CEPT ECC
Electronic Communications Committee

ECC Report 358

In-band and adjacent bands sharing studies to assess the feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband low/medium power (WBB LMP) systems providing local-area network connectivity

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0 EXECUTIVE SUMMARY

This Report supports the work of ECC in response to the "Mandate to CEPT on technical conditions regarding the shared use of the 3.8-4.2 GHz frequency band for terrestrial wireless broadband systems providing local-area network connectivity in the Union".

This Report includes technical in-band and adjacent band co-existence studies on the basis of the following scenarios:

1 in-band coexistence:
   - to ensure protection of fixed satellite service (FSS) and fixed service (FS), including the possibility for their future evolution and development;
   - for in-band sharing between different WBB LMP networks.

2 adjacent band coexistence:
   - between MFCN below 3.8 GHz and WBB LMP in the 3.8-4.2 GHz frequency band (interference from MFCN to WBB LMP and interference from WBB LMP to MFCN);
   - Adjacent band studies between WBB LMP in the 3.8-4.2 GHz frequency band and Radio Altimeters (RA) above 4.2 GHz are provided in ECC Report 362 [1]. As parameters for WAIC above 4.2 GHz were not provided, no studies have been performed.

Further, in this Report it is assumed that:
- the locations of WBB LMP base stations are known;
- the locations of FSS receiving Earth stations are known;
- the locations of FS stations are known;
- MFCN below 3.8 GHz is not constrained by WBB LMP above 3.8 GHz.

As FSS below 3.8 GHz is considered to be the same service as above 3.8 GHz, the operation of FSS below 3.8 GHz is covered by the in-band sharing studies in 3.8-4.2 GHz.

This Report includes also a coexistence study between WBB LMP and VLBI Global Observing System (VGOS) stations operating in a few CEPT countries, supporting EU interests as part of the European Critical Infrastructure Project Galileo.

Synchronisation of WBB LMP

Two WBB LMP network technologies have been considered, one based on 3GPP technical specifications and the other based on DECT-2020 NR technical specifications. Networks using these two technologies cannot synchronise with each other due to different operational principles. Synchronised operation of WBB LMP networks with MFCN below 3800 MHz is only possible for WBB LMP based on 3GPP technical specifications. The study results of these two technologies are presented separately.

Power levels and antenna heights studied for WBB LMP

For the purpose of studies, the following maximum power levels for WBB LMP have been defined:
- 3GPP low power base stations with 31 dBm/100 MHz *e.i.r.p.;*
- 3GPP medium power base stations with up to 49 dBm/100 MHz or up to 51 dBm/100 MHz *e.i.r.p.;*
- The maximum power level for 3GPP WBB terminals (fixed/installed, and mobile/nomadic) of 28 dBm *e.i.r.p.* is considered and Power Control is applied;
- For DECT-2020 NR there is no technical distinction between devices ('base station' equipment or 'terminal equipment') and the maximum power level is 23 dBm *e.i.r.p.* with a channel bandwidth of 6.912 MHz. It is noted that for DECT-2020 NR, the technical specification mandates that all radio devices within the network shall employ TPC, including the fixed radio device (or 'base station' in traditional cellular networks).

For studies involving WBB medium power base stations, a range of antenna heights, up to 30 m above the ground, was studied. For studies involving outdoor 3GPP based WBB low power base stations, a maximum

antenna height above ground of 10-25 m was studied and for DECT-2020 NR WBB 10 m above ground was studied.

This Report contains studies and relevant analysis on a range of coexistence conditions (including geographical separation, frequency separation, etc.) depending on a range of agreed WBB LMP parameters (*e.i.r.p.*, antenna height, antenna gain, emission and reception masks, etc.), covering both AAS and non-AAS scenarios for medium power base stations and only non-AAS for low power base stations.

In-band coexistence of WBB LMP with FS and FSS

Regarding FS coexistence, one of the studies shows the importance that real terrain data are taken into account in the coexistence assessments, because the impact of real terrain on transmitted signal propagation can result in not only reduced, but also increased minimum separation distances/exclusion areas required between WBB LMP and FS.

It is not possible to define generic technical conditions that guarantee the protection of FS. Instead a case-by-case analysis is needed, in combination of considering appropriate mitigation techniques, to ensure the protection of current and future deployment of FS. In addition, due to the large separation distances that may be necessary, the protection of FS cannot always be managed at national level only but may require cross border coordination on a case-by-case basis as well as bilateral or even multilateral agreements between neighbouring countries.

It is not possible to define generic technical conditions that guarantee the protection of FSS. Careful planning and case-by-case analysis is needed, in combination of considering appropriate mitigation techniques, to ensure the protection of current and future deployment of FSS. In addition, due to the large separation distances that may be necessary, the protection of FSS cannot always be managed at national level only but may require cross border coordination on a case-by-case basis as well as bilateral or even multilateral agreements between neighbouring countries.

Nevertheless, appropriate mitigation techniques could be considered during coordination on a case-by-case basis to facilitate coexistence between WBB and FS/FSS systems, both at national level and with the neighbouring countries. CEPT is developing recommendations for administrations to provide guidance for coordination between these services.

Studies on WBB LMP networks with no synchronisation to other WBB LMP nor to MFCN

For the various type of use-cases there may be various needs of UL/DL resources and different technologies, resulting in unsynchronised operation. The studies are mainly based on the following assumptions:

- no synchronisation between WBB LMP local networks in the frequency band 3.8-4.2 GHz;
- no synchronisation between WBB LMP local networks in the frequency band 3.8-4.2 GHz and MFCN networks below 3.8 GHz.

Indoor-only, outdoor-only and outdoor/indoor deployment scenarios have been considered. The analysis of in-band and adjacent band operation demonstrate the feasibility of unsynchronised WBB LMP operation in the frequency band 3.8-4.2 GHz, but a coordination process may be needed.

Some studies investigated if stricter out of band emission and receiver blocking levels of LMPs and frequency separation could reduce the need for coordination between 3GPP WBB LMP and MFCN (below 3.8 GHz).

The following technical conditions were investigated:

- 60 MHz frequency separation for WBB MP to accommodate MFCN BS receiver blocking;
- out of band emission level of -45 dBm/MHz conducted power or -40 dBm/MHz *e.i.r.p.* per BS (sector) below 3800 MHz for LP and MP non-AAS BS;
- out of band emission level of -45 dBm/MHz TRP or -50 dBm/MHz TRP per BS (sector) for MP AAS BS;
- WBB LMP receiver blocking level of -15 dBm below 3800 MHz for wanted signal level: P_ref_sens+6 dB.

In addition to the above technical conditions, studies identified possible components for the coordination process to ensure the co-existence between WBB LMP and MFCN (below 3.8 GHz) e.g.:

- pfd or field strength values at the WBB LMP local area network coverage border;
- physical separation between WBB LMP and MFCN Macro BSs;
- synchronisation or semi-synchronisation between MFCN and WBB LMP networks.

Adjacent channel coexistence for WBB LMP networks synchronised with other WBB LMP or MFCN

Adjacent channel coexistence between synchronised WBB LMPs networks, when operating based on 3GPP technical specifications, is considered covered by 3GPP/ETSI standardisation. This assumption also accounts for adjacent band operation of these WBB LMP networks in the frequency band 3.8-4.2 GHz synchronised with MFCN below 3.8 GHz. Such synchronised coexistence scenarios across the frequency band 3.4-4.2 GHz for non-AAS and AAS take part of possible coordination solutions for WBB LMP networks based on 3GPP technical specifications.

Semi-synchronised operation between WBB LMP and MFCN networks

Studies were performed for semi-synchronised operation with DL to UL modifications (which is a specific sub-case of semi-synchronised operation) for WBB LMP networks based on 3GPP technical specifications. Considering LMP base station to MFCN base station interference, it can ensure the same protection of MFCN base stations below 3.8 GHz as synchronised operation. This approach could be considered on a case-by-case basis. It could better facilitate coexistence with some limitations on UL/DL sequences on WBB LMP frame structure providing higher uplink capacity but with some possible constraints on WBB LMP uplink performance.

Other aspects regarding the shared use of the frequency band 3.8-4.2 GHz for WBB LMP networks

There is a balance to be struck between how much coordination an administration is able to carry out at a local level between WBB LMP networks and incumbent services, and how restrictive the harmonised technical conditions on WBB LMP need to be. Some of the technical conditions that were studied in this Report would reduce to a certain extent the amount of coordination needed when assigning frequencies to WBB LMP installations.

In order to facilitate and maximise the opportunities for the deployment of WBB LMP and to manage remaining coordination cases that may not be addressed by the harmonised technical conditions, administrations may want to complement certain aspects of their use of the frequency band 3.8-4.2 GHz at the national and/or the local level circumstances, for example on synchronisation, pfd limits, separation distance and/or frequency separation requirements.

CEPT plans to develop ECC Recommendations for administrations to provide guidance on the approach to coexistence in the band. There may be also a need to develop relevant cross-border recommendations.

Finally, the relevant study results in this Report could be used for developing guidelines to ensure protection and future evolution on a case-by-case basis of FSS receiving earth stations and of terrestrial fixed links sharing the band 3.8-4.2 GHz with WBB LMP, for managing co-existence between WBB LMPs and between WBB LMP and MFCN below 3.8 GHz.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AAS	Active Antenna Systems
BEM	Block Edge Mask
BS	Base Station
CEPT	European Conference of Postal and Telecommunications Administrations
DECT-2020 NR	Digital Enhanced Cordless Telecommunications-2020 New Radio
DL	Downlink
ECC	Electronic Communications Committee
e.i.r.p.	Effective Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
EU	European Union
FS	Fixed Service
FSS	Fixed Satellite Service
MFCN	Mobile Fixed Communications Network
non-AAS	Non Active Antenna Systems
NRB	Number of Resource Block
PtP	Point-to-Point
PmP	Point-to-Multipoint
RA	Radio Altimeters
RB	Resource Block
Rx	Receiver
TDD	Time division duplex
TPC	Transmitter Power Control
Tx	Transmitter
UL	Uplink
UK	United Kingdom
VGOS	VLBI Global Observing System
VLBI	Very Long Baseline Interferometry
WAIC	Wireless Avionics Intra-Communications
WBB LMP	Terrestrial wireless broadband low/medium power systems providing local-area network connectivity

1 INTRODUCTION

This Report investigates the technical feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems (WBB systems) providing local-area network connectivity with base stations operating at low/medium power (here and after with abbreviation WBB LMP) with focus on vertical industries and other terrestrial wireless use cases, proving the results of:

- sharing and compatibility studies between WBB LMP networks;
- sharing and compatibility studies between WBB LMP networks and incumbent users in the 3.8-4.2 GHz frequency band, notably receiving satellite earth stations in the fixed satellite service and terrestrial fixed links to ensure the protection and the future evolution and development of these incumbent users sharing this band;
- sharing and compatibility studies between WBB LMP networks and spectrum users in adjacent bands (such as MFCN below 3.8 GHz).

The adjacent band co-existence study between WBB LMP in 3.8-4.2 GHz band and Radio Altimeters in 4.2 - 4.4 GHz band is covered by the separate ECC Report 362 [1].

2 DEFINITIONS

2.1 SYNCHRONISATION

The definitions below may not necessarily apply to an entire network. In particular, there are use cases where different base stations within a network may be unsynchronised or semi-synchronised.

2.1.1 Synchronised operation

The synchronised operation in the context of this Report means operation of TDD in several different networks, where no simultaneous UL and DL transmissions occur, i.e. at any given moment in time either all networks transmit in DL or all networks transmit in UL. This requires the alignment of all DL and UL transmissions for all TDD networks involved as well as a common phase clock reference synchronising the beginning of the frame across all networks.

2.1.2 Unsynchronised operation

The unsynchronised operation in the context of this Report means operation of TDD in several different networks, where at any given moment in time at least one network transmits in DL while at least one network transmits in UL. This might happen if the TDD networks either do not align all DL and UL transmissions or do not synchronise at the beginning of the frame i.e. no common phase clock reference.

2.1.3 Semi-synchronised operation

The semi-synchronised operation corresponds to the case where a part of the frame is consistent with synchronised operation as described above, while the remaining portion of the frame is consistent with unsynchronised operation as described above. This requires the adoption of a frame structure for all TDD networks involved, including slots where the UL/DL direction is not specified, as well as a common phase clock reference synchronising the beginning of the frame across all networks.

2.1.4 Semi-synchronised operation with DL to UL modifications for WBB LMP

In this Report, a specific sub-case of semi-synchronised operation, in which only DL to UL modifications are allowed to WBB LMP network compared to the frame structure of the MFCN network, is considered. This case is especially interesting for those scenarios where WBB LMP networks require more UL resources than those available in the frame structure of the MFCN network below 3800 MHz. In the case of semi-synchronised operation with DL to UL modifications, only the default DL transmission direction in the frame structure may be modified into UL. As a result, if only DL to UL modifications are performed by the WBB LMP networks, MFCN below 3800 MHz will not receive additional BS-to-BS cross-interference from the WBB LMP network. However, WBB LMP network could receive additional BS-to-BS cross-interference which might need to be handled.

The approach could be implemented with either one of the frame structures recommended in ECC Recommendation (20)03 [2].

Figure 1 illustrates the concepts via an example of the three different synchronisation options.

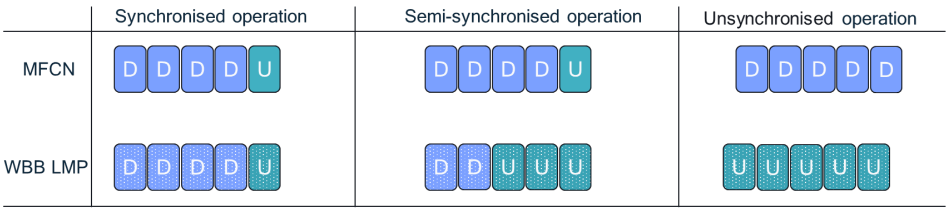


Figure 1: Different synchronisation options

Although semi-synchronised operation is also possible employing UL to DL modifications, this case is not considered in this Report since this would cause additional BS-to-BS cross-interference from the WBB LMP network to MFCN below 3800 MHz.

From the perspective of flexibility for local network deployments, unsynchronised operation is usually the preferred option. However, for some cases, especially if the required separation distance for unsynchronised operation is a challenge, synchronisation might be necessary. For those cases, additional frame structure flexibility is achieved by employing semi-synchronised operation.

The benefits of semi-synchronised operation with DL to UL modifications compared to unsynchronised operation are as follows:

- The protection to MFCN BS below 3800 MHz will be identical to synchronised operation. Considering LMP base station to MFCN base station interference;
- The separation distance to MFCN can be significantly reduced compared to unsynchronised case, although there might be possible constraints on WBB LMP uplink performance.

Compared to synchronised operation the benefit is the possibility to use more UL resources than provided by the defined frame structure of the MFCN network below 3800 MHz.

It should be noted that semi-synchronisation is realised in the same way as synchronised operation and simply requires setting the corresponding network parameters related to the DL to UL modifications in the frame structure of the WBB LMP.

2.2 LICENSED AREA

In the context of some studies in this Report, the licensed area of WBB LMP is geographical zone bounded by specific conditions to be met (e.g. a pfd/field strength not to be exceeded) at a given height at the border of the licensed area.

3 ALLOCATIONS AND APPLICATIONS IN THE FREQUENCY BAND 3800-4200 MHZ AND ADJACENT BANDS

Allocation of services and applications according to ECA Table [3] in ECO Frequency Information System (EFIS) for the frequency range 3400-4400 MHz are provided in Table 1.

Table 1: Services and systems to be considered for studies

Studies	Allocation	Application
In-band (sharing): 3800-4200 MHz	FIXED	Fixed link
	FIXED-SATELLITE (space-to-Earth)	Earth station
	MOBILE (Note 1)	WBB LMP (Note 2)
Adjacent band (compatibility): 3400-3800 MHz and 4200-4400 MHz, as applicable	FIXED	Fixed link
	FIXED-SATELLITE (space-to-Earth)	Earth station
	MOBILE	MFCN (Note 3)
	AERONAUTICAL MOBILE (R)	WAIC (Note 4)
	AERONAUTICAL RADIONAVIGATION	RA (Note 5)

Note1: The band 3800-4200 MHz is allocated on a secondary basis in the Radio Regulations [4] in Region 1 to the mobile service and in some CEPT countries the mobile service may be on secondary basis.

Note 2: WBB LMP – terrestrial wireless broadband low/medium power systems providing local-area network connectivity.

Note 3: MFCN – mobile/fixed communications networks which includes IMT and other communications networks in the mobile and fixed services" which would include fixed wireless access but not point-to-point links.

Note 4: WAIC – wireless avionics intra-communication.

Note 5: RA – Radio Altimeters.

3.1 ALLOCATIONS AND APPLICATIONS IN THE FREQUENCY BAND 3800-4200 MHZ

3.1.1 Fixed satellite service

For decades and in accordance with, the Article 5 of the ITU-R Radio Regulation, the fixed satellite service (FSS) has utilised the 3400-4200 MHz and 5850-6725 MHz frequency bands for space-to-Earth (downlink) and Earth-to-space (uplink) links, respectively. FSS earth stations in CEPT countries have mainly been used in the 3600-3800 MHz and 3800-4200 MHz bands, rather than the lower 3400-3600 MHz band.

With the introduction of 5G in the 3.4-3.8 GHz band in Europe, ECC Decision (11)06 [5] asks that administrations consider relocating earth stations operating in the 3400-3800 MHz band from areas with foreseen extensive 5G use, and instead consider using higher bands above 3800 MHz for future FSS usage. As a result, many stations have migrated to the 3800-4200 MHz frequency band.

The 3.8-4.2 GHz band is important for FSS due to its unique characteristics, including wide geographic coverage over continents and resistance to rain fade. This band is essential for services provided to inter-tropical regions, and many earth stations are located in Europe for inter-continental communications. Applications include connectivity for enterprises and public institutions, mobile backhauling, and video distribution. The successful operation of this system depends on interference-free reception of the downlink signal.

Existing FSS earth stations in the 3800-4200 MHz band are limited in number and well-identified in location. Future new earth station sites can also be expected to be located in well-defined locations. As a result of the introduction of MFCN below 3800 MHz, some administrations have implemented national frameworks (e.g. through PFD or PSD limits, or requirements on OOBE levels from adjacent band MFCN BS) in order to protect

FSS earth stations and provide visibility and legal certainty for their future development in the 3800-4200 MHz band.

As the 3800-4200 MHz band is the only remaining part of the C-band for downlink communication, CEPT has assessed and proposed conditions to preserve this band for the long-term development of FSS in accordance with the objectives of the EC mandate.

3.1.2 Fixed service

Fixed service (FS) is a primary user of the 3800-4200 MHz frequency range in Europe and includes both military and civil usage.

Military usage includes fixed microwave links that support military communications and surveillance systems. Military entities use these links for command and control, situational awareness, intelligence, surveillance and reconnaissance (ISR), and other applications.

Civil use is primarily fixed point-to-point microwave links, connecting different points in a network, such as data centres or remote locations. These links are commonly used for various applications such as internet access, broadcasting, public safety and emergency services, and transportation systems.

ERC Recommendation 12-08 [6] provides a channel plan for the 3600-4200 MHz frequency range. In particular its Annex B Part 1 defines a channel arrangement in 3.8-4.2 GHz for Point-to-Point (PtP) and Point-to-multi-Point (PmP) links based on Recommendation ITU-R F.382 [7] with 29 MHz paired channels.

3.1.3 VLBI (Very Long Baseline Interferometry) stations

There is a globally well-distributed network of VLBI Global Observing System (VGOS) stations, which are highly sensitive passive receivers and are expected eventually to number ~40. Some VGOS observatories are installed around Europe (Wettzell in Germany, Ny-Ålesund in Norway, Flores and Santa Maria in Portugal, Gran Canaria and Yebes in Spain, Onsala in Sweden, Metsähovi in Finland and Matera in Italy). These are part of the European Critical Infrastructure Project Galileo which has to be supported from all European countries.

The start frequencies of these VGOS stations, like type VGOS-992 A8, is 3960.4 MHz (Block A) (see Report ITU-R RA.2507, page 25 [8]).

It is recognised that for the moment these observations, which are operating in the spectrum bands of the 2 - 14 GHz range, have no radio astronomy allocation in 3.8-4.2 GHz and therefore cannot claim interference protection on international or European level. Nevertheless, administrations are urged to take all practicable steps to protect these observatory operations from harmful interference.

3.2 ALLOCATIONS AND APPLICATIONS IN ADJACENT BANDS

3.2.1 MFCN

The 3400-3800 MHz band is harmonised for MFCN in CEPT (and in the EU in accordance with EC Decision [9]) and is recognised to be the 5G primary band in Europe.

The band 3400-3800 MHz has been auctioned in the majority of CEPT countries (see ECO Report 03 [10] and EU 5G Observatory Report [11]). Under the relevant authorisations and rights of use granted accordingly, mobile operators have invested heavily to roll out 5G and will continue during the coming years. Those networks are widely deployed outdoors with AAS base stations. Non-AAS small cells could be also rolled out indoors.

It is important, that the MFCN service is adequately protected from possible interferences caused by WBB LMP deployments.

3.2.2 Fixed satellite service (space-to-Earth) below 3.8 GHz

With the introduction of 5G in the 3.4-3.8 GHz band in Europe, CEPT has recommended that administrations consider relocating earth stations operating in the 3400-3800 MHz band from areas with foreseen extensive 5G use. In addition, CEPT recommended administrations to avoid authorising new FSS sites in the 3400-3800 MHz band in areas intended for 5G, and instead consider using higher bands above 3800 MHz for future FSS usage. As a result a limited number of FSS earth stations remain in the band below 3800 MHz.

As this is the same service as above 3.8 GHz, it is expected that operation of FSS below 3.8 GHz should be covered by the in-band sharing studies.

In case of conducting adjacent band studies the characteristics for FSS earth station remain the same as in section 5.1.2.

3.2.3 Aeronautical radionavigation service in the frequency band 4.2-4.4 GHz (Radio Altimeters)

Within the International Telecommunication Union (ITU) Radio Regulations (RRs) the frequency band 4200 - 4400 MHz is globally allocated to the aeronautical radionavigation service (ARNS) and is reserved exclusively for Radio Altimeters installed on board aircraft and for the associated transponders on the ground by Radio Regulations footnote No. 5.438.

In addition, the frequency band is shared with Wireless Avionics Intra-Communications (WAIC) systems.

More detailed information is available in ECC Report 362 [1].

3.2.4 Aeronautical mobile (R) service above 4.2 GHz (WAIC)

The use of the frequency band 4200-4400 MHz by stations in the aeronautical mobile (R) service for Wireless Avionics Intra-Communications (WAIC) is secondary to Radio Altimeters and operate on a no-protection, no-interference basis with respect to Radio Altimeters. (WAIC) systems shall operate in accordance with recognised international aeronautical standards and the use shall be in accordance with Resolution 424 (WRC-15).

4 TERRESTRIAL WIRELESS BROADBAND SYSTEMS PROVIDING LOCAL AREA (I.E. LOW/MEDIUM POWER) NETWORK CONNECTIVITY IN THE FREQUENCY BAND 3800-4200 MHZ

This section provides an overview of the WBB LMP use cases and associated parameters. As described in the EC mandate, this WBB LMP application is aimed at providing local area network connectivity in a shared manner. The following sub-sections attempt to capture and address the wide range of use-cases and requirements of potential users, such as enterprises and local communities.

4.1 USE CASES

The 400 MHz available in the 3.8-4.2 GHz frequency band can enable the deployment of terrestrial wireless broadband systems to provide local area connectivity for a variety of services in indoor and outdoor environments. In addressing the EC Mandate tasks on the shared use of the 3.8-4.2 GHz band for local area connectivity, it is important to address the technological and deployment requirements for a wide range of use-cases and users, ranging from "vertical industries"[1] to local communities. Some examples of the non-exhaustive list of use-cases which could utilise the 3.8-4.2 GHz frequency band are listed in Table 2.

Table 2: WBB LMP use-case examples

Local areas services	Use-case example
Transport	Connectivity in transport hubs including logistics in ports, remote control of cranes, autonomous driving of vehicles and ships
Manufacturing	Connectivity to support smart factories and warehouses including sensor and machine connectivity, real-time monitoring of production lines, predictive maintenance, automation and other types of IoT applications
Construction	Connectivity for remote site surveys and remote monitoring and operations in construction sites
Entertainment and content production	Connectivity for UHD video live-streaming and use of AR/XR applications for immersive user experience. Support of multiple camera feeds and control signals within TV production environments (indoors/outdoors)
Education	Connectivity for video streaming in online learning platforms supported by the use of AR/XR applications
Health	Connectivity for sensors and medical equipment to support real-time remote medical operations
Utilities	Connectivity for smart grid real-time operations, including network control and optimisation as well as remote infrastructure monitoring and management
Smart cities	Connectivity for urban planning and real-time information conveyance
Rural broadband connectivity	Connectivity for industries located in rural environments such as e.g. agriculture, mining and fishing as well as for local communities through Fixed Wireless Access (FWA)

It should be noted that some use-cases may be time-critical in nature and have strict requirements, such as strict latency and reliability requirements as well as requirements for flexible UL/DL ratios.

