribution by about 1 dB.

A16.20 We also highlighted that fixed links with forward error correction ("**FEC**") and adaptive modulation and coding ("**AMC**") are expected to be more resilient to interference.[15] We said that we would conduct a measurement campaign to understand in more detail the resilience of fixed link receivers to interference from mobile base stations and to inform the F_{WCR} we used for coexistence with fixed links specifically.[16]

A16.21 Given the uncertainty over the F_{WCR}, we conducted a sensitivity analysis considering F_{WCR} = 6 dB and F_{WCR} = 18 dB to see to what extent our results for coexistence between mobile base stations and fixed links would be affected.[17]

[12] May 2022 Consultation, paragraph A6.47.
[13] May 2022 Consultation, paragraph A6.53.
[14] May 2022 Consultation, paragraph A6.56.
[15] May 2022 Consultation, paragraph A6.44.
[16] May 2022 Consultation, paragraphs A6.59 to A6.61.
[17] May 2022 Consultation, paragraph A6.45.

Our updated view

A16.22 We remain of the view that F_{WCR} = 12 dB is appropriate for assessing coexistence between mobile base stations and other mmWave services for the reasons given above. We have gathered new evidence on the resilience of fixed links to interference from mobile and consider that F_{WCR} = 12 dB remains appropriate for coexistence with fixed links too, but for reasons we have now modified considering this new evidence. Our report on the resilience of mmWave fixed links to interference from 5G signals is presented in annex 17 and we discuss how we have taken this evidence into account next.

A16.23 The values we use to coordinate fixed links with one another are given in our fixed links technical frequency coordination criteria ("**TFAC**").[18] An important criterion we use for our fixed links planning is the wanted to unwanted ratio ("**W/U**") which describes how much stronger the wanted signal must be relative to interfering signals to enable a certain throughput to be achieved by the fixed link.

A16.24 Our measurements found that the fixed links we measured could typically sustain their throughput at a W/U which was 11 to 12 dB lower than the value given in the TFAC for a wide range of interferer types. This suggests that the fixed links we measured were more resilient to 5G interferers than would be implied by simply using the W/U values in the TFAC which are designed for coordination of fixed links with one another.

A16.25 Care must be taken with the quantitative analysis of these results. It is important to note that the TFAC W/U values are calculated considering four equal power interferers arriving at the fixed link receiver in order to mitigate the risk of aggregate interference.[19] Our measurements considered only a single 5G interferer and so this 6 dB difference should be taken into account when comparing W/U values.

Mitigations no longer considered in our assessment of F_{WCR} for coexistence and coordination with fixed links

A16.26 We no longer consider that the time averaging of beam patterns can be considered a mitigation for mobile base station interference to fixed links. In annex 17 we show how we produced a bursty interferer with bursts of interference which were a few frames in duration. This bursty interferer was designed to simulate both the inherent burstiness of mobile network traffic flows and the effect of a moving beam from an active antenna system temporarily pointing towards a fixed link. We observed that the fixed links we measured were no more resilient to this sort of bursty interference than they were to the continuous 5G interferer. Indeed, a fixed link could take several seconds to recover from a short interference event. Therefore, we have excluded the concept of time averaging mobile base station beams patterns from our updated assessment of F_{WCR} for coexistence and coordination with fixed links.

[18] Ofcom's Technical Frequency Assignment Criteria "OfW 446: Technical Frequency Assignment Criteria for Fixed Point-to-Point Radio Services with Digital Modulation (v17.0)", published 5 August 2022.
[19] OfW 446, p. 59 and p.74 (column "n").

Our updated assessment of F_{WCR} for coexistence and coordination with fixed links

A16.27 We continue to consider that an F_{WCR} of 12 dB is appropriate for our coexistence studies and for coordination of new users with fixed links. In coming to this assessment we have exercised our judgement considering the following factors:

a) **Fixed link receiver resilience to mobile interference:** Our measurements suggested that fixed links we measured might be more resilient to mobile interference than might be expected by simply using the W/U levels used for coordination between fixed links for coexistence with mobile base stations too. We observed that the W/U margin for the fixed links we measured was typically 11 to 12 dB relative to the value in the TFAC. However, these values need to be adjusted to take into account that the TFAC values include a 6 dB margin for aggregation from four interferers so the equivalent difference when considering a single interferer is 5 to 6 dB.

   We acknowledge that the measurements we have taken were on newer fixed link equipment. It is therefore possible that some old fixed links equipment still in the field is not as resilient to mobile interference as the fixed links equipment we measured. Therefore we consider that fixed links might be 0 to 6 dB more resilient to mobile interference than the W/U value for coordination between fixed links in the TFAC might suggest.

b) **Multiple concurrent beams:** We continue to consider that our logic for how multiple concurrent beams might reduce the peak EIRP of a mobile base station remains valid and that each doubling in the number of beams will reduce the peak EIRP by 6 dB.

c) **Fade margin and statistical factors:** There are statistical factors which mean that any risk of interference from mmWave mobile to fixed links is unlikely to be present all of the time. Based on a worst case interference scenario, all of the following must be true for interference to occur:

   i) The mmWave mobile base station beam needs to be pointing towards the fixed link receiver; and

   ii) The fixed link wanted signal must be faded at the same time; and

   iii) The mmWave mobile base station interfering signal must not be faded at the same time.

Fixed links are planned considering a fade margin which means that the power transmitted is greater than that necessary to provide the service when environmental conditions are good and the wanted signal is unfaded. During a fading event, such as when it is raining, the received wanted signal drops and the fade margin allows the service quality to be maintained during the fading event. When the 26 GHz fixed link band was planned, we did this using a 10 dB fade margin.[20] We did not plan the 40 GHz fixed links, but we consider that the same fade margin is likely to be relevant for this band too.

We acknowledge that it is difficult to quantify the impact of these statistical factors, especially how these statistical effects might act in combination. Nevertheless, there is likely to be some benefit from the fixed link fade margin for mitigating the impact of occasional interference risk events caused by mobile base stations.

A16.28 We have also considered what the impact might be if we have set our central case F_{WCR} too high. We observed that all the fixed links that we measured employed AMC and that this was effective at improving resilience to interference, albeit at the cost of reduced throughput. We therefore consider that the impact if we have set F_{WCR} too high is that the throughput of some fixed links may be degraded, but it is unlikely that the service would be interrupted for fixed links that use AMC, and any throughput degradation may only be noticeable for fixed links which are carrying traffic at levels relatively close to the capacity of the fixed link.

A16.29 We therefore expect that any interference risk that might occur if we have set F_{WCR} too high is unlikely to have a large practical impact. Were harmful interference to occur, we would expect new users of mmWave spectrum to cooperate with fixed links users and for the new user to remedy the situation.

Building entry loss for indoor low power base stations

Background

A16.30 Building entry loss ("**BEL**") is a value we use to model the radio isolation between indoor radio equipment and outdoor radio equipment. The value of BEL can vary depending on location, with lower values when radio equipment is deployed closer to the outside, e.g. by a window, and with higher values when the radio equipment is deployed deep indoors. BEL is important for us to consider in our coexistence modelling because the radio isolation between indoor users and outdoor users can reduce the risk of interference between those users.

A16.31 In our statement on "Enabling Wireless Innovation through Local licensing" (the "**July 2019 Statement**")[21] we made 26 GHz available indoors. We said that our analysis showed that indoor low power deployments were at a low risk of causing interference to existing

[20] The 26 GHz band is closed and so is not in the current version of the TFAC, but we can confirm that the 26 GHz band was planned on the basis of a 10 dB fade margin.

[21] Ofcom's Statement, "Enabling Wireless Innovation through Local licensing", published 25 July 2019.

users.[22] In the modelling supporting that decision we calculated BEL using Recommendation ITU-R P.2109-0[23] which we noted gave results which strongly correlated with measurement data collected on BEL in the UK for the 26 GHz frequency band.[24]

A16.32 In our consultation on "Protecting passive services at 23.6-24 GHz from future 26 GHz uses" (the "**December 2021 Consultation on protecting passive services at 24 GHz**")[25] we built on our previous work in the July 2019 Statement and updated our approach by considering the 26 GHz base station antenna gain and BEL distributions separately.[26] We noted that Recommendation ITU-R P.2109-0 models two building types, "traditional" and "thermally efficient" and that thermally efficient buildings typically have a significantly higher BEL than traditional buildings.[27] We considered that a conservative approach was appropriate for our analysis and so only considered the BEL of traditional buildings.[28] We considered that taking the BEL at the 30th percentile of locations was appropriate for our coexistence analysis, which gave a value of BEL = 14 dB, and that this value of BEL might represent an indoor environment with light obstacles and some reflections within the building.[29]

Our updated view

A16.33 Building on this previous work, we continue to consider that taking a value of BEL = 14 dB is appropriate for our coexistence studies at 26 GHz. Furthermore, we now also propose to introduce a value for BEL for Shared Access coordination and that an appropriate value would be 14 dB based on our previous studies. We note that we have used a BEL of 12 dB in sub-6 GHz bands for Shared Access coordination, but we consider that 14 dB is more appropriate for mmWave bands because the attenuation of signals by objects including buildings is higher at mmWave than in sub-6 GHz bands.

Method for identifying fixed links around high density areas that are unlikely to coexist with mobile deployments in high density areas

Background

A16.34 In the May 2022 Consultation, we said that fixed links were likely to constrain the deployments of new uses in high density areas and that we therefore proposed to revoke licences authorising fixed links in and around high density areas.[30] In annex 6 of that consultation we set out how we had calculated the spectrum availability for mobile base

[22] July 2019 Statement, paragraph 5.3.
[23] ITU, "Recommendation P.2109-0: Prediction of building entry loss", published June 2017.
[24] July 2019 Statement, paragraph A3.10.
[25] Ofcom's Consultation, "Protecting passive services at 23.6-24 GHz from future 26 GHz uses", December 2021.
[26] December 2021 Consultation on protecting passive services at 24 GHz, paragraph A2.16.
[27] December 2021 Consultation on protecting passive services at 24 GHz, paragraph A2.35.
[28] December 2021 Consultation on protecting passive services at 24 GHz, paragraph A2.36.
[29] December 2021 Consultation on protecting passive services at 24 GHz, paragraph A2.37.
[30] May 2022 Consultation, p. 4.

station deployments in six high density areas taking the incumbent 26 and 40 GHz fixed service users into account.

A16.35 In this part of the coexistence annex we modify our previous analysis to identify which fixed links near high density areas are unlikely to coexist with mobile base station deployments in high density areas. The resulting list of fixed links which would be subject to the revocation process on the basis of this updated analysis is in annex 18.

A16.36 We have structured this part of the annex as follows:

- dominant direction of interference between fixed links and mobile base stations; and
- identifying fixed links around high density area that may not coexist with new mobile base stations in those high density areas.

Dominant direction of interference between fixed links and mobile base stations

A16.37 We have examined whether there is a dominant direction of interference risk and we found that fixed links were more at risk of receiving interference from mobile base stations than the other way around. We examined this so we could understand whether we could simplify our analysis by only looking at interference in a single direction.

A16.38 In identifying the dominant interference path between fixed links and mmWave, we have used Equation A16.2 to calculate the isolation that would be required for both potential interference paths, i.e., fixed link transmitter to mmWave base station receiver and mmWave base station to fixed link receiver.

A16.39 The parameters fed into Equation A16.2 and the calculated required isolation, *Lp*, are shown below in Table A16.3.

A16.40 For fixed links, we used values of $G_t = G_r =$ 36 dBi, $P_t =$ 23 dBm because these are typical values for 26 GHz fixed links registered in our licensing database and we consider that 40 GHz fixed links parameters are likely to be similar. In the May 2022 Consultation,[31] we discussed the parameters for fixed links and noted that the typical antenna gains are between 31 dBi and 48 dBi.

A16.41 For the mobile base station antenna gain, we have used an average value of 16 dBi when the victim is a mmWave base station and the boresight gain towards the horizon of 28 dBi when the mmWave base station is the interferer. This is because the mmWave base station is able to implement receiver processing techniques such as null beamforming towards the direction of the interfering fixed link and improve the resilience of the mobile base station to interference. Fixed links are point-to-point systems and so fixed link receivers will not be able to take advantage of null beamforming techniques.

[31] May 2022 consultation, Table A6.2.

Table A16.3: Parameters used for determining the dominant direction of interference

Parameter	Fixed Link to mobile	Mobile to fixed link	Units
Victim receiver bandwidth	200	56	MHz
Interferer transmit power (P_t)	23	30[32]	dBm
Interferer transmitter antenna gain (G_t)	36	28[32]	dBi
Victim receiver antenna gain (G_r)	16[33]	36	dBi
Victim receiver noise figure (*NF*)	10	6.5[34]	dB
Victim receiver system noise (*N*)	-81	-90	dBm
Victim receiver protection ratio ($\frac{I}{N}$)	0[2]	-10[31]	dB
Bandwidth adjustment factor (A_{BW})	5.5	-5.5	dB
Required isolation (L_p)	**161**	**188**	**dB**

A16.42 Our results show that the typical required isolation for the protection of mobile base stations from fixed links interference will be 161 dB whilst the typical required isolation for the protection of the fixed link receivers from mobile base stations is 188 dB. Taking the difference between these two values, we observe that the interference path from the mobile base station to the fixed link typically requires 27 dB more isolation than the interference path from the fixed link to the mobile base station. We therefore consider that the dominant path of interference will be from mobile base stations to fixed links and so we have carried out the rest of the coexistence analysis in this part of this annex taking this into account.

Identifying fixed links around high-density areas that may not coexist with new mobile base stations in high density areas

A16.43 In this section, we present the method we have adopted to determine which fixed links in the 26 GHz and 40 GHz bands around high density areas may not coexist with mmWave.

A16.44 The method adopted in this section is similar to the spectrum availability analysis presented in the May 2022 Consultation,[35] where a "reverse" coverage prediction is carried out in HTZ Communications (which is a radio planning tool which we used in this study). By a "reverse coverage prediction" we mean that the fixed links are modelled as the

[32] May 2022 Consultation, Table A6.1.
[33] May 2022 Consultation, Table A6.4.
[34] May 2022 Consultation, paragraph A6.2.
[35] May 2022 Consultation, paragraph A6.41.

transmitters and their "coverage area" represents the area in which a mobile base station deployment might risk causing interference to one or more of the fixed links. The coverage obtained from HTZ Communications considers every pixel within a 50km/100km[36] radius from the centre of a high density area.

A16.45 The threshold values used in the method presented in this section are the same as those used in the May 2022 Consultation[37] using the equation we have reproduced below as Equation A16.3.

Equation A16.3

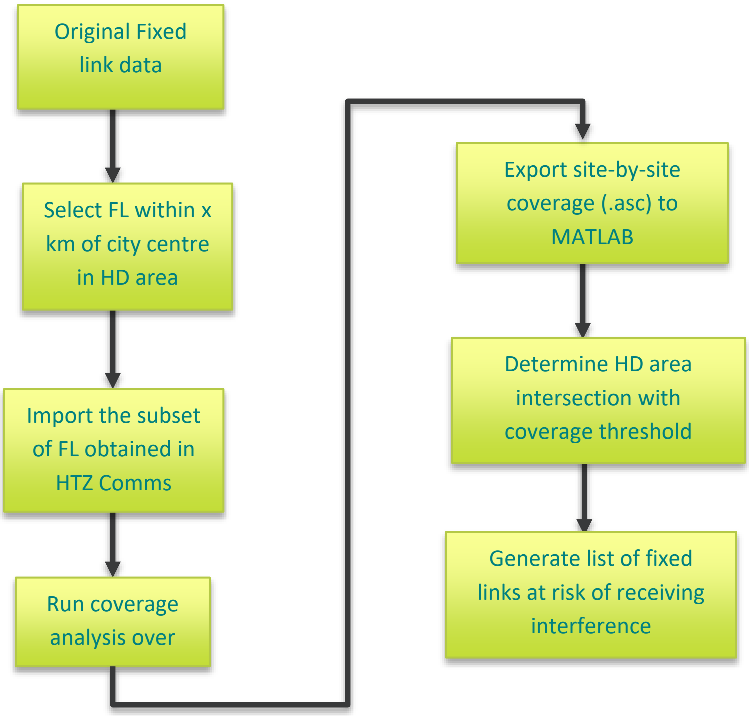
$$Threshold\ Value(dBm) = -\left(P_t + G_t - N + A_{MI} + A_{BW} - \frac{I}{N} + F_{WCR}\right) + 30\ dBm$$

A16.46 A flowchart illustrating the high-level approach adopted in this study is shown Figure A16.1. The parameters for the mobile base stations and fixed links used in this study were presented in the May 2022 Consultation.[38]

A16.47 A step-by-step description of the process is available below. A list of the reference centre locations (as easting and northing coordinates) of the high density areas used in the analysis is given in Table A16.5.

[36] We have used 50km for all high density areas except London, where we used 100km.
[37] May 2022 Consultation, paragraph A6.38.
[38] May 2022 Consultation, paragraphs A6.11 and A6.30.

Figure A16.1: Flowchart of the simulation process for identifying fixed links that are unlikely to be able to coexist with mobile base stations in high density areas



Steps for determining which fixed links around high density areas are likely to receive interference from mobile base station in those high density areas

- Import the CSV file containing fixed links around a selected high density area into HTZ Communications (50km for most high density areas and 100km for London).
- Use HTZ Communications to generate the coverage plot:
  - Open HTZ Communications
  - Load clutter and digital elevation data in HTZ Communications
  - Set the nominal power of each fixed links to 1 W
- Under Network Calculation, select Tx/Rx FS coverage.
  - Set the heights of the Rx antennas to 6m for low power or 15m for medium power
  - Set the simulation distances to 50km or 100km for London
  - Select the P.452-17 model under the Model options
  - Load the additional clutter losses for this model developed by Siradel for Ofcom.
  - Execute the coverage simulation
- Export coverage results as site-by-site ASC files and post process the coverage intersection of each ASCII file in MATLAB or a suitable program.
  - Use the threshold to determine if the receive power for each fixed link in each pixel exceeds the threshold
  - Generate a csv of the fixed links which exceed the threshold and intersect the high density area

- Identify unique occurrences of each fixed link licence.

Table A16.5: Easting and northing coordinates of the centre points of the high density areas used in the analysis

Index	High density area	Easting	Northing
1	Greater London	529083	181248
2	Greater Manchester	383819	398052
3	Greater Glasgow	260107	665646
4	Greater Birmingham	406689	286822
5	Cardiff & Newport	318371	176329
6	Tyne & Wear	425048	564892
7	Bristol & Bath	359207	173624
8	Liverpool	339580	391971
9	Edinburgh	325847	674007
10	Leeds & Bradford Area	430131	433794
11	Sheffield City Region	435555	387556
12	Nottingham	457533	340219
13	Northampton	476582	261726
14	Southend	589041	186294
15	Brighton	532295	106504
16	Luton	509075	222598
17	Coventry	433452	279025
18	Belfast	146225	529465
19	Aberdeen	393827	805926
20	Stoke-on-Trent	389312	346827
21	Leicester	458918	305470
22	Southampton	443124	114302
23	Colchester	600371	225211
24	Exeter	293223	93222
25	Hull	509563	431573
26	Bournemouth & Poole	404084	93151
27	Derby	435990	335741
28	Loughborough	453158	319659
29	Portsmouth & Gosport	460910	104188
30	Gloucester & Cheltenham	383315	218577
31	Newbury	447051	166693
32	Plymouth	249851	57181
33	Chester	340863	367095
34	York	460203	451989

Index	High density area	Easting	Northing
35	Oxford	452152	206486
36	Peterborough	517395	299503
37	Shrewsbury	349844	312894
38	Cambridge	546280	258402
39	Ashford	601069	143464
40	Norwich	622565	310023
41	Milton Keynes	485346	238891
42	Crawley	527107	136836
43	Medway Towns	576982	171779
44	Stafford	392889	322818
45	Chelmsford	570871	206551
46	Teesside	447497	517355
47	Preston	353628	430057
48	Swansea	265305	193308
49	Blackpool	331959	437224
50	Dundee	340737	732624
51	Basildon	571605	189030
52	Swindon	415705	185804
53	Lincoln	497114	370385
54	Southport	333285	415878
55	Ipswich	616840	244691
56	Harrogate	431106	455411
57	Basingstoke	462029	151411
58	Warrington	362068	388915
59	Redditch	404765	266849
60	Worcester	385608	255092
61	Hastings	579826	111257
62	Dover	630443	142199
63	Folkestone & Hythe	609523	133639
64	Stansted Airport	554337	223173
65	Reading	471256	173468
66	Farnborough & Aldershot	487038	152835
67	Doncaster	457775	402588
68	Bracknell	486727	168309

Results

A16.48 Our analysis shows that the number of fixed links *around* high density areas that are likely to receive interference from mobile deployments in high density areas was:

- 215 links in the 26 GHz band;
- 1087 links used by MBNL in the 40 GHz band; and
- 2 links used by H3G in the 40 GHz band.