[1] such as transport, logistics, automotive, health, energy, smart factories, media and entertainment

The wide range of local use-cases, used across different industrial and non-industrial environments both indoors and outdoors, will benefit from harmonised technical conditions.

An example use-case, requiring coverage of a given industrial site, demonstrating how different BS deployment configurations can affect the coverage and deployment complexity of WBB LMP networks in the frequency band is provided in A1.1.1. This annex also presents results of live testing between WBB LMP PMSE use case and 5G MFCN and shows equipment used the uplink biased 2:7 TDD frame structure compared with the 3:1 frame structure used by MFCN.

4.2 WBB LMP PARAMETERS USED FOR STUDIES

Two WBB LMP technologies have been considered, one based on 3GPP technical specifications and the other based on DECT-2020 NR standards.

4.2.1 3GPP 5G NR

Table 3: Parameters of the WBB LMP providing local area network connectivity in 3.8-4.2 GHz

Parameter	Low Power BS	Medium Power BS
Bandwidth	10 MHz to 100 MHz	10 MHz to 100 MHz
Antenna height	Outdoor: Limited to a maximum of 10 m above ground Indoor: Any height within building	No limit
Deployment scenario	Rural, suburban and urban Outdoor/indoor or Indoor-only	Rural, suburban and urban Outdoor
BS Tx *e.i.r.p.* limit (for AAS and non-AAS)	24 dBm / carrier for carriers ≤ 20 MHz; or 18 dBm / 5 MHz for carriers > 20 MHz	42 dBm / carrier for carriers ≤ 20 MHz; or 36 dBm / 5 MHz for carriers > 20 MHz
Maximum terminal power	Mobile/nomadic: TRP 28 dBm (Note 2) Fixed: *e.i.r.p.* 28 dBm (Note 2)	Mobile/nomadic: TRP 28 dBm (Note 2) Fixed: TRP 28 dBm and *e.i.r.p.* 35 dBm/5 MHz (Note 1)
Note 1: Higher *e.i.r.p.* limit for fixed terminals in the medium power BS case is to account for the use case of Fixed Wireless Access (FWA) Note 2: The authorisation of 28 dBm includes a 2 dB tolerance consistent with the European harmonisation.		

Table 4: Out-of-block emission limits of the WBB LMP providing local area network connectivity in 3.8-4.2 GHz, derived from ECC Decision (11)06 [5]

Frequency offset	Maximum mean e.i.r.p. density
-5 to 0 MHz offset from lower channel edge 0 to 5 MHz offset from upper channel edge	(P_{max} – 40) dBm / 5 MHz e.i.r.p. per antenna
-10 to -5 MHz offset from lower channel edge 5 to 10 MHz offset from upper channel edge	(P_{max} – 43) dBm / 5 MHz e.i.r.p. per antenna
Out of block baseline power limit (BS) < -10 MHz offset from lower channel edge > 10 MHz offset from upper channel edge	(P_{max} – 43) dBm / 5 MHz e.i.r.p. per antenna
Note: P_{max} is the maximum mean carrier power in dBm for the base station measured as e.i.r.p. per carrier, interpreted as per antenna	

Table 5: Out-of-band emission limits of the WBB LMP providing local area network connectivity in 3.8-4.2 GHz, derived from ECC Decision (11)06 [5]

Frequency offset	Maximum mean e.i.r.p. density
3795-3800 MHz, 4200-4205 MHz	(P_{max} – 40) dBm / 5 MHz e.i.r.p. per antenna
3790-3795 MHz, 4205-4210 MHz	(P_{max} – 43) dBm / 5 MHz e.i.r.p. per antenna
3760-3790 MHz, 4210-4240 MHz	(P_{max} – 43) dBm / 5 MHz e.i.r.p. per antenna
Below 3760 MHz, above 4240 MHz	-2 dBm / 5 MHz e.i.r.p. per antenna
Note: P_{max} is the maximum mean carrier power in dBm for the base station measured as e.i.r.p. per carrier, interpreted as per antenna	

Note: Although the out-of-band emission levels for AAS antennas in ECC Decision (11)06 [5] are specified based on TRP, some studies used *e.i.r.p.*, as shown in Tables 4 and 5, as a metric for the unwanted emissions of AAS antennas. Such use of *e.i.r.p.* aimed for a comparison of the unwanted emissions between AAS and non-AAS antennas in the coexistence of WBB MP with other services, using the same reference metric.

In Table 4 and Table 5 "per antenna" means per radiating unit/component (irrespective of the number of radiating elements that make up that unit/component). Therefore, when applying the "per antenna" limit to an AAS unit, this should be interpreted as a "per sector" limit as an AAS sector is seen as one "radiating unit".

The WBB MP AAS BS emission mask from 3GPP TS38.104 was used in some studies.

Table 6: Parameters of the WBB LMP providing local area network connectivity in 3.8-4.2 GHz

Parameter	Low Power BS	Medium Power BS
TDD / FDD	TDD	TDD
BS Sectorisation	1	1
Use case information single BS cell range (AAS and non-AAS)	0.05–0.4 km for outdoor BS typical antenna height above ground 10 m 0.01–0.1 km for indoor BS	0.05-3 km antenna height above ground 5 m ~ 30 m for indoor/outdoor BS (Note 1)

Parameter	Low Power BS	Medium Power BS
	any height within building	
BS TDD activity factor	25-75%	25-75%
Network loading factor	50% (for the network) 50% and/or 100% (for a single base station)	50% (for the network) 50% and/or 100% (for a single base station)
BS frequency reuse	1	1
Terminal antenna gain	-4 dBi	-4 dBi
Antenna gain for AAS/non-AAS	See Table 7 for AAS and Table 8 for non-AAS	
MIMO (number of RF chains)	4T/4R for Medium Range and Local Area BS	
MIMO gain	6 dB for 4T/4R	
BS Noise Figure	13 (subtract 5 for MIMO processing gain) dB (Note 2) Note: not include MIMO Rx gain, if for MIMO processing gain is used	10 (subtract 5 for MIMO processing gain) dB (Note 3) Note: not include MIMO Rx gain, if for MIMO processing gain is used
UE Noise Figure	9 dB	9 dB
Interference criteria	I/N threshold -6 dB and/or 5% throughput loss	I I/N threshold -6 dB and/or 5% throughput loss
Estimated indoor/outdoor UE percentage (Note 4)	For outdoor BS: 70/30% For indoor BS: 100/0%	For outdoor BS rural: 50/50% For indoor BS: 100/0% For incremental approach: For outdoor BS suburban: 70/30%
Building entry loss (dB)	12 dB (Note 5)	12 dB (Note 5
UE height	For outdoor BS: 1.5 m For indoor BS: all UE are indoor at the same floor as indoor BS at 1.5 m above floor	For outdoor BS: 1.5 m For indoor BS: all UE are indoor at the same floor as indoor BS at 1.5 m above floor
Note 1: The BS cell range depends on the antenna height and indoor/outdoor deployment Note 2: Picocell Noise Figure as per Report ITU-R M.2292 [21] Note 3: Microcell Noise Figure as per Report ITU-R M.2292 Note 4: Report ITU-R M.2292 Note 5: The coordination approach BEL value of 12 dB is described in Ofcom's consultation Enabling opportunities for innovation: Shared access to spectrum supporting mobile, see paragraph 5.54 [23], and is based on the BEL CDFs of traditional and thermally efficient buildings defined in Recommendation ITU-R P.2109 [18]		

Table 7 and Table 8 define antenna patterns for simulation of AAS and non-AAS systems respectively. It should be noted that some existing national frameworks for WBB LMP do not account for the pointing direction and pattern of the antenna in their coordination processes, applying licenced *e.i.r.p.* in the coordination where WBB LMP is the interferer and peak Rx gain where WBB LMP is the victim for coordination. To account for this difference in the approach, both an omnidirectional antenna pattern and those defined in Table 5 and Table 6 could be studied for all cases. Omnidirectional antennas can be used for simulation, if the antenna pointing is not known.

Table 7: WBB LMP base station AAS antenna characteristics

AAS antenna pattern	Recommendation ITU-R M.2101, section 5 [24] Extended AAS Model 3GPP TR 38.803, section 5.2.3.2.4 [25]
Element gain (dBi)	6.4
Horizontal/vertical front-to-back ratio (dB)	30 for both H/V
Antenna polarisation	Linear ±45°
Antenna array configuration (Row × Column) (Note 1)	8x8 elements 4x4 elements (4x8 elements could be used as well)
Horizontal/Vertical radiating element/sub-array spacing, dh /dv	0.5 of wavelength for H, 0.7 of wavelength for V
Number of element rows in sub-array, Msub (Note 2)	3
Vertical radiating element spacing in sub-array, dv,sub (Note 2)	0.7 of wavelength of V
Pre-set sub-array down-tilt, θsubtilt (degrees) (Note 2)	3
Base station horizontal coverage range (degrees)	±60°
Base station vertical coverage range (degrees) (Note 3)	0 to -30
Mechanical downtilt (degrees)	0 and 10
Note 1: For the small/micro cell case, 8×8 means that there are 8 vertical and 8 horizontal radiating elements. For the extended AAS model case, 4×8 means that there are 4 vertical and 8 horizontal radiating sub-arrays. Note 2: Only needed when sub-array antenna model is used Note 3: The vertical coverage range is given in global coordinate system, i.e. 0° being at the horizon.	

Table 8: Directional WBB LMP base station non-AAS antenna characteristics

Non-AAS antenna pattern	Recommendation ITU-R F.1336 [26]
Sectorisation	1 sector for single BS; tri-sector for network layout simulation
Non-AAS BS downtilt (degrees)	0 and 10
Frequency reuse	1
Non-AAS BS antenna pattern	Recommendation ITU-R F.1336 (recommends 3.1) ka = 0.7 kp = 0.7 kh = 0.7 kv = 0.3 Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. Vertical beamwidths of actual antennas may also be used when available.

Non-AAS antenna pattern	Recommendation ITU-R F.1336 [26]
Antenna polarisation	Linear ±45°
Non-AAS BS Tx and Rx antenna gain per RF chain (including system loss)	10 dBi for Medium Range (MR) BS 6 dBi for Local Area (LA) BS 0 dBi (omni) for indoor BS
Note: The combination of power and antenna gain should be such that the maximum defined *e.i.r.p.* per sector/BS is not exceeded	

Table 9: Adjacent band receiver characteristics for WBB LMP base station

Parameter	Low Power BS (Note 1)	Medium Power BS (Note 1)
Level of the wanted signal	RefSens + 6 dB	RefSens + 6 dB
ACS (1st Adjacent channel)	-44 dBm	-47 dBm
In-band blocking (0 - (second adjacent channel to 60 MHz offset from band edge)	-35 dBm	-38 dBm
Out-of-band blocking > (beyond 60 MHz offset from band edge)	-15 dBm	-15 dBm
Note 1: From 3GPP TS 38.104 Note 2: The antenna connector of the radio module is the reference point. The reference sensitivity (RefSens) is the minimum mean power received at the antenna connector at which a specified minimum performance shall be met.		

Relative ACS and in-band blocking to be derived with the associated bandwidth and NF (Report ITU-R M.2039 [12]).

After initial study receiver blocking level of -15 dBm below 3800 MHz for improved resilience to interference below 3800 MHz could be investigated. The studies have been developed on the basis of an incremental approach, with initial studies based on the parameters for terrestrial wireless broadband systems with low/medium power providing local-area network connectivity in 3.8-4.2 GHz (WBB LMP) that are already in use in some existing national frameworks.

The following parameters for WBB LMP from Table 10 have then been used for an incremental approach, differing from those used in the initial studies.

Table 10: Parameters for the incremental studies for non-AAS and AAS medium power BS

Parameter	Medium Power BS
Maximum antenna height	30 m
Deployment scenario	Rural, suburban and urban
BS Tx *e.i.r.p.* limit (for AAS and non-AAS)	51 dBm/100 MHz

4.2.2 DECT-2020 NR

4.2.2.1 Technical parameters for DECT

Table 11 summarises the technical parameters of DECT devices used in studies. These parameters are taken from the ETSI TS 103 636-2 v1.4.1 [13], with modified noise figures due to higher frequencies. The requirements in the specification apply to all DECT-2020 NR devices as there is no distinction between base station' equipment and 'user device' equipment. Devices within a DECT-2020 NR network may be considered a radio device fixed terminal (RDFT) or radio device portable terminal (RDPT) and can dynamically change their roles depending on the network's needs. Consequently, only a single set of parameters for DECT-2020 NR is considered, i.e. all technical parameters for radio devices in Table 11 apply equally to all devices in the WBB LMP network.

Table 11: Parameters of DECT-2020 NR providing local network connectivity in the 3.8-4.2 GHz band

Parameter	Value		
Nominal channel bandwidth (MHz)	1.728	3.456	6.912
Transmission channel bandwidth (MHz)	1.539	3.051	6.075
Transmitter power (dBm)	23	23	23
Radiated power e.i.r.p. (dBm)	23 per carrier, limited to 24 dBm/10 MHz		
Transmitter Power Control	In the range -40 dBm to Max. *e.i.r.p.* (23 dBm)		
Antenna gain	0 dBi		
Antenna height	Outdoor: Limited to a maximum of 10 m above ground Indoor: Any height within building		
Noise figure (dB)	9	9	9
Rx indoor receiving level	20 dB to reference sensitivity		
Rx outdoor receiving level	20 dB to reference sensitivity		
Rx sensitivity (dBm)	-97.7	-94.7	-91.7
Protection criteria	S/(N+I)=5 dB		

4.2.2.2 Transmitter spectrum emission requirements

Out of band emissions

The spectrum emission masks of the device applies to frequencies (Δf_{OOB}) starting from the ± edge of the assigned channel (Table 12, Table 13 and Table 14). For frequency offsets greater than Δf_{OOB} the spurious emission requirements are applicable.

Table 12: Spectrum emission limit for 1.728 MHz channel bandwidth

Spectrum emission limit (dBm)		
Δf_{OOB} (MHz)	1.728 MHz channel bandwidth	Measurement bandwidth
±0 to 0.0945	-10	30 kHz
±0.0945 to 1.6335	-10	1 MHz

Spectrum emission limit (dBm)		
±1.6335 to 1.8225	-13	1 MHz
±1.8225 to 3.3615	-20	1 MHz
±3.3615 to 3.456	-23	1 MHz

Table 13: Spectrum emission limit for 3.456 MHz channel bandwidth

Spectrum emission limit (dBm)		
Δf_{OOB} (MHz)	3.456 MHz channel bandwidth	Measurement bandwidth
±0 to 0.2025	-10	30 kHz
±0.2025 to 3.2535	-10	1 MHz
±3.2535 to 3.6585	-13	1 MHz
±3.6585 to 6.7095	-20	1 MHz
±6.7095 to 6.912	-23	1 MHz

Table 14: Spectrum emission limit for 6.912 MHz channel bandwidth

Spectrum emission limit (dBm)		
Δf_{OOB} (MHz)	6.912 MHz channel bandwidth	Measurement bandwidth
±0 to 0.4185	-10	30 kHz
±0.4185 to 6.4935	-10	1 MHz
±6.4935 to 7.3305	-13	1 MHz
±7.3305 to 13.4055	-20	1 MHz
±13.4055 to 13.824	-23	1 MHz

Spurious emissions

The spurious emission limits apply for the frequency ranges that are more than Δf_{OOB} (MHz) in Table 12, Table 13 and Table 14 from the edge of the channel bandwidth. The spurious emission limits in Table 15 apply for all transmitter bands and channel bandwidths.

Table 15: Spurious emission limits

Spurious emission limit (dBm)		
Frequency Range	Maximum Level	Measurement bandwidth
9 kHz ≤ f < 150 kHz	-36	1 kHz
150 kHz ≤ f < 30 MHz	-36	10 kHz
30 MHz ≤ f < 1000 MHz	-36	100 kHz

Spurious emission limit (dBm)		
1 GHz ≤ f < 12.75 GHz	-30	1 MHz
12.75 GHz ≤ f < 5th harmonic of the upper frequency edge in GHz	-30	1 MHz

4.2.2.3 Receiver characteristics

Adjacent channel selectivity

Table 16: Adjacent channel selectivity

Adjacent Channel Selectivity				
Rx parameter	Channel bandwidth (MHz)			Unit
	1.728	3.456	6.912	
Own signal input level	$RX_{sensitivity}$ + 14 dB			dBm
$P_{Interferer}$	$RX_{sensitivity}$ + 39 dB	$RX_{sensitivity}$ + 39 dB	$RX_{sensitivity}$ + 39 dB	dBm
$BW_{Interferer}$	1.728	3.456	6.912	MHz
$F_{Interferer}$ (offset)	1.728 or -1.728	3.456 or -3.456	6.912 or -6.912	MHz

In-band blocking characteristics

Table 17: In-band blocking

In-band blocking				
Rx parameter	Channel bandwidth (MHz)			Unit
	1.728	3.456	6.912	
Own signal input level	$RX_{sensitivity}$ + 6 dB			dBm
$P_{Interferer}$	$RX_{sensitivity}$ + 52 dB	$RX_{sensitivity}$ + 52 dB	$RX_{sensitivity}$ + 52 dB	dBm
$BW_{Interferer}$	1.728	3.456	6.912	MHz
$F_{Interferer}$ (offset from operating channel edge)	2.592 + additional channel frequency step Or -2.592 - additional channel frequency step	5.184 + additional channel frequency step Or -5.184 - additional channel frequency step	10.368 + additional channel frequency step Or -10.368 - additional channel frequency step	MHz

5 OTHER PARAMETERS AND ASSUMPTIONS FOR STUDIES ON 3800-4200 MHZ

5.1 PARAMETERS FOR SHARING STUDIES WITH IN-BAND SERVICES

5.1.1 Fixed service

Table 18: Main differences between generic and case study deployment parameters

Parameter	Generic case	Deployment Case study 1	Deployment Case study 2
Antenna height	50 m	180 m	2.1-100 m
Antenna gain	42 dBi	38 dBi	33-47 dBi
Worst-case frequency	3800 MHz		

System parameters for PtP FS systems.

Table 19: System parameters for PtP FS systems from Recommendation ITU-R F.758-7 (excerpt from Table 17) [20]

Frequency range (MHz)	3600-4200		3700-4200
Reference ITU-R Recommendation	F.635 [27]		F.382 [28]
Modulation	64-QAM	512-QAM	QPSK
Channel spacing and receiver noise bandwidth (MHz)	10, 30, 40, 60, 80, 90	10, 30, 40, 60, 80, 90	28, 29
Maximum Tx output power range (dBW)	−1	7	0
Maximum Tx output power density range (dBW/MHz) (Note 1)	−16…−11	−9.0	−15
Minimum feeder/multiplexer loss range (dB)	0	3	3
Maximum antenna gain range (dBi)	42	40	37
Maximum *e.i.r.p.* range (dBW)	41	44	38
Maximum e.i.r.p. density range (dBW/MHz) (Note 1)	26…31	28	23
Receiver noise figure (dB) (Note 2)	3	2	4
Receiver noise power density typical (=NRX) (dBW/MHz)	−141	−142	−140
Normalised Rx input level for 1 × 10–6 BER (dBW/MHz)	−114.5	−106.5	−126.5
Nominal long-term interference power density (dBW/MHz) (Note 2 and Note 3)	−141 + I/N	−142 + I/N	−140 + I/N
Note 1: To calculate the values for the Tx/e.i.r.p. densities, channel spacing/bandwidth needs to be identified. In these Tables, the channel spacing indicated in bold text is used. Note 2: Only 3 dB receiver noise figure was used in the study. Note 3: Nominal long-term interference power density is defined by “Receiver noise power density + (required I/N)” as described in § 4.13 in Annex 2 (see also § 4.1 in Annex 1) of Recommendation ITU-R F.758-7 [20]			

5.1.1.1 FS long term protection criteria

Table 20: System parameters for PtP FS systems from Recommendation ITU-R F.758-7 (excerpt from Table 5) [20]

I/N (Note 1)	Frequency range	Sharing/compatibility conditions (Note 2)
≤ –10 dB for 20% of time	Above 3 GHz	Sharing with more than one co-primary service
Note 1: These values of I/N apply to the aggregate interference from the operations of the shared service. Note 2: For purposes of this Recommendation, compatibility studies refer to those studies performed between FWS and: – systems in services having allocation on a secondary basis in bands allocated to the fixed service on a primary basis; – systems in services having allocation in other bands (e.g. in adjacent bands); or – sources of emissions other than radio services.		

Separate consideration is given to short-term interference, which is the term used to describe the highest levels of interference power that occur for less than 1 percent of the time, and to long-term interference, which addresses the remaining portion of the interference power distribution.

The derivation of permitted short-term interference levels, and associated time percentages, is a complex process which is not presented in Recommendation ITU-R F.758-7 [20]. In order to understand the potential impact of WBB LMP interference on FS, short-term protection could be modelled as sensitivity analysis, taking into account FS availability requirements. A suitable case study could be submitted with the reasonings on the assumptions.

5.1.2 Fixed satellite service (space-to-Earth)

In the 3.8-4.2 GHz band, earth stations communicate only with geostationary satellites (GSO).

5.1.2.1 FSS earth station receiver characteristics

FSS parameters are based on characteristics provided by ITU-R WP 4A2 as well as on characteristics of existing FSS earth stations where indicated, as shown in the following table.

Table 21: FSS earth station parameters

Parameter	Typical value
Antenna size (m)	2.4-12 m
Carrier bandwidth	40 MHz
Antenna reference pattern	Recommendation ITU-R S.465 [29]
Receiving system noise temperature	120 K for small antennas (1.2-3 m) 70 K for large antennas (4.5 m and more)
Antenna elevation pointing	10 degrees
Antenna centre height above ground	10 m

[2] Document 5A/395, available at https://www.itu.int/md/meetingdoc.asp?lang=en&parent=R19-WP5A-C-0395

5.1.2.2 FSS protection criteria

Table 22: Protection criteria for FSS (in-band)

Frequency range	Protection Criteria	Percentage of time for which the I/N value could be exceeded (%)	I/N criteria (dB)
3800-4200 MHz	Long term Short term	20% 0.005% (Note)	−10.5 −1.3 (Note)
Note: Studies using short-term protection criteria could be assessed on the basis that these values were put forward by WP 4A to facilitate and complete the work for WRC-23 agenda items and these values may evolve in the future based on inputs to the ITU-R. In 2023 WP 4A had not completed its work in developing short-term protection criteria, however WP 5D was invited to consider these short-term protection criteria to the extent practicable.			

5.2 PARAMETERS FOR COMPATIBILITY STUDIES WITH ADJACENT BAND SERVICES

5.2.1 Mobile service below 3.8 GHz

5.2.1.1 MFCN

The parameters of MFCN services to be used for the coexistence studies with terrestrial WBB LMP in the adjacent band are provided in Table 23 and Table 24.

Table 23: General parameters of the MFCN systems to be used in the coexistence studies - Beamforming antenna characteristics for IMT in 1710-4990 MHz

	Parameter	Rural macro	Suburban macro	Urban macro	Urban small cell (outdoor)/Micro cell	Indoor (small cell)
1	Base station beamforming antenna characteristics					
1.1	Antenna pattern	Refer to the extended AAS model in Recommendation ITU-R M.2101 [24]			Refer to section 5 of Recommendation ITU-R M.2101 [24]	N/A
1.2	Element gain (dBi) (Note 1)	6.4	6.4	6.4	6.4	N/A
1.3	Horizontal/vertical 3 dB beam width of single element (degree)	90° for H 65° for V	90° for H 65° for V	90° for H 65° for V	90° for H 65° for V	N/A
1.4	Horizontal/vertical front-to-back ratio (dB)	30 for both H/V	30 for both H/V	30 for both H/V	30 for both H/V	N/A
1.5	Antenna polarisation	Linear ±45°	Linear ±45°	Linear ±45°	Linear ±45°	N/A
1.6	Antenna array configuration (Row × Column) (Note 2)	4 × 8 elements	4 × 8 elements	4 × 8 elements	8 × 8 elements	N/A

	Parameter	Rural macro	Suburban macro	Urban macro	Urban small cell (outdoor)/Micro cell	Indoor (small cell)
1.7	Horizontal/Vertical radiating element/sub-array spacing, dh /dv	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 0.7 of wavelength for V	N/A
1.7a	Number of element rows in sub-array, Msub	3	3	3	N/A	N/A
1.7b	Vertical radiating element spacing in sub-array, dv,sub	0.7 of wavelength of V	0.7 of wavelength of V	0.7 of wavelength of V	N/A	N/A
1.7c	Pre-set sub-array down-tilt, θsubtilt (degrees)	3	3	3	N/A	N/A
1.8	Array Ohmic loss (dB) (Note 1)	2	2	2	2	N/A
1.9	Conducted power (before Ohmic loss) per antenna element/sub-array (dBm) (Note 5, 6)	31.7 (Note 8) 28 (for sensitivity analysis)	31.7 (Note 8) 28 (for sensitivity analysis)	31.7 (Note 8) 28 (for sensitivity analysis)	16	N/A
1.10	Base station horizontal coverage range (degrees)	±60	±60	±60	±60	N/A
1.11	Base station vertical coverage range (degrees) (Notes 3, 4, 7)	90-100	90-100	90-100	90-120	N/A
1.12	Mechanical downtilt (degrees) (Note 4)	3	6	6	0-10	N/A
1.13	Maximum base station output power/sector (e.i.r.p.) (dBm)	76 (Note 8) 72.28 (for sensitivity analysis)	76 (Note 8) 72.28 (for sensitivity analysis)	76 (Note 8) 72.28 (for sensitivity analysis)	61.53	N/A

Note 1: The element gain in row 1.2 includes the loss given in row 1.8 and is per polarisation. This means that this parameter in row 1.8 is not needed for the calculation of the BS composite antenna gain and e.i.r.p.

Note 2: For the small/micro cell case, 8 × 8 means that there are 8 vertical and 8 horizontal radiating elements. For the extended AAS model case, 4 × 8 means that there are 4 vertical and 8 horizontal radiating sub-arrays.

Note 3: The vertical coverage range is given in a global coordination system, i.e. 90° being at the horizon.

Note 4: The vertical coverage range in row 1.11 includes the mechanical downtilt given in row 1.12.

Note 5: The conducted power per element assumes 8 × 8 × 2 elements for the micro/small cell case, and 4 x 8 x 2 sub-arrays for the macro case (i.e. power per H/V polarised element).

Note 6: In sharing studies, the transmit power calculated using row 1.9 is applied to the typical channel bandwidth given in Table 5-1 and 6-1 respectively for the corresponding frequency bands.

Note 7: In sharing studies, the UEs that are below the base station vertical coverage range can be considered to be served by the "lower" bound of the electrical beam, i.e. beam steered towards the max. coverage angle. A minimum BS-UE distance along the ground of 35 m should be used for urban/suburban and rural macro environments, 5 m for micro/outdoor small cell, and 2 m for indoor small cell/urban scenarios.

Note 8: Typical *e.i.r.p.* value of 5G currently deployed in a field

Table 24: MFCN characteristics and deployment related parameters

Parameter	5G NR BS	5G NR UE
Channel bandwidth (MHz)	100 (98.280 MHz NRB=273 RB=12*30kHz)	
BS non-AAS antenna gain	0 dBi for indoor BS (Recommendation ITU-R F.1336-omni [26])	
BS antenna height (m)	20 for outdoor urban macrocell BS 25 for outdoor suburban macrocell BS 6 for outdoor urban/suburban small cell BS 3 above floor for indoor BS	
BS Tx Mask	3800-3840 MHz: SEM Above 3840 MHz: -30 dBm/MHz	
BS Rx Mask	3800-3820 MHz: ACS of 34.3 dBc (-52 dBm) 3820-3860 MHz: in-band blocking of 43.3 dBc (-43 dBm) 3860-4200 MHz: out-of-band blocking of 71.3 dBc (-15 dBm) Note: values above are valid for 100 MHz bandwidth and for a macro cell BS with NF=3 dB	
BS noise figure (dB)	3	9
Cell range (m) Note: typical values from deployed networks	Urban: 400 ~ 600 Suburban: 800 ~ 1500 Rural: 1600 ~ 3000	
UE Tx power (dBm)		23
UE Tx Mask		SEM in 3GPP TS 38.101
UE antenna gain (dBi)		-4
Body loss (dB)		4
Indoor/outdoor UE		Urban/suburban: 70/30% Rural: 50/50%
Building wall loss (dB)	12	
UE heights (above ground or building floors) (m)	N/A	1.5
TDD activity factor	75% DL	25% UL

5.4 PROPAGATION PARAMETERS

5.4.1 Propagation parameters for WBB LMP vs MFCN and WBB LMP vs WBB LMP co-existence

Table 25: Propagation model for the BS-to-BS link

<table>
<tr><th>Case</th><th>Urban/Suburban</th><th>Rural</th></tr>
<tr><td>Both ends above clutters</td><td colspan="2">Recommendation ITU-R P.452 [19] / Recommendation ITU-R P.2001 [22] (50% of time, without clutter loss)
Note: Recommendation ITU-R P.1546 [16] may be used for studies beyond radio horizon</td></tr>
<tr><td>One end above clutters and one end within clutters
to be used >= 250 m</td><td>Recommendation ITU-R P.452 [19] / Recommendation ITU-R P.2001 [22] (50% of time), with Recommendation ITU-R P.2108 [15] (fixed clutter loss corresponding to 50% locations (for urban) or 30% (for suburban) applied to one end).
Other values for clutter loss can be used as a sensitivity analysis.</td><td>Recommendation ITU-R P.1546 (50% of time)</td></tr>
<tr><td>Both ends within clutters
to be used >= 1 km (with appropriate LoS probability)</td><td>Recommendation ITU-R P.452 [19] / Recommendation ITU-R P.2001 [22] (50% of time), with Recommendation ITU-R P.2108 [15] (fixed clutter loss corresponding to 50% locations (for urban) or 30% (for suburban) applied to two ends).
Other values for clutter loss can be used as a sensitivity analysis.</td><td></td></tr>
<tr><td>Both BSs below rooftops and in the same street adjacent to each other</td><td>3GPP TR 38.901 Umi LOS</td><td></td></tr>
<tr><td>Both BSs are in indoor area in the same building</td><td>Recommendation ITU-R P.1238 [17] for BSs in the same building, other valid model can be used with explanation</td><td></td></tr>
<tr><td>One or two BSs are in indoor area in different building</td><td>Outdoor model + Wall Loss 12 dB at each indoor BS or Recommendation ITU-R P.2109 [18] for incremental study</td><td></td></tr>
</table>

5.4.2 Propagation parameters for WBB LMP vs other services

Table 26: Propagation models used in the simulations with systems other than MFCN

Link	Model
Outdoor LMP BS to FS/FSS receiving earth station	Recommendation ITU-R P.452-16 [19] / Recommendation ITU-R P.2001-4 [22] (Note 1)
Indoor LMP BS to FS/FSS receiving earth station	Recommendation ITU-R P.452-16 [19] / Recommendation ITU-R P.2001-4 [22] (Note 1) + Wall Loss 12 dB at each indoor BS or fixed value taken from Recommendation ITU-R P.2109 for incremental study (Note 2)
Note 1: If the study assumes non-time variant assumptions, e.g. both victim services and interfering services are static, the percentage of time assumed for Recommendation P.452-16 [19] / Recommendation ITU-R P.2001-4 [22] be the percentage of time linked to the protection criteria of the victim service. In the case of a time-varying Monte Carlo analysis, the percentage of time should be random at each iteration along with time variant variables Non time variant variables shall not be randomised. To extend P.452 model time percentage (Tpc) range to 0-100%, the SG3 guidance (or similar) in Liaison statement to WP6A ([198]) should be included, namely, that Tpc range should be 0-100% and for Tpc > 50% the losses are equal to the case Tpc = 50 Where the antenna heights of the transmitter and/or receiver are below the nominal clutter heights specified in Recommendation ITU-R P.452, table 4, clutter attenuation based on Recommendation ITU-R P.452 or Recommendation ITU-R P.2108 [15] at a specified % shall be considered. In case of ITU-R P.2108 implementation the choice of % should be documented. Note 2: In case of Recommendation ITU-R P.2109 implementation the choice of value should be documented.	

5.5 COEXISTENCE SCENARIOS

A table of allocation of services and application according to ECO Frequency Information System (EFIS) for frequency range 3400-4400 MHz is provided in Table 1. An overview of the interference scenarios studied in this Report is provided in Table 27.

Table 27: Overview of studied interference scenarios (interference links)

Interfering system	Victim system	Studies
Between WBB LMP		
WBB LP (outdoor)	WBB LP (outdoor)	In-band
WBB LP (indoor)	WBB LP (outdoor)	In-band
WBB LP (outdoor)	WBB LP (indoor)	In-band
WBB MP	WBB MP	In-band
WBB MP	WBB LP (indoor)	In-band
WBB MP	WBB LP (outdoor)	In-band
Between WBB LMP and MFCN		
WBB LP (indoor)	MFCN	Adjacent band
WBB LP (outdoor)	MFCN	Adjacent band

Interfering system	Victim system	Studies
WBB MP	MFCN	Adjacent band
MFCN (outdoor and indoor)	WBB LP (indoor)	Adjacent band
MFCN (outdoor)	WBB LP (outdoor)	Adjacent band
MFCN	WBB MP	Adjacent band
Between WBB LMP and FS		
WBB LP (outdoor and indoor)	FS	In-band
WBB MP	FS	In-band
Between WBB LMP and FSS (s-E)		
WBB LP (outdoor and indoor)	FSS (s-E)	In-band
WBB MP	FSS (s-E)	In-band
Between WBB LMP and other applications		
WBB LP (outdoor)	VGOS (Note 1)	In-band
WBB MP	VGOS (Note 1)	In-band
Note 1: The in-band interference scenario between WBB LMP and VLBI Global Observing System (VGOS) stations operating in few CEPT countries, is supporting EU interests as part of the European Critical Infrastructure Project Galileo.		

Studies between WBB LMP and Radio Altimeters were conducted and described in ECC Report 362 [1].

6 SHARING STUDIES WITH IN-BAND SERVICES

6.1 BETWEEN 3GPP WBB LMP IN THE FREQUENCY BAND 3.8-4.2 GHZ

6.1.1 Study 1 – Co-channel coexistence study between WBB LMPs in the frequency band 3.8-4.2 GHz for unsynchronised case

The detailed study can be found in Attachment 01 which is attached to this Report.

Study is based on I/N protection ratio.

This study focuses on the coexistence between two unsynchronised WBB LMP networks operating co-channel and outdoors. The deployment and operational characteristics of the two networks were sourced from the agreed parameters for studies. Non-AAS antennas were considered for Low Power BS, while AAS antennas with a 4x8 element configuration were considered for the Medium Power BS. The high level WBB LMP operational and deployment parameters are shown in Table 28.

Table 28: Main WBB LMP operational and deployment parameters

Parameter	Value
Max. *e.i.r.p.* (Low Power WBB)	31 dBm/100 MHz
Max. *e.i.r.p.* (Medium Power WBB)	49 dBm/100 MHz 51 dBm/100 MHz
Antenna height (Low Power WBB)	10 m
Antenna height (Medium Power WBB)	12 m (dense suburban) 15 m (rural)
Propagation model	Recommendation ITU-R P.452 [19]
Clutter (Fixed % from Recommendation ITU-R P.2108 [15])	50% (urban) 30% (dense suburban) 0% (rural)
WBB LMP protection criterion	I/N = -6 dB

Regarding the methodology of the study, Monte-Carlo simulations were performed in a 3GPP compliant simulator, where the dynamic nature of WBB LMP services were captured. Each simulation step was considered to be 250 m with 10000 interference snapshots being captured at each one of those steps, creating an interference CDF. For each separation distance step of 250 m the worst-case interference snapshot was considered which was then assessed against the I/N protection criterion to determine the minimum separation distance required.

The results indicate that to satisfy the I/N=-6 dB protection criterion, the minimum separation distance between two Low Power WBB LMPs is below 250 m in urban environments, and approximately 600 m in rural environments. For a Low Power WBB LMP BS to satisfy the I/N protection criterion of a Medium Power WBB LMP BS in an urban environment, the separation distance was about 300 m. When assuming two rural Medium Power WBB LMP, the minimum separation distances become approximately 22 km and 23 km for *e.i.r.p.* of 49 dBm/100 MHz and 51 dBm/100 MHz respectively and approximately 500 m in dense suburban environments. The separation distance required between a suburban and a rural Medium Power WBB LMP was found to be approximately 1 km.

The results of the studies are shown in Figure 2.

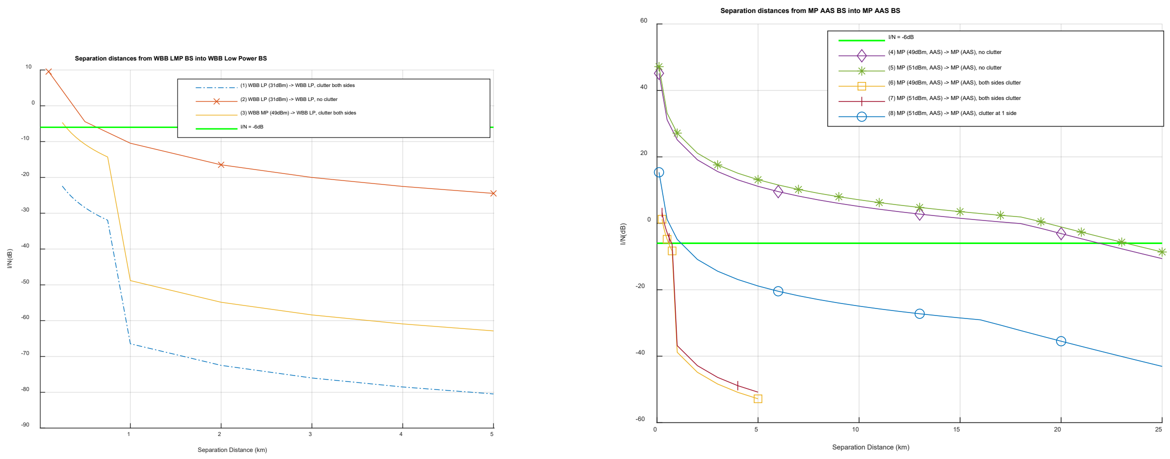


Figure 2: The minimum separation distance between two WBB LMPs to satisfy the I/N= - 6 dB protection criterion

6.1.2 Study 2 – Co-channel and adjacent channel coexistence study between WBB LMPs in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 02 which is attached to this Report

The study is based on 5% throughput loss..

This study provides technical analysis of the in-band co-channel and adjacent-channel co-existence between two local area networks operating within the frequency band 3800-4200 MHz. As shown in Figure 3, two neighbouring local area networks are modelled as a single BS to a single BS. UEs are uniformly and randomly distributed within the interfering WBB LMP_A network area and also within the victim WBB LMP_B network area. Monte-Carlo simulations are performed to simulate the victim WBB LMP_B network BS uplink throughput loss caused by the interference from the interfering WBB LMP_A network BS downlink emissions.

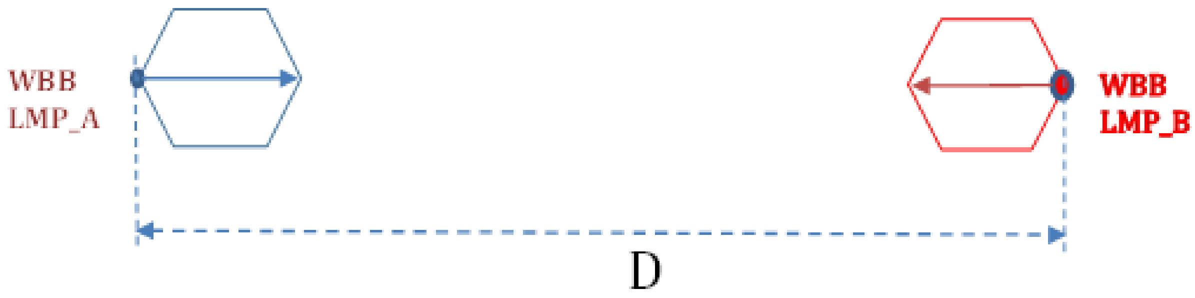


Figure 3: A local area network is modelled by a single BS

In this technical study, WBB Low Power non-AAS BS with *e.i.r.p.* =31 dBm/100 MHz and Medium Power non-AAS and AAS BS with *e.i.r.p.* =49 dBm/100 MHz are considered with Monte-Carlo simulations. For WBB LP non-AAS BS with 31 dBm/100 MHz *e.i.r.p.*, the BS antenna height is set at 10 m, in urban and suburban area and it is below the clutters. The BS-to-BS link propagation model for this case was Recommendation ITU-R P.452 [19] as well as Recommendation ITU-R P.2108 [15] with 50% clutter loss.

For the case of WBB MP non-AAS and AAS BS with 49 dBm/100 MHz *e.i.r.p.*, the BS antenna height was at 20 m in urban area, 25 m in suburban area, and 30 m in rural area. The propagation model Recommendation ITU-R P.452 [19] without adding clutter loss was used for the BS-to-BS link. In rural area, Recommendation ITU-R P.1546 [16] rural propagation model is used for BS-to-BS link.

For unsynchronised operation between two neighbouring local area networks, the first step is that the victim BS uplink throughput loss was simulated. The separation distance D corresponding to 5%, 10%, 20%, and 30% throughput loss for each case was obtained. The second step is to simulate the median power level at the middle point (D/2) from the WBB LMP BS and is simulated with an omni-directional 0 dBi antenna gain at 3 meters height. The third step is to convert the median power level (dBm) into the field strength E (dBµV/m) with the following equation:

$$E = Pr + 20 * \log_{10} F + 77.2 \quad (1)$$

Where:

- F is the frequency in MHz and Pr is the median power level in dBm.

For the synchronised case, the field strength value was simulated at the local area network cell coverage edge with an omni-directional antenna with 0 dBi antenna gain at 3 m height.

Simulation results for unsynchronised operation are provided in Table 29.

Table 29: Field strength values (dBµV/m/5 MHz) at 3 m at each local area network coverage border for unsynchronised operation with neighbouring local area networks

Environment	Urban/Suburban			Rural		
Power class	LP *e.i.r.p.*<=31 dBm/100 MHz	MP 31 dBm/100 MHz < *e.i.r.p.*<= 51 dBm/100 MHz		LP *e.i.r.p.* <=31 dBm/100 MHz	MP 31 dBm/100 MHz < *e.i.r.p.* <= 51 dBm/100 MHz	
BS type	Non-AAS	Non-AAS	AAS	Non-AAS	Non-AAS	AAS
Non-Preferential frequency	37	-17	0	33	22	35
Preferential frequency	48	26	48	48		

Note:

Non-Preferential frequency is defined as the case where the local area network has full or partial frequency overlap with at least one of the neighbouring local area networks.

Preferential frequency is defined as the case where the local area network has no-frequency overlap (full or partial) with any neighbouring local area networks.

Based on the simulation results, it is proposed to use the following field strength values at the local area network coverage border for unsynchronised operation.

Table 30: Field strength values (dBµV/m/5 MHz) at 3 m at each local area network coverage border between WBB LMP neighbouring local area networks in unsynchronised operation

Environment	LP BS Urban/Suburban/Rural	MP BS Urban/Suburban/Rural
Non-Preferential frequency	32	N.A
Preferential frequency	48	26 for non-AAS BS 48 for AAS BS

In case of synchronised operation with neighbouring local area networks, the field strength values in Table 31 can be considered for both non-AAS and AAS.

Table 31: Field strength values (dBµV/m/5 MHz) at 3 m at each local area network coverage border for synchronised operation with neighbouring local area networks (for both non-AAS and AAS BS)

Environment	Field strength value (dBµV/m/5 MHz)
Urban/Suburban/Rural	61

There are several possible case-by-case coordination solutions between two local area networks. This study proposes two:

- 1) Synchronisation between two neighbouring local area networks;
- 2) Field strength levels at the local area network coverage edge between two local area networks.

The field strength level can be defined as function of the acceptable throughput loss. As a sensitivity analysis the field strength level of throughput losses of 10%, 20%, and 30% was given for information in addition to the agreed 5% throughput loss. The choice of the field strength values at different throughput losses can be made at national level (on case-by-case basis) based on the principle of equal access to the spectrum use.

6.1.3 Summary and Conclusions

Table 32: Separation distances between WBB LMPs in unsynchronised operation

LMP VS LMP Co-channel		Synhronisation	Unsynhronised			Unsynhronised		
		Protection criterion	I/N = -6 dB			uplink throughput los 5 %		
			Study 1			Study 2 Separation distance uplink throughput loss in %		
Scenario No.	***Scenario type***	***Clutter assumption***	***Interference from***	***Interference to***	***Separation distance I/N = -6 dB***	***Interference from***	***Interference to***	***5%***
1a Urban	Outdoor WBB LP vs Outdoor WBB LP	Both sides within clutter as per P.2108 50% applied at each side	Outdoor WBB LP BS EIRP = 31 dBm Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	No separation distance requirement observed beyond the initial 250m separation configuration	Outdoor WBB LP BS EIRP = 31 dBm Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	No separation distance requirement observed beyond the initial 250m separation configuration
1b Urban	Outdoor WBB LP vs Outdoor WBB LP	Both sides within clutter (P1546 Urban)				Outdoor WBB LP BS EIRP = 31 dBm Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	No separation distance requirement observed beyond the initial 250m separation
2a Rural	Outdoor WBB LP vs Outdoor WBB LP	Both sides above clutter (no clutter considered)	Outdoor WBB LP BS EIRP = 31dBm Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	~600 m	Outdoor WBB LP BS EIRP = 31 dBm/100 MHz Non-AAS cell range=350 m, downtilt=0° Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	3 km
2b Rural	Outdoor WBB LP vs Outdoor WBB LP	Both sides above clutter (no clutter considered)				Outdoor WBB LP BS EIRP = 31 dBm/100 MHz AAS 8 x 8 Hbs=10m	Outdoor WBB LP BS Hbs=10m	1.4 km
3 Urban	Outdoor WBB MP vs Outdoor WBB LP	Both sides within clutter as per P.2108 50% applied at each side	Outdoor WBB MP BS EIRP = 49dBm AAS (4x8) Hbs=15m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	~300m			
4 Rural	Outdoor WBB MP vs Outdoor WBB MP	Both sides above clutter (no clutter considered)				Outdoor WBB MP BS non-AAS BS EIRP=49 dBm/100 MHz, cell range=1000 m with downtilt of -3° Hbs=30m		26.8 km
5 Rural	Outdoor WBB MP vs Outdoor WBB MP	Both sides above clutter (no clutter considered)		Outdoor WBB MP BS 21.5 dBi antenna gain AAS (4x8)	~ 23 km	Outdoor WBB MP BS AAS 8 x 8 BS EIRP=49 dBm/100 MHz, cell range=1000 m with downtilt of -3° Hbs=30m		10.5 km
6 Dense sub-urban	Outdoor WBB MP vs Outdoor WBB MP	Both sides within clutter as per P.2108 30% applied at each side	Outdoor WBB MP BS EIRP = 49dBm AAS (4x8) Hbs=12m	Outdoor WBB MP BS 21.5 dBi antenna gain AAS (4x8) Hbs=12m	~500m			
7 Dense sub-	Outdoor WBB MP vs Outdoor WBB MP	Both sides within clutter as per P.2108 30% applied at each side	Outdoor WBB MP BS EIRP = 51dBm AAS (4x8) Hbs=12m	Outdoor WBB MP BS 21.5 dBi antenna gain AAS (4x8) Hbs=12m	~500m			
8 Rural to dense sub-	Outdoor WBB MP vs Outdoor WBB MP	30% applied at one side	Outdoor WBB MP BS EIRP = 51dBm AAS (4x8) 15m height	Outdoor WBB MP BS 21.5 dBi antenna gain AAS (4x8) 12m height	~ 1km			

Table 33: Separation distances - for different throughput losses (5% is reference)

LMP VS LMP
Co-channel

Synhronisation: Unsynhronised
Protection criterion: uplink throughput los 5 %
Study 2 Separation distance uplink throughput loss in %

Scenario No.	Scenario type	Clutter assumption	Interference from	Interference to	<0.1%	5%	10%	20%	30%
1a Urban	Outdoor WBB LP vs Outdoor WBB LP	Both sides within clutter as per P.2108 50% applied at each side	Outdoor WBB LP BS EIRP = 31 dBm Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	1 km	No separation distance requirement observed beyond the initial 250m separation configuration	-	-	-
1b Urban	Outdoor WBB LP vs Outdoor WBB LP	Both sides within clutter (P1546 Urban)	Outdoor WBB LP BS EIRP = 31 dBm Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m	1 km	No separation distance requirement observed beyond the initial 250m separation configuration	-	-	-
2a Rural	Outdoor WBB LP vs Outdoor WBB LP	Both sides above clutter (no clutter considered)	Outdoor WBB LP BS EIRP = 31 dBm/100 MHz Non-AAS cell range=350 m, downtilt=0° Non-AAS Hbs=10m	Outdoor WBB LP BS 12 dBi antenna gain Non-AAS Hbs=10m		3 km	2.5 km	2.1 km	1.9 km
2a Rural	Outdoor WBB LP vs Outdoor WBB LP	Both sides above clutter (no clutter considered)	Outdoor WBB LP BS EIRP = 31 dBm/100 MHz AAS 8 x 8 Hbs=10m	Outdoor WBB LP BS Hbs=10m		1.4 km	1 km	0.6 km	0.4 km
4a Rural	Outdoor WBB MP vs Outdoor WBB MP	Both sides above clutter (no clutter considered)	Outdoor WBB MP BS non-AAS BS EIRP=49 dBm/100 MHz, cell range=1000 m with downtilt of -3° Hbs=30m			26.8 km	24.5 km	22 km	20.6 km
4b Rural	Outdoor WBB MP vs Outdoor WBB MP	Both sides above clutter (no clutter considered)	Outdoor WBB MP BS AAS 8 x 8 BS EIRP=49 dBm/100 MHz, cell range=1000 m with downtilt of -3° Hbs=30m			10.5 km	8.4 km	6 km	4.7 km

Both studies (Study 1 and Study 2) described in the section 6.1 provide Monte-Carlo simulations on the co-existence between two WBB LMP local area networks. Study 1 simulated the separation distance using a protection criterion of I/N=-6 dB for a co-channel scenario, while study 2 simulated the separation distance and the field strength values at the middle point for co-channel and adjacent channel scenarios based on the criterion that uplink throughput loss should not be exceeded by 5%, 10%, 20% and 30%.