A16.49 We note we are also proposing to clear from the 26 GHz and 40 GHz bands those fixed links which have one or both end points in high density areas. annex 18 shows the full list of links that would be subject to the revocation process, on the basis of the analysis set out in this annex.

Mobile base station coexistence with radio astronomy at 40 GHz

A16.50 In the May 2022 consultation[39] we noted that 42.5 – 43.5 GHz has been allocated internationally for radioastronomy and that there was one grant of recognised spectrum access ("**RSA**") for radioastronomy in the UK. This grant of RSA was issued to the science and technology facilities council ("**STFC**") for a radio telescope in Cambridge and we also noted that there was a 50km exclusion zone around that radio telescope for the relevant frequencies of H3G's 40 GHz licence.

A16.51 We said that we would continue to protect the radioastronomy use in Cambridge at these frequencies. We also said that we would review whether the current exclusion zone remains an appropriate mechanism for ensuring coexistence, considering the parameters for new uses operating in this band.

A16.52 In this part of this annex, we first explain the parameters and assumptions we have used in modelling the radio astronomy service ("**RAS**") and then we describe our method and present our results. Finally, we include some information on how interference can be mitigated for outdoor deployments.

A16.53 We understand that the Cambridge radio astronomy site is the only UK site that is active within the 42.5-43.5 GHz band based on our discussions with the STFC.

A16.54 Our analysis led to the following conclusions:

a) Spectrum availability for the new uses in the Cambridge high demand area will be affected for both outdoor low power and medium power co-channel deployment (42.5-43.5 GHz). We consider that outdoor low power co-channel deployment is likely to be possible in the areas of Cambridge furthest from the radio telescope but that co-channel medium power deployments are likely to be very challenging anywhere in the Cambridge high density area.

[39] Paragraphs 7.11 – 7.14

b) We consider that interference mitigation measures are likely to be needed for outdoor low power and medium power deployments in Cambridge in the spectrum adjacent to the radio astronomy band (40.5-42.5 GHz). A combination of careful site engineering, radio planning and base station equipment with improved unwanted emissions performance will be required to deploy in the adjacent channel.

c) The risk of interference from low power indoor deployments in the Cambridge high density area is very low across the 40 GHz band. This is because buildings are likely to sufficiently attenuate the signals from low power indoor base stations towards the Cambridge radioastronomy site. We therefore consider that additional mitigations are unlikely to be necessary to ensure coexistence between low power indoor base stations in the Cambridge high demand area and the Cambridge radioastronomy site.

d) The risk of interference to the Cambridge radioastronomy site from medium power deployments is within 20 to 40km of the site depending on local terrain. It is therefore likely that low and medium power base stations could be deployed in high density areas further away from Cambridge such as Luton, Peterborough and Stansted Airport without additional interference mitigations for the protection of radioastronomy.

Site parameters for modelling coexistence

A16.55 The parameters used for modelling the radio astronomy site are listed in Table A16.6. The parameters for the indoor mobile base station are presented in the Shared Access licence guidance[40] while the outdoor mobile base station parameters are in the May 2022 Consultation.[41]

Table A16.6: Parameters of the Cambridge radio astronomy site (RAS)

Parameter	Units	Value	Comment
Antenna center height above ground	m	32	As provided by STFC
Antenna gain (omni)	dBi	0	This is in accordance with annex 1 of ITU-R RA.769-2
Frequency range	GHz	42.5 – 43.5	42.5 – 43.5 GHz has been allocated internationally for radioastronomy
RAS location	NGR	SU 539423, 254028	This is the site location of the Cambridge RAS as obtained from the Cambridge RSA
	Lat/long	52.16833333, 0.03972222	-

[40] Ofcom's Guidance Document "Shared Access Licence", published 20 September 2022, paragraph 3.12.
[41] May 2022 Consultation, paragraph A6.11.

Parameter	Units	Value	Comment
Input power threshold interference level	dBW	-207	This approach of using the Spectrum quality benchmark (SQB) as the protection criterion was used in the December 2021 consultation on "Protecting passive services at 23.6-24 GHz from future 26 GHz uses".[42] The SQB level has been obtained from ITU-R RA.769-2 and has also been specified in the system parameters document for radio astronomy studies ahead of WRC 19.
Assumed spectral line channel bandwidth	kHz	500	

Method

A16.56 We have used HTZ Communications for coverage modelling of the Cambridge RAS. This tool allows us to model the isolation between the Cambridge radioastronomy site and nearby locations by taking into account detailed parameters about the deployments as well as clutter and terrain on the propagation path.

A16.57 We carried out a "reverse coverage" calculation to assess the area over which there is a risk of interference from mobile base station deployments to the radioastronomy site in Cambridge. A "reverse coverage" calculation considers every pixel in the area around the Cambridge radioastronomy site and calculates whether emissions from a base station deployed in that pixel would exceed the protection criteria of the radioastronomy site. The steps followed in configuring the software are listed below.

Steps for determining the area around the radioastronomy site in which there is a risk that the radioastronomy protection criteria could be exceeded

- Load clutter and digital elevation data in HTZ Communications
- Create a new station in HTZ and set its antenna and location parameters and the corresponding mmWave base station bandwidth.
- Set the nominal power of the RAS to 100 W. This is set to ensure the field strength obtained in the threshold calculations is a positive number.
- Under Network Calculation, select Tx/Rx FS coverage.
  - Set the heights of the Rx antennas to 3m for indoor low power base stations; 6m for low power base stations; or 15m for medium power base stations.
  - Set the simulation coverage area distance to 100km. This is because we found that this coverage distance was sufficient to identify all the pixels where base station deployments might risk causing interference to the radioastronomy telescope in Cambridge.
  - Select the P.452-17 model under the Model options and set the time percentage to 50 %.
  - Load the additional clutter losses for this model developed by Siradel for Ofcom.

[42] December 2021 Consultation on protecting passive services at 24 GHz, paragraph A2.17

- Run the simulations

- Once the simulation is complete, select User Palette under the Tools tab and input the threshold levels. We varied the threshold considering a range of worst case reduction factors (F_{WCR}) to test the sensitivity of our model to more realistic assumptions. We describe how the threshold levels were calculated in more detail below.

A16.58 To determine the threshold value to use in determining the area around the radioastronomy site in which there is a risk that the radioastronomy protection criteria could be exceeded, we used Equation A16.4:

Equation A16.4

$$Threshold\ Value(dBm) =$$

$$PTx_{RAS} + 30 - \left(P_t + G_t - (I_{sqb} + 30) + A_{MI} - L_{bel} + F_{WCR}\right)$$[43]

where,

PTx_{RAS} is the nominal power in dBW selected for the transmit power of the RAS for the purposes of modelling the reverse coverage calculation only, noting that the radioastronomy telescope is a passive receiver.

P_t is the transmit power of the interfering system in dBm / (BW in MHz)

G_t is the gain of the interfering system towards the victim receiver in dBi

I_{sqb} is Spectrum quality benchmark in dBW/MHz. This was calculated using the SQB values in Table A1.1 and normalising the input power spectral density from 500 kHz to 200 MHz using the following equation:

$$I_{sqb} = -207 + 10\log_{10}\left(\frac{200000000}{500000}\right) = -181 \text{ dBW / 200 MHz}$$

$A_{MI} = -ACLR$ in dB if adjacent channel operation is considered; and

$A_{MI} = 0$ dB for co-channel operation

L_{bel} is the building entry loss in dB. For outdoor base stations, $L_{bel} = 0$ dB. For indoor base stations L_{bel} = 14.8 dB which was calculated using Recommendation ITU-R P.2109-0[44] and taking the value of BEL corresponding to the 30th percentile of locations in traditional buildings at 42.5 GHz. This value is slightly higher than the value of BEL we calculated for 26 GHz earlier in this annex (14 dB) because BEL is higher at 42.5 GHz than 26 GHz.

Results

Co-channel outdoor deployments (42.5-43.5 GHz)

[43] This equation is derived from I/N of an interferer to a victim receiver $\frac{I}{N} = P_t + G_t + G_r - L_p - N - L_{bel} + A_{MI} + A_{BW} + F_{WCR}$ as shown in A6.34 of the May 2022 Consultation. The values for the worst-case reduction are introduced via the HTZ user pallete. The central case for our worst-case reduction factor (F_{WCR}) $is\ 12\ dB$. This approach was presented in A6.34 – A6.41 of the May 2022 Consultation.

[44] ITU, "Recommendation P.2109-0: Prediction of building entry loss", published June 2017.

A16.59 The area in which there is a risk that the Cambridge radioastronomy protection criteria might be exceeded by co-channel outdoor base stations is shown in Figure A16.2 and Figure A16.3. The dark blue grids of squares in our plots are our high density areas as described in annex 6. In order to consider the sensitivity of the results to our modelling assumptions we have considered a range of worst case reduction factors with F_{WCR} = 0 dB being the worst case, F_{WCR} = 12 dB being our central case and F_{WCR} = 18 dB being a more optimistic case.

A16.60 In Figure A16.2 we observe that low power base stations may be able to be deployed in some areas of Cambridge when considering our central case, F_{WCR} = 12 dB. However, for medium power base stations in Figure A16.3, we observe that it is likely to be very challenging to deploy medium power base stations in Cambridge and that this remains true even for the most optimistic case we considered.

A16.61 Considering both Figure A16.2 and Figure A16.3 we observe that there is unlikely to be any constraint on the ability of licensees to deploy base stations in high density areas that are further away from the radio astronomy site than the Cambridge high density area.

Figure A16.2: area in which there is a risk that the Cambridge RAS protection criteria might be exceeded for co channel low power outdoor deployment[45]

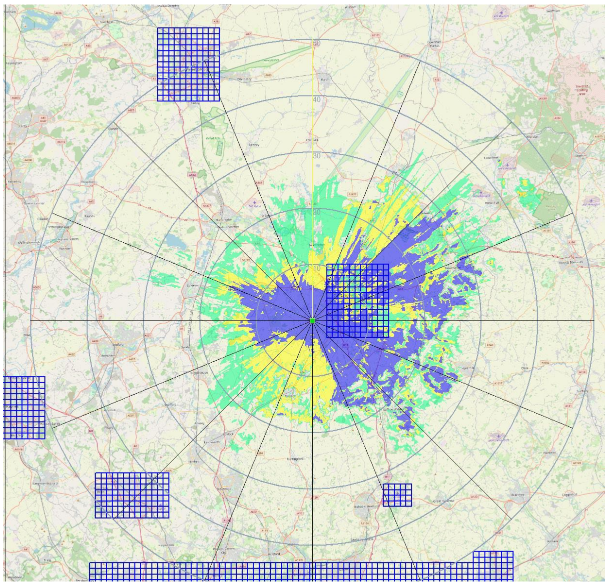
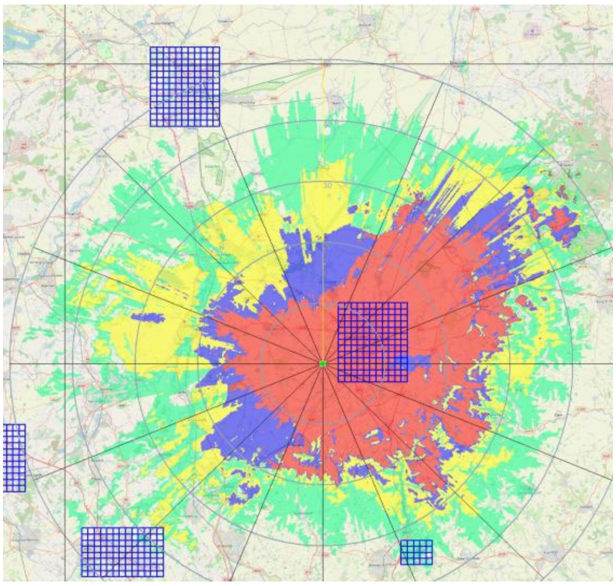


Figure A16.3: area in which there is a risk that the Cambridge RAS protection criteria might be exceeded for co channel medium power deployment



Legend for Figure A16.2 and Figure A16.3
(N.B. a worst case reduction factor of 12 dB is our central case):

	WCR factor (dB)
	0
	6
	12
	18

[45] The coverage rings around the RAS are 10, 20, 30, 40 and 50 km radius. The areas outlined in dark blue squares are the high density areas.

First adjacent channel outdoor deployments (42.3-42.5 GHz)

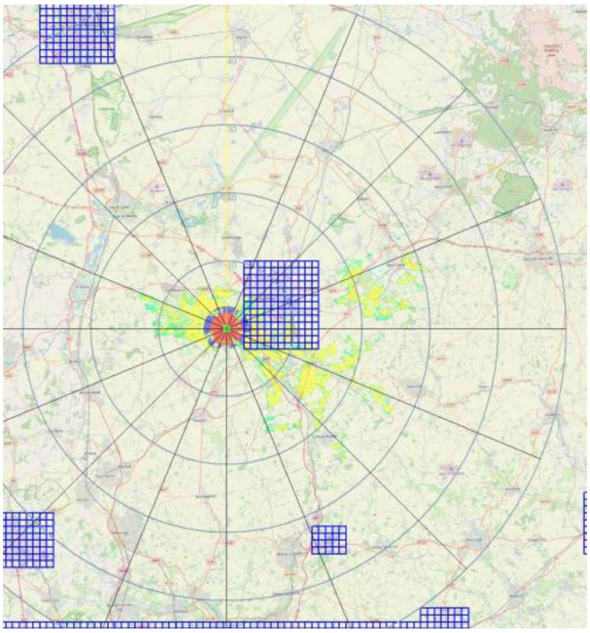
A16.62 We have considered the risk of interference from mobile base stations to the Cambridge radio astronomy site when the mobile base station is operation in the first adjacent channel to radio astronomy (42.3-42.5 GHz). In the first adjacent channel we have modelled the out-of-band emissions to be 26 dB below in the in-band power levels as specified in the emissions mask we have used for coexistence at 40 GHz.[46]

A16.63 In Figure A16.4 and Figure A16.5, the areas where mobile base station deployment might risk causing interference to the Cambridge radioastronomy site are shown. We have also included the additional isolation compared with our central case (F_{WCR} = 12 dB) that might be required to enable deployments across the entirety of the Cambridge high demand area whilst also protecting the Cambridge radio astronomy site. The additional isolation required is recorded at the point where the reverse coverage area just intersects with the edge of the Cambridge high density area.

A16.64 We observe from Figure A16.4 that there is a low risk of interference from low power base stations operating in 42.3-42.5 GHz across most of the Cambridge high density area. However, there remains some risk of interference from medium power deployments across significant parts of the Cambridge high density area to the radio astronomy site. We discuss later in “Interference mitigation for outdoor low and medium power base stations” what this might mean for the deployment of outdoor base stations in 40.5-42.5 GHz.

[46] May 2022 Consultation, Figure A6.3.

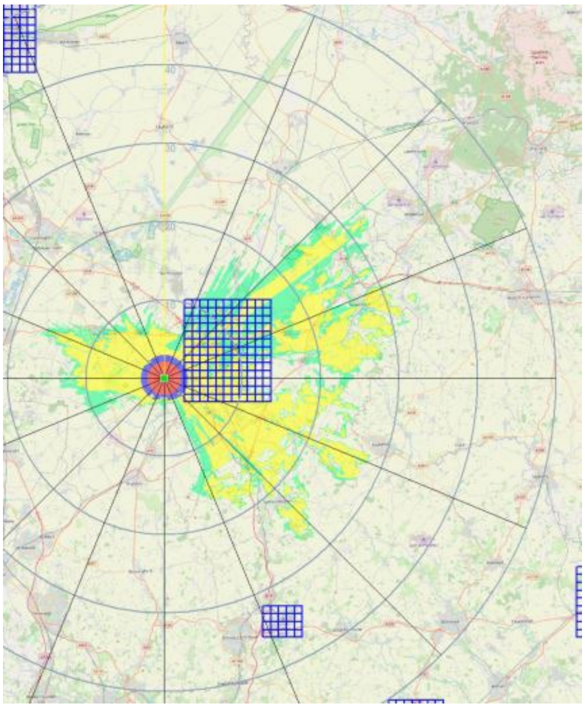
Figure A16.4: area in which there is a risk that the Cambridge RAS protection criteria might be exceeded for low power outdoor deployment in the first adjacent channel



	F_{WCR} (dB)
Green	0
Yellow	12

	Additional Isolation required relative to F_{WCR} = 12 dB case (dB)
Blue	24
Red	27

Figure A16.5: area in which there is a risk that the Cambridge RAS protection criteria might be exceeded for medium power deployment in the first adjacent channel



	F_{WCR} (dB)
Green	0
Yellow	12

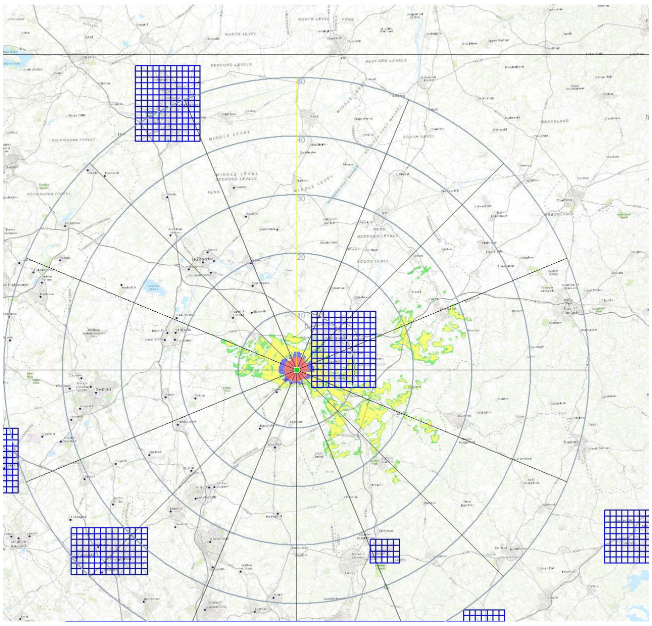
	Additional Isolation required relative to F_{WCR} = 12 dB case (dB)
Blue	36
Red	39

Indoor low power deployments

A16.65 The reverse coverage maps for indoor low power base station co-channel deployments are shown in Figure A16.6 and the results for first adjacent channel deployments in Figure A16.7. We have also included the additional isolation compared with our central case (F_{WCR} = 12 dB) that might be required to enable deployments across the entirety of the Cambridge high density area whilst also protecting the Cambridge radio astronomy site.

A16.66 These results show that there is little risk of interference from indoor low power mobile deployments across most of the Cambridge high density area to the Cambridge radio astronomy site, both in-band (42.5-43.5 GHz) and out-of-band (40.5-42.5 GHz). There remains some risk of interference from indoor low power mobile deployments in the areas of the Cambridge high density area which are closest to the Cambridge radio astronomy site.

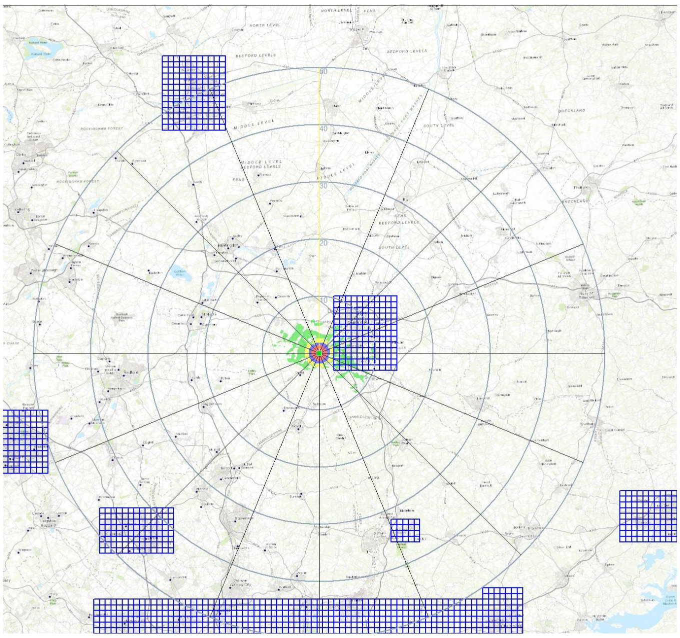
Figure A16.6: area in which there is a risk that the Cambridge RAS protection criteria might be exceeded by low power indoor deployments which are co-channel [BEL = 14.8 dB: Traditional Building, 30th percentile of locations]



	F_{WCR} (dB)
Green	0
Yellow	12

	Additional Isolation required relative to F_{WCR} = 12 dB case (dB)
Blue	27
Red	30

Figure A16.7: area in which there is a risk that the Cambridge RAS protection criteria might be exceeded by low power indoor deployments which are in the first adjacent channel [BEL = 14.8 dB Traditional Building, 30th percentile of locations]



	F_{WCR} (dB)
Green	0
Yellow	12

	Additional Isolation required relative to F_{WCR} = 12 dB case (dB)
Blue	27
Red	30

Interference mitigation for outdoor low and medium power base stations

A16.67 Given the outcome of our coexistence study, licensees may need to engineer their sites to reduce the risk of interference from outdoor base station deployments in the Cambridge high density area to the radio astronomy site at Cambridge. Co-channel (42.5-43.5 GHz) medium power deployments are likely to require the most mitigations whilst low power outdoor or deployments in adjacent spectrum (40.5-42.5 GHz) will require fewer.