The simulation results show that:

1 In urban/suburban areas, when WBB non-AAS Low Power BSs are within clutter (minimum 250 m apart as per study assumption), there is no particular requirement of separation distance and no coordination measure is required for this situation even in co-channel in such scenarios.

2 In rural areas, when non-AAS WBB low power BSs are above clutter, the required separation distance between low power non-AAS WBB BSs in the co-channel scenario can be up to 3 km depending the antenna height, downtilt etc.

3 The more challenging co-existence scenario is that between the WBB Medium Power BSs. In those cases the required separation distance can go up to 26.8 km depending on the type of antenna, the antenna

height, downtilt, environment, etc. The result of the studies also indicates that co-existence between co-channel WBB Medium Power BSs using AAS antennas is less challenging compared to using non-AAS antennas. The required separation distances for WBB AAS Medium Power BS range up to 23 km depending on the AAS configuration, the *e.i.r.p.*, antenna height, downtilt, environment etc.

4 Adjacent channel operation between neighbouring WBB Medium Power BSs is more feasible than co-channel based on the simulation results.

Study 2 also investigated the separation distance and maximum field strength values in the middle point between two LMPs for co-channel and adjacent channel scenarios based on the criterion that uplink throughput loss should not be exceeded by 5%, 10%, 20%, and 30%. The proposed mean/median field strength values (not to be exceeded) at the WBB LMP local area network licensed area edge was proposed to be considered for improving planning and coordination at network licensed area border provided in Table 34.

Table 34: Field strength values (dBµV/m/5 MHz) at 3 m at each local area network licensed area border between neighbouring local area networks in unsynchronised operation

Environment	LP WBB BS Urban/Suburban/Rural (dBµV/m/5 MHz) at 3 m	MP WBB BS Urban/Suburban/Rural (dBµV/m/5 MHz) at 3 m
Co-channel	32	NA
Adjacent channel	48	26 for non-AAS BS 48 for AAS BS
Note: Co-channel case is defined as the case where the local area network has full or partial frequency overlap with at least one of the neighbouring local area networks. Adjacent channel case is defined as the case where the local area network has no-frequency overlap (full or partial) with any neighbouring local area networks.		

Table 35: Field strength values (dBµV/m/5 MHz) at 3 m at each local area network coverage border for synchronised operation with neighbouring local area networks (for both non-AAS and AAS BS)

Environment	Field strength value (dBµV/m/5 MHz)
Urban/Suburban/Rural	61

The above study results could be used for developing guidelines for managing co-existence between WBB LMPs.

6.2 BETWEEN 3GPP WBB LMP AND FS IN FREQUENCY BAND 3.8-4.2 GHZ

6.2.1 Study 1 – Sharing study between WBB LMP and FS in the frequency band 3.8-4.2 GHz for co-frequency case

The detailed study can be found in Attachment 03 which is attached to this Report.

This sharing study describes the interference scenarios from a single WBB LMP BS transmitter to a co-frequency FS receiver (50 m above ground for generic case, 80 m for real deployment/average height and 180 m for real deployment/worst case).

The results indicate that the required separation distances to protect FS (80 m antenna height) from WBB LMP may go up to 90.5 km for medium power WBB BS (25 m above ground, i.e. above typical clutter height) and up to 38.5 km for low power WBB BS (10 m above ground, i.e. bellow typical clutter height) for a worst-case realistic scenario (MCL). This distance reduces to about 300 m for the WBB low power BS, if the BS is placed in the side lobe of the FS antenna. No clutter was applied for the medium power BS scenario, the antenna height for both services is considered above the average clutter level. The interference distances would decrease significantly if the BS is placed inside the clutter. The results for the medium power WBB BS show interference distances of up to 46 km for the FS side lobe. Coordination with a medium power WBB BS could therefore be challenging.

6.2.2 Study 2 – Sharing study between WBB LMP and FS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 04 which is attached to this Report.

This sharing study considers co-frequency coexistence analyses between WBB LMP BS interferer and real FS victim receivers in Italy. Results in terms of separation distances/exclusion areas have been evaluated considering both flat terrain and the real terrain elevation.

Low Power (LP) WBB deployment (antenna height 10 m, below typical clutter height) has been considered in dense urban, urban and suburban environments. The FS antenna heights range from 7.3 m to 100 m.

The separation distances in the direction of the FS main lobe that have been obtained in the coexistence analyses in case of LP WBB considering flat terrain vary from 6 km to almost 46.3 km depending on the FS receiver antenna height, the maximum FS antenna gain, the FS elevation angle and the feeder loss.

Medium Power (MP) WBB deployment (antenna height 30 m, above typical clutter height) has been considered in rural environment. The FS antenna heights range from 2.1 m to 84 m. No clutter was applied, the antenna height for both services is considered above the average clutter level.

The separation distances in the direction of the FS main lobe that have been obtained in the coexistence analyses in case of MP WBB in rural scenario considering flat terrain vary from 34.5 km to 101 km depending on the FS receiver antenna height, the maximum FS antenna gain, the FS elevation angle and the feeder loss.

Sharing studies considering real data of the FS links as well as real terrain elevation have been performed.

Comparing the results of the analysis in terms of separation distances and exclusion areas, considering both the flat terrain and the real terrain elevation, some conclusions can be drawn:

- The real terrain data should be taken into account in the coexistence assessments on a case-by-case basis. Flat terrain is not the worst case, in fact real terrain can hinder (this occurs when the first Fresnel zone of the FS link is intersected by the terrain) or favour (when there is not any intersection) propagation;
- When real terrain data is taken into account;
- the exclusion area may not be continuous;
- the separation distance alone could be used as a coexistence condition only if the exclusion zone remains continuous;
- the calculation of the exclusion area and the population within it provides more relevant information on the reduction of the impact of the interference in real cases.

It follows from the above considerations that in all real cases not only the theoretical maximum separation distance but also the exclusion area should be assessed, both taking into account the real terrain data, therefore a case-by-case coexistence assessment is needed.

Since it is not possible a priori to define the technical conditions that guarantee the protection of the incumbent FS, and its future development, particular attention shall be paid to the borders.

According to the analyses, coexistence between FS and both low and medium power WBB systems could not always be managed at national level and may require bilateral or even multilateral agreements among neighbouring countries, taking into account the use of appropriate mitigation techniques that could facilitate coexistence on a case-by-case basis.

6.2.3 Study 3 – Sharing study between WBB LMP and FS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 05 which is attached to this Report.

In this study, interference analysis is conducted on various FS stations, with antenna heights ranging from 15 m to 80 m. The following specific assumptions were considered in this study:

- maximum *e.i.r.p.* of 51 dBm of the WBB MP BS;
- 10 m of antenna height of the WBB MP BS;
- flat terrain;
- urban scenario;
- clutter loss based on Recommendation ITU-R P.2108 [15], with fixed percentage of locations equal to 50% (in line with the characterisation of the clutter in urban scenario) on one end of the propagation path, based on the assumption that statistical clutter loss models should only be used to characterise clutter for urban and suburban scenarios when the radio path is not precisely known;
- determination of the basic transmission losses based on Recommendation ITU-R P.452 [19] with a random time percentage.

Simulation results indicate that to prevent harmful interference from an active antenna system (AAS) WBB MP base station (BS), separation distances up to 56 km might be necessary in urban or suburban scenario. Additionally, note that for larger AAS antenna arrays, the separation distances decrease due to the enhanced directivity of such larger arrays.

Furthermore, for sensitivity analyses, additional assumptions on the user terminal (UE) deployments and the WBB BS activity factor are considered to determine their impact on the required separation distances to prevent harmful interference:

Assuming that Hotspot deployments are similar to those for WBB MP networks, a Rayleigh distribution for the UE ground distance from its BS is deemed suitable for non-public local networks provided that these networks are deployed where users are expected to remain in the local network cell, rather than moving between different cells as in MFCN networks.

It is assumed that a WBB base station is active either 100% or 50% of the time, accounting for varying network loading factors. Considering a TDD activity factor of 75% for downlink (3:1), the equivalent activity factors become 75% (100%x0.75) and 37.5% (50%x0.75) respectively.

This study shows that considering the mentioned factors (BS activity factor, UE Rayleigh distribution, network loading factors), the distances are reduced by an average of 15% in the case of the main lobe and 25% in the case of the side lobe. The accuracy of these results can be improved if local clutter data is used instead of statistical clutter assumptions.

Finally, the sensitivity analysis assessment for the chosen short-term protection criterion indicates that for some instances the required separation distances are nearly the same or lower compared to those needed for the long-term protection criterion, i.e. FS short-term protection is less stringent than long-term protection.

6.2.4 Summary and Conclusions

Based on agreed assumptions on WBB LMP and FS parameters, these studies reveal that in case of flat terrain different separation distances may be necessary between WBB LMP and FS systems in order to protect FS links:

- in case of WBB LP studies show that maximum separation distances in the direction of the FS main lobe could range up to 56.5 km while in the side lobe maximum separation distances could be up to 300 m (clutter was assumed for these values);
- in case of WBB MP studies show that maximum separation distances in the direction of the FS main lobe could range up to 113 km while in the side lobe maximum separation distances could be up to 69 km (no clutter assumed for these values).

The mentioned separation distances depend on various factors such as clutters (which depends on the environment: rural, suburban, urban, indoor/outdoor), direction/antenna, antenna heights, the maximum FS antenna gain, the FS elevation angle, the feeder loss and others. In case of WBB LP indoor the separation distances in the direction of the FS main lobe vary from 2.6 km to 25.5 km and they can be less than 100 m in the side lobe. These values depend on the building material and consequently on the BEL (building entry loss).

One of the studies shows the importance that real terrain data are taken into account in the coexistence assessments, because real terrain cannot only hinder, but also favour propagation significantly and then affect the minimum separation distances/exclusion areas accordingly.

In conclusion, according to the analyses, it is not possible to define generic technical conditions that guarantee the protection of FS, including its long-term development, but a case-by-case analysis is needed. In addition, due to the large separation distances that may be necessary for coexistence even without considering real terrain data and to the potentially unfavourable impacts of real terrain on separation distances and exclusion areas that are required, coexistence between FS and both low and medium power WBB systems cannot always be managed at national level only but may require cross border coordination on a case-by-case basis and related bilateral or even multilateral agreements among neighbouring countries.

6.3 BETWEEN 3GPP WBB LMP AND FSS IN FREQUENCY BAND 3.8-4.2 GHZ

6.3.1 Study 1 – Sharing study between WBB LMP and FSS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 06 which is attached to this Report.

The study concentrates on studying the required separation distance to protect FSS earth stations from WBB LMP base stations deployments. Various assumptions were considered in the study, including:

a) Three different maximum *e.i.r.p.* levels for WBB LMP BS:
   i) "Low power": maximum e.i.r.p. = 18 dBm/5 MHz
   ii) "Medium power": maximum e.i.r.p. = 36 dBm/5 MHz
   iii) Intermediate value: maximum e.i.r.p. = 24 dBm/5 MHz

b) BS antenna types to consider differences in radiation patterns: AAS (dynamic pointing considered with Monte-Carlo analysis) and non-AAS (fixed pointing)

c) BS antenna height of 10 m and 20 m. This characteristic impacts the line-of-sight (LoS) distance (higher antenna height means longer LoS distance) as well as on the consideration of clutter (if station is higher than assumed nominal clutter height, clutter was not considered)

Table 36 summarises the results of the separation distances for the various cases to meet the long-term and short-term FSS protection criteria.

Table 36: Results of the separation distances for the various cases to meet the long-term and short-term FSS protection criteria

Case #	Antenna type and clutter consideration	Max. e.i.r.p.	Distance to meet the FSS long-term protection criteria (km)	Distance to meet the FSS short-term protection criteria (km)
1.1	AAS antenna without clutter	36 dBm/5 MHz	36.5	275
1.2		18 dBm/5 MHz	21.5	90
1.3		24 dBm/5 MHz	25.5	160

Case #	Antenna type and clutter consideration	Max. e.i.r.p.	Distance to meet the FSS long-term protection criteria (km)	Distance to meet the FSS short-term protection criteria (km)
1.1	AAS antenna with clutter (31 dB, 50% location)	36 dBm/5 MHz	14	18
1.2		18 dBm/5 MHz	2	2
1.3		24 dBm/5 MHz	4.2	4.2
2.1	Non-AAS antenna without clutter	36 dBm/5 MHz	47.5	273
2.2		18 dBm/5 MHz	32.5	104
2.3		24 dBm/5 MHz	38.1	163
2.1	Non-AAS antenna with clutter (Recommendation ITU-R P.452 [19] clutter)	36 dBm/5 MHz	35	120
2.2		18 dBm/5 MHz	20.9	23
2.3		24 dBm/5 MHz	25.3	29
3.1	Omnidirectional antenna without clutter	36 dBm/5 MHz	47.9	276.8
3.2		18 dBm/5 MHz	33.3	109.2
3.3		24 dBm/5 MHz	38.5	167.2
3.1	Omnidirectional antenna with clutter (Recommendation ITU-R P.452 [19] clutter)	36 dBm/5 MHz	35.8	126.2
3.2		18 dBm/5 MHz	21.5	23.1
3.3		24 dBm/5 MHz	25.9	29.1

From Table 36, it is clear that the low power level WBB LMP BS drastically reduces the required separation distance and that clutter attenuation also drastically impacts the results of the study. This study also shows that the higher the BS, the larger the separation distance and the less likely clutter attenuation would apply. This study was conducted without using terrain data and results will differ on case-by-case basis. However, the study provides a good idea of the coordination distance (for long-term protection criteria) required depending on the WBB LMP power level:

- For low power (18 dBm/5 MHz) around 20 km;
- For medium power (36 dBm/5 MHz) around 40 km.

6.3.2 Study 2 – Sharing study between WBB LMP and FSS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 07 which is attached to this Report.

This study focuses on the coexistence between WBB LMP networks and FSS earth station receivers. The deployment and operational characteristics of the WBB LMP networks were sourced from the agreed parameters for studies. Non-AAS antennas were considered for Low Power BS, while AAS antennas with a 4x8 element configuration were considered for the Medium Power BS. The high level WBB LMP operational and deployment parameters are shown in Table 37.

Table 37: The high level WBB LMP operational and deployment parameters

Parameter	Value
Max. *e.i.r.p.* (Low Power WBB)	31 dBm/100 MHz
Max. *e.i.r.p.* (Medium Power WBB)	49 dBm/100 MHz 51 dBm/100 MHz
Antenna height (Low Power WBB)	10 m
Antenna height (Medium Power WBB)	12 m (dense suburban) 15 m (rural)
Propagation model	Recommendation ITU-R P.452 [19]
Clutter (Fixed % from Recommendation ITU-R P.2108 [15])	FSS earth station receiver 30% at all times WBB LMP 50% (urban) 0% (rural)
FSS ES long-term protection criterion	I/N = -10.5 dB for 20% of time

Regarding the methodology of the study, Monte-Carlo simulations were performed in a 3GPP compliant simulator, where the dynamic nature of WBB LMP services was captured. Each simulation step was considered to be 250 m with 10000 interference snapshots being captured at each one of those steps, creating an interference CDF. For each separation distance step of 250 m the worst-case interference snapshot was considered which was then assessed against the FSS ES I/N protection criterion to determine the minimum separation distance required.

The results indicate that to satisfy the FSS ES long-term protection criterion I/N=-10.5 dB, the minimum separation distance for a Low Power WBB LMP BS is approximately 850 m in urban and approximately 4 km in rural environments. For rural Medium Power WBB LMP BS with *e.i.r.p.* 49 dBm/100 MHz and 51 dBm/100 MHz the minimum separation distances required are approximately 12.5 km approximately 16 km respectively. When a higher elevation angle for the FSS earth station receiver is considered (i.e. 48 degrees instead of 10 degrees), the required separation distance from a rural Medium Power BS becomes approximately 2.5 km.

The results of the study are shown in the Figure 4.

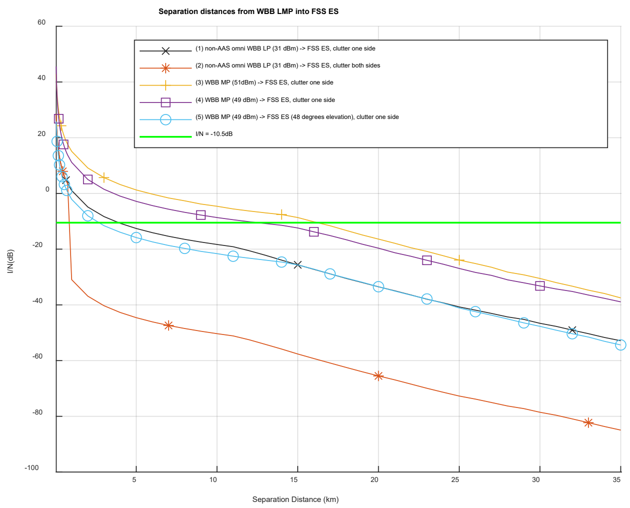


Figure 4: The minimum separation distance to satisfy FSS ES long-term protection criterion of I/N = - 10.5 dB

6.3.3 Study 3 – Sharing study between WBB LMP and FSS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 08 which is attached to this Report.

This sharing study between WBB LMP base stations and FSS earth stations was two-fold.

The first part is a collection of static studies and was done considering a site-specific environment (Rambouillet, France), taking into account Low Power (31 dBm *e.i.r.p.*/100 MHz) and Medium Power (51 dBm *e.i.r.p.*/100 MHz) non-AAS WBB base stations and using the FSS long-term protection criteria (exceedance of I/N=-10.5 dB for no more than 20% of the time). Different antenna height and down-tilt angle combinations were considered.

The attenuation loss due to the terrain and buildings was determined using Recommendation ITU-R P.452-16 [19] and the terrain path profile. The terrain path profile was computed using a combination of the SRTM database (1 Arcsec resolution) and the French IGN building database (5 m resolution).

The calculations resulted in required protection distances between WBB LMP base stations and FSS earth stations ranging from 5.3 to 15.5 km for the Low Power case and ranging from 17.5 to 26.6 km for the Medium Power case, depending on the antenna height and down-tilt angle.

The second part is a collection of dynamic studies and was done considering a more generic smooth Earth approach, taking only into account Medium Power (51 dBm *e.i.r.p.*/100 MHz) AAS (4x8) base stations and using the FSS long-term protection criteria (exceedance of I/N=-10.5 dB for no more than 20% of the time).

The individual runs were performed using a Monte-Carlo analysis assuming many random UE locations within the coverage area of the base station and the attenuation loss was determined using Recommendation ITU-R P.452-16 [19] for a random percentage of time (between 0% and 100%) for each of the random UE. In addition, an arbitrary statistical clutter attenuation was also taken into account in some cases on one side of the propagation path using Recommendation ITU-R P.2108-1 [15] for two different percentages of time (30% and 50%).

The simulations resulted in required protection distances between WBB LMP base stations and FSS earth stations ranging from 27 to 52 km depending on the clutter loss considered.

6.3.4 Study 4 – Sharing study between WBB LMP and FSS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 09 which is attached to this Report.

The results of this single-entry study indicate that separations distances ranging from less than one kilometre to few tens of kilometres may be needed to prevent harmful interference to FSS earth stations. These results consider clutter on one side or both sides of the propagation path.

Assuming clutter is present at one end of the propagation path and considering that the WBB base station and the FSS earth station are pointing towards each other, the results indicate that the longest separation distance is approximately 16.5 km for medium-power WBB base stations without AASs (corresponding to a maximum *e.i.r.p.* of 49 dBm/100 MHz). In this scenario, if natural or artificial clutter is present at both ends of the propagation path, separation distances are reduced to less than 1.5 km.

Conversely, for the situation where the WBB base station is pointing in the opposite direction of the FSS earth station, results indicate that for all cases tested (including natural or artificial clutter at one or both ends of the propagation path) separation distances are below 1 km.

For the cases presented in this study, note that the size of the AAS antenna changes little the long-term criterion results.

By means of coordination on a case-by-case basis, e.g., boresight pointing direction of the WBB base station, separation distances can be decreased to just few kilometres to prevent harmful interference to FSS earth stations for a wide range of WBB base station antenna configurations and *e.i.r.p.* levels.

6.3.5 Study 5 – Sharing study between WBB LMP and FSS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 10 which is attached to this Report.

This study provides a co-frequency compatibility analysis between WBB LMP base station (BS) as interferer and FSS earth station (ES) as victim receiver. It has been conducted considering:

- A static analysis that provides a clear picture of the various parameters impacting the interference received by the FSS ES from WBB LMP BS and allows identifying possible ways to mitigate the interference by applying site specific adjustments;
- A statistical case study analysis which explores site-specific configuration for two locations of FSS hubs and allows assessing the impact of the terrain and environment around the FSS ES in the received interference, including considering both long-term and short-term interferences.

Different configurations have been investigated, including various transmitting power, the consideration of clutter loss and antenna pointing. Under baseline assumptions, these assumptions could be summarised as follows.

The WBB transmitting powers are 21 dBm/40 MHz for low power, 35 dBm/40 MHz for medium power and 37 dBm/40 MHz for incremental medium power BS. The required separation distance increases with the raise of the BS power.

Angular discrimination was considered, with an elevation discrimination assuming BS mechanical down-tilt of 0° for LP BS and 6° for MP BS cases and FSS elevation angle spanning from 10° to 50°. Azimuth discrimination was also assessed, with two cases where the BS points towards the FSS (0°) or sees the FSS from the back-lobes (180°). The required separation distance reduces with the raise of either the vertical or azimuthal angular discrimination.

The impact of clutter loss was verified, considering no clutter loss, suburban clutter (29 dB) or urban clutter (31 dB). Clutter reduces the required separation distance.

The BS antenna height was assessed from 10 m up to 35 m and it plays a role in the received interference by the FSS antenna. Increasing the antenna height increases the required separation distance.

Impact of environment between the transmitting BS and receiving FSS earth station plays a key role in the level of interference received by the victim FSS system. In some cases, a hilly terrain reduces the likelihood of interference compared to a flat terrain.

Sensitivity analysis was also conducted, which extended further some of the values used for these parameters.

Based on the assumptions considered in this study, the analysis shows that where there is a necessity to protect an FSS ES, the following specific actions or measures could be implemented, as appropriate:

- Blocks of vegetation or building that stand in the direct line between the two antennas create clutter loss that attenuates the power of interfering signal. Therefore, it is beneficial to avoid positioning a WBB LMP BS antenna at any place where there is line of sight and direct visibility with an FSS earth station;
- Deploying the lower power of the WBB BS at the lowest altitude above ground level benefits the sharing result and reduces the separation required between WBB LMP and FSS ES;
- Avoiding pointing the WBB LMP towards the FSS earth station reduces the level of interference received at the FSS receiver, thus reducing the required separation distance. It is therefore suitable to position the WBB LMP BS antenna so that it does not point in the direction of the FSS earth station that would be seen, in the best case, from the backside lobe where the BS antenna gain is the lowest;
- Using terrain data could enhance the analysis and define more accurate conditions of operation of the two systems.

Finally, the study concludes that a coordination distance of 40 km around an FSS ES location, with no consideration of terrain, is suitable to protect FSS ES receivers. Below that distance the use of one or combination of some of the various mitigation techniques mentioned above could be implemented on a case-by-case basis to minimise the interference received, reduce the required separation distance between the WBB LMP and the FSS earth stations and facilitate the deployment of WBB LMP networks while protecting existing and future use of FSS systems.

6.3.6 Study 6 – Sharing study between WBB LMP and FSS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 11 which is attached to this Report.

This sharing study analyses the interference scenario between WBB LMP transmitters and FSS receivers by simulating examples of two existing FSS earth stations in Germany, using real terrain data and real ES parameters.

This sensitivity study is a complement to the theoretical approaches by applying the agreed WBB LMP base station (BS) parameters to realistic earth station scenarios.

The study is based on MATLAB simulations using Recommendation ITU-R P.452-17 [19] and terrain data (DTM) (no clutter heights used along the path) in combination with Recommendation ITU-R P.2108-1, section 3.1 [15] ("representative clutter section") to provide more realistic path loss results than the same Recommendations using section 3.2 ("statistical clutter section) instead. The results for both sections of Recommendation ITU-R P.2108-1 are included to show their differences in combination with real deployment data. The simulation results show that the separation distances required to protect FSS earth station from WBB LMP BS go up to 70 km for WBB MP BS (for long-term criteria) and up to 17 km for WBB LP BS (for long-term criteria) when simulated with real terrain data and using the clutter correction in Recommendation ITU-R P.2108-1, section 3.1 (representative clutter). Additional calculations are performed to highlight the impact of using statistical clutter value (Recommendation ITU-R P.2108-1, section 3.2) for the clutter attenuation.