A16.68 In ECC REC 15(01),[47] guidance for mitigating interference is given for operators deploying mobile networks in border areas at sub-6 frequency bands. We consider that some of the techniques presented in ECC REC 15(01) could also be relevant to the deployment of mmWave base stations and can be applied to mitigate the risk of interference from outdoor base station deployment to the radioastronomy site at Cambridge. The relevant techniques presented in ECC REC 15(01) for mitigating the risk of interference are:

a) **Antenna tilting and restricted beamforming**: this technique covers methods such as antenna downtilt and antenna pointing. By pointing the antenna away from radioastronomy site, interference towards the RAS can be significantly reduced.

b) **Downlink power reduction:** reducing the downlink power of the base station sectors that point towards the RAS can improve coexistence. The consequence of this will be reduced cell range.

A16.69 In addition to the recommendations in ECC REC 15(01), we consider that base station equipment with improved unwanted emissions performance can also contribute to interference mitigation from outdoor low and medium power deployments for base stations operating in the adjacent band (40.5-42.5 GHz).

[47] ECC, "ECC REC 15(01): ECC Recommendation of 13 February 2015 on cross-border coordination for mobile/fixed communications networks (MFCN) in the frequency bands: 694-790 MHz, 1452-1492 MHz, 3400-3600 MHz and 3600-3800 MHz", published 10 June 2022, paragraph A1.5.

A17. Fixed link resilience to 5G mmWave mobile - measurement evidence

Summary

A17.1 This annex explains the technical measurements we have carried out to estimate how resilient fixed links are likely to be to interference from new mobile services operating in the same band.

A17.2 We measured the resilience of three fixed links from three different vendors in the presence of interference from 5G mmWave mobile signals. To assess resilience, we recorded the reduction in data throughput that occurred as we increased the power of an unwanted interfering signal. We recorded the power of the wanted signal relative to the power of the unwanted signal, the wanted to unwanted ratio ("**W/U**").

A17.3 Our measurements suggested that fixed links we measured might be more resilient to mobile interference than might be expected by simply using the W/U levels, which we use for coordination between fixed links. We have used these observations to inform our selection of an appropriate Worst Case Reduction Factor ("$\mathbf{F_{WCR}}$") which is a factor we use to improve the realism of our coexistence modelling. We discuss how we have taken these observations into account for making a judgement on F_{WCR} in annex 16.

A17.4 We took fixed links receiver resilience measurements using a 5G interferer which transmitted bursts of data which were a few frames in duration, intended to simulate the behaviour of real mobile data flows and active antenna beam movement. We found that the fixed links were no more or less resilient than with constant 5G interference. After an interference event which caused the link to fail, we observed that one of the fixed links ("Device A") took around 3 seconds to reestablish a link and around 8 seconds to return to the full, uninterfered throughput. We have concluded from these observations that time-averaging beam radiation patterns or traffic profile variations from mobile base stations over a period of a few frames or more is unlikely to be relevant for assessing coexistence between mobile base stations and fixed links. We discuss how we have updated our previous view on this in the discussion on the F_{WCR} in annex 16.

A17.5 The rest of this annex is structured as follows:

- **Background**: why we have carried out these measurements, how they will be used and our approach to measurements.
- **Approach to the measurements**: how we set up and configured the measurement equipment.
- **Measurement Results**: all the measurement results along with some observations.
- **Comparison of measured and TFAC W/U levels**: we compare the measured W/U levels with those that we currently use for coordination between fixed links
- **Test Setup**: the measurement setup along with the software used.

Background

A17.6 In the May 2022 Consultation we proposed to make a large amount of millimetre wave (mmWave) spectrum available across the 26 GHz and 40 GHz bands for use of mobile technology, including 5G.[48] We noted that there are existing fixed links in both of these bands and said that we would conduct further work, including measurements, to better understand the ability for potential future users in the bands to coexist with existing fixed links.[49] Our decision to conduct measurement work is in line with our Statement "Supporting the UK's wireless future – Our spectrum management strategy for the 2020s" (our "**Spectrum Strategy**"), which sets out Ofcom's intention to use information regarding the real performance of equipment and services where this is available, rather than particular equipment standard limits,[50] with a particular focus on receiver performance.[51]

Approach to the measurements

A17.7 We carried out these measurements at Baldock Radio Station using the measurement setup shown in Figure A17.15. The transmit power of the transmitting fixed link was adjusted until we measured that the received power level at the receiving fixed link was 3 dB above the minimum receiver sensitivity level (RSL), as stated by the link's manufacturer for given modulation and bandwidth. Data was transmitted over each fixed link using laptops running Jperf,[52] one laptop at the transmitting fixed link and another laptop at the receiving fixed link. The average data rate across 30 second intervals was recorded to establish the reference "throughput without interference" level.

A17.8 We generated interfering signals on a Rhode and Schwarz SMW200A signal generator and injected these into the fixed link wanted signal path. The impact on the average data rate over 30 seconds was recorded. The power for the 5G interferer was adjusted until the point at which interference began to cause a reduction in throughput was observed (at least 90% throughput maintained). Measurements were taken by adjusting the 5G interferer power to be higher and lower than this point and the 5G interference power and fixed link throughput were recorded.

A17.9 We studied several different fixed link profiles and interferer profiles in order to understand which factors had the greatest impact on our results. These are described in more detail in the next sub-section (paragraphs A17.10 to A17.14).

[48] May 2022 Consultation, p. 1.
[49] May 2022 Consultation, paragraph 5.17.
[50] Ofcom's Statement "Supporting the UK's wireless future – Our spectrum management strategy for the 2020s", published 19 July 2021, paragraph 3.60.
[51] Spectrum Strategy, paragraph 3.66.
[52] Jperf is an application that sends data packets and allows the user to configure the data packet size, type and duration.

Fixed link parameters

A17.10 We tested three different fixed links, which we refer to as Devices A, B and C. They are all made by different vendors.

A17.11 We tested each of the fixed links in the following different scenarios.

Modulation order

A17.12 We disabled the adaptive modulation and coding for the fixed links we tested so that we could more easily observe the throughput reduction in the presence of 5G mobile interference. We studied modulation rates of 64, 512, 1024 and 2048 QAM for Device A and Device B, and rates of 64, 128 and 256 QAM for Device C because it did not support higher modulation rates. The results presented consider 512 QAM as a typical modulation rate for Device A and Device B and 256 QAM as typical for Device C.

A17.13 We also took some measurements where the fixed link adaptive modulation was enabled to test our previous view that this could make the links more resilient to interference at the cost of fixed link throughput. We understand that even though the fixed links still maintain a connection, the drop in throughput may not be acceptable in some cases. We also acknowledge that the ability for fixed links to trade-off between resilience and link capacity may not be true for older devices, which do not support adaptive modulation.

System bandwidth

A17.14 We considered 56 MHz bandwidth as the central case for all the fixed links measured. However, we also took measurements of 28, 14 and 7 MHz bandwidths as these are all possible bandwidth configurations for mmWave fixed links.

Interferer parameters

A17.15 The following interferers were injected into the fixed link wanted signal path:

Continuous wave (CW)

A17.16 A continuous wave carrier is a waveform of constant amplitude and frequency. It is unmodulated and continuously on, rather than pulsed. It allows us to check at what power level the link is being blocked by the carrier wave. Blocking is an interference effect caused by very high power entering the receiver and overloading the receiver. This is a different interference mechanism to interference caused by wideband noise which is why we used a CW signal to test it.

Additive white gaussian noise (AWGN)

A17.17 We included a AWGN signal as an interferer in our measurements because it simulates wide band uniform noise interference. We expected that AWGN would be the most disruptive type of interferer and we can use these results to compare with the interference caused by 5G mobile interferers.

5G mobile

A17.18 We generated simulated 5G signals on a Rhode and Schwarz SMW200A signal generator. The simulated 5G signals were time division duplexed (TDD) with either a 50% or an 80% downlink ratio. These downlink ratios were used because it is likely that some private networks may use a 50% downlink ratio and it is likely that public mobile networks will use an 80% downlink ratio.[53] For the purposes of calculating the W/U ratio we adjusted for TDD signals so that the unwanted power (U) we consider is the power transmitted during the "on" period only and is not the average over the whole transmit cycle.

A17.19 The 5G interferer signal had a bandwidth of 100 MHz, which is wider than the fixed link receiver bandwidths considered (7, 14, 28 and 56 MHz). We have therefore normalised our W/U calculations to only consider the 5G interferer power falling into the receiver bandwidth. Power falling outside of the receiver bandwidth will have a much smaller impact on coexistence than the power falling co-channel and so should not be included in our calculation of the unwanted power.

Bursty 5G mobile

A17.20 Mobile signals tend to be "bursty" because demand is often variable and base stations do not transmit at full power when lightly loaded. For example, we observed that 4G signals were bursty and that this could have an impact on coexistence with digital terrestrial television (DTT) in our previous measurement work.[54] Beamforming behaviour at mmWave could further increase the burstiness of interference energy towards fixed links as beams move around the cell to search for new users to attach to the network or serve data to users at different locations within the cell. We simulated this burstiness in our measurements by using the signal generator to generate the 5G mobile signal with a 10% mark-to-space ratio for the following on:off durations: 100ms:900ms; 50ms:450ms; and 20ms:180ms. We chose these durations because a 5G frame is 10ms long, so these on periods could be representative of a typical transmission burst towards a user.

Frequency overlap

A17.21 Unless stated otherwise, we measured the victim and the interferer signals when they were co-channel with the same centre frequency. For example, the full 56 MHz of the fixed link signal overlaps with the simulated 5G signal in the co-channel test case because the bandwidth of the 5G signal was 100 MHz and we used the same centre frequency for both. In addition, we tested partial overlaps of 38 MHz and 8 MHz. For partial overlap cases, the co-channel power adjustment of the unwanted signal (U) was done by factoring in the

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[53] ECC, "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", published 6 March 2020, p. 30, section 4.5.2. [accessed 7 March 2022]

[54] "As part of our measurements, we have also investigated the impact of time discontinuous or bursty LTE signals in relation to interference to DTT reception. Such bursty signals occur when the base station is not fully loaded with user traffic and does not transmit with all resource blocks at its disposal." (Ofcom's Technical Report "*Technical analysis of interference from mobile network base stations in the 800 MHz band to digital terrestrial television*", published 10 June 2011, paragraph 5.38 [accessed 7 March 2022])

fraction of the interfering signal bandwidth overlapping the wanted signal. For instance, in the 38 MHz overlap case, $10 \cdot \log_{10}(38/100)$ in decibels is added to the unwanted power value. It is added to the value as ratios can be applied by addition in the logarithmic domain.

Receiver sensitivity level used in testing

A17.22 The receiver sensitivity level (RSL) for each fixed link was found from the specification sheets provided by each fixed link manufacturer. A central case with 512 QAM modulation and 56 MHz bandwidth was considered based on typical 26 GHz fixed link parameters. The modulation and bandwidth of each fixed link signal were varied from this central case and the RSL adjusted accordingly using the data from the manufacturer. The power transmitted by the fixed link was adjusted until the received signal level was 3 dB above the receiver sensitivity level. The centre frequencies noted here for each fixed link were kept the same for all subsequent tests in this report.

Table A17.1: **Receiver sensitivity level and received signal strength for Device A and Device B**

		Device A at 23.044 GHz		Device B at 26.005 GHz	
Receiver Bandwidth *MHz*	Modulation order *QAM*	Receiver sensitivity level *dBm*	Received signal level *dBm*	Receiver sensitivity level *dBm*	Received signal level *dBm*
7	512	-68.5	-65.0	-68.0	-65.0
14	512	-68.5	-65.0	-68.5	-65.0
28	512	-64.5	-61.0	-65.0	-62.0
56	64	-70.0	-67.0	-71.0	-68.0
56	512	-62.0	-59.0	-62.0	-59.0
56	1024	-57.5	-54.0	-58.0	-55.0
56	2048	-55.0	-52.0	-54.0	-51.0

Table A17.2: Receiver sensitivity level and received signal strength for Device C

		Device C at 26.033 GHz	
Receiver Bandwidth *MHz*	Modulation order *QAM*	Receiver sensitivity level *dBm*	Received signal level *dBm*
7	256	-72.5	-69.0
14	256	-69.5	-66.0
28	256	-67.5	-64.0
56	64	-70.5	-67.0
56	128	-67.5	-64.0
56	256	-64.0	-61.0

Measurement results

A17.23 In this sub-section we set out our main findings from the measurements.

A17.24 In the figures we have plotted the Average Data Rate in Mbit/s against the W/U ratio.

A17.25 The results are organised as follows:

- interference impact of continuous co-channel signals;
- interference impact for different fixed link modulation rates;
- interference impact for different frequency offsets between the fixed link and mobile interferer;
- interference impact for different fixed link bandwidths; and
- interference impact for different bursty interferers.

Behaviour of Device C

A17.26 We observed that Device C did not always behave as expected. We have omitted the graphs for Device C where we consider those results to be unreliable and we have not used them to inform our analysis. We have included the graphs for Device C where it was clear that it was behaving as expected.

A17.27 We contacted the manufacturer for further information as to why Device C was not providing the expected results. We were advised that Device C's adaptive modulation and coding, if switched off, automatically turns back on if the fixed link signal is interrupted. As our tests involved creating interference to the fixed link until the link was interrupted, we have concluded that Device C was turning the adaptive modulation and coding back on every time we caused interference to the fixed link that caused it to fail. Therefore, the modulation rates reported by Device C may not be a true reflection of the actual modulation and coding rate being used by Device C.

Interference impact of continuous co-channel signals

A17.28 We tested all three fixed links against four different types of interferer (see Table A17.4 below for the interferer parameters). Below, we show the fixed links receiver resilience measurements we took in the presence of a continuously transmitted co-channel interferer.

Table A17.3: Fixed link parameters

Device	Modulation Rate *QAM*	System Bandwidth *MHz*
A	512	56
B	512	56
C	256	56

Table A17.4: Interferer parameters

Interferer type	Duty Cycle *%*	Interferer Bandwidth *MHz*
TDD 80%	80	100
TDD 50%	50	100
Continuous Wave (“**CW**”)	100	CW
Additive white gaussian noise (“**AWGN**”)	100	100

Figure A17.1: Device A

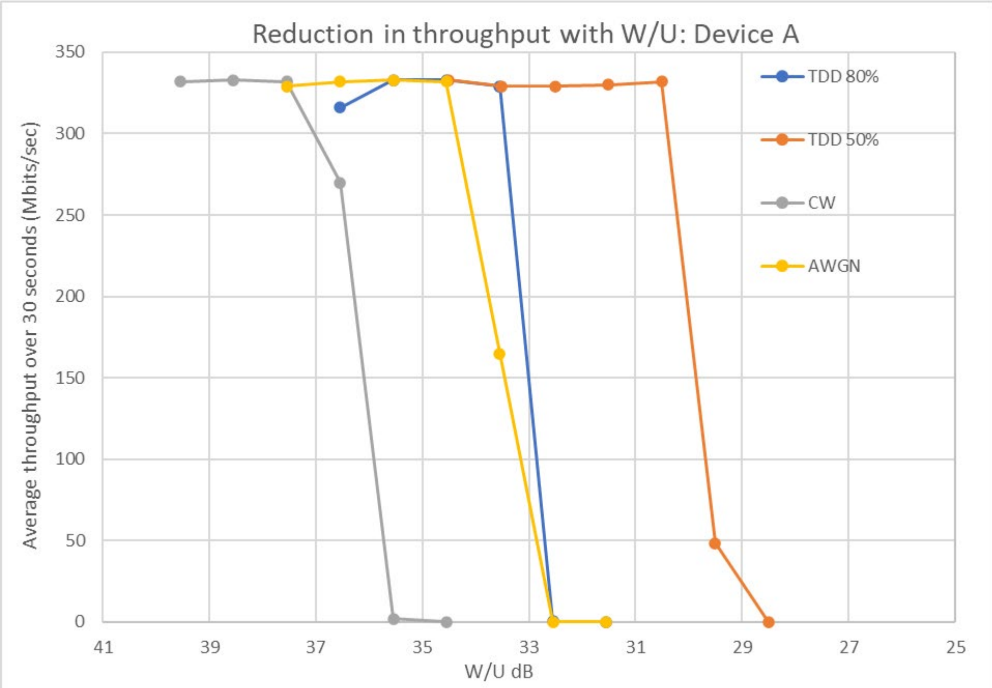


Figure A17.2: Device B

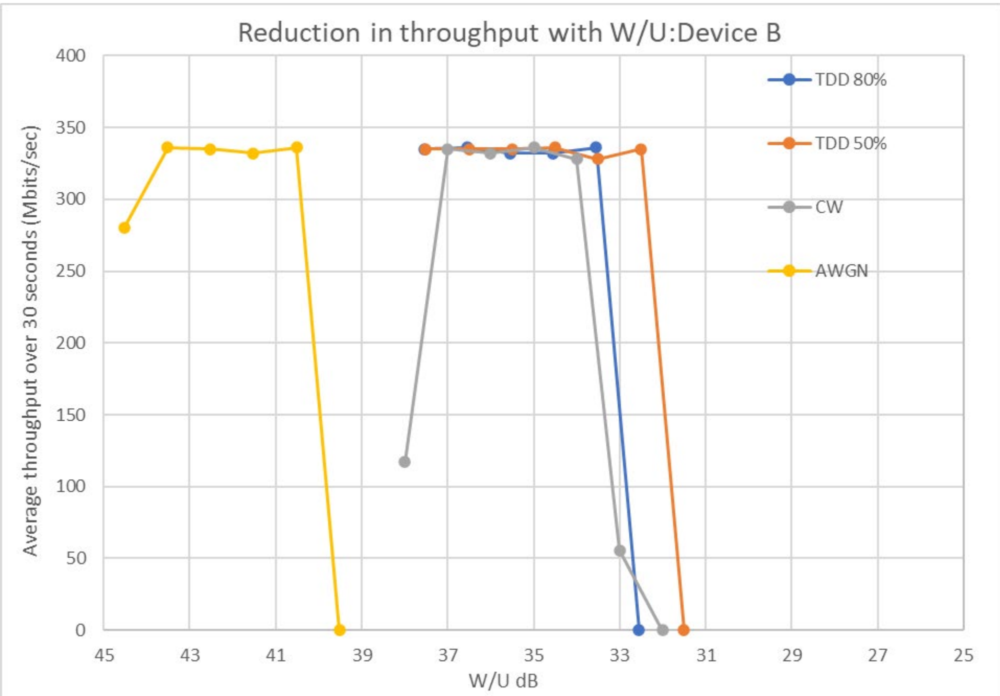
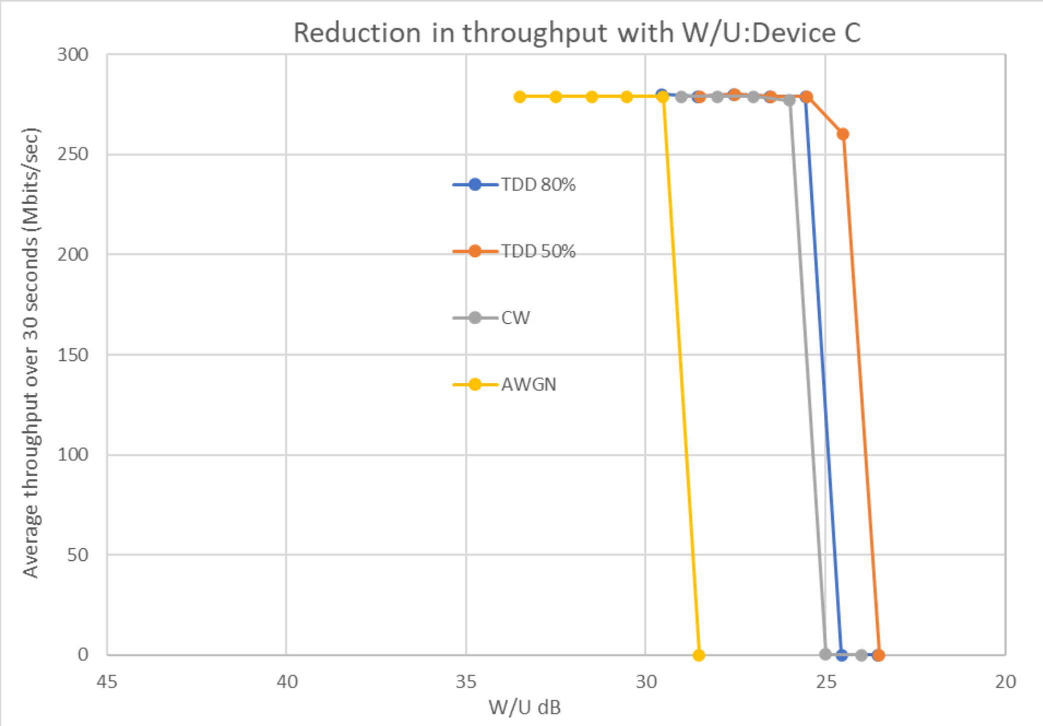


Figure A17.3: Device C



Observations

A17.29 Of the four interferers we tested, all three fixed links were most resilient to the TDD 50% interferer. However, the difference in resilience of the fixed links to the TDD 50% interferer and the TDD 80% interferer is small. The fixed links are all slightly more resilient to the 5G interferers (50% TDD and 80% TDD) than the generic interferers (CW and AWGN). Device C was most resilient overall. However, this is likely to be because it was operating at a lower modulation order of 256QAM, compared to 512QAM for Device A and Device B links.

Interference impact for different fixed link modulation rates

A17.30 We also studied the fixed links' resilience to the impact of a continuously transmitted co-channel mobile TDD 80% interferer. We studied a range of fixed link modulation rates. We have omitted the results from Device C for reasons mentioned in A17.26 above.

Table A17.5: Fixed link parameters

Device	Modulation Rates *QAM*				System Bandwidth *MHz*
A	64	512	1024	2048	56
B	64	512	1024	2048	56

Table A17.6: Interferer parameters

Interferer	Duty Cycle *%*	Interferer Bandwidth *MHz*
TDD 80%	80	100

Figure A17.4: Device A

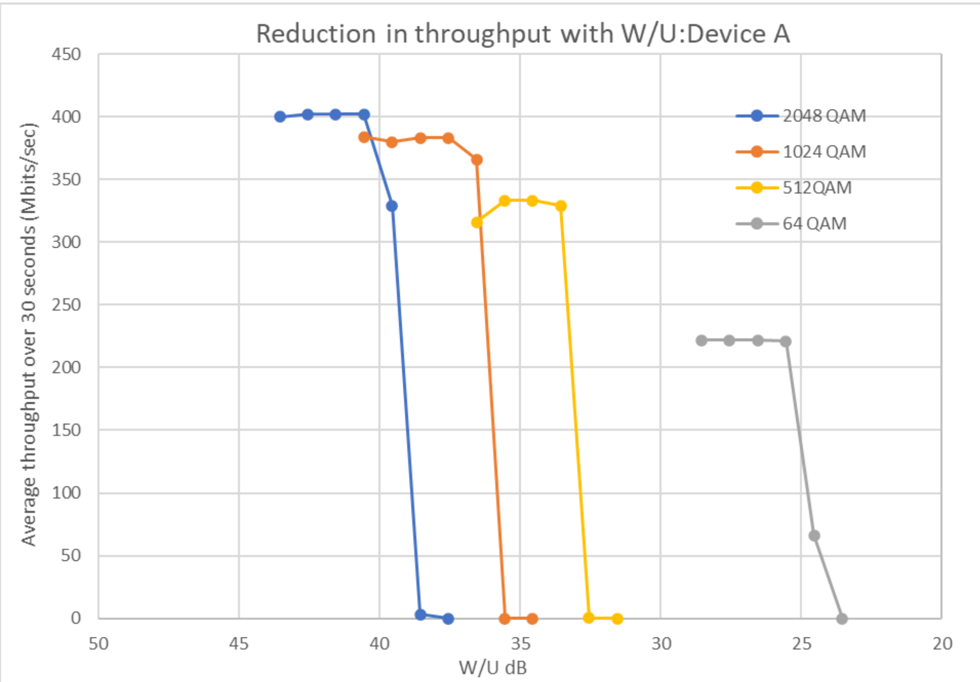
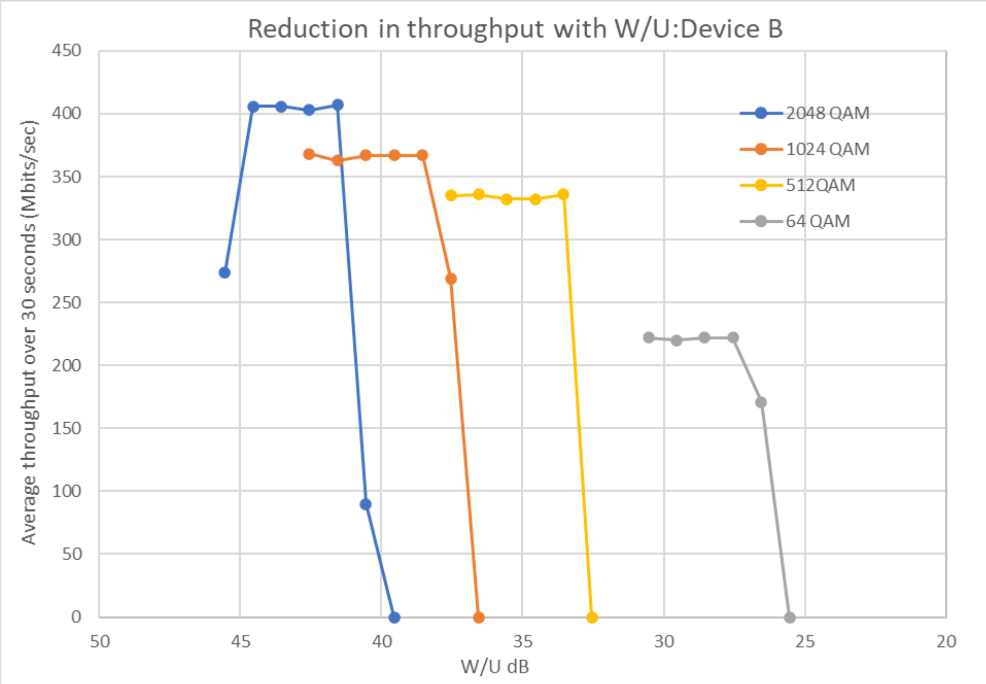


Figure A17.5: Device B



Observations

A17.31 Device A and Device B show a clear relationship between modulation of the fixed link signal and the resilience of the fixed link signal to interference from the 5G interferer. When the modulation rate is higher, the uninterfered throughput is higher, but it takes less interferer power (i.e. the wanted to unwanted ratio (W/U) is higher) when the throughput collapses to zero.

Interference impact for different frequency offsets between the fixed link and 5G interferer

A17.32 The following fixed links receiver resilience measurements consider a continuously transmitted co-channel mobile TDD 80% interferer. We tested a range of frequency offsets to see how this affected the performance of the link and for each we have calculated the overlap between the interfering signal and the receiver bandwidth. Device C behaved in a way which was as expected so we have not omitted the results in this case.

Table A17.7: Fixed link parameters

Device	Centre Frequency *GHz*	Modulation Rate *QAM*	System Bandwidth *MHz*
Device A	23.044	512	56
Device B	24.600	512	56
Device C	26.033	256	56

Table A17.8: Interferer parameters

Interferer	Frequency	Frequency Offset #1 *MHz*	Frequency Offset #2 *MHz*	Frequency Offset #3 *MHz*	Modulation Rate *QAM*	System Bandwidth *MHz*
TDD 80%	Centre Frequency Offset	0	40	70	512	56
	Overlap	56	38	8		

Figure A17.6: Device A

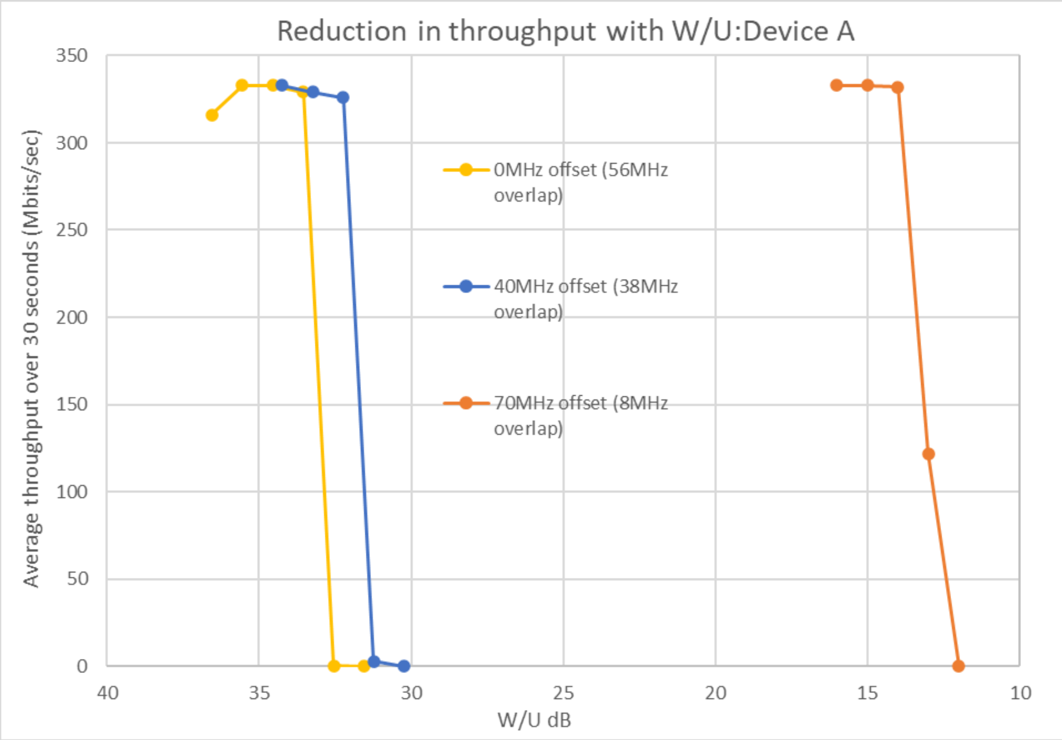


Figure A17.7: Device B

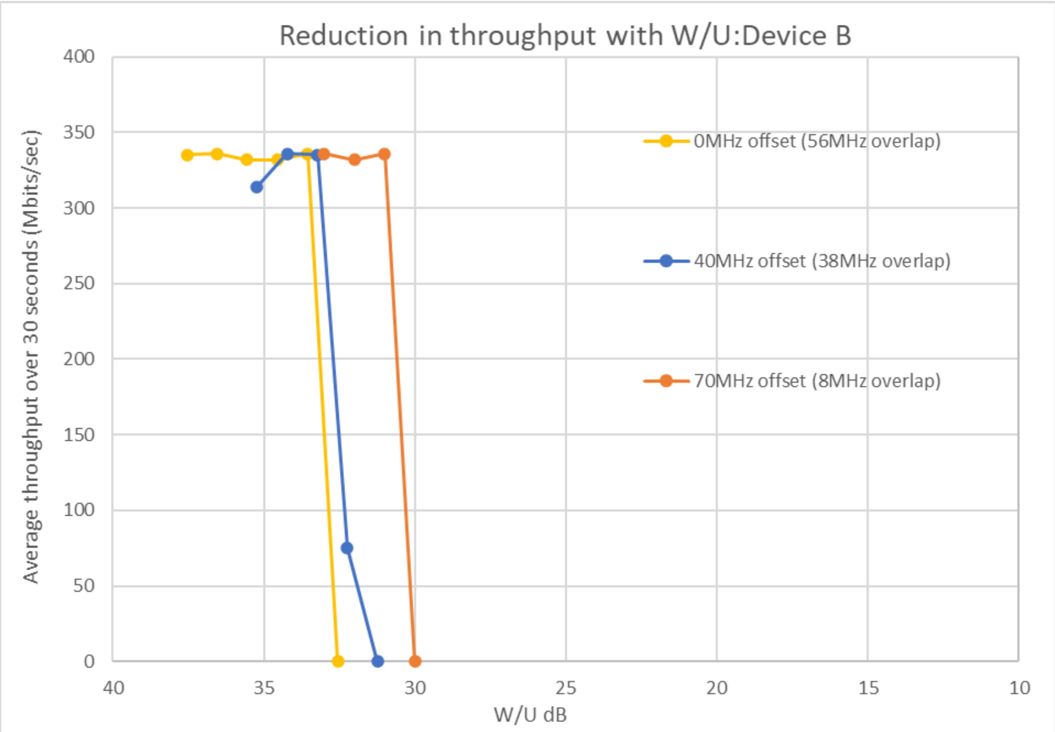
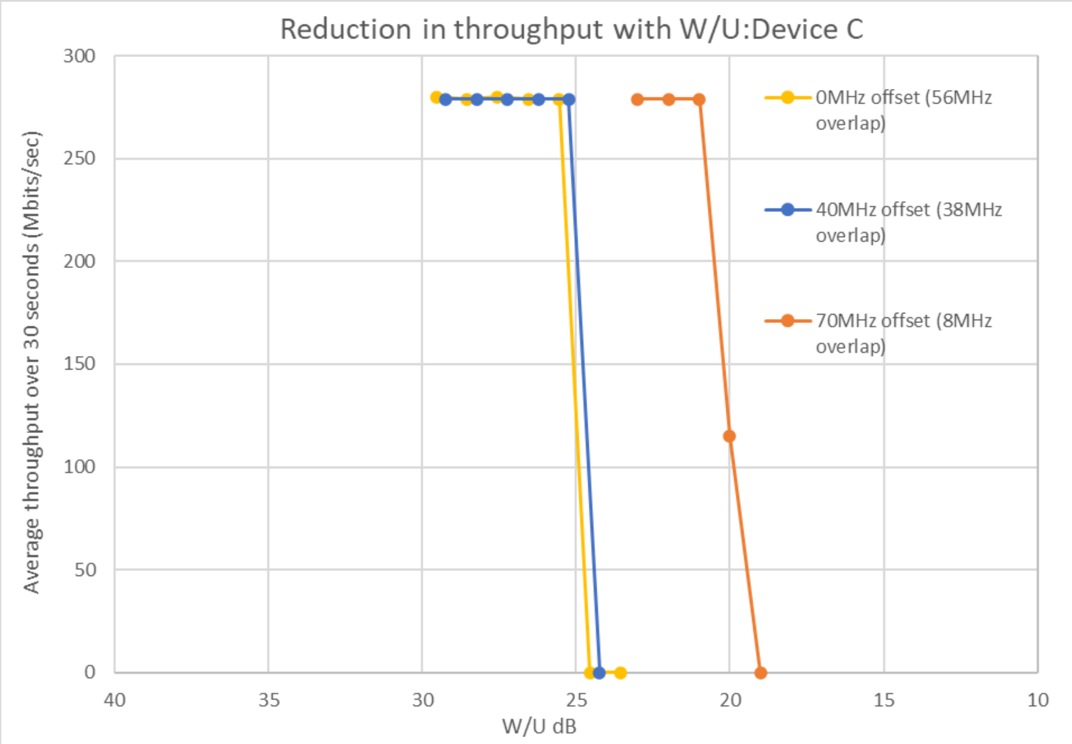


Figure A17.8: Device C



Observations

A17.33 As expected, having a larger frequency offset between the frequencies used by the fixed link and the frequencies used by the 5G signal increased the fixed links' resilience to the 5G signal. Device A and Device B performed similarly for smaller frequency separations with the interferer. However, Device A was almost 20 dB more resilient to interference than Device B when there was a larger 70 MHz separation (8 MHz overlap) with the interfering mobile signal. Device C's results showed that for the 70 MHz separation (8 MHz overlap), it was approximately 5 dB more resilient to 5G interference than when the 5G interferer was at 0 MHz offset.

A17.34 We note that these results show a variation in receiver performance when the interferer is at different frequency offsets from the wanted signal. As noted in our Spectrum Strategy[55] we expect that some receivers will perform better than others and these results corroborate that view. We believe we do not need to adjust our approach to coexistence and coordination, to account for the impact of variation in receiver performance at different frequency offsets between the fixed links and 5G interferer.

Interference impact for different fixed link bandwidths

A17.35 We also conducted the following receiver fixed link resilience measurements with a continuously transmitted co-channel mobile TDD 80% interferer. We compared several

[55] Spectrum Strategy, A1.83

different fixed link bandwidths to study how these affect the resilience of the link. We have omitted the results from Device C for reasons mentioned in A17.26.

Table A17.9: Fixed Link parameter

Device	System Bandwidths *MHz*				Modulation *QAM*
Device A	7	14	28	56	512
Device B	7	14	28	56	512

Table A17.10: Interferer parameters

Device	Duty Cycle *%*	Interferer Bandwidth *MHz*
TDD 80%	80	100

Figure A17.9: Device A

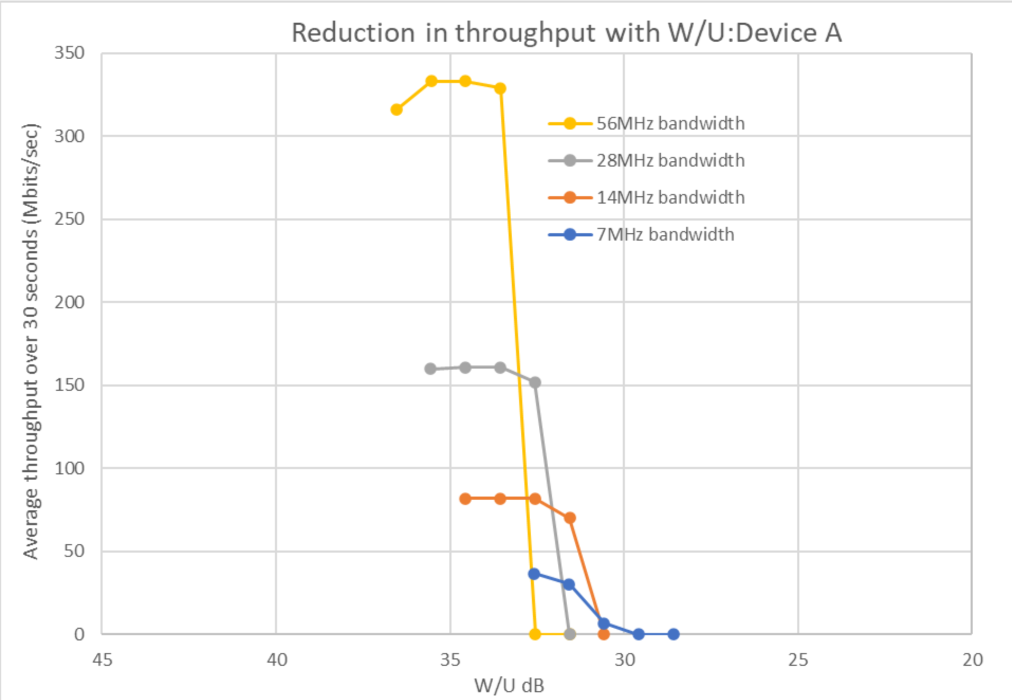
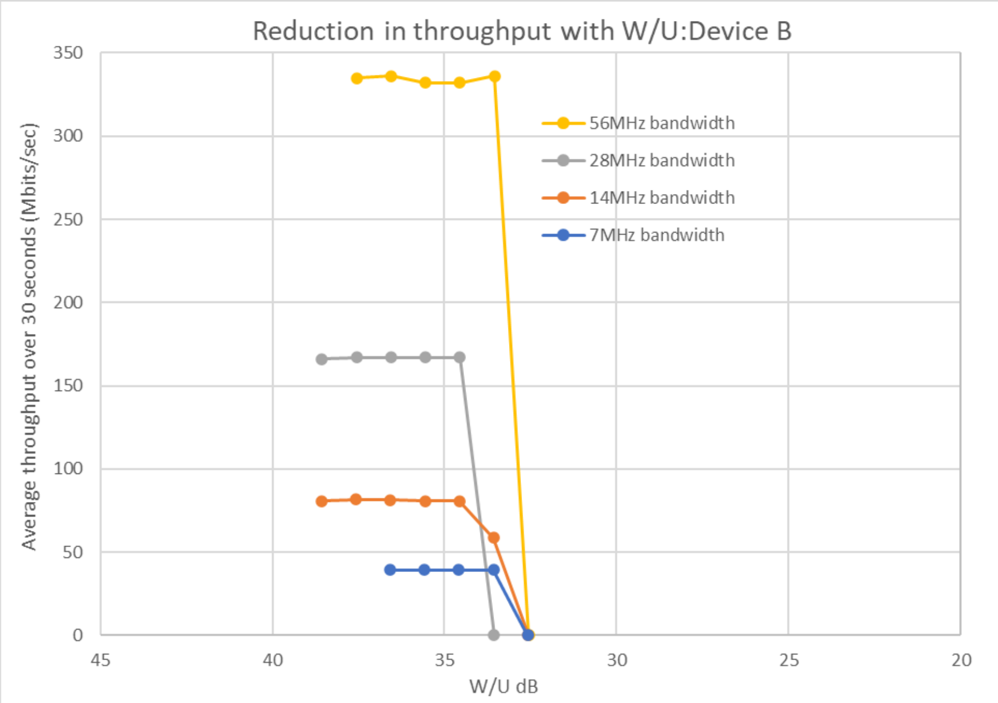


Figure A17.10: Device B



Observations

A17.36 Device A is slightly more resilient to 5G interference for narrower fixed link bandwidths whilst Device B has a similar resilience for all fixed link bandwidths considered. All bandwidths have a W/U between approximately 32 and 34 dB for both Device A and Device B. These results corroborate our view that fixed link bandwidth has little impact on coexistence with other potential interferers including mobile.