The different sensitivity simulations in this study show that the resulting interference distances are highly dependent on realistic assumptions like the local terrain data and actual antenna height of the WBB LMP BS to ensure the protection of existing FSS earth station from the WBB LMP BS.

6.3.7 Study 7 – Additional sharing studies between WBB LMP base stations and FSS earth stations in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 12 which is attached to this Report.

In this study, interference analysis is conducted on various FSS earth stations, with antenna diameters ranging from 3 m to 32 m. The following specific assumptions were considered in this study:

- maximum *e.i.r.p.* of 51 dBm of the WBB MP BS;
- 10 m of antenna height of the WBB MP BS;

- flat terrain;
- urban scenario;
- clutter loss based on Recommendation ITU-R P.2108 [15], with fixed percentage of locations equal to 50% (in line with the characterisation of the clutter in urban scenario) on one end of the propagation path, based on the assumption that statistical clutter loss models should only be used to characterise clutter for urban and suburban scenarios when the radio path is not precisely known.

Simulation results indicate that to prevent harmful interference from an WBB MP AAS BS, separation distances up to 23 km might be necessary in urban or suburban scenario. Additionally, it is noteworthy that larger AAS antenna arrays result in decreased separation distances due to the enhanced directivity of such arrays.

Furthermore, for sensitivity analyses, additional assumptions on the user terminal (UE) deployments and the WBB BS activity factor are considered to determine their impact on the required separation distances to prevent harmful interference:

- Assuming that Hotspot deployments are similar to those for WBB MP networks, Rayleigh distribution for the UE ground distance from its BS is deemed suitable for non-public local networks provided that these networks are deployed where users are expected to remain in the local network cell, rather than moving between different cells as in MFCN networks;
- It is assumed that a WBB base station is active either 100% or 50% of the time, accounting for varying network loading factors. Considering a TDD activity factor of 75% for downlink (3:1), the equivalent activity factors become 75% (100%x0.75) and 37.5% (50%x0.75) respectively.

This study shows that taking into account the mentioned factors leads to a reduction in distances. Depending on the cases considered the separation distance is reduced by a few km (2 km in one case) up to several km (16 km in one case). It is noted that the accuracy of these results can be improved if local clutter data is used instead of statistical clutter assumptions.

Lastly, in the sensitivity analysis assessment for the short-term protection criterion, the results show that the separation distances are in the same range as for the long-term protection criterion (up to approximately 11.4 km for a specific FSS earth station case in Germany). On the other hand, the short-term results are not significantly influenced by the activity factor, as the cumulative distribution function (CDF) curves exhibit steep slopes at the short-term low probabilities values, i.e. 0.005%.

6.3.8 Summary and Conclusions

Table 38: Separation distances between WBB LMP and FSS for long-term protection criteria

FSS Long term protection criteria

Scenario No.	Scenario descrinbtion	Max. e.i.r.p. (dBW/5MHz)	No clutter		Clutter with P.452	Specific Deployment and use of terrain data			Clutter one side (29-31 dB, 30-50% location in P.2108)	
	AAS (8x8)	18 (LP)	21.5 (H = 20m)						2 (H = 10m)	
		24	25.5 (H = 20m)						4.2 (H = 10m)	
		36 (MP)	36.5 (H = 20m)						14 (H = 10m)	10.5 (H = 10)
		38 (INCR)							11.5 (H = 10)	
	AAS (4x8)	18 (LP)								
		36 (MP)							12.5 (H = 15m)	
		38 (INCR)	52 (H = 20)						30 (H =20)	16 (H = 15m)
	AAS (4x4)	18 (LP)								
		36 (MP)							13.5 (H = 10)	
		38 (INCR)							14.5 (H = 10)	
	non AAS	18 (LP)	32.5 (H = 20m)		20.9 (H = 10m)	5.3 (H = 5m)	14.12 (H = 10m)	15.5 (H = 20m)	4.5 (H = 10)	4 (H = 10m)
		24	38.1 (H = 20m)		25.3 (H = 10m)					
		36 (MP)	47.5 (H = 20m)	39.1 (H = 10m)	35 (H = 10m)	17.5 (H = 10m)	21.7 (H = 20m)	26.6 (H = 30m)	16.5 (H = 10)	18 (H = 10m)
		38 (INCR)								
	Omnidirectional	18 (LP)	33.3 (H = 20m)		21.5 (H = 10m)	9.3 (H = 10m) FUS	17.2 (H = 10m) DLR		4.7 (H = 10m) FUS	4 (H = 10m) DLR
		24	38.5 (H = 20m)		25.9 (H = 10m)					
		36 (MP)	47.9 (H = 20m)		35.8 (H = 10m)	26.5 (H = 25m) FUS	70 (H = 25m) DLR			17.2 (H = 25m) DLR
		38 (INCR)								
	Omnidirectional INDOOR	18 (LP)				8.6 (H = 10m) FUS			2.3 (H = 10m) FUS	
	Summary range	18 (LP)	21.5-33.3 km		20.9-21.5 km	5.3-17.2 km			2-4.7 km	
		36 (MP)	36.5-47.9 km		35-35.8km	17.5-70km			10.5-18	
		38 (INCR)	52						11.5-30 km	

Scenario No.	Scenario descrinbtion	Max. e.i.r.p. (dBW/5MHz)	No clutter		Clutter both side (29-31 dB x 2, 30-50% location in P.2108 at receiver and transmitter)		FSS min gain (-10dBi) + No clutter	FSS min gain (-10dBi) + Clutter one side (29-31 dB, 30-50% location in P.2108)		FSS min gain (-10dBi) + Clutter both side (29-31 dB x 2, 30-50% location in P.2108)	
	AAS (8x8)	18 (LP)	21.5 (H = 20m)								
		24	25.5 (H = 20m)								
		36 (MP)	36.5 (H = 20m)		<1 (H=10)			<1 (H=10)		<1 (H=10)	
		38 (INCR)			<1 (H=10)			<1 (H=10)		<1 (H=10)	
	AAS (4x8)	18 (LP)									
		36 (MP)						2.5km (H =15m)			
		38 (INCR)	52 (H = 20)								
	AAS (4x4)	18 (LP)									
		36 (MP)			<1 (H=10)			<1 (H=10)		<1 (H=10)	
		38 (INCR)			1 (H=10)			<1 (H=10)		<1 (H=10)	
	non AAS	18 (LP)	32.5 (H = 20m)		<1 (H=10)	0.85 (H = 10m)		<1 (H=10)		<1 (H=10)	
		24	38.1 (H = 20m)								
		36 (MP)	47.5 (H = 20m)	39.1 (H = 10m)	1.5 (H=10)	0.81 (H = 10m)	25.85 (H = 10m)	<1 (H=10)	3.35 (H = 10m)	<1 (H=10)	0.11 (H = 10m)
		38 (INCR)									
	Omnidirectional	18 (LP)	33.3 (H = 20m)		0.39 (H = 10m) DLR						
		24	38.5 (H = 20m)								
		36 (MP)	47.9 (H = 20m)								
		38 (INCR)									
	Omnidirectional INDOOR	18 (LP)									
	Summary range	18 (LP)	21.5-33.3 km		<1 km			<1 km		<1 km	
		36 (MP)	36.5-47.9 km		<1 - 1.5 km		25.85km	<1 - 3.35 km		<1 km	
		38 (INCR)	52		<1 - 1.5 km			<1 - 3.35 km		<1 km	

Table 39: Separation distances between WBB LMP and FSS for short-term protection criteria

FSS Short term protection criteria

Scenario No.	Scenario descrinbtion	Max. e.i.r.p. (dBW/5MHz)	No clutter	Clutter with P.452	Specific Deployment and use of terrain data	Clutter one side (29-31 dB, 30-50% location in P.2108)
	AAS (8x8)	18 (LP)	90 (H = 20m)			2 (H = 10m)
		24	160 (H = 20m)			4.2 (H = 10m)
		36 (MP)	275 (H = 20m)			18 (H = 10m)
		38 (INCR)				20 (H = 10)
	AAS (4x8)	18 (LP)				
		36 (MP)				
		38 (INCR)				
	AAS (4x4)	18 (LP)				
		36 (MP)				
		38 (INCR)				22.5 (H = 10)
	non AAS	18 (LP)	104 (H = 20m)	23 (H = 10m)		
		24	163 (H = 20m)	29 (H = 10m)		
		36 (MP)	273 (H = 20m)	120 (H = 10m)		
		38 (INCR)				
	Omnidirectional	18 (LP)	109 (H = 20m)	23 (H = 10m)	9.3 (H = 10m) FUS	
		24	167 (H = 20m)	29 (H = 10m)		
		36 (MP)	277 (H = 20m)	126(H = 10m)	35 (H = 25m) FUS	
		38 (INCR)				
	Omnidirectional	18 (LP)				
	Summary range	18 (LP)	90-109 km	23km	9.3 km	2 km
		36 (MP)	273-277 km	120-126km	35km	18km
		38 (INCR)				20-22.5km

As highlighted in Table 38 and Table 39 summarise the results of the various studies, the separation distances required between WBB LMP and FSS can vary significantly depending on the assumptions taken. An overall depiction of generic studies (without terrain data) are provided below:

- Considering the FSS ES long term protection criteria:
  - Medium power WBB LMP: 36.5-47.9 km (without clutter) and 10.5-18 km (with one sited clutter);
  - Low power WBB LMP: 21.5-33.3 km (without clutter) and 2-4.7km (with one sited clutter).
- Considering the FSS ES short term protection criteria:
  - Medium power WBB LMP: 273-277 km (without clutter) and 18 km (with one sited clutter);
  - Low power WBB LMP: 90-109 km (without clutter) and 2 km (with one sited clutter).

Some studies show that the real terrain should be taken into account in the coexistence assessments, because the impact of real terrain data on spectrum propagation can result in not only reduced but also increased separation distances required between WBB LMP and FSS. Resulting separation distances from those studies range in 5.3-17.2 km for WBB Low Power stations and 17.5-70 km for WBB Medium Power stations when considering long term protection criterion. One study considering the real terrain and the short-term protection criteria indicated separation distances of up to 9.3 km for WBB LP and 35 km for WBB MP for one earth station example.

The results of Study 5 suggest a coordination distance around an FSS earth station location of 40 km is suitable to protect FSS earth station receivers, below which the use of one or combination of some of the various mitigation techniques presented in that study could be implemented to minimise the interference received and reduce the required separation distance between the WBB LMP and the FSS earth station.

According to the analyses, it is not possible to define technical conditions that guarantee the protection of FSS, including its long-term development, but instead a case-by-case analysis is needed. In addition, coexistence between FSS and both low and medium power WBB systems may require cross border coordination and related bilateral or even multilateral agreements among neighbouring countries on a case-by-case basis.

6.4 BETWEEN DECT-2020 NR AND OTHER RADIO APPLICATIONS IN THE FREQUENCY BAND 3.8 - 4.2 GHZ

The detailed study can be found in Attachment 13 which is attached to this Report.

In-band coexistence studies are based on Minimum Coupling Loss (MCL) analysis using the agreed protection criteria for each service and propagation parameters. For in-band adjacent channel analysis, Net Filter Discrimination (NFD)[3] has been used to account for the defined mask of the interfering transmitter and defined receiver filter mask.

Medium power operation is not envisioned for DECT-2020 NR, therefore only 'low power' is considered in these studies. The e.i.r.p of DECT-2020 NR is 23 dBm (assuming a 0 dBi antenna) for the current bandwidth options of 1.728 MHz, 3.456 MHz and 6.912 MHz. If wider area coverage is needed by a user at their site, additional DECT-2020 NR devices can be deployed within a self-organising mesh network rather than increasing the output power (and the consequential increase in possible interference to other users). For the purpose of these studies, only the bandwidth option of 6.912 MHz is included on the assumption that narrow bandwidths would improve coexistence, particularly with adjacent channel applications.

6.4.1 Between DECT-2020 NR systems

DECT-2020 NR uses advanced spectrum protocols that enable local device-based interference management through autonomous time-accurate interference avoidance between DECT-2020 NR devices in the same network and also with devices operating in other DECT-2020 NR networks. These protocols can manage coexistence between networks locally and therefore the need to study DECT-to-DECT coexistence is largely inconsequential but is included for information and completeness.

The analysis was performed with 6.912 MHz channel bandwidth systems (operating in the centre of the 10 MHz channel raster). The maximum separation distance needed between DECT-2020 NR deployments is 582 m when considering the co-channel operation with no clutter. This distance reduces to 250 m when assuming clutter at one terminal. Separation distances for two immediate adjacent 10 MHz channels are 30 m.

6.4.2 Between DECT-2020 NR and 3GPP WBB LMP systems

6.4.2.1 DECT-2020 NR interfering 3GPP WBB LMP

Two 3GPP WBB bandwidths have been assumed within these studies, i.e. 10 MHz and 100 MHz victim bandwidths for both low and medium power 3GPP WBB scenarios. In the co-channel case with 100 MHz 3GPP WBB channels, one 6.912 MHz DECT-2020 NR interferer has been assumed to be operating in each 10 MHz of the 100 MHz 3GPP WBB channel to assess the effect of aggregated interference from DECT-2020 NR, which represents the theoretical worst case and not necessarily experienced in practice.

For co-channel, when clutter is applied separation distances of the order of 2 to 3 km are calculated. When no clutter is applied, separation distances increase to approximately 30 to 33 km. There is no discernible increase in separation distances when considering aggregation.

For adjacent channel studies, separation distances range between 1.1 and 5 km, depending on LP or MP 3GPP WBB and their receiver bandwidths.

For shared spectrum operation DECT-2020 NR has the capability to detect interference from any other systems sharing the same or adjacent spectrum. DECT-2020 NR supports polite spectrum operation, i.e. the device senses the spectrum use prior its own transmission to avoid collision with other transmissions and to enable operation on least interfered channels by supporting Listen Before Talk (LBT) protocol. These polite protocols may enhance spectrum sharing but have not been considered in the MCL analysis.

[3] The NFD is calculated using the method given in ETSI TR 101 854. A bandwidth correction is applied if the interfering transmitter's bandwidth is greater than that of the victim receiver. The NFD is included in the MCL as a loss on the radio interference path

6.4.2.2 3GPP WBB LMP interfering DECT-2020 NR

Studies show in the co-channel case separation distances range from 0.25 km to 3.6 km depending on assumed clutter losses and bandwidth of the interferer. In the adjacent channel case, separation distances are approximately 100 m or less.

For the 3GPP WBB as the interferer and DECT-2020 NR as the victim, only the medium power (3GPP WBB) case has been modelled as the worst-case scenario. Separation distances for low power 3GPP WBB would be less than those derived here.

6.4.2.3 Conclusions on interference between DECT-2020 NR and 3GPP WBB LMP

It is noted that the difference in required separation distances between DECT-2020 NR into 3GPP WBB and vice versa is primarily a consequence of the assumed operation and protection criteria which are more conservative when considering protection of 3GPP WBB.

For 3GPP WBB LMP the interference threshold level is -105 dBm/10 MHz or -95 dBm/100 MHz i.e. 6 dB below thermal noise and for DECT-2020 NR the respective interference threshold was -76.7 dBm/6.912 MHz, i.e. 20 dB above thermal noise. The interference threshold used for DECT-2020 NR is consistent with other compatibility studies in CEPT.

6.4.3 Between DECT-2020 NR and FSS

The studies of DECT-2020 NR into the FSS considers both long-term and short-term interference scenarios. The effect of applying clutter at one terminal significantly reduces the required separation distances. Studies consider the DECT-2020 NR interferer at 0, 10 and 180 degrees azimuth with respect to the FSS antenna.

For long-term interference, at 0 degrees azimuth, i.e. the DECT-2020 NR interferer is on the maximum FSS antenna gain with the inclination set to 10 degrees, the separation distances range from 3 to 51 km depending on the application of clutter. In the adjacent channel separation distances range between 0.6 and 15 km. Outside the main beam separation distances reduce as would be expected.

In the short-term scenario, separation distances vary between 91 km and 1.2 km in the co-channel, 0 degree azimuth case. In the adjacent channel, separation distances vary between 13 km and 0.37 km, and reduce further when azimuth separation increases.

6.4.4 Between DECT-2020 NR and FS

The study assesses the geographical separation required when the DECT-2020 NR interfering signal is incident to the victim receiver at 0-, 10- and 180-degrees azimuth. The largest separation distance for a single-entry interferer at 0 degrees without clutter is 130 km. This reduces to 37 km when clutter is assumed.

In the adjacent channel case, separation distances reduce to between 81 km and 5 km depending on applying clutter. In off-axis geometries separation distances reduce significantly, for example down to 1.3 km when clutter is applied in the co-channel, 10-degree azimuth case.

6.4.5 Conclusions for DECT-2020 NR

Table 40 provides a summary of the co-channel MCL analysis outlined above when considering clutter at the DECT-2020 NR terminal operating with a maximum antenna height of 10 m.

Table 40: Summary of DECT-2020 NR in-band coexistence studies

Interferer	Victim	Co-channel separation distance (km)	Comment
DECT-2020 NR	DECT-2020 NR	0.250	DECT-2020 NR spectrum management functionality removes the need to consider separation distances between different DECT-2020 NR networks
DECT-2020 NR	3GPP LP WBB	1.8	For 10 MHz 3GPP WBB
		0.7	For 100 MHz 3GPP WBB
DECT-2020 NR	3GPP MP WBB	2.7	For 10 MHz 3GPP WBB
		1.0	For 100 MHz 3GPP WBB
3GPP MP (only MP considered as the worst-case)	DECT-2020 NR	0.29	For 10 MHz 3GPP WBB
		0.25	For 100 MHz 3GPP WBB
DECT-2020 NR	FSS	3	Long-term interference
		1.2	Short-term interference
DECT-2020 NR	FS	37	
Note: The e.i.r.p of DECT-2020 NR is 23 dBm (0 dBi antenna gain).			

Studies show that the required separation distances needed between DECT-2020 NR WBB LMP and 3GPP WBB LMP networks, and between DECT-2020 NR WBB LMP and incumbent services demonstrate the feasibility for DECT-2020 NR LMP WBB operation in the 3.8-4.2 GHz band. As noted above, adjacent (in frequency and/or geography) DECT-2020 NR WBB LMP networks can be locally managed autonomously by the devices themselves, removing the need for manual coordination and the requirement for a separation distance.

6.5 BETWEEN 3GPP WBB LMP AND COMPATIBILITY STUDIES WITH OTHER APPLICATIONS

6.5.1 Study 1 – Sharing study between WBB LMP and VGOS in the frequency band 3.8-4.2 GHz

The detailed study can be found in Attachment 14 which is attached to this Report.

The results in this sharing study between the Geodetic Observatory Wettzell (GOW) type VGOS-992 and WBB LMP BS indicate that the maximum required separation distances to protect the GOW from WBB LMP may go up to 125 km for medium power BS and up to 100 km for low power BS for a worst-case scenario. The results for the medium power BS also show that a cross-border interference could occur.

The study recognises that for the moment these observations, which are operating in the spectrum bands of the 2-14 GHz range, have no radio astronomy allocation in 3.8-4.2 GHz and therefore cannot claim interference protection on international or European level. Nevertheless, administrations are urged to take all practicable steps to protect these observatory operations from harmful interference. Measures to minimise restrictions on WBB LMP roll-out could be, such as:

- restricting the transmitter power of the WBB LMP BS;
- reducing the antenna height of the WBB LMP BS;
- adjusting the antenna elevation angle of the WBB LMP BS;
- adjusting the direction of the antenna of the WBB LMP BS (away from Wettzell).

7 COMPATIBILITY STUDIES WITH ADJACENT BAND SERVICES

7.1 BETWEEN 3GPP WBB LMP AND MFCN BELOW 3.8 GHZ

7.1.1 Study 1 – Adjacent-band co-existence study between WBB LMP and 5G MFCN in unsynchronised operation

The detailed study can be found in Attachment 15 which is attached to this Report.

This study provides technical analysis on the interference between a single WBB LMP BS and a single 5G MFCN AAS BS (both as interferer and as victim) using Monte-Carlo simulations. The protection threshold for 5G MFCN BS and WBB LMP BS is I/N=-6 dB. The study results are expressed as separation distances assuming no clutter loss or clutter loss at the vicinity of WBB LMP BS or/and 5G MFCN BS. Study results provide useful information for the coordination between WBB LMP BS and 5G MFCN BS.

This study focuses on the coexistence between WBB LMP networks and MFCN networks operating in an unsynchronised manner in immediately adjacent-bands and outdoors. The deployment and operational characteristics of the WBB LMP networks were sourced from the agreed parameters for studies. Non-AAS antennas were considered for Low Power BS while AAS antennas with a 4x8 element configuration were considered for the Medium Power BS. MFCN networks were assumed to be deployed with BS with AAS antennas with 4x8 and 8x8 elements configuration. The high level WBB LMP operational and deployment parameters are shown in Table 41.

Table 41: WBB LMP and MFCN operational and deployment parameters

Parameter	Value
Max. *e.i.r.p.* of WBB Low Power BS	31 dBm/100 MHz
Max. *e.i.r.p.* of WBB Medium Power BS	49 dBm/100 MHz 51 dBm/100 MHz
Antenna height of WBB Low Power BS	10 m
Antenna height of WBB Medium Power BS	12 m (dense suburban) 15 m (rural)
Antenna height of MFCN BS	25 m
Propagation model	Recommendation ITU-R P.452 [19]
Clutter (Fixed % from Recommendation ITU-R P.2108 [15])	MFCN 0% at all times WBB LMP 50% (urban) 30% (suburban) 0% (rural)
MFCN protection criterion	I/N = -6 dB

The study assesses the coexistence both when the WBB LMP network acts as the interferer towards MFCN as well as when the MFCN network acts as the interferer towards the WBB LMP network. Regarding the methodology of the study, Monte-Carlo simulations were performed in a 3GPP compliant simulator, where the dynamic nature of WBB LMP and MFCN services was captured. Each simulation step was considered to be 250 m with 10000 interference snapshots being captured at each one of those steps, creating an interference

CDF. For each separation distance step of 250 m the worst-case interference snapshot was considered which was then assessed against the WBB LMP or MFCN I/N protection criterion to determine the minimum separation distance required.

The results of the study indicate that to satisfy the I/N protection criterion of MFCN, the separation distances MFCN BS and WBB LP BS are below 250 m when both are located at an urban environment and approximately 850 m when both are located in a rural environment. The separation distance required to satisfy the MFCN criterion of I/N = -6 dB between MFCN BS and WBB MP networks with *e.i.r.p.* 49 dBm/100 MHz and 51 dBm/100 MHz located in urban and dense suburban environments is below 250 m. When both networks were located in rural environments, the separation distance to protect MFCN services was approximately 1 km.

When the MFCN network acts as an interferer, for the WBB LMP services to be protected against the I/N protection criterion, the required separation distances are below 250 m for urban Low Power WBB and approximately 1.6 km for rural Low Power WBB. Medium Power WBB dense suburban environment need to maintain approximately up to 300 m separation in order to be protected from MFCN in and approximately 5.75 km in rural environments.

The results of the study are shown in Figure 5, Figure 6 and Figure 7.