Interference impact of different bursty interferers

A17.37 We created six waves for the bursty interferer measurements, half with 80% TDD and half with 50% TDD. The properties we used to configure the waves are shown in Table A17.11. We have omitted the results from Device C for reasons mentioned in A17.26.

A17.38 For 80% TDD tests, 8 out of every 10 time slots were downlink (DL) slots and contained 5G interferer signals and the remaining were uplink (UL) slots which were empty. And similarly for TDD 50% test, 5 out of every 10 time slots have UL slots.

A17.39 To simulate burstiness, we switched these signals on/off for the times stated in Table A17.11 below. We note that the switching frequency was much slower than the TDD switching effect, with the interferer enabled for several frames before being disabled again.

Table A17.11: Bursty Interferer Properties

Wave	TDD	On time *ms*	Off time *ms*

80p_50.450	80%	50	450
50p_50.450	50%	50	450
80p_100.900	80%	100	900
50p_100.900	50%	100	900
80p_20.180	80%	20	180
50p_20.180	50%	20	180

Table A17.12: Fixed Link parameters

Device	Bandwidth *MHz*	Modulation *QAM*
Device A	56	512
Device B	56	512

Figure A17.11: Device A Bursty interferer

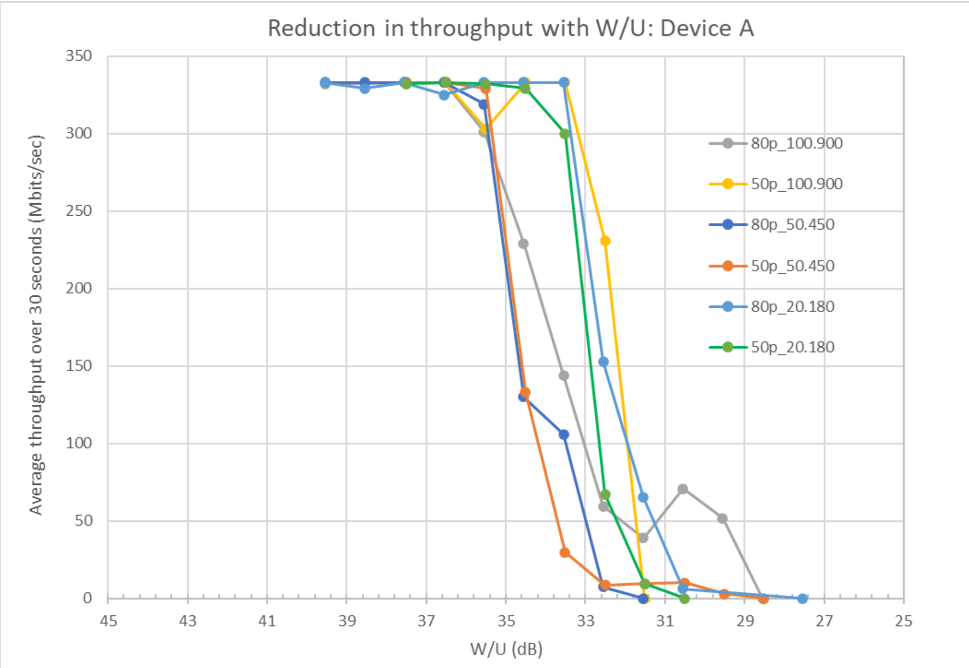
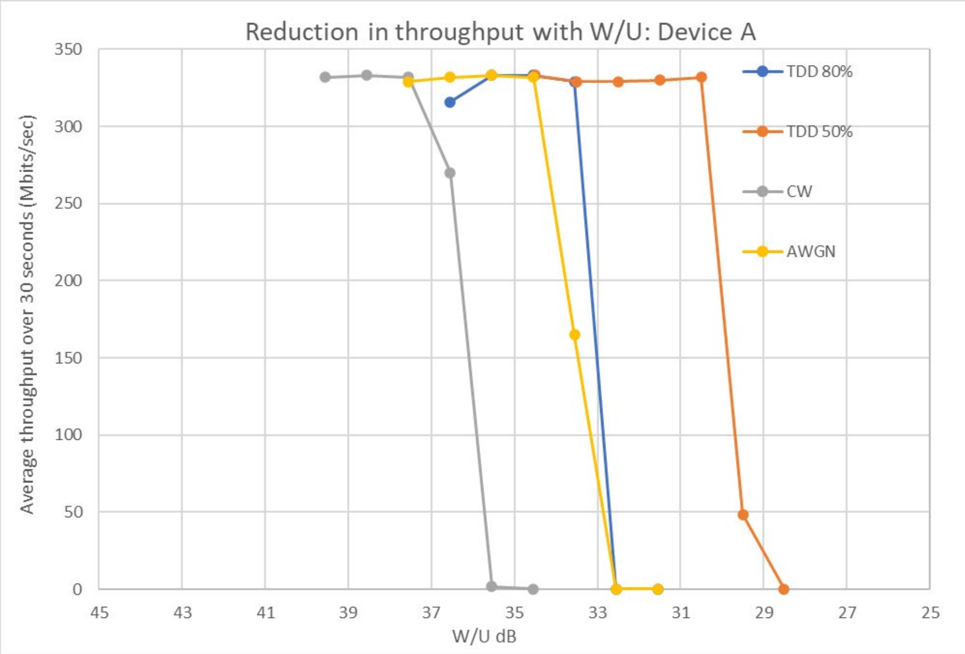


Figure A17.12: Device A constant interferer



Observations

A17.40 For all of the bursty interferers, the point at which the throughput in the wanted fixed link begins to drop is a higher W/U ratio than our constant 5G interferer for both 50% TDD and 80% TDD. This means that the fixed link is a few dB less resilient to bursty 5G interferers than constant 5G interferers. However, the point at which the fixed link completely fails is at a lower W/U than for the constant 5G interference. This suggests that some data is still getting through at the lower W/U.

Figure A17.13: Device B bursty interferer

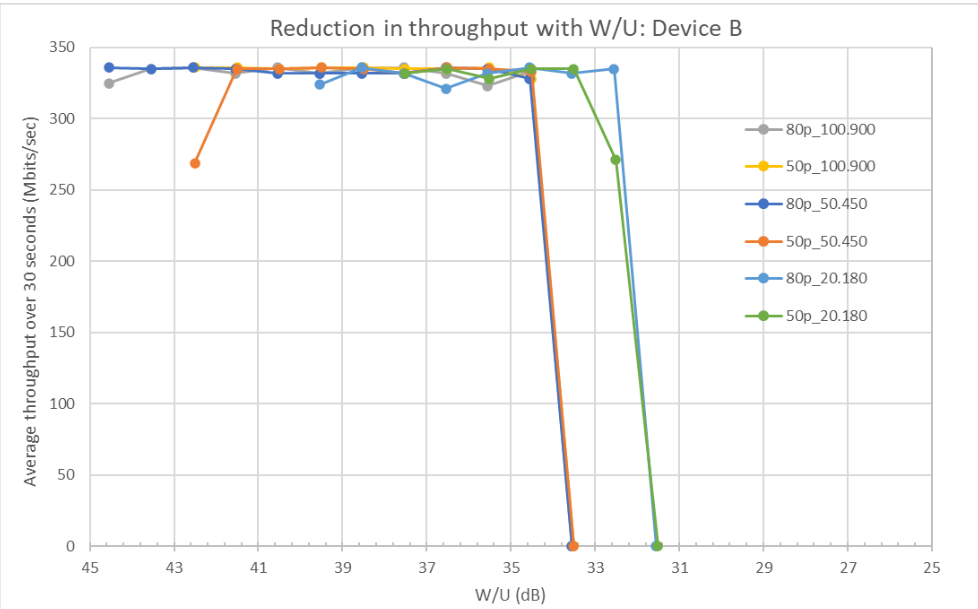
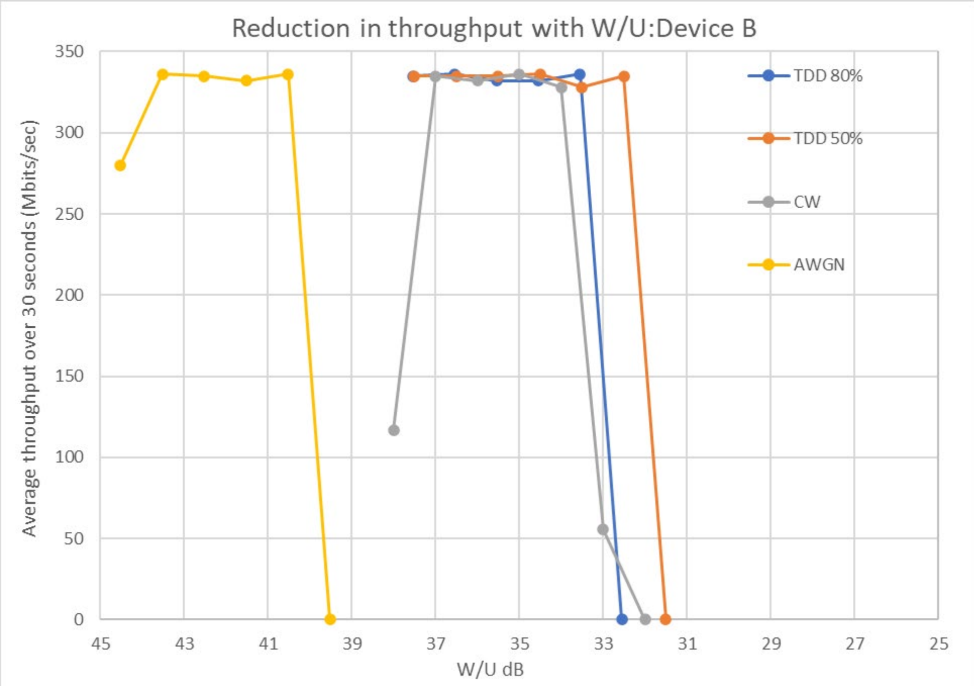


Figure A17.14: Device B constant interferer



Observations

A17.41 The W/U level at the point of the fixed link throughput degradation was 2 dB higher for the 50 and 100 ms interference bursts when compared with the constant interferer. However, for the shorter 20 ms interferer bursts, the W/U level at the point of fixed link throughput degradation was similar to the constant interferer. This means that the fixed link was slightly more resilient to both the constant interferer and the 20 ms interferer bursts than the 50 and 100 ms interferer bursts.

Comparison of measured and TFAC W/U levels

A17.42 The measurement work in this annex has sought to understand how interference from 5G base stations could impact fixed links. In this next section we analyse our measured results by comparing them with the values set out in our technical frequency assignment criteria OfW 446 (TFAC).[56] We note that the TFAC values relate to 23 GHz spectrum, as the TFAC does not include the 26 GHz band. However, we believe the 23 GHz band is a reasonable proxy for the 26 GHz band, given the two bands are close in frequency.

A17.43 We note that the values in the TFAC are primarily designed for coordinating fixed services with one another. To inform us on how 5G interference to fixed links might differ from fixed service interference to fixed links we have compared the W/U levels necessary for a fixed link to support a specific modulation and coding rate as specified in the TFAC with

[56] Ofcom's Technical Frequency Assignment Criteria "OfW 446: Technical Frequency Assignment Criteria for Fixed Point-to-Point Radio Services with Digital Modulation (v17.0)", published 5 August 2022.

those W/U levels that we measured for three fixed links. We have used the measured W/U level at the point where the throughput begins to drop below full throughput and compared this with the TFAC W/U by subtracting the measured value from the TFAC value, to show the margin between the two.

A17.44 We have not included the Device C results in our comparison because we could not be certain that the reported modulation order was correct, as described in "Behaviour of Device C" in A17.26 above.

Table A17.13: comparison of the W/U given in the TFAC with the measured W/U at the onset of interference considering a 5G mobile interferer with an 80% TDD downlink ratio

Receiver Bandwidth *MHz*	Modulation order *QAM*	Device	W/U from TFAC *dB*	W/U with TDD 80% *dB*	TDD 80% margin to TFAC *dB*
56	64	Device A	37	25.55	11.45
		Device B	37	27.55	9.45
56	512	Device A	45	33.55	11.45
		Device B	45	33.55	11.45
56	1024	Device A	-	36.55	-
		Device B	-	38.55	-
56	2048	Device A	-	40.55	-
		Device B	-	41.55	-
28	512	Device A	45	32.56	12.44
		Device B	45	34.56	10.44
14	512	Device A	45	31.57	13.43
		Device B	45	34.57	10.43
7	512	Device A	-	31.58	-
		Device B	-	33.58	-

Table A17.14: comparison of the W/U given in the TFAC with the measured W/U at the onset of interference considering CW, AWGN and 5G mobile TDD 50% interferers

				CW		AWGN		TDD 50%	
Receiver Band-width *MHz*	Modul-ation order *QAM*	Device	W/U from TFAC *dB*	W/U *dB*	margin to TFAC *dB*	W/U *dB*	margin to TFAC *dB*	W/U *dB*	margin to TFAC *dB*
56	512	Device A	45	36.55	8.45	34.55	10.45	30.51	14.49
		Device B		34.00	11.00	40.52	4.48	32.51	12.49

Observations

A17.45 For the 5G mobile TDD 80% downlink interferer results shown in Table A17.13, the measured W/U level before any drop in throughput of the fixed link is lower than the value in the TFAC by between 9.45 and 13.43 dB. This difference was similar across all modulation rates for both devices and typically around 11-12 dB. This suggests that both fixed links are more resilient to 5G interferers than if we simply extended the existing TFAC values to 5G interferers. Care must be taken in quantifying the difference, because the TFAC W/U levels were developed for fixed service to fixed service coexistence and considering more than one interferer. We discuss this in more detail in annex 16, specifically where we discuss improving realism in our coexistence modelling and the worst case reduction factor.

A17.46 For narrower fixed link receiver bandwidths, Device A link shows a marginal improvement in resilience, but Device B shows no improvement. Both Device A and Device B show slightly more resilience to the TDD 50% interferer than TDD 80% interferer, but any difference is small. Overall, Device A and Device B were more resilient to the 5G mobile interferers than the generic, CW and AWGN interferers.

Test setup

Figure A17.1: Test setup diagram

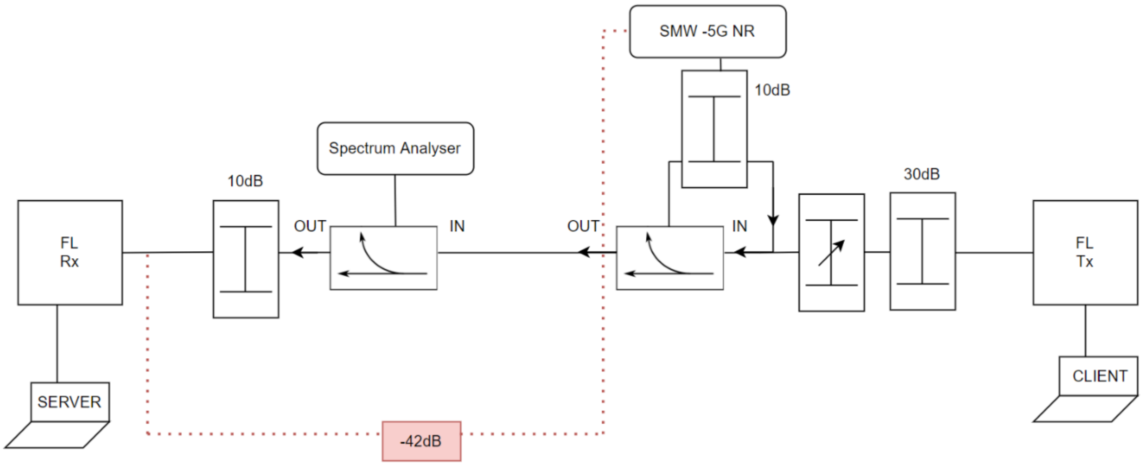


Table A17.15: Fixed link parameters

Fixed Link	Frequencies GHz	Unit type	Power source
Device A	Tx: 23.044 Rx:22.006	1 unit	Main's power
Device B	Tx:24.600 Rx: 25.608	Indoor and Outdoor unit	420W DC power supply
Device C	Tx:26.033 Rx:25.025	Indoor and Outdoor unit	420W DC power supply

Data throughput measurements

A17.47 To monitor the data throughput of the fixed links, two laptops were used running Jperf: one connected to the fixed link transmitter and one to the fixed link receiver. First, the wanted power level was set at the transmitting fixed link, such that the received power by the receiving fixed link was 3 dBs above the RSL (receiver sensitivity level). The throughput was measured as an average over 30 seconds for a certain power level of the unwanted signal, making sure the throughput remained unchanged from what it was before interference was introduced. The unwanted signal power level was then increased, and the throughput measured again. The power of the unwanted signal is increased until the average throughput is 0 Mbps.

A17.48 Figure A17.16 shows the throughput while the fixed link is running without interference, as depicted on the Jperf software. Figure A17.17 shows the throughput drop as the power of the interfering signal is switched on, followed by the throughput increasing again when the interferer is switched off. We observed that Device A took around 3 seconds to establish maximum throughput from startup and around 8 seconds to return to full, uninterfered throughput after an interference event which caused the link to fail had ended.

Figure 17.16: Jperf software showing throughput without interference

Figure A17.17: Jperf software showing throughput with interference

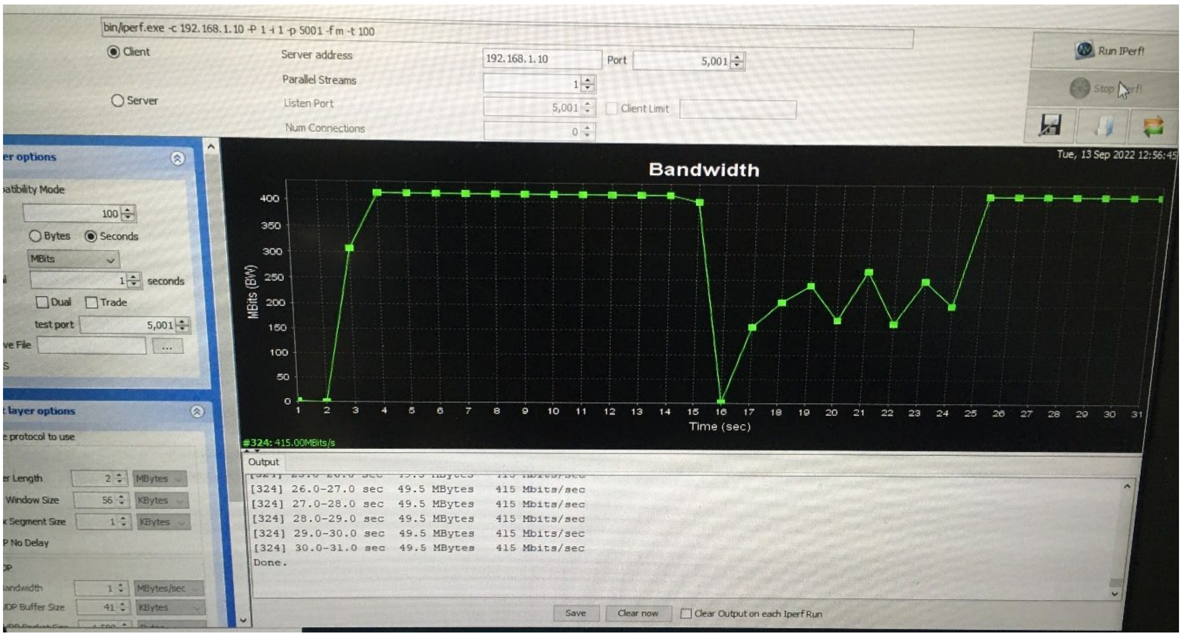


Table A17.16: A summary of all the modulation and bandwidth combinations measured for each fixed link

Bandwidth MHz	Modulation QAM	Device A	Device B	Device C
56	2048	x	x	-
	1024	x	x	-
	512	x	x	-
	256	-	-	x
	128	-	-	x
	64	x	x	x
28	512	x	x	-
	256	-	-	x
14	512	x	x	-
	256	-	-	x
7	512	x	x	-
	256	-	-	x

A18. Fixed links for revocation

Fixed links in the 26 GHz band

A18.1 As set out in section 5 of this document, we have decided to start the process to revoke fixed links which are authorised to use the 26 GHz band, and which operate (a) in high density areas, or (b) around high density areas such that they are likely to receive interference from new mobile users operating in high density areas.