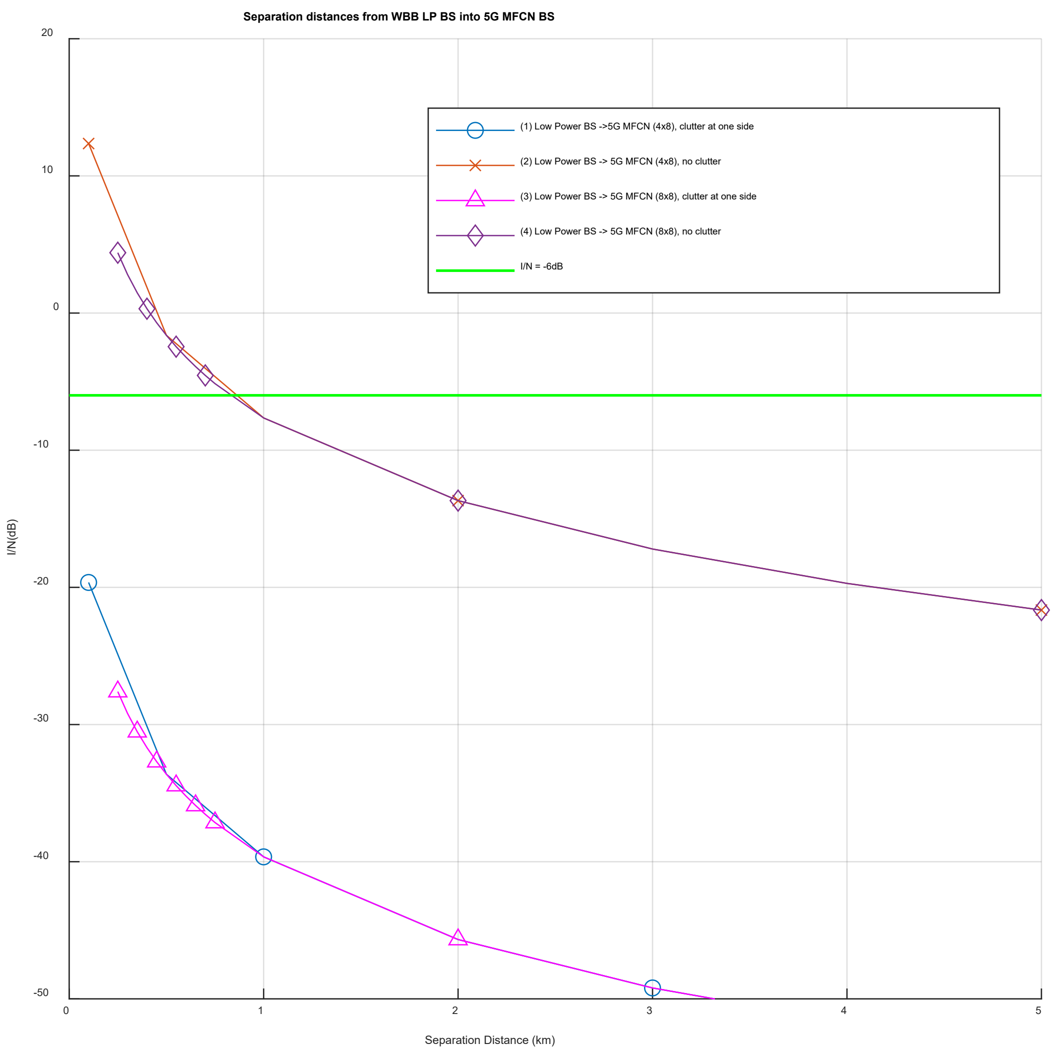
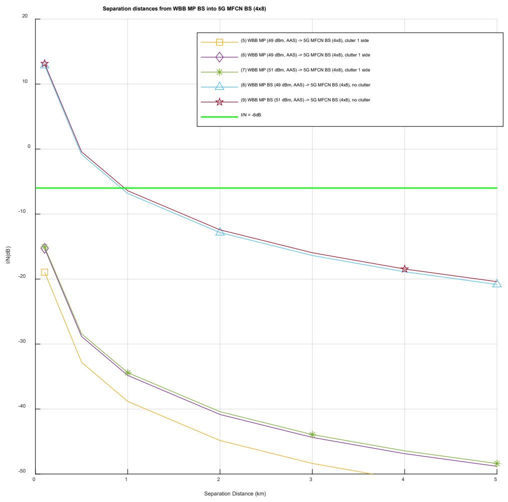


Figure 5: Separation distances from WBB LP BS into 5G MFCN BS



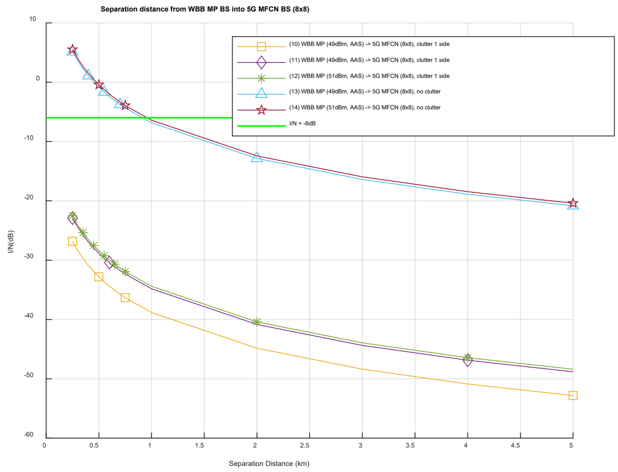
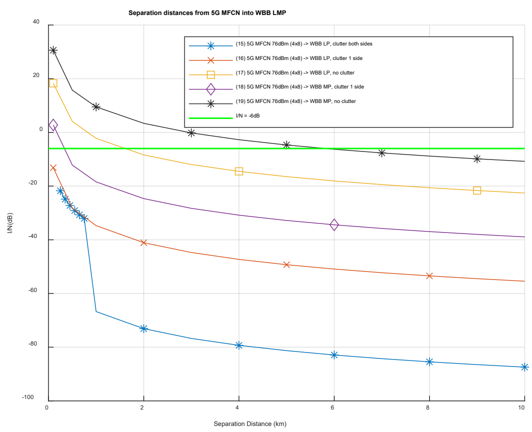


Figure 6: Separation distances from WBB MP BS into 5G MFCN BS with 4x8 elements (left) and from WBB MP BS into 5G MFCN BS with 8x8 elements (right)



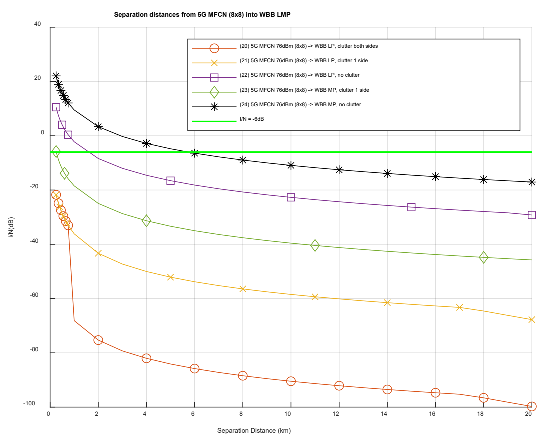


Figure 7: Separation distances from 5G MFCN with 4x8 elements into WBB LMPs (left) and from 5G MFCN with 8x8 elements into WBB LMPs (right)

7.1.2 Study 2 – Adjacent-band co-existence study between WBB LMP and 5G MFCN in unsynchronised operation

The detailed study can be found in Attachment 16 which is attached to this Report.

This study presents the simulation results as separation distance for the case with and without clutter loss applied to one or both ends in different environments.

This study provides Monte-Carlo simulations results of interference from WBB LMP BS to 5G MFCN BS by modelling the local area network as a single BS and 5G MFCN network as a single BS. The 5G MFCN BS out-of-band blocking characteristics used in the simulation is a type 1-H (-15 dBm4 at frequency offset from the band edge). This single BS to single BS simulation scenario does not take into account the inter-cell interference within 5G MFCN network.

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[4] Interfering signal level for a 6 dB desensitization, equivalent to -25.6 dBm level for 1 dB desensitization of the Macro BS AAS receiver.

The interference from 5G MFCN BS to WBB LMP BS was also simulated, the simulation results show WBB LMP BS suffers a lot of interference from 5G MFCN BS due to receiver blocking as well as out-of-band emissions from 5G MFCN BS above 3800 MHz. An improved WBB LMP BS receiver blocking level improves the situation but is not sufficient.

The conclusions of this study are:

- unsynchronised operation between WBB LMP in 3800-3860 MHz and 5G MFCN below 3800 MHz co-existence is difficult without coordination;
- WBB LMP BS with in-band power level <= 30 dBm/100 MHz in 3860-4200 MHz can co-exist with 5G MFCN below 3800 MHz in unsynchronised operation without coordination;
- synchronisation or semi-synchronisation between WBB LMP and 5G MFCN is a good solution to ensure a good co-existence.

7.1.3 Study 3 – Adjacent-band co-existence study between unsynchronised WBB LMP local area network and 5G MFCN for 100 m separation distance

The detailed study can be found in Attachment 17 which is attached to this Report.

This study provides simulation results of interference from WBB LMP BS to 5G MFCN BS and of interference from 5G MFCN to WBB LMP. In the simulation, both 1-O and 1-H 5G MFCN base station out-of-band blocking levels are considered. The microcellular 5G MFCN network is modelled with a cluster of 19 tri-sector sites (57 cells), the victim 5G MFCN BS is placed in the centre of this network cluster. In this way the intra-network intercell interference is taken into account in the 5G MFCN uplink throughput loss. 100 m separation distance between the 5G MFCN reference cell base station and WBB LMP base station was used in the simulations.

WBB low power non-AAS BS with an *e.i.r.p.* of 31 dBm/100 MHz with an antenna gain of 12 dBi is considered. Two types of WBB medium power base stations are considered:

1. Non-AAS BS with transmit power of 49 dBm/100 MHz *e.i.r.p.* and 51 dBm/100 MHz *e.i.r.p.* with an antenna gain of 16 dBi;

2. AAS BS with 4x4 AAS antenna configuration (antenna gain 18.5 dBi), the AAS BS transmit power of 49 dBm/100 MHz *e.i.r.p.* (30.5 dBm/100 MHz TRP) and 51 dBm/100 MHz *e.i.r.p.* (32.5 dBm/100 MHz TRP).

Summary of simulation results:

1. The technical conditions for WBB LP BS in 3800-4200 MHz in unsynchronised operation with 5G MFCN below 3800 MHz - Table 42.

Table 42: The technical conditions for WBB LP BS in 3800-4200 MHz in unsynchronised operation with 5G MFCN below 3800 MHz

	Maximum In-band Power Limit and antenna height	Additional Baseline OOBE below 3800 MHz
Low Power non-AAS BS	31 dBm/100 MHz (*e.i.r.p.* per cell) Antenna height <= 10 m	-45 dBm/MHz conducted per cell

2. The technical conditions for WBB MP BS in 3860-4200 MHz in unsynchronised operation with 5G MFCN below 3800 MHz - Table 43.

Table 43: The technical conditions for WBB MP BS in 3860-4200 MHz in unsynchronised operation with 5G MFCN below 3800 MHz

	Maximum In-band Power Limit	Additional Baseline OOBE below 3800 MHz
Medium Power non-AAS BS	51 dBm/100 MHz *e.i.r.p.* per cell	-45 dBm/MHz conducted per cell
Medium Power AAS BS	51 dBm/100 MHz *e.i.r.p.* per cell (33 dBm/100 MHz TRP per cell)	-45 dBm/MHz TRP per cell (Note 1)
Note 1: in urban environment an OOBE of -35 dBm/MHz TRP can provide a sufficient protection, but in rural environment an OOBE of -54 dBm/MHz TRP would be required.		

3 The technical conditions for WBB LMP BS in 3800-4200 MHz in synchronised operation or semi-synchronised operation with 5G MFCN below 3800 MHz - Table 44.

Table 44: The technical conditions for WBB LMP BS in 3800-4200 MHz in synchronised operation or semi-synchronised operation with 5G MFCN below 3800 MHz

	Maximum In-band Power Limit	Additional Baseline OOBE below 3800 MHz
Non-AAS BS	51 dBm/100 MHz *e.i.r.p.* per cell	-25 dBm/MHz conducted per cell
AAS BS	51 dBm/100 MHz *e.i.r.p.* per cell (33 dBm/100 MHz TRP per cell)	-23 dBm/MHz TRP per cell

4 The technical conditions for WBB LMP terminals, operating with antenna heights up to 10 m, in 3800-4200 MHz with 5G MFCN below 3800 MHz - Table 45.

Table 45: The technical conditions for WBB LMP terminals in 3800-4200 MHz in synchronised operation or semi-synchronised operation with 5G MFCN below 3800 MHz

	Maximum In-band Power Limit	Power control
All type terminals including Mobile, Nomadic, IoT, Machine, FWA	28 dBm *e.i.r.p.*	Obligatory

5 When the WBB LMP BS and 5G MFCN small cell BS are deployed in the same street in outdoor area or in the same indoor area, synchronisation or other coordination measures are required.

7.1.4 Study 4 – Adjacent-band co-existence study between WBB LMP and 5G MFCN in semi-synchronised operation

The detailed study can be found in Attachment 18 which is attached to this Report.

This study focuses on the specific sub-case of semi-synchronised operation, in which DL to UL modifications are allowed. This case is especially interesting for those scenarios where WBB LMP networks require more UL resources than those available in the frame structure of the MFCN network. In the case of semi-synchronised operation with DL to UL modifications, only the default DL transmission direction in the default MFCN frame structure may be modified into UL. As a result, if DL to UL modifications are only performed by the WBB LMP networks, MFCN below 3800 MHz will not receive additional BS-to-BS cross interference from the WBB LMP network. While semi-synchronised operation is also possible employing UL to DL modifications, this case is not considered in this study since this would cause additional BS-to-BS cross interference from the WBB LMP network to MFCN below 3800 MHz.

Table 46 summarises results of the reduction of the separation distance to achieve an average UL TP loss of 5% in the WBB LMP network for different scenarios compared to unsynchronised operation. For no clutter loss the reduction of the separation distance is between 47% and 76%, while for clutter at the receiver side a reduction of the separation distance by 27% to 50% can be achieved.

Table 46: Reduction of the separation distance with semi-synchronised compared to unsynchronised operation to achieve 5% average UL TP loss

#	Description	No clutter	Clutter at receiver side
1	WBB LP BS Non-AAS, urban	51%	27%
2	WBB LP BS Non-AAS, rural	47%	30%
3	WBB LP BS AAS, urban	76%	approx. 50%
4	WBB LP BS AAS, rural	72%	49%

Table 47 summarises the proposed tolerable interference margin in dB depending on the percentage of synchronised slots for low and medium power WBB networks. For completeness, in case AAS BS will not be allowed in the regulation, simulation results for medium power WBB networks with non-AAS have been added, which were obtained by replacing the AAS antennas with non-AAS antennas for the WBB MP network. Comparing the tolerable interference margin between AAS and non-AAS for MP and 90% synchronised slots, the tolerable interference margin increases by more than 12 dB when employing AAS, which shows that due to the adaptive antenna concept and the pointing of the beams the tolerable interference can be further reduced compared to non-AAS.

Table 47: Tolerable interference margin in dB compared to unsynchronised operation for semi-synchronised operation depending on the percentage of synchronised slots for different scenarios

	Tolerable interference margin in dB (Note)		
% synchronised slots	Non-AAS LP	AAS MP	Non-AAS MP
0	0.0	0.0	0.0
10	0.5	0.7	0.6
20	1.1	1.5	1.2
30	1.7	2.4	2.0
40	2.4	3.6	2.9
50	3.4	5.0	4.1
60	4.5	7.0	5.6
70	6.0	10.1	7.8
80	8.4	16.2	11.6
90	14.1	32.9	20.3
Note: Tolerable interference margin of semi-synchronised operation compared to unsynchronised operation in dB depending on the percentage of slots synchronised with the MFCN network below 3800 MHz.			

In summary, by using the tolerable interference margin in Table 47 the I/N thresholds for semi- synchronised operation can be obtained for LP and MP WBB networks depending on the percentage of DL to UL modifications and using the I/N threshold for unsynchronised operation as a reference.

The particular semi-synchronisation could be further investigated as part of relevant guidelines in order to implement this approach on case-by-case basis in order to ensure more efficient usage of the spectrum as appropriate.

This study describes the semi-synchronisation, a special case in which only DL to UL modifications are allowed to avoid interference from WBB LMP to 5G MFCN. With respect to the regulatory conditions for semi-synchronised operation with DL to UL modifications, it is recommended that the BEM below 3800 MHz should be identical to synchronised operation.

7.1.5 Study 5 – Adjacent-band co-existence study between WBB LMP and 5G MFCN in indoor area of the same building in unsynchronised operation

The detailed study can be found in Attachment 19 which is attached to this Report.

The study is based on 5% throughput loss.

This study provides simulations of interference from WBB LMP indoor smallcell BS to 5G MFCN indoor smallcell BS in unsynchronised operation, the simulation results show that the co-existence between WBB LMP indoor BS and 5G MFCN smallcell indoor BS in the same room is difficult, even with a reduced conducted OOBE level of -60 dBm/MHz for WBB LMP indoor BS. It is possible to deploy WBB LMP indoor BS and 5G MFCN indoor BS in different rooms on the same floor or on different floors. The study results show the indoor deployment of WBB LMP and 5G MFCN should be in synchronised operation or coordinated when they are in unsynchronised operation.

7.1.6 Study 6 – Adjacent-band co-existence study between WBB LMP and 5G MFCN in indoor/outdoor/urban/suburban/rural area in unsynchronised operation

The detailed study can be found in Attachment 20 which is attached to this Report.

This study proposes a combination of WBB LMP out-of-band emission level and blocking requirement coordination method for WBB LMP deployment in unsynchronised operation with 5G MFCN: based on I/N=-6 dB protection, by considering the WBB LMP BS OOBE and 5G MFCN BS receiver selectivity (in-band and out of band blocking for 5G MFCN BS type 1-H and 1-O), the MFCN protection pfd level or field strength level at the border of WBB licensed area. This threshold was derived using I/N=-6 dB protection criterion for MFCN and an 80th percentile of 5G MFCN BS AAS antenna gain (due to its varying nature) for different environments (Urban, Suburban and Rural).

The examples of the calculated field strength levels at border of WBB LMP licensed area to be measured at the 5G MFCN BS antenna height are:

- 34.5 dB(μV/m)/100 MHz for urban environment;
- 32.8 dB(μV/m)/100 MHz for suburban environment;
- 32.2 dB(μV//m)/100 MHz for rural environment.

The coordination process is to be decided at national level on a case-by-case basis.

The following technical conditions are proposed to facilitate reducing the number of coordination cases:

Table 48: WBB LP non-AAS BS

Frequency range	OOBE <3800 MHz	In-block Power	Receiver blocking <3800 MHz
3800-4200 MHz	-45 dBm/MHz conducted	31 dBm/100 MHz *e.i.r.p.*	-15 dBm at 6 dB desensitisation

Table 49: WBB MP Non-AAS and AAS BS

Frequency range	OOBE <3800 MHz	In-block Power	Receiver blocking <3800 MHz
3800-4200 MHz	-45 dBm/MHz conducted for MP non-AAS BS -45 dBm/MHz TRP for MP AAS BS	51 dBm/100 MHz *e.i.r.p.*	-15 dBm at 6 dB desensitisation

7.1.7 Study 7 – Adjacent-band co-existence study between WBB LMP and 5G MFCN in unsynchronised operation

The detailed study can be found in Attachment 21 which is attached to this Report.

In this study a Monte-Carlo analysis is performed using SEAMCAT to analyse coexistence conditions between unsynchronised WBB LMP and MFCN below 3800 MHz. A single WBB LMP BS (non-AAS / AAS) is placed in LOS of a 5G MFCN BS (AAS / non-AAS). Appropriate antenna pattern and down tilt considered as in agreed parameters. Minimum separation distance of 100 m between the WBB LMP BS and the 5G MFCN BS is assumed considering the dense urban and suburban environments The distance between the BS is incrementally increased until uplink throughput loss at 5G MFCN BS is less than 5%. Furthermore, effect of strict block edge mask (BEM), guard band and in-block power reduction are also analysed for better coexistence.

The study results shows that adjacent channel unsynchronised coexistence between outdoor MFCN below 3800 MHz and WBB LMP above 3800 MHz is quite challenging as technical conditions will be too restrictive.

Separation distance of at least 10km is needed between MFCN and WBB MP networks to keep the interference level < 5% in MFCN UL throughput. The study also shows that by defining only a strict BEM will not solve the problem, blocking impact from WBB LMP systems also needs to be considered for which guard band of at least 60 MHz is needed between the two networks.

The impact of MFCN macro-BS interference towards unsynchronised WBB LMP BS is not analysed in this study. However, considering the high power of macro-BS the separation distance could be considerably large to achieve the desirable quality of service in a WBB LMP network depending upon the use case

For efficient use of spectrum synchronised operation seems a better option in case enough geographical or frequency separation is not available.

The interference from 5G MFCN to WBB LMP was not studied.

The conclusions of this study based on 100 m separation distance and 5% 5G MFCN (AAS BS) UL throughput loss can be summarised as:

Table 50: Technical conditions for WBB LMP non-AAS BS

Frequency range	OOBE <3800 MHz	In-block Power
3800-3860 MHz	-40 dBm/MHz *e.i.r.p.*	28 dBm/100 MHz *e.i.r.p.*
3860-4200 MHz	-40 dBm/MHz *e.i.r.p.*	51 dBm/100 MHz *e.i.r.p.*

Table 51: Technical conditions for WBB MP AAS BS

Frequency range	OOBE	In-block Power
3800-3860 MHz	-43 dBm/5 MHz TRP	23.2 dBm/100 MHz *e.i.r.p.*
3860-4200 MHz	-43 dBm/5 MHz TRP	51 dBm/100 MHz *e.i.r.p.*

7.1.8 Summary

The observations drawn from the studies in this Report are strongly correlated to the input assumptions used in the various studies. If local or national circumstances are different from those assumptions e.g. clutter, availability of terrain information, density of existing and planned/future deployments, etc., then different coexistence conclusions may be reached.

All studies assumed unsynchronised WBB LMP operation with in-band *e.i.r.p.* of up to 31 dBm/100 MHz for WBB LP and up to 51 dBm/100 MHz for WBB MP base stations.

There are 4 issues identified by the results of the studies:

- Issue 1: Possible need for lower unwanted emission levels for unsynchronised WBB LMPs to protect MFCN below 3.8 GHz;
- Issue 2: Possible need for frequency separation for unsynchronised WBB LMPs to protect MFCN below 3.8 GHz due to MFCN receiver blocking, in particular with WBB MP BS;
- Issue 3: Possible need to define better Rx blocking levels below 3.8 GHz in order to ensure they are not impacted by the emissions of MFCN below 3.8 GHz;
- Issue 4: Possible need for defining the maximum *e.i.r.p.* for fixed WBB terminals.

The studies were performed based on two protection criteria. Studies 1 and 6 used the I/N protection criterion (i.e. I/N = -6 dB), while studies 2, 3, 4, 5, 7 used the throughput loss metric (i.e. throughput loss not to be exceeded by more than 5%).

Issue 1 (unwanted emissions below 3.8 GHz)

The observations from studies 3, 6 and 7 regarding the need for lower unwanted emissions for WBB LMPs to protect MFCN below 3.8 GHz are shown in Table 52.

Table 52: Unwanted emissions in Studies 3, 6 and 7 for WBB LMPs BS to facilitate coexistence with MFCN below 3.8 GHz for unsynchronised scenario

Studies	Low Power unwanted emissions below 3.8 GHz	Medium Power non-AAS unwanted emissions below 3.8 GHz	Medium Power AAS unwanted emissions below 3.8 GHz
Study 3	-45 dBm/MHz conducted	-45 dBm/MHz conducted	-45 dBm/MHz TRP
Study 6	-45 dBm/MHz conducted	-45 dBm/MHz conducted	-45 dBm/MHz TRP

Studies	Low Power unwanted emissions below 3.8 GHz	Medium Power non-AAS unwanted emissions below 3.8 GHz	Medium Power AAS unwanted emissions below 3.8 GHz
Study 7	-40 dBm/MHz *e.i.r.p.*	-40 dBm/MHz *e.i.r.p.*	-43 dBm/5 MHz TRP

Studies 3 and 7 assumed minimum separation distance of 100 m, while Study 6 assumed conditions with smaller cell sizes, which will reduce the coordination cases.

In study 7, the Monte-Carlo simulations were performed over a single MFCN Macro BS isolated from the network i.e. without considering intra-network inter-cell interference (interference caused from adjacent cells of the same MFCN network) in the assessment of the throughput loss. For a given MFCN cell size in the same environment, such approach of modelling the MFCN network as a single BS may result in overestimating the degradation of the MFCN throughput from external interference (WBB LMP). On the other hand, study 3 assumes MFCN network as a cluster of 7 trisector sites and intra-network inter-cell interference (within the MFCN network) but over a fully loaded network, resulting in underestimating the impact (throughput loss) from the external interference (WBB LMP station).

The reality could be in between the two values proposed by these studies which should be considered while analysing the results of these two studies.

Issue 2 (need for frequency separation from 3.8 GHz border)

Study 7 suggests that defining only a strict BEM will not solve the interference problems from unsynchronised WBB LMPs to MFCN below 3.8 GHz, as the MFCN receiver blocking also needs to be considered. Study 3 and Study 7 conclude that, to prevent unsynchronised WBB LMPs causing interference to MFCN below 3.8 GHz (100-meter distance) due to the MFCN receiver blocking, a 60 MHz frequency separation is needed between the two networks. Study 3 also suggests that for Medium Power AAS BS operating in 3860-4200 MHz, an unwanted emission below 3.8 GHz of -35 dBm/MHz TRP can provide sufficient protection in urban environments, but in rural environments due to larger cell size of 5G MFCN network, an unwanted emission below 3.8 GHz of -54 dBm/MHz TRP would be required.

Issue 3 (blocking levels below 3.8 GHz for WBB LMP receivers)

Study 6 suggests that to avoid interference from MFCN below 3.8 GHz, unsynchronised WBB LMP receivers should have blocking level of -15 dBm at 6 dB desensitisation below 3.8 GHz.

Issue 4 (WBB terminal maximum power limits)

Study 3 suggests to limit the WBB terminal maximum power as 28 dBm *e.i.r.p.* for fixed WBB terminals provided these are using power control.

Additional considerations

In order to facilitate the deployment of terrestrial wireless broadband systems providing local-area network connectivity, administrations may want to complement certain aspects of their use of the band 3.8-4.2 GHz to national and/or local level circumstances, managing the remaining coordination requirements not addressed by the harmonised technical conditions (for example through synchronisation and/or frequency separation requirements). CEPT is developing recommendations for administrations to provide guidance on the approach to coexistence in the band.

Considerations for the coordination of unsynchronised WBB LMPs with MFCN below 3.8 GHz:

- Through geographical separation: The results of Study 1, presented in the form of geographical separation (separation distances), provide information for the coordination between WBB LMPs and MFCN using the parameters of the studies (i.e. without making use of the suggested technical conditions described in the above tables);
- Through protection threshold: Study 6 provides an example, for different environments, of the maximum acceptable signal strength level measured at the receiving antenna of a 5G MFCN BS located at the border

of the WBB LMP license area: 34.5 dB(µV/m)/ 100 MHz for urban environment, 32.8 dB(µV/m)/ 100 MHz for suburban environment, 32.2 dB(µV/m)/ 100 MHz for rural environment;

- Through synchronisation: Study 5 examines the interference from WBB indoor low power BS to 5G MFCN indoor small cell BS suggesting that coexistence in the same room is challenging, while coexistence in different rooms or different floors of the same building is possible. The study results also show the indoor deployment of WBB LMP and 5G MFCN should be in synchronised operation or coordinated when they are in unsynchronised operation;
- Through semi-synchronisation: Study 4 examines the effects of semi-synchronisation in coexistence between WBB LMPs and MFCN below 3.8 GHz. The results of the study suggest that, if DL to UL modifications are only performed by the WBB LMP networks, MFCN below 3.8 GHz will not receive additional BS-to-BS cross interference from the WBB LMP network, compared to the synchronised case. The study concludes that compared to the unsynchronised case, using semi-synchronisation the separation distances (based on the throughput loss metric) can be reduced by a range of 27-72% depending on the environment and the clutter assumed.

7.2 BETWEEN DECT-2020 NR AND MFCN BELOW 3.8 GHZ

The detailed study can be found in Attachment 22 which is attached to this Report.

Within a DECT-2020 NR network, all devices have the same technical characteristics even if they have different roles within the network, and all devices implement TPC regardless of whether they are a ‘base station’ (sink node) or ‘terminal’ (router or leaf node). All messages, including beacon transmissions are adjusted to cover the 'next hop' devices and not to cover as wide an area as possible. Consequently, within a DECT-2020 NR network the average radio device transmit power is much lower than the maximum transmitter output power, and an average out-of-band emission (OOBE) level would be much lower than the specified OOBE level. This is an inherent feature of the automatic interference management capability of DECT-2020 NR to reduce transmitted power and therefore reduce the risk of interference to other users.

The focus of this study was to assess the risk of interference from DECT-2020 NR WBB LMP into MFCN below 3.8 GHz. This analysis adopts a Monte-Carlo approach to assess the risk, from a theoretical statistical basis, of interference of a single DECT device randomly placed within the service area of the MFCN base station (600 m cell range). No minimum geographical separation distance between WBB LMP and MFCN networks was assumed.

The analysis applies the agreed technical and propagation parameters and the protection requirements for the MFCN base station receiver. For distances above 250 meters, the clutter loss corresponds to the median value of Recommendation ITU-R P.2108. Net Filter Discrimination (NFD) is used to combine the DECT-2020 NR transmitter spectrum emission mask (from Table 14) and MFCN receiver mask (based on values taken from the relevant parameters from Table 25) into an NFD value. The NFD calculation is extended to cover in-band interference and out-of-band blocking of the MFCN base station receiver. As the frequency separation increases the integration of the transmitter and receiver masks changes accordingly, with the NFD levelling off at 3915 MHz.

The study assumes outdoor operation of 6.912 MHz bandwidth DECT-2020 NR operating in the centre of the 10 MHz channel raster at 23 dBm e.i.r.p. (0 dBi antenna gain) with transmission power control (TPC) giving a range of *e.i.r.p.* from -40 dBm to 23 dBm (see ETSI TR 103 943 V1.1.1 (2024-01) [14]) and an urban macro MFCN, with a 100 MHz MFCN carrier centred at 3.75 GHz, with assumed NFDs for DECT-2020 NR immediately adjacent to the 3.8 GHz border, i.e. 21.0574 dB at 3.805 GHz and the other at the point where the NFD levels off at 29.1195 dB at 3.915 GHz. Clutter is applied at the DECT-2020 NR end based on Recommendation ITU-R P.2108 [15] (for distances above 250 meters, the clutter loss corresponds to the median value of Recommendation ITU-R P.2108).

The parameters for MFCN are taken from Table 23 and Table 24. The MFCN base station is placed at a fixed location on a smooth Earth. A mobile terminal is randomly located within the service area of the base station (600 m cell range for the urban macro case) and the base station antenna is electronically steered towards the mobile terminal. The DECT-2020 NR device is also randomly placed within the base station service area and the interference from DECT-2020 NR at the base station receiver is calculated based on the agreed parameters set out in this Report.

Parameters that are changed within each snapshot of Monte-Carlo simulation:

1. The position of the DECT-2020 NR device (randomly within the service area of the MFCN BS);
2. The pathloss between the DECT-2020 NR device and the MFCN BS antenna (calculated using Recommendation ITU-R P.452);
3. For distances above 250 meters, the clutter loss corresponds to the median value of Recommendation ITU-R P.2108;
4. The position of a randomly placed MFCN UE gives the victim antenna relative gain, i.e. the MFCN base station gain in the direction of the DECT-2020 NR device;
5. Transmit power of the DECT-2020 NR device with Transmission Power Control active (randomly generated from the uniform distribution in the range from -40 dBm to 23 dBm).

The probability where the interference from DECT-2020 NR device exceeds the protection threshold of -6 dB I/N at the base station receiver is given by:

$$\text{Probability of interference} = \sum\text{Snapshots where protection criterion is exceeded} / \sum\text{Snapshots} \quad (1)$$

As can be seen in Table 53, the analysis indicates that for DECT-2020 NR operating with TPC at 3.805 GHz the probability where DECT-2020 NR transmitters exceed the protection criterion of -6 dB I/N for MFCN is 1.76% and improves to 0.515% as the frequency separation is increased to 3.915 GHz (where the NFD levels off).

Table 53: Probability that a randomly placed DECT-2020 NR radio device exceeds -6 dB I/N at the MFCN base station receiver (Urban Macro case)

MFCN Scenario	Centre frequency of DECT-2020 NR	NFD value	Probability that a randomly placed DECT-2020 NR radio device exceeds -6 dB I/N at the MFCN base station receiver
Urban Macro	3805 MHz	-21.1 dB	1.76%
Urban Macro	3915 MHz	-29.1 dB	0.52%

The study showed that the probability of interference to an adjacent channel MFCN base station of one randomly placed transmitting DECT device is between 0.52-1.76% (depending on frequency separation) providing that TPC is used. This assumes there is only one MFCN BS with a cell range of 600 m.

It should be noted that other assumptions, for example MFCN cell size or power control algorithm behaviour, would give different results on the probability of interference.

8 CONCLUSIONS

This Report supports the work of ECC in response to the "Mandate to CEPT on technical conditions regarding the shared use of the 3.8-4.2 GHz frequency band for terrestrial wireless broadband systems providing local-area network connectivity in the Union".

This Report includes technical in-band and adjacent band co-existence studies on the basis of the following scenarios:

1. in-band coexistence:
   - to ensure protection of fixed satellite service (FSS) and fixed service (FS), including the possibility for their future evolution and development;
   - for in-band sharing between different WBB LMP networks.
2. adjacent band coexistence:
   - ;between MFCN below 3.8 GHz and WBB LMP in the 3.8-4.2 GHz frequency band (interference from MFCN to WBB LMP and interference from WBB LMP to MFCN).
   - Adjacent band studies between WBB LMP in the 3.8-4.2 GHz frequency band and Radio Altimeters (RA) above 4.2 GHz are provided in ECC Report 362 [1]. As parameters for WAIC above 4.2 GHz were not provided, no studies have been performed.

Further, in this Report it is assumed that:
- the locations of WBB LMP base stations are known;
- the locations of FSS receiving Earth stations are known;
- the locations of FS stations are known;
- MFCN below 3.8 GHz is not constrained by WBB LMP above 3.8 GHz.

As FSS below 3.8 GHz is considered to be the same service as above 3.8 GHz, the operation of FSS below 3.8 GHz is covered by the in-band sharing studies in 3.8-4.2 GHz.

This Report includes also a coexistence study between WBB LMP and VLBI Global Observing System (VGOS) stations operating in a few CEPT countries, supporting EU interests as part of the European Critical Infrastructure Project Galileo.

Synchronisation of WBB LMP

Two WBB LMP network technologies have been considered, one based on 3GPP technical specifications and the other based on DECT-2020 NR technical specifications. Networks using these two technologies cannot synchronise with each other due to different operational principles. Synchronised operation of WBB LMP networks with MFCN below 3800 MHz is only possible for WBB LMP based on 3GPP technical specifications. The study results of these two technologies are presented separately.

Power levels and antenna heights studied for WBB LMP

For the purpose of studies, the following maximum power levels for WBB LMP have been defined:
- 3GPP low power base stations with 31 dBm/100 MHz *e.i.r.p.;*
- 3GPP medium power base stations with up to 49 dBm/100 MHz or up to 51 dBm/100 MHz *e.i.r.p.;*
- The maximum power level for 3GPP WBB terminals (fixed/installed, and mobile/nomadic) of 28 dBm *e.i.r.p.* considered and Power Control is applied;
- For DECT-2020 NR there is no technical distinction between devices ('base station' equipment or 'terminal equipment') and the maximum power level is 23 dBm *e.i.r.p.* with a channel bandwidth of 6.912 MHz. It is noted that for DECT-2020 NR, the technical specification mandates that all radio devices within the network shall employ TPC, including the fixed radio device (or 'base station' in traditional cellular networks).

For studies involving WBB medium power base stations, a range of antenna heights, up to 30 m above the ground, was studied. For studies involving outdoor 3GPP based WBB low power base stations, a maximum antenna height above ground of 10-25 m was studied and for DECT-2020 NR WBB 10 m above ground was studied.

This Report contains studies and relevant analysis on a range of coexistence conditions (including geographical separation, frequency separation, etc.) depending on a range of agreed WBB LMP parameters (*e.i.r.p.*, antenna height, antenna gain, emission and reception masks, etc.), covering both AAS and non-AAS scenarios for medium power base stations and only non-AAS for low power base stations.

In-band coexistence of WBB LMP with FS and FSS

Regarding FS coexistence, one of the studies shows the importance that real terrain data are taken into account in the coexistence assessments, because the impact of real terrain on transmitted signal propagation can result in not only reduced, but also increased minimum separation distances/exclusion areas required between WBB LMP and FS.

It is not possible to define generic technical conditions that guarantee the protection of FS. Instead a case-by-case analysis is needed, in combination of considering appropriate mitigation techniques, to ensure the protection of current and future deployment of FS. In addition, due to the large separation distances that may be necessary, the protection of FS cannot always be managed at national level only but may require cross border coordination on a case-by-case basis as well as bilateral or even multilateral agreements between neighbouring countries.

It is not possible to define generic technical conditions that guarantee the protection of FSS. Careful planning and case-by-case analysis is needed, in combination of considering appropriate mitigation techniques, to ensure the protection of current and future deployment of FSS. In addition, due to the large separation distances that may be necessary, the protection of FSS cannot always be managed at national level only but may require cross border coordination on a case-by-case basis as well as bilateral or even multilateral agreements between neighbouring countries.

Nevertheless, appropriate mitigation techniques could be considered during coordination on a case-by-case basis to facilitate coexistence between WBB and FS/FSS systems, both at national level and with the neighbouring countries. CEPT is developing recommendations for administrations to provide guidance for coordination between these services.

Studies on WBB LMP networks with no synchronisation to other WBB LMP nor to MFCN

For the various type of use-cases there may be various needs of UL/DL resources and different technologies, resulting in unsynchronised operation. The studies are mainly based on the following assumptions:

- no synchronisation between WBB LMP local networks in the frequency band 3.8-4.2 GHz;
- no synchronisation between WBB LMP local networks in the frequency band 3.8-4.2 GHz and MFCN networks below 3.8 GHz.

Indoor-only, outdoor-only and outdoor/indoor deployment scenarios have been considered. The analysis of in-band and adjacent band operation demonstrate the feasibility of unsynchronised WBB LMP operation in the frequency band 3.8-4.2 GHz, but a coordination process may be needed.

Some studies investigated if stricter out of band emission and receiver blocking levels of LMPs and frequency separation could reduce the need for coordination between 3GPP WBB LMP and MFCN (below 3.8 GHz).

The following technical conditions were investigated:

- 60 MHz frequency separation for WBB MP to accommodate MFCN BS receiver blocking;
- out of band emission level of -45 dBm/MHz conducted power or -40 dBm/MHz *e.i.r.p.* per BS (sector) below 3800 MHz for LP and MP non-AAS BS;
- out of band emission level of -45 dBm/MHz TRP or -50 dBm/MHz TRP per BS (sector) for MP AAS BS;
- WBB LMP receiver blocking level of -15 dBm below 3800 MHz for wanted signal level: P_ref_sens+6 dB.

In addition to the above technical conditions, studies identified possible components for the coordination process to ensure the co-existence between WBB LMP and MFCN (below 3.8 GHz) e.g.:

- pfd or field strength values at the WBB LMP local area network coverage border;
- physical separation between WBB LMP and MFCN Macro BSs;
- synchronisation or semi-synchronisation between MFCN and WBB LMP networks.

Adjacent channel coexistence for WBB LMP networks synchronised with other WBB LMP or MFCN

Adjacent channel coexistence between synchronised WBB LMPs networks, when operating based on 3GPP technical specifications, is considered covered by 3GPP/ETSI standardisation. This assumption also accounts for adjacent band operation of these WBB LMP networks in the frequency band 3.8-4.2 GHz synchronised with MFCN below 3.8 GHz. Such synchronised coexistence scenarios across the frequency band 3.4-4.2 GHz for non-AAS and AAS take part of possible coordination solutions for WBB LMP networks based on 3GPP technical specifications.

Semi-synchronised operation between WBB LMP and MFCN networks

Studies were performed for semi-synchronised operation with DL to UL modifications (which is a specific sub-case of semi-synchronised operation) for WBB LMP networks based on 3GPP technical specifications. Considering LMP base station to MFCN base station interference, it can ensure the same protection of MFCN base stations below 3.8 GHz as synchronised operation. This approach could be considered on a case-by-case basis. It could better facilitate coexistence with some limitations on UL/DL sequences on WBB LMP frame structure providing higher uplink capacity but with some possible constraints on WBB LMP uplink performance.

Other aspects regarding the shared use of the frequency band 3.8-4.2 GHz for WBB LMP networks

There is a balance to be struck between how much coordination an administration is able to carry out at a local level between WBB LMP networks and incumbent services, and how restrictive the harmonised technical conditions on WBB LMP need to be. Some of the technical conditions that were studied in this Report would reduce to a certain extent the amount of coordination needed when assigning frequencies to WBB LMP installations.

In order to facilitate and maximise the opportunities for the deployment of WBB LMP and to manage remaining coordination cases that may not be addressed by the harmonised technical conditions, administrations may want to complement certain aspects of their use of the frequency band 3.8-4.2 GHz at the national and/or the local level circumstances, for example on synchronisation, pfd limits, separation distance and/or frequency separation requirements.

CEPT plans to develop ECC Recommendations for administrations to provide guidance on the approach to coexistence in the band. There may be also a need to develop relevant cross-border recommendations.

Finally, the relevant study results in this Report could be used for developing guidelines to ensure protection and future evolution on a case-by-case basis of FSS receiving earth stations and of terrestrial fixed links sharing the band 3.8-4.2 GHz with WBB LMP, for managing co-existence between WBB LMPs and between WBB LMP and MFCN below 3.8 GHz.

ANNEX 1: EXAMPLE DEPLOYMENT SCENARIOS FOR LOCAL AREA NETWORKS IN THE FREQUENCY BAND 3.8-4.2 GHZ

A1.1 EXAMPLE OF COVERAGE OF AN INDUSTRIAL SITE

In addressing the EC Mandate tasks on the shared use of the 3.8-4.2 GHz band for local area networks, it is important to capture and address the wide range of use-cases and requirements of potential users, such as enterprises and local communities. This section presents an example use-case using a commercially available system in the 3.8-4.2 GHz frequency band, demonstrating how different Base Station (BS) deployment configurations can affect the coverage and the deployment complexity of local area networks in this frequency band for the coverage of a given industrial site. This does not consider sharing with in-band and adjacent band services.

A1.1.1 Use cases and deployment environments

The 400 MHz available in the 3.8-4.2 GHz frequency band could enable terrestrial wireless broadband systems for local area networks to provide a variety of services for various users, such as local communities as well as industrial connectivity and automation. The wide range of use-cases for different industrial and non-industrial environments require different technical conditions to maximise capacity and cost-efficient connectivity for both indoor and outdoor environments.

Some industrial use-case examples in 3.8-4.2 GHz band are listed below, for both indoor and outdoor environments:

- Indoors: connectivity for remote asset monitoring and control, IoT based automation, quality and control management, predictive maintenance, energy optimisation etc.;
- Outdoors: connectivity for logistics in ports, IoT services in agriculture, location tracking of moving assets, offshore operations etc.

A1.1.2 Coverage scenarios

An outdoor industrial use-case – coverage of an industrial site near the sea (of an area of approximately 4 km2) is considered. The impact of different BS transmit power levels and antenna heights to the received signal strength at various locations around the industrial site is evaluated. Four different deployment scenarios to provide coverage to the 4 km2 industrial area using a commercially available system are considered. Network deployment scenarios are provided in Table 54.

Table 54: Network deployment scenarios

Deployment Scenario	*e.i.r.p.*	BS height	Number of BS location	Number of Remote Radio Head (RRH)
1	44 dBm	15-40 m	7	14
2	24 dBm	15 m	8	13
3	24 dBm	25 m	8	13
4	24 dBm	5 m	43	110

The received signal strength (Reference Signal Received Power, RSRP) is simulated at a receiver height of 1.5 m above ground.

A1.1.2.1 Deployment Scenario 1

Table 55 summarises the parameters of a simulated local area network for deployment Scenario 1. Figure 8 presents the received signal strength, in terms of RSRP. To achieve optimal coverage under this scenario, the deployment of the same type of antennas at different heights between 15 and 40 metres were considered in network planning tool. The results indicate that by deploying 14 RRHs (Remote Radio Head) in 7 BS locations it is possible to provide adequate coverage (RSRP ≥ -105 dBm) for 75.3% of the whole industrial site considered, with 33.8% of it having RSRP ≥ -90 dBm.

Table 55: Network parameters for deployment Scenario 1

Parameter	Value
e.i.r.p.	44 dBm
Bandwidth	20 MHz
Base Station heights	15-40 m
Number of BS locations	7
Number of RRHs	14
Receiver height	1.5 m

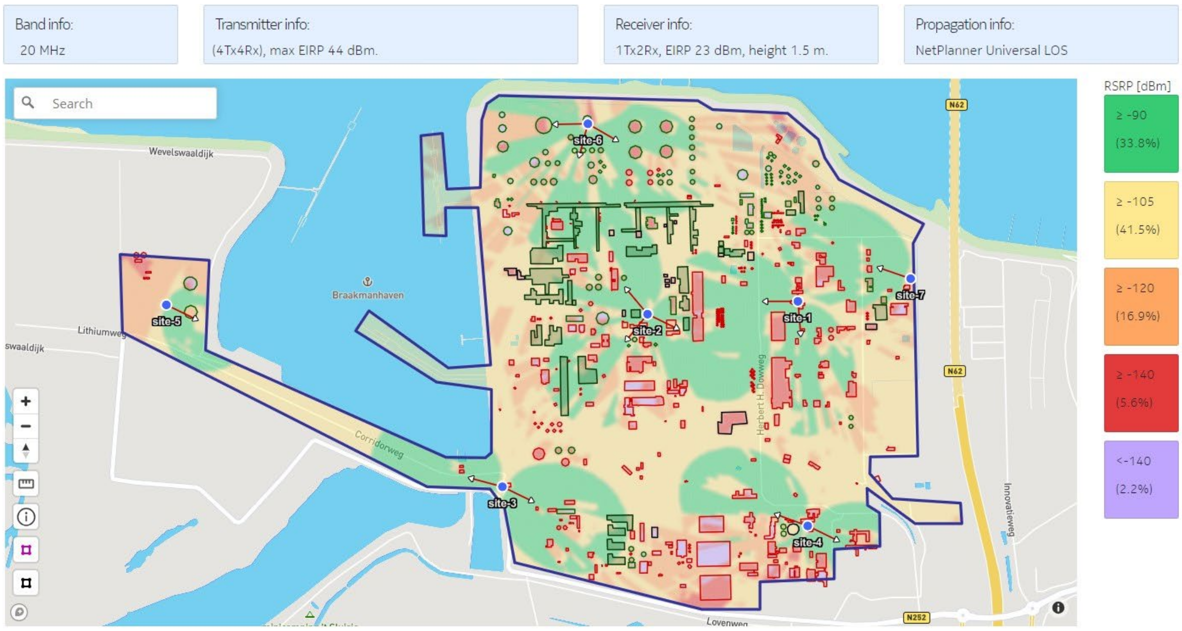

Figure 8: Simulated received signal strength (RSRP) of a local area network deployment as per the parameters of deployment Scenario 1

A1.1.2.2 Deployment Scenario 2

To illustrate the importance and the impact of the transmit power levels in planning the coverage of the same area, a comparison of the RSRP levels when deploying a local area network with lower BS power levels than those of deployment Scenario 1 and with fixed antenna heights at 15 m is provided.

Table 56 summarises the parameters of a simulated local area network for deployment Scenario 2.

Table 56: Network parameters for deployment Scenario 2

Parameter	Value
e.i.r.p.	24 dBm
Bandwidth	20 MHz
Base Station height	15 m
Number of BS location	8
Number of RRH	13
Receiver height	1.5 m

Figure 9 shows that by deploying 13 RRHs in 8 BS locations, adequate coverage (RSRP ≥ -105 dBm) is achieved only for 11.7% of the whole area considered, with 0% of it having RSRP ≥ -90 dBm.

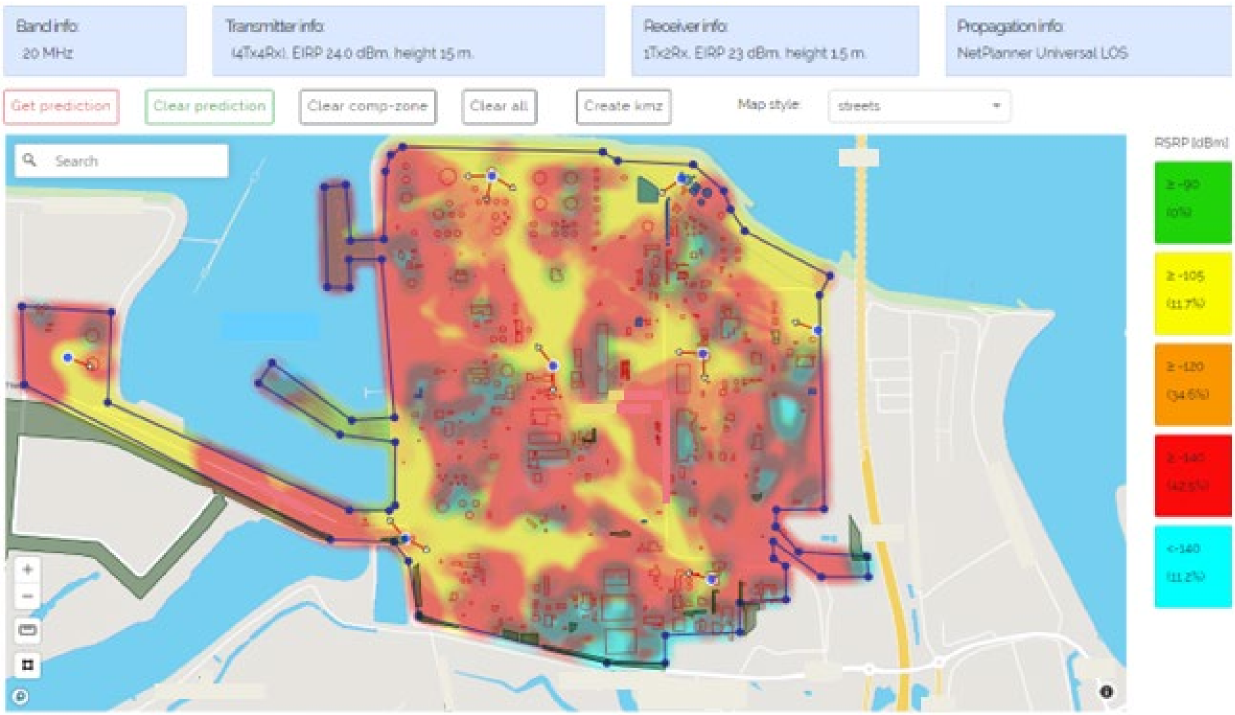

Figure 9: Simulated received signal strength (RSRP) of a local area network deployment as per the parameters of deployment Scenario 2

A1.1.2.3 Deployment Scenario 3

The same BS power level as in Scenario 2 (i.e. 24 dBm) with a height of 25 m was considered to assess the impact on coverage.