A18.2 Below, we provide a list of:

a) The fixed links operating in the 26 GHz band **in** high density areas. We will start the process to revoke licences authorising use of these links after publication of our next document.

b) The fixed links operating in the 26 GHz band **outside** of high density areas, which our coexistence analysis suggests would be likely to receive interference from new mobile users operating in high density areas. Subject to the outcome of our consultation on how we have identified these links, we will also start the process to revoke licences authorising use of these links after publication of our next document.

26 GHz links operating in high density areas

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1149788/1	12H AG	SU 94760 81382	SU 98194 79795
0497880/3	Airwave Solutions Limited	SK 50350 43550	SK 49300 39736
0498836/4	Airwave Solutions Limited	TL 56275 29927	TL 56090 23517
0502181/3	Airwave Solutions Limited	SP 31420 83180	SP 33575 80940
0503665/3	Airwave Solutions Limited	ST 26154 84882	ST 25358 91110
0505629/2	Airwave Solutions Limited	TQ 77643 14017	TQ 84309 12204
0506536/3	Airwave Solutions Limited	NZ 59250 16860	NZ 56946 18265
0508330/3	Airwave Solutions Limited	SP 75681 60723	SP 75216 57393
0508914/3	Airwave Solutions Limited	NJ 86297 13645	NJ 91072 08073
0508921/2	Airwave Solutions Limited	SP 56732 10510	SP 49868 13043
0509041/3	Airwave Solutions Limited	NS 52380 56761	NS 48850 59001
0509579/3	Airwave Solutions Limited	SE 04413 30690	SE 07795 25380
0509610/3	Airwave Solutions Limited	SO 95674 85947	SO 96065 78568
0509613/2	Airwave Solutions Limited	SO 91641 85633	SO 90080 84620
0509698/4	Airwave Solutions Limited	SK 16375 04340	SK 11350 00300
0509807/4	Airwave Solutions Limited	NT 27106 65189	NT 24960 69480
0509808/4	Airwave Solutions Limited	NT 27106 65189	NT 22188 61934
0509809/3	Airwave Solutions Limited	NT 38165 71355	NT 30860 70820
0509821/4	Airwave Solutions Limited	NT 25681 73468	NT 24960 69480
0510215/3	Airwave Solutions Limited	SP 56800 10300	SP 54449 06173
0510996/3	Airwave Solutions Limited	NT 20769 70624	NT 13027 71896
0510997/3	Airwave Solutions Limited	NT 20769 70624	NT 22493 72826

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
0511197/3	Airwave Solutions Limited	SK 26799 94025	SK 30768 95256
0511201/3	Airwave Solutions Limited	SE 33020 21195	SE 29261 25868
0511380/3	Airwave Solutions Limited	SE 15580 28780	SE 18364 30586
0511381/4	Airwave Solutions Limited	SE 13350 34590	SE 17367 32258
0511382/4	Airwave Solutions Limited	SE 16400 37400	SE 15281 40035
0511383/4	Airwave Solutions Limited	SE 20315 40250	SE 15281 40035
0512183/2	Airwave Solutions Limited	TQ 03684 75569	TQ 01850 67501
0512218/3	Airwave Solutions Limited	TQ 33230 69600	TQ 35426 62978
0512220/5	Airwave Solutions Limited	TQ 07416 76034	TQ 07286 78420
0512222/4	Airwave Solutions Limited	TQ 18998 85563	TQ 15625 88130
0512341/6	Airwave Solutions Limited	TQ 19747 65958	TQ 20419 66893
0513313/2	Airwave Solutions Limited	TQ 29700 90100	TQ 30685 90110
0526467/3	Airwave Solutions Limited	SE 19337 34525	SE 23720 35070
0533382/3	Airwave Solutions Limited	SD 31836 11119	SD 31265 12276
0533384/2	Airwave Solutions Limited	SD 31836 11119	SD 30874 08213
0533390/3	Airwave Solutions Limited	SJ 35812 88824	SJ 35312 81754
0549228/2	Airwave Solutions Limited	ST 14165 81500	ST 18510 76013
0567039/2	Airwave Solutions Limited	SE 07605 13839	SE 08502 16420
0567041/1	Airwave Solutions Limited	SE 07605 13839	SE 05880 13860
0578151/1	Airwave Solutions Limited	TQ 58140 94810	TQ 59744 94020
0578153/2	Airwave Solutions Limited	TQ 58140 94810	TQ 59114 91527
0612151/1	Airwave Solutions Limited	SJ 80390 84900	SJ 75890 78960
0612857/1	Airwave Solutions Limited	SD 69560 06490	SD 66000 14900
0613538/1	Airwave Solutions Limited	SD 98710 05015	SD 97196 06508
0621321/2	Airwave Solutions Limited	TQ 32785 80840	TQ 33460 84860
0734798/1	Airwave Solutions Limited	SE 10200 21675	SE 07795 25380
0782833/1	Airwave Solutions Limited	SJ 46805 93643	SD 52232 01849
0810901/1	Airwave Solutions Limited	TQ 29700 90100	TQ 24750 96340
0817910/2	Airwave Solutions Limited	TQ 31679 79756	TQ 28966 81542
0830150/1	Airwave Solutions Limited	TQ 36180 85750	TQ 36675 83799
0830152/1	Airwave Solutions Limited	TQ 28025 81725	TQ 27110 81760
0836489/2	Airwave Solutions Limited	SP 01055 85318	SO 96065 78568
0841433/1	Airwave Solutions Limited	TQ 40087 81635	TQ 38620 83880
0841870/1	Airwave Solutions Limited	TQ 40820 91734	TQ 42829 93015
0885331/1	Airwave Solutions Limited	SE 11078 14090	SE 08502 16420
0888826/1	Airwave Solutions Limited	SE 16439 37437	SE 15141 37774
0987931/2	Airwave Solutions Limited	SJ 96567 52771	SJ 90728 54316
0987933/1	Airwave Solutions Limited	SJ 85755 52021	SJ 90728 54316
0987935/2	Airwave Solutions Limited	SJ 85755 52021	SJ 87186 48455
0987970/2	Airwave Solutions Limited	SD 60759 06533	SD 58080 05680
0988406/2	Airwave Solutions Limited	SE 26052 37025	SE 25491 39904
0988408/1	Airwave Solutions Limited	SE 30896 39493	SE 35180 37405
0988420/1	Airwave Solutions Limited	SE 23052 39458	SE 25490 39903
0990374/1	Airwave Solutions Limited	SJ 38399 96699	SJ 38309 91819
0990378/2	Airwave Solutions Limited	SJ 38436 96749	SJ 36390 92770

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
0990388/2	Airwave Solutions Limited	SJ 80798 89431	SJ 76027 87856
0990420/2	Airwave Solutions Limited	SO 96769 99486	SP 01610 98499
0990422/2	Airwave Solutions Limited	SK 00460 03145	SK 04311 00630
0990426/2	Airwave Solutions Limited	SK 00460 03145	SP 01610 98499
0997734/2	Airwave Solutions Limited	SO 96766 88724	SO 92430 91844
0997736/2	Airwave Solutions Limited	SO 88670 89552	SO 92430 91844
0997739/2	Airwave Solutions Limited	SO 96771 88728	SO 92552 87619
0997745/3	Airwave Solutions Limited	SO 96766 88724	SO 98170 95027
0997789/4	Airwave Solutions Limited	SP 24513 89805	SP 17673 86930
0997814/3	Airwave Solutions Limited	TQ 35048 73475	TQ 39040 75220
0997818/1	Airwave Solutions Limited	SU 63615 51725	SU 61586 50238
0997837/7	Airwave Solutions Limited	TQ 33940 71230	TQ 40060 69330
0997841/4	Airwave Solutions Limited	TQ 37289 66653	TQ 40060 69330
0997843/6	Airwave Solutions Limited	TQ 37284 66646	TQ 32460 66660
1003719/1	Airwave Solutions Limited	SU 68351 09497	SU 66526 06463
1003721/4	Airwave Solutions Limited	SU 72181 07421	SU 66527 06464
1003728/4	Airwave Solutions Limited	SU 64627 01956	SU 66527 06464
1003773/1	Airwave Solutions Limited	SZ 01969 91239	SY 99795 96613
1003900/4	Airwave Solutions Limited	TQ 18777 78293	TQ 23680 77980
1003915/1	Airwave Solutions Limited	TQ 79565 11055	TQ 84320 12210
1003917/2	Airwave Solutions Limited	TQ 80087 08827	TQ 84310 12216
1004063/3	Airwave Solutions Limited	SP 75904 60415	SP 77170 64634
1004065/1	Airwave Solutions Limited	TL 06534 26506	TL 05250 21742
1004067/2	Airwave Solutions Limited	TL 06112 28319	TL 05251 21743
1004776/2	Airwave Solutions Limited	TQ 80089 13153	TQ 84310 12216
1006916/2	Airwave Solutions Limited	SK 16405 04360	SK 20950 04265
1006940/3	Airwave Solutions Limited	NZ 45530 16150	NZ 48579 14034
1006943/2	Airwave Solutions Limited	NZ 45530 16150	NZ 42299 21063
1006975/1	Airwave Solutions Limited	SJ 30593 88097	SJ 30744 91874
1006979/2	Airwave Solutions Limited	SJ 22470 86298	SJ 27034 89577
1006981/2	Airwave Solutions Limited	SJ 31462 86777	SJ 30745 91875
1006983/2	Airwave Solutions Limited	SJ 28770 91936	SJ 27034 89577
1007068/3	Airwave Solutions Limited	TQ 51400 88230	TQ 51885 92950
1007094/5	Airwave Solutions Limited	NJ 93677 06711	NJ 94281 02533
1007145/2	Airwave Solutions Limited	TM 10353 46162	TM 15787 44794
1007237/1	Airwave Solutions Limited	TQ 27601 75542	TQ 24011 72170
1007256/2	Airwave Solutions Limited	SO 97835 86665	SP 00799 90880
1007270/2	Airwave Solutions Limited	SO 96771 88728	SP 00799 90880
1007297/3	Airwave Solutions Limited	TQ 17943 80920	TQ 23265 86543
1007302/3	Airwave Solutions Limited	TQ 17943 80920	TQ 22346 82870
1009809/1	Airwave Solutions Limited	NZ 36861 63919	NZ 30901 64189
1009892/1	Airwave Solutions Limited	SP 84496 40164	SP 82120 35622
1010579/3	Airwave Solutions Limited	SK 97468 72055	SK 97991 65205
1010584/1	Airwave Solutions Limited	SX 49620 51726	SX 47274 56430
1010589/1	Airwave Solutions Limited	SX 51416 59907	SX 53133 55545

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1010637/3	Airwave Solutions Limited	NZ 29917 56231	NZ 28698 51800
1016701/2	Airwave Solutions Limited	NZ 26597 66911	NZ 27869 71370
1016717/1	Airwave Solutions Limited	SE 08026 16447	SE 08033 22062
1016721/1	Airwave Solutions Limited	SE 15816 11819	SE 15356 07695
1016724/2	Airwave Solutions Limited	SE 15816 11819	SE 13557 06980
1016742/2	Airwave Solutions Limited	SE 10356 30083	SE 10923 26925
1016890/1	Airwave Solutions Limited	SK 35629 87694	SK 33334 90560
1016900/1	Airwave Solutions Limited	SP 33109 78359	SP 36929 82379
1016933/1	Airwave Solutions Limited	SX 48184 54709	SX 53133 55545
1016940/2	Airwave Solutions Limited	SU 41879 11899	SU 46662 13739
1016955/1	Airwave Solutions Limited	SX 49620 51726	SX 53133 55545
1017304/2	Airwave Solutions Limited	NS 60941 67775	NS 58333 63607
1017306/2	Airwave Solutions Limited	NS 60942 67776	NS 56957 69456
1017313/1	Airwave Solutions Limited	NS 49712 70645	NS 52837 68377
1017603/2	Airwave Solutions Limited	NS 59979 59049	NS 56551 61511
1020795/1	Airwave Solutions Limited	SP 33109 78359	SP 30034 78137
1021072/2	Airwave Solutions Limited	SK 36478 82867	SK 34200 87445
1021087/1	Airwave Solutions Limited	SK 47400 83087	SK 47261 86417
1021095/2	Airwave Solutions Limited	SU 39944 14963	SU 42398 11606
1021114/2	Airwave Solutions Limited	NS 59979 59049	NS 65200 60870
1021119/1	Airwave Solutions Limited	NO 47799 33369	NO 42859 33078
1022664/2	Airwave Solutions Limited	SU 45219 12314	SU 42382 11581
1022752/1	Airwave Solutions Limited	NS 61323 64038	NS 62585 58251
1022756/2	Airwave Solutions Limited	NS 64583 63111	NS 62586 58252
1022782/3	Airwave Solutions Limited	NS 70553 60058	NS 68862 65248
1022800/2	Airwave Solutions Limited	SK 53590 45022	SK 57274 47271
1022814/2	Airwave Solutions Limited	NT 22230 76705	NT 24866 73941
1026227/1	Airwave Solutions Limited	NS 72933 64194	NS 77656 66964
1030037/2	Airwave Solutions Limited	TQ 29136 83254	TQ 27264 85458
1030088/2	Airwave Solutions Limited	TL 19911 94660	TL 19047 98454
1030110/1	Airwave Solutions Limited	SE 26508 33290	SE 27990 36122
1030114/1	Airwave Solutions Limited	SK 53099 99858	SE 57052 03466
1030342/4	Airwave Solutions Limited	NS 75150 56790	NS 71858 53700
1030346/2	Airwave Solutions Limited	NS 77414 49717	NS 78696 54164
1030372/2	Airwave Solutions Limited	SJ 68733 86636	SJ 63682 90009
1032245/2	Airwave Solutions Limited	TG 12660 02400	TG 17315 06537
1032270/2	Airwave Solutions Limited	SJ 84503 41867	SJ 90300 45100
1032291/1	Airwave Solutions Limited	ST 15789 73563	ST 11060 74110
1032295/1	Airwave Solutions Limited	ST 15789 73563	ST 19989 73573
1032871/2	Airwave Solutions Limited	SU 72647 77324	SU 68506 73068
1033489/3	Airwave Solutions Limited	SE 17475 20729	SE 14361 16387
1033850/4	Airwave Solutions Limited	SE 18590 16106	SE 14361 16387
1033852/1	Airwave Solutions Limited	SE 17579 17943	SE 11971 17418
1035780/2	Airwave Solutions Limited	NS 54997 64570	NS 52631 68169
1036272/1	Airwave Solutions Limited	NZ 45632 16134	NZ 42397 21045

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1036655/2	Airwave Solutions Limited	SK 58108 35070	SK 56481 38821
1036671/2	Airwave Solutions Limited	SJ 91234 16209	SJ 95501 20106
1038008/2	Airwave Solutions Limited	NO 30836 30281	NO 36009 30671
1038118/2	Airwave Solutions Limited	NS 61934 52870	NS 63099 56852
1038129/1	Airwave Solutions Limited	TQ 35048 73475	TQ 31157 71823
1038168/3	Airwave Solutions Limited	TQ 49404 75313	TQ 47192 70552
1038177/1	Airwave Solutions Limited	NO 43000 28400	NO 46110 31030
1038271/3	Airwave Solutions Limited	NZ 27157 59373	NZ 20744 62579
1038280/1	Airwave Solutions Limited	TL 71127 03730	TL 71980 07242
1038286/3	Airwave Solutions Limited	TL 75147 12180	TL 73059 07767
1038621/3	Airwave Solutions Limited	NS 75150 56790	NS 69234 56088
1038630/2	Airwave Solutions Limited	NZ 45684 31627	NZ 50710 32640
1038632/2	Airwave Solutions Limited	NZ 45684 31627	NZ 50837 30093
1039891/2	Airwave Solutions Limited	NT 25499 70570	NT 27405 74865
1044003/2	Airwave Solutions Limited	TQ 58140 94810	TQ 59123 91479
1044034/2	Airwave Solutions Limited	SJ 94192 47457	SJ 90287 45095
1044036/2	Airwave Solutions Limited	SJ 94192 47503	SJ 95654 42050
1044050/5	Airwave Solutions Limited	SD 72520 03430	SD 67520 01080
1044062/2	Airwave Solutions Limited	TQ 63844 76107	TQ 68328 77635
1044072/1	Airwave Solutions Limited	SE 28044 20616	SE 27921 26675
1044296/3	Airwave Solutions Limited	SE 60619 51779	SE 60865 56205
1046436/2	Airwave Solutions Limited	NZ 27561 62012	NZ 25046 64592
1048924/2	Airwave Solutions Limited	SK 42567 92723	SK 38891 91183
1049419/2	Airwave Solutions Limited	SK 51853 95943	SK 47128 92436
1051682/2	Airwave Solutions Limited	SK 58246 38280	SK 57801 40191
1051697/3	Airwave Solutions Limited	SK 62677 43246	SK 58582 42140
1058622/1	Airwave Solutions Limited	TQ 76711 67509	TQ 70415 66285
1061648/3	Airwave Solutions Limited	SP 05518 80115	SP 04030 83910
1073842/1	Airwave Solutions Limited	NZ 34793 73684	NZ 33698 69062
1076792/1	Airwave Solutions Limited	TQ 40151 92284	TQ 32090 96689
1076818/1	Airwave Solutions Limited	SP 01063 85330	SO 98959 81443
1078805/1	Airwave Solutions Limited	SU 56520 03622	SU 60730 00230
1078989/1	Airwave Solutions Limited	NT 18749 71267	NT 25055 69440
1081344/1	Airwave Solutions Limited	SP 88076 34175	SP 85107 38627
1081346/1	Airwave Solutions Limited	NS 61932 52865	NS 56011 53124
1081555/1	Airwave Solutions Limited	SK 61411 01075	SK 59300 04750
1082973/1	Airwave Solutions Limited	TQ 43160 72110	TQ 48303 75382
1084630/1	Airwave Solutions Limited	ST 76957 65491	ST 72880 65920
1089635/2	Airwave Solutions Limited	SU 67227 73942	SU 71148 73387
1092127/1	Airwave Solutions Limited	ST 57391 66513	ST 50671 66487
1092154/1	Airwave Solutions Limited	SP 34227 83832	SP 36930 82380
1092158/1	Airwave Solutions Limited	TQ 75739 61352	TQ 75956 56170
1092160/1	Airwave Solutions Limited	TQ 75739 61352	TQ 81399 58666
1093578/1	Airwave Solutions Limited	SK 34850 83160	SK 32380 87189
1095072/2	Airwave Solutions Limited	SP 54460 04067	SP 48343 02928

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1095076/1	Airwave Solutions Limited	TL 52429 57754	TL 48271 55499
1105112/1	Airwave Solutions Limited	ST 57391 66513	ST 58795 72818
1110374/2	Airwave Solutions Limited	TG 22549 05665	TG 25730 02780
1110540/1	Airwave Solutions Limited	SP 32002 86850	SP 33575 80940
1112282/1	Airwave Solutions Limited	ST 12359 83593	ST 11568 88061
1112507/1	Airwave Solutions Limited	SU 47300 66990	SU 52865 66117
1113178/1	Airwave Solutions Limited	SJ 58764 83740	SJ 53570 82947
1113182/1	Airwave Solutions Limited	SJ 41227 86637	SJ 38050 89122
1113200/2	Airwave Solutions Limited	TQ 32863 79942	TQ 29220 81925
1115064/1	Airwave Solutions Limited	SJ 41226 86637	SJ 43410 82593
1115260/1	Airwave Solutions Limited	SU 47300 66990	SU 46980 72626
1117285/1	Airwave Solutions Limited	SJ 31015 94219	SJ 34599 95879
1118116/1	Airwave Solutions Limited	TQ 02020 78200	SU 98205 79803
1129633/1	Airwave Solutions Limited	SP 56629 10513	SP 50580 09010
1129635/1	Airwave Solutions Limited	SP 51328 05770	SP 48348 02927
1130174/1	Airwave Solutions Limited	SU 76770 73180	SU 71152 73411
1130687/1	Airwave Solutions Limited	SK 53958 19888	SK 54149 24818
1136696/1	Airwave Solutions Limited	SK 50363 43533	SK 45591 46480
1137072/1	Airwave Solutions Limited	TQ 38393 57220	TQ 33578 53353
1138900/2	Airwave Solutions Limited	NS 82900 64820	NS 77664 66950
1139774/2	Airwave Solutions Limited	TQ 24431 81181	TQ 27286 85386
1145330/1	Airwave Solutions Limited	SP 05419 75570	SP 10655 79580
1145333/1	Airwave Solutions Limited	SP 05419 75570	SP 00680 73700
1145340/2	Airwave Solutions Limited	SE 29966 29919	SE 30515 34380
1148893/1	Airwave Solutions Limited	TR 26577 46633	TR 30499 44481
1148895/1	Airwave Solutions Limited	TR 31890 40338	TR 27405 39738
1149208/1	Airwave Solutions Limited	SO 94800 22000	SO 99364 24808
1150467/1	Airwave Solutions Limited	SJ 80750 48428	SJ 74490 47661
1152251/1	Airwave Solutions Limited	SU 65439 75927	SU 64720 81306
1154227/1	Airwave Solutions Limited	SE 36214 34490	SE 29986 34096
1155811/1	Airwave Solutions Limited	SP 04694 93068	SP 00799 90880
1158721/1	Airwave Solutions Limited	SU 93640 75310	SU 95104 80944
1169526/1	Airwave Solutions Limited	NZ 26617 66906	NZ 25653 62754
1173685/1	Airwave Solutions Limited	SK 35226 86131	SK 32380 87189
1179561/2	Airwave Solutions Limited	TQ 49772 85444	TQ 44320 86664
1179791/1	Airwave Solutions Limited	NZ 26822 60274	NZ 25653 62754
1220021/1	Airwave Solutions Limited	TQ 67635 69840	TQ 63682 74131
1245526/1	Airwave Solutions Limited	TQ 39560 91650	TQ 32070 96672
1245841/1	Airwave Solutions Limited	TQ 38540 57308	TQ 33578 53353
1262996/1	Airwave Solutions Limited	TQ 32100 62350	TQ 28980 58499
0480790/1	Arqiva Limited	TL 48100 63000	TL 39200 59400
0489682/1	Arqiva Limited	TL 12800 91500	TL 17800 96900
1095285/1	Arqiva Limited	SP 56700 10600	SP 48400 02900
1217812/1	Arqiva Limited	SS 67180 94020	SS 65800 93080
1217813/1	Arqiva Limited	SS 67180 94020	SS 65800 93080

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1094644/2	Associated British Ports	SU 41883 10755	SU 43203 07886
1098138/1	Associated British Ports	SU 41911 10507	SU 39353 12213
1098142/1	Associated British Ports	SU 41906 10503	SU 37796 11584
1098144/1	Associated British Ports	SU 42754 09553	SU 43940 12528
0809260/1	British Telecommunications Public Limited Company	SO 96800 88700	SP 06600 87200
0958905/1	British Telecommunications Public Limited Company	SK 93950 68160	SK 97988 65205
1001761/3	British Telecommunications Public Limited Company	TA 11825 30289	TA 09410 28650
1001778/3	British Telecommunications Public Limited Company	TA 07815 31745	TA 09410 28650
1002254/2	British Telecommunications Public Limited Company	TA 10344 32330	TA 09410 28650
1002278/2	British Telecommunications Public Limited Company	TA 10520 30978	TA 09410 28650
1045099/1	British Telecommunications Public Limited Company	TA 07297 28731	TA 09410 28650
1061680/2	British Telecommunications Public Limited Company	SK 43520 81310	SK 46940 76987
1064991/1	British Telecommunications Public Limited Company	TQ 53220 96360	TQ 59730 94000
1066983/1	British Telecommunications Public Limited Company	TQ 93550 86600	TQ 87429 85848
1069985/1	British Telecommunications Public Limited Company	SJ 47124 08041	SJ 49350 12250
1101004/1	British Telecommunications Public Limited Company	SK 35051 36161	SK 39545 36877
1101995/1	British Telecommunications Public Limited Company	TQ 03036 60280	TQ 00651 58595
1104584/1	British Telecommunications Public Limited Company	TL 66750 05500	TL 70820 07070
1104606/1	British Telecommunications Public Limited Company	TL 71190 09560	TL 70820 07070
1104614/1	British Telecommunications Public Limited Company	TL 34300 04400	TL 36155 00604
1134556/1	British Telecommunications Public Limited Company	SE 60620 51780	SE 66520 47670
1165122/1	British Telecommunications Public Limited Company	TQ 07900 78750	TQ 09880 79960
1180045/2	British Telecommunications Public Limited Company	SE 30000 30870	SE 31161 28207
1196621/1	British Telecommunications Public Limited Company	TA 08247 29972	TA 09410 28650
1199982/1	British Telecommunications Public Limited Company	TA 07815 31745	TA 09410 28650
1200003/1	British Telecommunications Public Limited Company	TA 03565 28961	TA 09410 28650
1200718/1	British Telecommunications Public Limited Company	TA 10773 34382	TA 09410 28650
1132154/1	C.E.M. Day Limited	SS 67180 94020	SS 66866 96594
1106162/1	DRW NX UK LTD	TQ 32941 81954	TQ 29222 81925
1126267/2	DRW NX UK LTD	SU 94828 81384	TQ 01405 81010
1152400/2	DRW NX UK LTD	SU 94823 81381	TQ 01405 81010
1152417/2	DRW NX UK LTD	SU 94823 81381	TQ 01405 81010
1225453/2	DRW NX UK LTD	SU 94823 81381	TQ 01405 81010
1267960/1	DRW NX UK LTD	SU 94828 81384	TQ 01405 81010
1267970/2	DRW NX UK LTD	SU 94828 81384	TQ 01405 81010
1272820/1	DRW NX UK LTD	TQ 33740 82307	TQ 29223 81925
0502723/1	EE Limited	SO 96820 88710	SO 91900 86750
0513451/1	EE Limited	SD 35780 39060	SD 32750 33850
0822745/1	Ingenitech Ltd	SJ 73802 96948	SJ 77552 98319
0921179/1	Ingenitech Ltd	SD 77537 01668	SJ 81772 97093
0966774/1	Ingenitech Ltd	SD 77562 01643	SJ 78832 92084
1013011/3	Ingenitech Ltd	SD 77562 01643	SJ 75147 96933
1030677/1	Ingenitech Ltd	SD 77562 01643	SJ 81621 98778
1044701/1	Joint Radio Company Limited	SK 49667 89717	SK 50176 92287
1045019/2	Joint Radio Company Limited	SE 60370 06140	SE 56668 03580

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1045418/2	Joint Radio Company Limited	SE 11920 22010	SE 12500 19700
1049732/1	Joint Radio Company Limited	SK 31132 96884	SK 26433 99072
1199266/1	KBR (Keeping Business Running) Limited	NZ 56759 24163	NZ 54189 16131
1206900/1	KBR (Keeping Business Running) Limited	NZ 45874 15999	NZ 54189 16131
1265905/1	KBS Maritime Limited	SZ 62687 99273	SU 61970 01251
0735087/3	London Borough of Hounslow	TQ 18339 78035	TQ 13438 76316
0735099/3	London Borough of Hounslow	TQ 13365 77829	TQ 13438 76316
0753708/1	London Borough of Hounslow	TQ 10295 73496	TQ 13438 76316
0809500/1	London Borough of Hounslow	TQ 10295 73496	TQ 11534 75100
0818794/1	London Borough of Hounslow	TQ 18339 78035	TQ 15715 74637
0823745/2	London Borough of Hounslow	TQ 18339 78035	TQ 15715 74637
0814194/2	M247 UK Limited	SD 88416 02108	SJ 84075 97678
0850480/4	M247 UK Limited	SP 13279 87203	SP 06415 86827
0868351/1	M247 UK Limited	SJ 85759 99733	SJ 89035 93398
0870169/3	M247 UK Limited	SJ 85759 99733	SJ 85404 95024
0870173/1	M247 UK Limited	SD 88373 02180	SJ 89044 96631
0873386/2	M247 UK Limited	SJ 34044 90811	SJ 34380 95020
0903655/1	M247 UK Limited	SJ 79319 94150	SJ 77818 97419
0923600/1	M247 UK Limited	SE 30260 34242	SE 30250 36724
0936047/1	M247 UK Limited	SJ 91336 93140	SJ 87525 95373
0967603/2	M247 UK Limited	SD 88373 02180	SD 91052 05917
0971324/1	M247 UK Limited	SE 41580 33996	SE 36103 36759
0972729/1	M247 UK Limited	SP 07362 87239	SP 07701 84159
0976739/1	M247 UK Limited	SJ 85783 97385	SJ 87525 95373
0983353/1	M247 UK Limited	SJ 85043 90584	SJ 87525 95373
0997412/1	M247 UK Limited	SE 40959 33752	SE 36104 36777
1011277/2	M247 UK Limited	SJ 78076 97222	SJ 84082 98431
1025496/3	M247 UK Limited	SJ 79319 94150	SJ 71708 93175
1031769/3	M247 UK Limited	SJ 77636 95689	SJ 76386 92588
1073709/3	M247 UK Limited	SD 88373 02180	SD 91478 04597
1074414/1	M247 UK Limited	SJ 89754 89437	SJ 98338 82313
1074453/2	M247 UK Limited	SE 29699 34637	SE 36104 36777
1078669/1	M247 UK Limited	SJ 43390 99264	SJ 34246 95623
1084691/1	M247 UK Limited	NZ 32067 68668	NZ 24990 64664
1090181/1	M247 UK Limited	SE 25960 38940	SE 24419 28571
1097251/2	M247 UK Limited	NZ 23268 63573	NZ 28060 67763
1098681/1	M247 UK Limited	SP 13279 87203	SP 20283 91780
1102801/2	M247 UK Limited	SJ 59526 88044	SJ 50871 92591
1107862/2	M247 UK Limited	SJ 43187 82722	SJ 51738 76932
1108766/2	M247 UK Limited	SJ 42652 96225	SJ 34265 95569
1113289/1	M247 UK Limited	SJ 80935 98938	SD 69937 05232
1115935/1	M247 UK Limited	SP 11793 89694	SP 06463 86735
1117555/1	M247 UK Limited	SJ 80801 89421	SJ 89261 90120
1117906/1	M247 UK Limited	SE 29374 33492	SE 20863 29222
1121471/1	M247 UK Limited	SJ 88043 99710	SD 84165 08401

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1124519/2	M247 UK Limited	SP 15567 91888	SP 06463 86735
1124549/1	M247 UK Limited	SJ 43186 82720	SJ 42002 74993
1141951/1	M247 UK Limited	SJ 89803 89342	SJ 95864 88517
1148284/1	M247 UK Limited	SE 17011 33480	SE 07888 31698
1151566/1	M247 UK Limited	SJ 35815 94045	SJ 34285 95543
1152961/2	M247 UK Limited	SD 70783 07554	SD 74621 17637
1153120/2	M247 UK Limited	SD 88419 02100	SJ 93713 96854
0998384/1	Mckay Brothers Communications Ltd	TR 07793 59033	TR 30486 44440
0998385/1	Mckay Brothers Communications Ltd	TR 07793 59033	TR 30486 44440
1002605/1	Mckay Brothers International SA	TQ 72238 90336	TQ 80365 87712
1002606/1	Mckay Brothers International SA	TQ 72238 90336	TQ 80365 87712
1002620/1	Mckay Brothers International SA	TQ 72238 90336	TQ 80365 87712
1002623/1	Mckay Brothers International SA	TQ 72238 90336	TQ 80365 87712
1118054/1	Mckay Brothers International SA	SU 94826 81383	SU 97924 80194
1118067/1	Mckay Brothers International SA	SU 94826 81383	SU 97924 80194
1122129/1	Mckay Brothers International SA	SU 94826 81383	SU 97965 80235
1122418/1	Mckay Brothers International SA	SU 94826 81383	SU 97965 80235
1131954/2	Mckay Brothers International SA	SU 94822 81383	SU 97963 80195
0880934/1	Mobile Broadband Network Limited	SE 14200 15000	SE 09054 15576
0881081/1	Mobile Broadband Network Limited	TM 19332 44781	TM 15785 40820
0881106/1	Mobile Broadband Network Limited	SD 90370 03260	SJ 93107 98422
0881141/1	Mobile Broadband Network Limited	SD 87215 00814	SJ 93107 98422
0881633/1	Mobile Broadband Network Limited	NZ 49177 18640	NZ 49535 20358
0881886/1	Mobile Broadband Network Limited	TQ 23259 75309	TQ 28517 80103
0882108/1	Mobile Broadband Network Limited	TQ 27097 77246	TQ 28517 80103
0882381/1	Mobile Broadband Network Limited	SK 10872 10960	SK 11300 00300
0937329/1	Mobile Broadband Network Limited	TQ 24100 74971	TQ 27810 76482
0938199/1	Mobile Broadband Network Limited	TQ 33225 69600	TQ 29966 66300
0938241/1	Mobile Broadband Network Limited	TQ 50500 79200	TQ 44280 84280
0938418/1	Mobile Broadband Network Limited	SP 12600 85000	SP 13300 77700
1056121/1	Mobile Broadband Network Limited	NO 39996 24300	NO 36297 29711
1066266/1	Mobile Broadband Network Limited	SK 33797 91653	SK 32444 87070
1088601/4	Mobile Broadband Network Limited	SS 56678 95080	SS 61156 99197
1197700/1	National Grid Telecoms Limited	ST 26156 84881	ST 32517 83805
1197766/1	National Grid Telecoms Limited	SS 61387 94072	SS 52661 99548
1197772/1	National Grid Telecoms Limited	ST 17218 81337	ST 15571 74826
1197775/1	National Grid Telecoms Limited	ST 14722 68874	ST 15571 74826
1197852/1	National Grid Telecoms Limited	ST 16911 79333	ST 15571 74826
1197879/1	National Grid Telecoms Limited	SP 17100 78800	SP 17281 83185
1197884/1	National Grid Telecoms Limited	SX 49739 51801	SX 49469 54221
1197896/1	National Grid Telecoms Limited	ST 18370 84147	ST 15571 74826
1197899/1	National Grid Telecoms Limited	SP 01900 77605	SO 96000 78500
1198050/2	National Grid Telecoms Limited	SO 99000 81200	SO 96000 78500
1198051/1	National Grid Telecoms Limited	SO 83900 54800	SO 86000 52100
1198060/1	National Grid Telecoms Limited	SJ 94100 47500	SJ 94400 48800

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1198085/1	National Grid Telecoms Limited	SP 79400 61100	SP 77000 56900
1198100/1	National Grid Telecoms Limited	SJ 92400 04000	SO 91400 99100
1198101/1	National Grid Telecoms Limited	SJ 95300 00100	SO 91000 96700
1198127/1	National Grid Telecoms Limited	SK 95488 69056	SK 98110 65152
1198130/1	National Grid Telecoms Limited	SO 97497 93263	SO 96684 89308
1198131/1	National Grid Telecoms Limited	SO 92232 87923	SO 96684 89308
1198184/1	National Grid Telecoms Limited	SS 67195 94023	SS 73946 93357
1030429/1	New Line Networks LLC	TQ 36460 78481	TQ 30206 78692
1030430/1	New Line Networks LLC	TQ 36460 78481	TQ 30206 78692
1030432/1	New Line Networks LLC	TQ 36460 78481	TQ 37650 79150
1030444/1	New Line Networks LLC	TQ 36460 78481	TQ 37650 79150
1126159/1	New Line Networks LLC	TQ 72248 90425	TQ 80390 87730
1126163/1	New Line Networks LLC	TQ 72248 90425	TQ 80390 87730
1126354/1	New Line Networks LLC	TQ 32941 81954	TQ 29223 81928
1126355/1	New Line Networks LLC	TQ 32941 81954	TQ 29223 81928
1132459/1	New Line Networks LLC	SU 94827 81387	TQ 07289 78404
1132464/1	New Line Networks LLC	SU 94827 81387	TQ 07289 78404
1153197/1	New Line Networks LLC	TQ 71571 90360	TQ 65006 89488
1153204/1	New Line Networks LLC	TQ 71571 90360	TQ 65006 89488
0959444/2	PD Teesport Limited	NZ 51196 20820	NZ 54326 23391
0959461/2	PD Teesport Limited	NZ 51959 34214	NZ 54326 23391
0959466/3	PD Teesport Limited	NZ 51959 34214	NZ 55720 28261
0959470/2	PD Teesport Limited	NZ 51959 34214	NZ 52648 33449
0959477/3	PD Teesport Limited	NZ 54903 24696	NZ 54362 23391
0879678/1	Port Of London Authority Limited	TQ 50741 79328	TQ 43574 76565
1046650/3	Port Of London Authority Limited	TQ 44465 80843	TQ 41714 79293
0940683/1	Qinetiq Group Plc	TR 03535 93283	TQ 95984 87619
0805855/1	Sandwell Homes Limited	SP 00851 91965	SP 02319 95642
0987029/3	Scot-Tel-Gould Limited	NJ 96642 03811	NJ 91100 06897
1180446/2	Trellisworks Limited	SU 40053 13950	SU 37418 13822
1181180/1	Trellisworks Limited	SU 41663 11964	SU 37418 13822
1181940/1	Trellisworks Limited	SU 40053 13950	SU 43182 12565
1189221/1	Trellisworks Limited	TQ 43548 88577	TQ 45071 88823
1217456/1	Trellisworks Limited	TQ 30910 95696	TQ 35355 93998
1245492/1	Trellisworks Limited	SU 40053 13950	SU 38212 13000
0495407/1	Vodafone Limited	TQ 21007 81541	TQ 24409 82119
0495592/1	Vodafone Limited	SK 41720 90820	SK 39526 89580
0498667/1	Vodafone Limited	SP 31050 78190	SP 33056 77666
0503062/1	Vodafone Limited	SE 32950 21110	SE 33100 20640
0503480/1	Vodafone Limited	SP 75650 60700	SP 73780 58800
0796028/2	Vodafone Limited	SP 40200 77600	SP 37206 79380
0867517/3	Vodafone Limited	TQ 07004 91591	TQ 11111 89928
0869020/4	Vodafone Limited	TL 14885 00036	TL 10716 03372
0872146/4	Vodafone Limited	TQ 56000 71830	TQ 56576 69010
0949738/1	Vodafone Limited	SJ 93650 00400	SO 91430 99080

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
0949783/1	Vodafone Limited	SE 57700 02800	SE 57060 03480
0949805/1	Vodafone Limited	SD 65820 14930	SD 66440 09160
0949993/1	Vodafone Limited	TQ 13320 75530	TQ 09850 70050
0949997/1	Vodafone Limited	ST 29450 95300	ST 31100 88060
0950020/1	Vodafone Limited	NZ 24430 64430	NZ 25050 64580
0950022/1	Vodafone Limited	NZ 27300 70700	NZ 25050 64580
0950030/1	Vodafone Limited	NZ 51550 26050	NZ 57040 18290
0950036/1	Vodafone Limited	SK 55700 38000	SK 56490 38810
0950047/1	Vodafone Limited	SJ 87600 46030	SJ 87600 45690
0950055/1	Vodafone Limited	SK 55700 38000	SK 56490 38810
0950057/1	Vodafone Limited	SK 56920 39780	SK 57470 38990
0950058/1	Vodafone Limited	SK 56920 39780	SK 57390 40220
0950073/1	Vodafone Limited	NS 51630 67130	NS 46020 59310
0950077/1	Vodafone Limited	SS 67200 94000	SS 75550 97560
0950089/1	Vodafone Limited	TF 18150 00400	TL 18200 96450
0950090/1	Vodafone Limited	TF 18150 00400	TL 15250 95350
0950132/1	Vodafone Limited	TL 46600 55200	TL 44750 57900
0950368/1	Vodafone Limited	SO 97800 96000	SO 91430 99080
0950370/1	Vodafone Limited	SP 91450 34230	SP 89712 35276
0950392/1	Vodafone Limited	SP 84500 40220	SP 90120 38379
0950439/1	Vodafone Limited	TQ 31380 79630	TQ 30200 78750
0950447/1	Vodafone Limited	NW 46187 29308	NW 47900 32900
0950477/3	Vodafone Limited	SJ 26050 90760	SJ 35900 90730
0950492/1	Vodafone Limited	TQ 66346 88151	TQ 68110 86610
0950515/1	Vodafone Limited	SJ 39400 96400	SJ 38000 96800
0950785/1	Vodafone Limited	SD 66300 14700	SD 67200 03400
0951150/1	Vodafone Limited	SD 53850 29550	SD 54450 33600
1038986/1	Vodafone Limited	TQ 16183 73575	TQ 16801 71370
1038990/1	Vodafone Limited	TQ 16183 73575	TQ 16801 71370
1040724/1	Vodafone Limited	TQ 43410 86360	TQ 37650 84050
1040730/1	Vodafone Limited	TQ 19360 85605	TQ 21820 82680
1046727/1	Vodafone Limited	TQ 21410 68597	TQ 19388 69575
1048465/1	Vodafone Limited	TQ 54702 94560	TQ 59140 91560
1048697/1	Vodafone Limited	TQ 54702 94560	TQ 59140 91560
1048766/3	Vodafone Limited	TL 14885 00036	TL 10716 03372
1053162/1	Vodafone Limited	TQ 40813 91728	TQ 41582 88544
1067916/1	Vodafone Limited	SD 92618 10073	SD 96047 10500
1085193/1	Vodafone Limited	TQ 06866 81845	TQ 04227 77616
1089272/1	Vodafone Limited	NZ 51170 26317	NZ 57038 18264
1097444/1	Vodafone Limited	SU 65569 04199	SU 66558 06451
1116256/2	Vodafone Limited	ST 23185 78860	ST 18337 76671
1171022/1	Vodafone Limited	TQ 40472 85289	TQ 39371 86877
1225417/1	Vodafone Limited	NW 46190 29225	NW 43825 29762
1281669/1	Voneus Limited	SS 61397 94069	SN 62787 04183
1281674/1	Voneus Limited	SN 63494 04012	SS 67629 94058

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1281675/1	Voneus Limited	SS 61397 94069	SS 53509 88604
0916544/5	WATMOS Community Homes	SP 01987 98486	SJ 99516 02379
0993901/2	Zycomm Electronics Limited	SK 35206 36495	SK 37552 42137

26 GHz links operating around high density areas, which coexistence analysis shows are likely to receive interference from new mobile services in high density areas

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
0497862/2	Airwave Solutions Limited	SU 71560 20240	SU 69300 25050
0497869/2	Airwave Solutions Limited	SU 58575 83111	SU 59889 89279
0497872/2	Airwave Solutions Limited	SU 52743 89911	SU 59889 89279
0497908/3	Airwave Solutions Limited	SK 51215 55070	SK 47500 59200
0501222/2	Airwave Solutions Limited	SK 05670 08840	SK 06673 04775
0502848/3	Airwave Solutions Limited	NZ 15445 73835	NZ 08700 70400
0505624/2	Airwave Solutions Limited	TQ 60742 44015	TQ 58290 40085
0505762/3	Airwave Solutions Limited	SX 69052 38690	SX 71808 37678
0507155/3	Airwave Solutions Limited	NS 82760 64770	NS 85779 63695
0507746/4	Airwave Solutions Limited	TQ 55382 60843	TQ 59494 60462
0509835/3	Airwave Solutions Limited	SK 15428 53140	SK 18207 45985
0509836/3	Airwave Solutions Limited	SK 47750 71950	SK 51617 75861
0509837/3	Airwave Solutions Limited	SK 51800 95900	SK 51473 90072
0510199/3	Airwave Solutions Limited	TL 32980 12590	TL 29305 06705
0510314/3	Airwave Solutions Limited	SD 58200 17700	SD 61900 13500
0510682/3	Airwave Solutions Limited	SJ 52628 45064	SJ 54751 44699
0511180/3	Airwave Solutions Limited	SK 29500 55320	SK 30494 51623
0511198/3	Airwave Solutions Limited	SK 26799 94025	SK 27500 99100
0511199/3	Airwave Solutions Limited	SE 25792 04548	SK 27500 99100
0511881/2	Airwave Solutions Limited	TR 20860 43923	TR 22320 43020
0512063/3	Airwave Solutions Limited	SP 01760 48224	SO 95190 47680
0512184/2	Airwave Solutions Limited	TQ 08456 52308	TQ 08383 50879
0512443/2	Airwave Solutions Limited	SU 78000 82210	SU 77464 82889
0525092/3	Airwave Solutions Limited	SD 89200 40000	SD 89690 42640
0526463/4	Airwave Solutions Limited	SE 43479 39311	SE 44079 40204
0526465/3	Airwave Solutions Limited	SE 43479 39311	SE 41411 32030
0567043/2	Airwave Solutions Limited	SE 04815 11125	SE 05880 13860
0587155/2	Airwave Solutions Limited	SJ 00786 81332	SH 95428 75942
0599917/2	Airwave Solutions Limited	SE 26343 43415	SE 25800 50900
0612155/1	Airwave Solutions Limited	SJ 88180 74360	SJ 93753 78658
0626990/1	Airwave Solutions Limited	SK 06310 73380	SK 05971 75354
0820758/1	Airwave Solutions Limited	SY 59459 90077	SY 63817 90465
0824347/1	Airwave Solutions Limited	SD 91800 26400	SD 92094 24519
0826448/2	Airwave Solutions Limited	SZ 23993 95929	SZ 23280 94920
0987701/3	Airwave Solutions Limited	SK 05650 08820	SK 05005 12492

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
0987924/1	Airwave Solutions Limited	SJ 95217 58716	SJ 99976 56162
0987957/3	Airwave Solutions Limited	SD 63271 10522	SD 61791 13461
0987984/2	Airwave Solutions Limited	SK 76700 20260	SK 80940 23330
0987998/2	Airwave Solutions Limited	SD 56458 25786	SD 59205 23408
0990368/2	Airwave Solutions Limited	SJ 72604 83104	SJ 77938 83073
0990403/1	Airwave Solutions Limited	TQ 36250 06997	TQ 41764 11226
0995266/3	Airwave Solutions Limited	SE 40647 47392	SE 38049 44239
0995268/2	Airwave Solutions Limited	SE 41877 43660	SE 44679 45667
0995272/1	Airwave Solutions Limited	SE 32865 45220	SE 38049 44239
0995276/3	Airwave Solutions Limited	SE 17793 45926	SE 21021 44585
0997751/3	Airwave Solutions Limited	SJ 67475 61178	SJ 67129 66977
0997787/4	Airwave Solutions Limited	SP 24513 89805	SP 22326 96909
1000956/4	Airwave Solutions Limited	TQ 48501 39232	TQ 43861 36301
1000980/1	Airwave Solutions Limited	SX 63089 48699	SX 63115 53846
1003733/2	Airwave Solutions Limited	SU 47115 08917	SU 50837 08869
1003753/1	Airwave Solutions Limited	SU 71559 20239	SU 74452 23340
1003789/1	Airwave Solutions Limited	SU 85841 35393	SU 83399 36286
1003799/1	Airwave Solutions Limited	SU 44910 29518	SU 41796 27039
1003908/3	Airwave Solutions Limited	TQ 81980 22310	TQ 76363 20387
1003910/2	Airwave Solutions Limited	TQ 70442 19621	TQ 76359 20384
1006971/2	Airwave Solutions Limited	SJ 36835 75468	SJ 31565 75540
1007060/2	Airwave Solutions Limited	SU 44932 29518	SU 48284 33432
1007178/2	Airwave Solutions Limited	TM 25916 49588	TM 24981 44864
1009760/2	Airwave Solutions Limited	NZ 20118 52975	NZ 14785 52700
1009780/1	Airwave Solutions Limited	TL 17031 13607	TL 18600 19618
1009785/1	Airwave Solutions Limited	TL 22362 16138	TL 18600 19618
1010522/3	Airwave Solutions Limited	SD 60239 37664	SD 63131 39503
1010543/1	Airwave Solutions Limited	SJ 91799 82499	SJ 97361 81479
1010547/1	Airwave Solutions Limited	SJ 94049 84733	SJ 97361 81479
1010601/5	Airwave Solutions Limited	TQ 75961 34992	TQ 71361 32317
1010614/1	Airwave Solutions Limited	NZ 10771 50970	NZ 14994 52814
1016354/5	Airwave Solutions Limited	SX 29995 56975	SX 27348 57734
1016810/1	Airwave Solutions Limited	SP 63752 47959	SP 67252 42805
1016819/1	Airwave Solutions Limited	SP 56733 54465	SP 51279 52124
1016839/1	Airwave Solutions Limited	SU 87913 95550	SU 86212 92549
1016912/1	Airwave Solutions Limited	SP 32930 66383	SP 29394 63119
1017296/2	Airwave Solutions Limited	SU 42626 05078	SU 45345 02662
1017299/1	Airwave Solutions Limited	SU 19746 05041	SU 19329 00229
1020798/1	Airwave Solutions Limited	SP 32930 66383	SP 32439 71768
1020811/2	Airwave Solutions Limited	NS 27758 74943	NS 31825 73883
1021069/1	Airwave Solutions Limited	SU 95307 89350	SU 90615 91112
1022670/1	Airwave Solutions Limited	TQ 12480 43980	TQ 06110 47160
1022729/2	Airwave Solutions Limited	NT 11938 82757	NT 09098 87512
1022744/2	Airwave Solutions Limited	NS 40735 74677	NS 37846 79641
1028624/3	Airwave Solutions Limited	TQ 87260 60629	TQ 89030 62765

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1029054/2	Airwave Solutions Limited	SE 69739 13774	SE 68250 07329
1029958/1	Airwave Solutions Limited	SE 47970 13002	SE 51945 07968
1030052/2	Airwave Solutions Limited	SJ 53768 81527	SJ 51959 76661
1030354/4	Airwave Solutions Limited	SK 57229 94805	SK 60435 88353
1030368/2	Airwave Solutions Limited	SJ 56891 97738	SJ 51147 95739
1032299/2	Airwave Solutions Limited	SX 07780 55095	SX 03339 54444
1033904/4	Airwave Solutions Limited	SE 44205 22149	SE 48892 19609
1035473/3	Airwave Solutions Limited	NO 37700 45670	NO 37630 39900
1037986/1	Airwave Solutions Limited	SK 54081 85717	SK 51473 90072
1038016/1	Airwave Solutions Limited	TQ 76264 87623	TQ 79180 83255
1038044/3	Airwave Solutions Limited	TQ 33266 23642	TQ 31699 17541
1038106/1	Airwave Solutions Limited	SK 74717 81813	SK 70825 80410
1038120/3	Airwave Solutions Limited	SJ 76400 08964	SJ 71040 08998
1040404/1	Airwave Solutions Limited	SK 70890 38852	SK 66520 34610
1040857/3	Airwave Solutions Limited	TQ 02002 91469	TQ 05662 94545
1041589/1	Airwave Solutions Limited	TQ 82641 59875	TQ 89030 62765
1044038/4	Airwave Solutions Limited	SK 07528 54253	SK 04437 50450
1044064/1	Airwave Solutions Limited	SE 44280 25065	SE 49012 22617
1046442/2	Airwave Solutions Limited	SU 81702 91785	SU 84798 92257
1049421/3	Airwave Solutions Limited	SK 51852 95943	SK 48215 98770
1051717/3	Airwave Solutions Limited	SK 06982 43069	SK 03042 43518
1058610/1	Airwave Solutions Limited	SE 43063 15479	SE 39479 13851
1059917/1	Airwave Solutions Limited	NZ 45188 36888	NZ 43259 41508
1059924/1	Airwave Solutions Limited	TQ 96511 50472	TR 01670 50485
1064571/1	Airwave Solutions Limited	SP 90180 89760	SP 96210 93042
1074755/1	Airwave Solutions Limited	SU 87930 95567	SU 95797 95512
1088409/1	Airwave Solutions Limited	SO 93248 83820	SO 96050 78565
1089630/1	Airwave Solutions Limited	SP 82419 29040	SP 76275 28465
1101877/1	Airwave Solutions Limited	TL 37206 40935	TL 37240 36480
1103383/1	Airwave Solutions Limited	TQ 33903 30678	TQ 28375 30990
1105615/1	Airwave Solutions Limited	SK 50102 64350	SK 47512 59115
1115066/1	Airwave Solutions Limited	ST 51664 98077	ST 49990 93735
1115069/1	Airwave Solutions Limited	ST 51664 98077	ST 55076 94554
1116893/1	Airwave Solutions Limited	SO 94765 73005	SO 96050 78565
1116895/1	Airwave Solutions Limited	SO 94765 73005	SO 95408 68510
1117279/1	Airwave Solutions Limited	SJ 52720 74960	SJ 58640 71440
1120024/1	Airwave Solutions Limited	TM 25894 75823	TM 24701 82554
1121072/1	Airwave Solutions Limited	SK 21505 26915	SK 17281 27873
1121759/1	Airwave Solutions Limited	ST 99716 69957	ST 94801 68594
1129641/1	Airwave Solutions Limited	SP 46603 21066	SP 44980 17653
1133624/1	Airwave Solutions Limited	TL 17583 49716	TL 20450 49460
1138896/1	Airwave Solutions Limited	TQ 49759 47498	TQ 54332 52492
1148056/2	Airwave Solutions Limited	TR 22913 38206	TR 27405 39738
1150465/1	Airwave Solutions Limited	SU 50380 79008	SU 52116 74131
1150544/1	Airwave Solutions Limited	SU 85655 94255	SU 86899 92938

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1152254/1	Airwave Solutions Limited	SU 65846 86265	SU 64720 81306
1158734/1	Airwave Solutions Limited	SK 60326 82154	SK 59277 87812
1158748/1	Airwave Solutions Limited	SX 31089 54721	SX 27348 57734
1159603/1	Airwave Solutions Limited	NY 94485 89586	NY 99387 85511
1160223/1	Airwave Solutions Limited	NZ 45432 05409	SE 45871 99505
1236345/1	Airwave Solutions Limited	SE 16807 46634	SE 21021 44585
1065333/2	Aquila Air Traffic Management Services Limited	SE 39216 79065	SE 37730 72407
1082461/2	Aquila Air Traffic Management Services Limited	SJ 47791 22930	SJ 54389 22431
1092601/2	Aquila Air Traffic Management Services Limited	SK 91806 16207	SK 99444 07221
1109472/2	Aquila Air Traffic Management Services Limited	SP 29236 06579	SP 22145 12311
1109513/3	Aquila Air Traffic Management Services Limited	SU 25076 35040	SU 29591 37985
1109515/2	Aquila Air Traffic Management Services Limited	SU 17953 39093	SU 10015 35438
1115133/2	Aquila Air Traffic Management Services Limited	SU 71601 93135	SU 63517 91343
0464291/1	Arqiva Limited	ST 78800 96500	ST 66600 90100
1079203/1	Arqiva Limited	SU 85650 94240	SU 87700 91090
1268543/1	Arqiva Limited	SE 26830 55600	SE 21150 51440
1094648/1	Associated British Ports	SU 48800 02500	SU 43200 07800
1098140/1	Associated British Ports	SU 48840 02526	SU 49223 05285
0501142/1	British Telecommunications Public Limited Company	SJ 81050 69980	SJ 93370 67680
0800457/1	British Telecommunications Public Limited Company	TG 38520 03370	TG 25850 02660
1041509/2	British Telecommunications Public Limited Company	SU 71570 20210	SU 74450 23400
1057739/1	British Telecommunications Public Limited Company	NZ 60770 22201	NZ 60450 25100
1057745/1	British Telecommunications Public Limited Company	NZ 28606 14649	NZ 31880 17700
1060758/1	British Telecommunications Public Limited Company	ST 16505 89610	ST 15290 86730
0839858/1	EE Limited	SK 51950 95950	SE 51800 07950
1158959/1	Joint Radio Company Limited	NS 64382 74410	NS 74855 81164
1131949/1	Mckay Brothers International SA	TQ 82877 83781	TQ 79838 82436
0456115/1	MLL Telecom Ltd	NZ 18400 47400	NZ 21000 45000
0881296/1	Mobile Broadband Network Limited	TL 12700 91300	TF 07249 00706
0881461/1	Mobile Broadband Network Limited	TL 05970 47885	TL 08523 50899
0882046/1	Mobile Broadband Network Limited	SZ 47500 83500	SZ 49076 95170
0902317/2	Mobile Broadband Network Limited	NW 23620 47251	NW 27709 44846
0938420/1	Mobile Broadband Network Limited	SE 31200 13800	SE 36100 08700
1004125/1	Mobile Broadband Network Limited	SD 52215 75470	SD 49627 69552
1011743/1	Mobile Broadband Network Limited	SP 62372 50638	SP 68918 46742
1019390/1	Mobile Broadband Network Limited	TM 09758 52750	TM 04374 58420
1046066/1	Mobile Broadband Network Limited	SK 60326 82154	SK 59279 87809
1053512/1	Mobile Broadband Network Limited	TR 16036 38763	TR 19452 46665
1058794/1	Mobile Broadband Network Limited	ST 47332 70636	ST 48803 67317
1060870/1	Mobile Broadband Network Limited	SP 16310 48830	SP 19516 42599

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1092082/1	Mobile Broadband Network Limited	SK 15495 23067	SK 17281 27871
1098622/1	Mobile Broadband Network Limited	SP 82441 03544	SP 82855 09328
1113603/1	Mobile Broadband Network Limited	SD 52217 75466	SD 48584 69202
1114430/1	Mobile Broadband Network Limited	NZ 14254 96524	NZ 18881 90274
1114434/2	Mobile Broadband Network Limited	NO 86845 87603	NO 82261 80270
1120313/1	Mobile Broadband Network Limited	NZ 45430 05425	SE 45900 99500
1121112/2	Mobile Broadband Network Limited	NJ 80662 27950	NJ 76005 32871
1129932/1	Mobile Broadband Network Limited	SE 09493 04075	SE 14714 08384
1146968/1	Mobile Broadband Network Limited	SJ 74127 69270	SJ 70803 65770
1188791/1	Mobile Broadband Network Limited	SK 41558 53417	SK 38911 59538
1266166/1	Mobile Broadband Network Limited	SX 71470 56572	SX 78187 53563
1197753/1	National Grid Telecoms Limited	ST 08685 85522	ST 11571 88054
1197760/1	National Grid Telecoms Limited	SS 86241 95014	SS 78131 93653
1197791/1	National Grid Telecoms Limited	ST 43649 55699	ST 33472 60891
1197866/1	National Grid Telecoms Limited	ST 51663 98075	ST 49599 93154
1197873/1	National Grid Telecoms Limited	ST 51663 98075	ST 50752 87639
1197874/1	National Grid Telecoms Limited	ST 51663 98075	ST 49507 90003
1197883/1	National Grid Telecoms Limited	SS 97955 67590	ST 02633 74094
1197936/1	National Grid Telecoms Limited	SP 77700 36200	SP 76900 31800
1197967/1	National Grid Telecoms Limited	SK 30665 51514	SK 28262 45380
1197994/1	National Grid Telecoms Limited	SO 96900 83900	SO 96000 78500
1198002/1	National Grid Telecoms Limited	SK 46200 39100	SK 49509 35744
1198009/1	National Grid Telecoms Limited	SJ 98600 14500	SJ 98800 09300
1198014/1	National Grid Telecoms Limited	SK 03600 09100	SK 05000 12400
1198037/1	National Grid Telecoms Limited	SK 46700 56700	SK 47500 59100
1198190/1	National Grid Telecoms Limited	SS 84752 82801	SS 78354 86832
1154983/2	New Line Networks LLC	TR 30711 50424	TR 20929 53431
1154991/3	New Line Networks LLC	TR 30711 50424	TR 20929 53431
0959474/3	PD Teesport Limited	NZ 54903 24696	NZ 55720 28261
0925390/1	Scot-Tel-Gould Limited	NJ 73092 16830	NJ 70928 18845
0496194/2	Vodafone Limited	TL 24106 16441	TL 24250 19420
0505493/1	Vodafone Limited	SK 53440 28780	SK 50845 25472
0505495/1	Vodafone Limited	SK 48775 32200	SK 49510 35740
0903548/1	Vodafone Limited	SU 92619 69341	SU 94090 67580
0949787/1	Vodafone Limited	SJ 69570 08990	SJ 71040 08990
0950091/1	Vodafone Limited	TL 24400 13400	TL 29170 06700
0950465/1	Vodafone Limited	SU 48831 91709	SU 49200 91600
0951262/1	Vodafone Limited	SE 82974 12561	SE 88110 09150
0953872/1	Vodafone Limited	SD 37405 07414	SD 39061 11140
0988886/4	Vodafone Limited	SU 37155 31073	SU 45909 35609
1010051/1	Vodafone Limited	SU 40278 89196	SU 46226 91554
1016515/1	Vodafone Limited	SO 93857 02345	ST 97856 97828
1042776/1	Vodafone Limited	NS 70307 70069	NS 66465 68770
1049076/1	Vodafone Limited	SJ 59379 32604	SJ 54260 28790
1058023/1	Vodafone Limited	TQ 16570 60300	TQ 15275 62480

Licence number	Licence holder name	Transmitter location NGR	Receiver location NGR
1075671/1	Vodafone Limited	SJ 22462 86284	SJ 26889 87327
1075673/1	Vodafone Limited	SJ 22462 86284	SJ 26889 87327
1188340/1	Vodafone Limited	TQ 16570 60300	TQ 15275 62480
0999632/2	Zycomm Electronics Limited	SK 36402 47146	SK 30551 51580
1031118/1	Zycomm Electronics Limited	SK 37099 47727	SK 40390 50720
1059637/1	Zycomm Electronics Limited	SK 21954 48722	SK 24878 39515

Fixed links in the 40 GHz band

A18.3 As set out in section 7 of this document, we have decided to start the process to revoke the existing block assigned spectrum access licences in the 40 GHz band. However, we will offer to re-authorise use of any fixed links which operate in low density areas, and are not likely to receive interference from new mobile services operating in high density areas.

A18.4 As explained in section 7, we will shortly issue a formal information request to MBNL and H3G, to establish which of their existing fixed links operate outside high density areas and are unlikely to receive interference from new mobile users in high density areas. We will offer to continue to license use of any of these links which our final coexistence analysis shows are unlikely to receive interference from mobile services in high density areas.