Even if higher antenna heights are considered, as shown in Table 57, the coverage provided to the area of the industrial site, as seen in Figure 10, did not improve.

Table 57: Network parameters for deployment Scenario 3

Parameter	Value
e.i.r.p.	24 dBm
Bandwidth	20 MHz
Base Station height	25 m
Number of BS location	8
Number of RRH	13
Receiver height	1.5 m

By deploying 13 RRHs in 8 BS location at 25 m height, adequate coverage (RSRP ≥ -105 dBm) is achieved for only 11.3% of the area, which is less than the coverage achieved in deployment Scenarios 1 and 2. This indicates that higher antenna heights, if considered independently, do not always present a solution for greater coverage. Therefore, having the possibility for deploying a range of antenna heights together with a range of BS transmit powers is a key aspect for finding an appropriate balance to overcome coverage challenges in industrial environments.

Figure 10: Simulated received signal strength (RSRP) of a local area network deployment as per the parameters of deployment Scenario 3

A1.1.2.4 Deployment Scenario 4

Deployment Scenario 4 evaluates the impact to received signal strength levels for a local area network with BSs at 5 m height transmitting at 24 dBm (parameters in Table 58). To improve the coverage of the industrial site area, the number of RRHs and BS locations has been increased, compared to the previous scenarios. Therefore, as seen in Figure 11, by deploying 110 RRHs in 43 locations, adequate coverage is provided for 49.8% of the area, with just 4.3% of it having RSRP levels greater than or equal to -90 dBm.

Table 58: Network parameters for deployment Scenario 4

Parameter	Value
e.i.r.p.	24 dBm
Bandwidth	20 MHz
Base Station height	5 m
Number of BS location	43
Number of RRH	110
Receiver height	1.5 m

Figure 11: Simulated received signal strength (RSRP) of a local area network deployment as per the parameters of deployment Scenario 4

A1.1.3 Additional considerations

The results of the coverage studies of a specific industrial site under the four different deployment scenarios provided in the previous section, highlight that power limits and heights for BS deployments will impact the ability of potential users on how to utilise the 3.8-4.2 GHz band for the wide variety of industrial applications. Different environments and use-cases will require different deployment characteristics for local area networks in order to accommodate the coverage and capacity demands.

Furthermore, the need for identifying numerous suitable locations to deploy an extended number of BSs in industrial environments, as well as the requirement of extensive network planning to provide adequate coverage, will impose additional challenges and cost implications to enterprises. This would increase the risk of reduced adaptation and ecosystem development in the band. These aspects are contradictory to the “low cost – easy deployment” concept of the use of the 3.8-4.2 GHz band for local area networks.

A1.1.4 Conclusions

Table 59 summarises the coverage percentages of the area of the industrial site with RSRP levels greater or equal to -105 dBm at the receiver height of 1.5 m, for the four different deployment scenarios.

Table 59: Summary of percentage of area with adequate signal strength

Scenario No.	*e.i.r.p.*	BS antenna height	Number of BS location	Number of Remote Radio Head (RRH)	Percentage of area with RSRP ≥ -105 dBm
1	44 dBm	15-40 m	7	14	75.3%
2	24 dBm	15 m	8	13	11.7%
3	24 dBm	25 m	8	13	11.3%
4	24 dBm	5 m	43	110	49.8%

Considering the wide range of industrial and local community type of use cases for the 3.8-4.2 GHz band, different applications will have different needs for coverage and capacity. Above section presented a specific use-case of demonstrating the coverage requirements of an industrial site area (~4 km2) for industrial operations. The results indicate that it is possible to provide adequate coverage for 75.3% of the area, using BSs with 44 dBm *e.i.r.p.* (14 RRHs in 7 locations) at heights between 15 and 40 metres. For the same area, when simulating BSs with lower power and fixed antenna heights (deployment Scenario 2 and 3), the coverage range was significantly reduced. Even when the coverage of the same area with a local area network of ~10x more RRHs in ~5x more BS locations (deployment Scenario 4) was simulated, the range of adequate coverage was ~50% less compared to that achieved with the BS power levels of deployment Scenario 1.

The transmit level and the technical deployment parameters of the BSs in the 3.8-4.2 GHz band should be able to accommodate the variety of use-cases for verticals in a cost-efficient and easy-implementable manner in the different deployment environments. As an example, the use of local area networks for mining applications would require greater coverage in isolated locations, where incumbent use of the band is highly likely to be absent.

Furthermore, current use of incumbents in the 3.8-4.2 GHz as well as in the adjacent bands presents significant variations and differences among the CEPT countries.

A1.2 LIVE TESTING BETWEEN WBB LMP PMSE USE CASE AND 5G MFCN

This section presents results of live testing between WBB LMP PMSE use case and 5G MFCN on the occasion of the Coronation of HM King Charles III in May 2023 in a small area of London. The BBC, in association with Neutral Wireless, used two 40 MHz bands blocks centred at 3835 MHz and 3875 MHz to implement a multicell network covering the procession route of 1 km. The guard band with the nearest mobile allocation at 3760 - 3800 MHz was 15 MHz. In order to accommodate a low latency constant bitrate encoder testbed while preserving the A/B spectrum reuse channel plan, an additional 40 MHz channel centred at 3915 MHz, still covered by the initial testing licence, was also used. Each cell used the uplink biased 2:7 TDD frame structure using a 40 MHz channel with SISO transmit. Downlink transmission powers were configured within the medium-power licence specification. An additional network designed to support low latency UHD camera feeds using constant bitrate encoders was deployed. This cell was configured to run the lower-latency 1:2 TDD frame structure, which significantly reduces latency and network jitter. While low latency was not the design goal for the newsgathering contribution network, one vendor reported a packet round trip time (RTT) of 37 ms from their encoder on The Mall to their data centre located in France; the transit time of 19 ms includes the 5G network (not optimised for latency), fibre backhaul and public internet connectivity and is impressive.

Over 20 broadcast camera crews successfully shared this network and reported stable performance. These devices were loaded with two SIM cards for the NPN, but also various SIMs for the public MNOs. The devices worked as expected, evenly splitting the stream bitrate over the public and private networks. However, as the crowds gathered and the public networks became congested, the device adapted to push the majority of the data over the private network. Users reported uninterrupted handover and continuous bitrate when walking the length of The Mall, with usable coverage found in unexpected and unplanned locations. The response from broadcasters was unanimously positive.

A1.2.1 Introduction

The opportunities presented by 5G Non-Public Networks (NPNs) for programme making have been the subject of several collaborative research projects. Mobile spectrum has traditionally been available only for public network as spectrum has been scarce and expensive. Identifying the value of smaller private networks, a block of spectrum in the 3.8-4.2 GHz has been made available in the UK by Ofcom for Shared Licence Access (SLA). This forms a subset of the 5G mobile band n77 for which commodity 5G terminal equipment is now readily available.

A1.2.1.1 Advantages of 5G compared to traditional Wireless PMSE

Wireless Equipment for Programme Making and Special Events (PMSE) has been in common use since 2002. Implementations are generally derived from DVB-T COFDM technology deployed in custom frequency bands with unified tuning ranges. 5G also uses COFDM technology but can potentially benefit from recent advances including MIMO. Unlike traditional digital wireless cameras links, 5G provides native bi-directional TCP/IP network connections which integrate easily with modern IP studio architectures. The radio modems operate in wider bandwidths enabling higher throughput for enhanced services like UHD.

Unlike conventional PMSE, where separate radio devices are deployed for audio and video applications in forward and reverse directions for each connecting device, 5G allows a single base station to support multiple connections which can including audio, video, camera control, tally light or virtually any service that can be encapsulated in IP. The 5G radio modems do not require modification for use in a custom PMSE band as the SLA spectrum is natively supported by existing bonded SIM devices routinely used for Content Production. These aspects reduce complexity and cost when compared to traditional wireless PMSE techniques.

A1.2.2 Previous 5G trials

Several 5G trials have taken place since 2021, including the IBC Media Accelerator Programme 2022 Project of the Year, live contribution into coverage of the funeral of HM The Queen and the Birmingham Commonwealth Games and the technology is steadily maturing. Trials have typically used one or two macro cells, but the cell handover mechanism in mobile technology allows the network coverage to be readily extended by deploying additional radio units. The use of software-defined radio for the base station deployments have been a feature of most trials, with equipment usually supplied by small vendors. For programme making, the uplink performance is the key requirement, so networks must operate in the 5G standalone (SA) mode; non-standalone (NSA) 5G networks use 4G technology for the uplink and have insufficient capacity for video PMSE applications.

Networks in the n77 band use time division duplex (TDD), which facilitates the wide tuning range (3.8-4.2 GHz). The TDD parameters can be tuned for optimum performance, which usually involves biasing the link for uplink-heavy operation, whereby the majority of radio slots are allocated for the video traffic sent by the mobile video terminals.

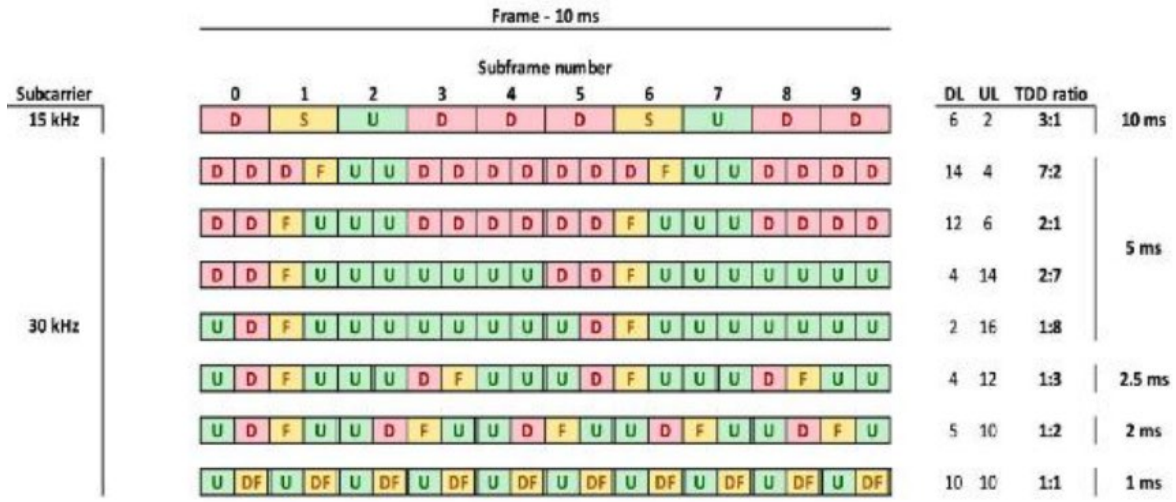

Figure 12: 5G TDD configurations

Public mobile network operators are restricted to using a 3:1 (downlink:uplink) ratio to ensure that networks transmit and receive at the same time and avoid interfering with one another. Of the 10 subframes that make up a single 10 ms frame, there are six for downlink, two for uplink, and two 'special' subframes, during which the transition from transmit to receive takes place. 5G new radio (NR) supports more numerologies than LTE, and when using 30 kHz subcarriers (available in the midband) there are 20 time slots, allowing for 14:4 (7:2), increasing downlink bandwidth while remaining compatible with the 3:1 requirement. This restriction does not currently extend to the n77 band.

A typical PMSE application will instead use a reversed TDD ratio of 2:7, whereby 14/20 radio slots are allocated for uplink and 4/20 for the downlink. This can be pushed further to 1:8 to maximise uplink throughput, or reduced to 1:2 or even 1:1 to minimise latency. The special subframes, which were restricted to nine symbol configurations in LTE, can be defined arbitrarily in 5G NR, and are known as 'flexible' slots. They contain a mixture of uplink and downlink symbols, separated by gap symbol(s). The lowest-latency 1:1 frame structure makes use of the flexible slot to provide the uplink or downlink (for example, 'DF' in Figure 12).

A1.2.2.1 5G network capacity

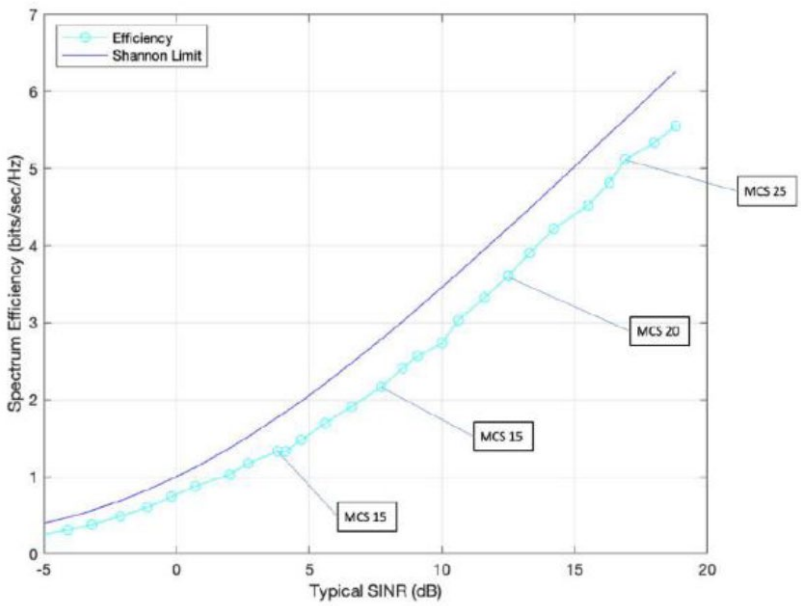

Figure 13: 5G NR MCS and capacity vs SINR

Like all radio systems, 5G is constrained by the Shannon-Hartley theorem and capacity is function of the signal to interference and noise ratio (SINR) on the radio link. At high SINR a higher order modulation and coding scheme (MCS) can be supported with a reduced level of forward error correction; for 5G NR links, modulation up to 256-QAM in the Physical Uplink Shared Channel (PUSCH) is defined with 2x2 MIMO. Practical implementations tend to be limited to 64-QAM and many commercial terminals have a single antenna, limiting the system to SISO operation. The typical relationship between SINR, MCS and capacity is shown in Figure 13.

A1.2.2.2 Bitrate requirements for ENG Video streams

The bitrate requirement for broadcast content video distribution is a matter for debate. Ideally, the streams would be lightly compressed to minimise cascading artefacts in the codec chains within a typical broadcast system. This would advocate the use of a mezzanine video codec with a bitrate requirement of around 190 Mb/s for HD. In practice this is far too high for practical 5G implementations, and most video links will make use of H.264 (AVC) or H.265 (HEVC) compression. The bit rate requirements for artefact-free video will be dependent on the nature of the content. Noise-like material with fine-scale detail (such as running water, smoke and large crowd scenes with considerable motion) is particularly hard to encode, but talking heads against near-stationary backgrounds are much easier as there is considerable temporal and spatial redundancy that can be exploited by the codecs. The precise requirements are usually evaluated by expert viewing panels on specially selected test sequences. This is a time-consuming process. The use of perceptual codec evaluation methods, such as VMAF (Video Multi-Method Assessment Fusion), provide useful indicators and a set of hardware-accelerated H.265 encoders were evaluated ahead of the Coronation event. For simple material like the EBU “park dancer” sequence (1920x1080p50, 8-bit 4:2:0 chroma), H.265 implementations tend to give similar results. VMAF scores exceeding 90 at bitrates as low as 4Mb/s can be achieved. Demanding material, like the SVT open content “crowd run”, requires higher bit rates and exaggerates the implementation differences between vendors; up to 20 Mb/s can be necessary to achieve VMAF geometric mean scores exceeding 90. This is summarised in Figure 14, where three codec implementations are compared with a software reference (FFmpeg).

Interlaced HD video content regularly used for broadcast halves the pixel rate compared to the progressive test sequences. A codec rate ceiling of 12 Mb/s was set for the Coronation News contributions, with codecs adapting automatically according to the available bandwidth and network conditions. Many broadcasters either chose to set their maximum bitrate lower or were restricted by software licences on their devices.

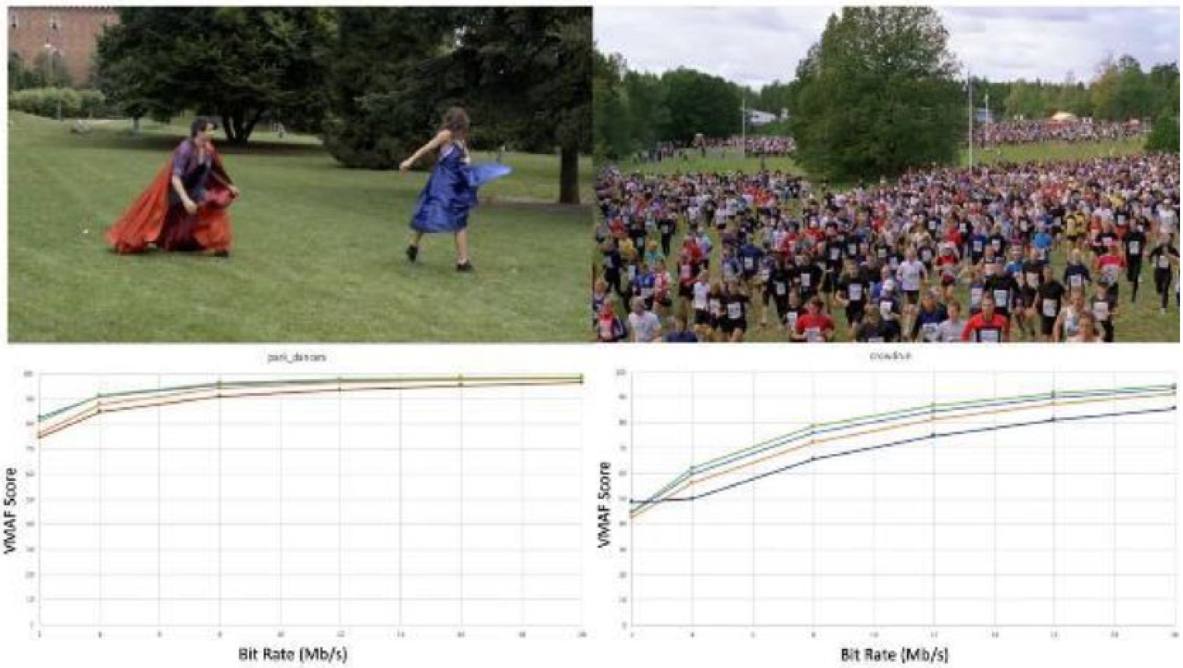

Figure 14: Video quality vs Bitrate for typical H.265 codecs

A1.2.3 Electronic news gathering using mobile networks

Electronic News Gathering (ENG) increasingly makes use of mobile systems utilising 3G and 4G bonded SIM devices in preference to the traditional private point-to-point radio links. The required uplink traffic for live HD broadcast video can, under normal network load, usually be carried on mobile network operator infrastructure. Systems are now readily available from a number of vendors that bond multiple MNO connections for resiliency and reduced individual network resources, which are cost effective and convenient. Since the mobile capacity is provided on a best-effort basis, bonded systems can fail at large events with big crowds as the mobile networks are likely to be congested by the volume of traffic.

A1.2.4 News links for the coronation of King Charles III

Previous experience suggested that bonded 3G/4G systems would not be reliable for the Coronation, and investigations and trials to deploy a private 5G standalone network in the n77 band started in March 2023. Spectrum surveys revealed that the target spectrum band was relatively clear and that an SLA assignment of 100 MHz was obtained from Ofcom. A commercial bonded cellular link was upgraded to support operation on a 5G Standalone Non Public Network and initial tests at Canada Gate confirmed stable operation over a cell radius of up to 350 m.

A1.2.4.1 5G coverage planning

To enable coverage along the 1 km length of The Mall, the road running between Buckingham Palace and Admiralty Arch, a network of four cell sites was planned using 100 MHz of radio spectrum, following the initial tests.

Site 1 provided blanket coverage in the vicinity of the Palace using an omni antenna, while sites 2, 3 and 4 used panel antennas pointing in opposite directions deployed at the fixed camera platforms. The coverage prediction for the downlink received signal reference power (RSRP) is shown in Figure 15. Site 1 used a trailer mast in the media compound with antennas rigged at 8 m. Sites 2, 3 and 4 were camera positions along The Mall with antennas at 4 m.

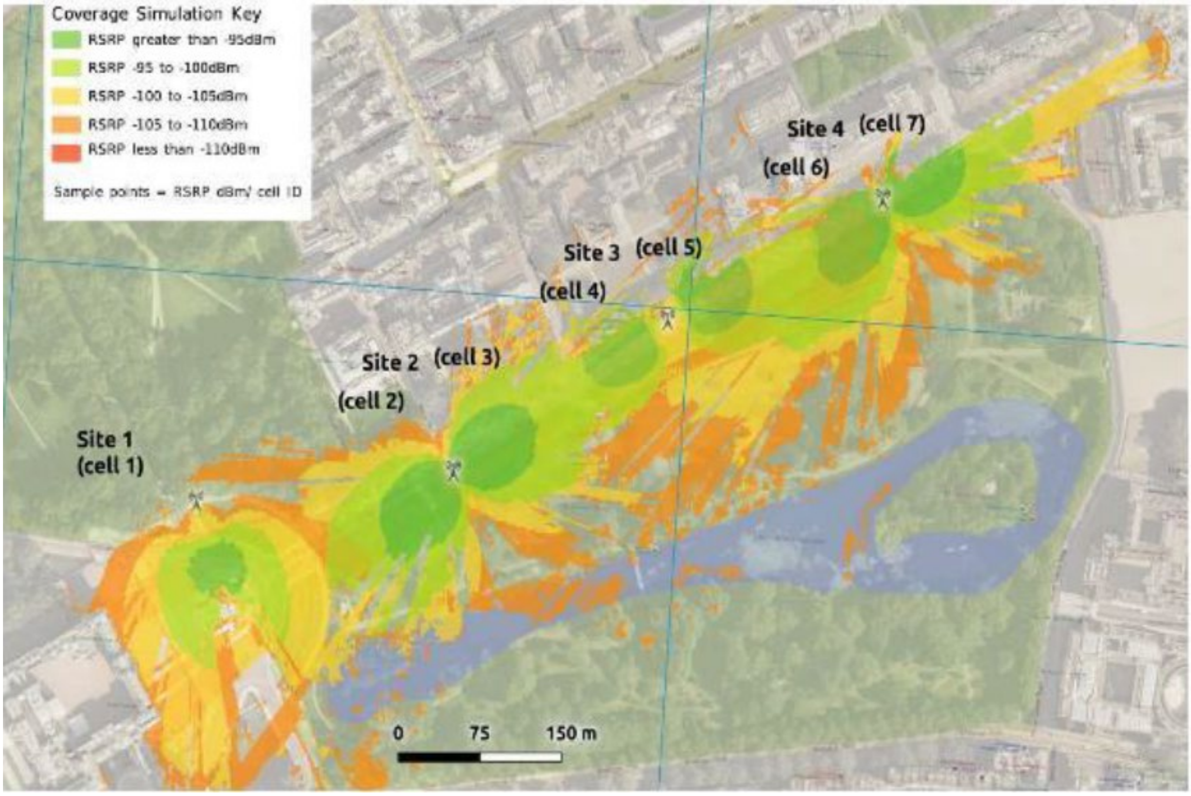

Figure 15: Predicted RSRP values for the 5G network

A1.2.4.2 5G network deployment

Rigging for the Coronation began one week prior to the event. Cell sites with remote radio heads (RRH) were connected back to the base band units (BBU) at the media compound in Green Park using 10 Gb/s armoured fibre (1310 nm, single mode). Tuning of the network began on 3 May, 3 days ahead of the Coronation. Cell 1 was complemented by an addition cell in non-overlapping radio channels. The lower frequency channel was configured in a low latency mode to support tests on experimental, low-latency UHD cameras from BBC R&D and Sony. The antenna arrangements for the cell sites are shown in Figure 16.

Figure 16: Antenna arrangements for Cell 2 ("The Mall") and Cell 1 ("Green Park")

A1.2.4.3 Spectrum measurements

A block of radio spectrum was initially allocated between 3835 and 3935 MHz, which was used for the initial trials as two 50 MHz channels to facilitate a standard A/B channel reuse plan along The Mall. Ofcom subsequently re-assigned spectrum, reducing the bandwidth to a pair of 40 MHz blocks centred at 3835 MHz and 3875 MHz. This was understood to be considered necessary to protect against potential interference to a nearby C-band satellite receiver site. This change though reduced the guard band with the nearest mobile allocation at 3760-3800 MHz from 35 MHz to 15 MHz. In order to accommodate a low latency constant bitrate encoder testbed while preserving the A/B spectrum reuse channel plan, an additional 40 MHz channel centred at 3915 MHz, still covered by the initial testing licence, was also used.

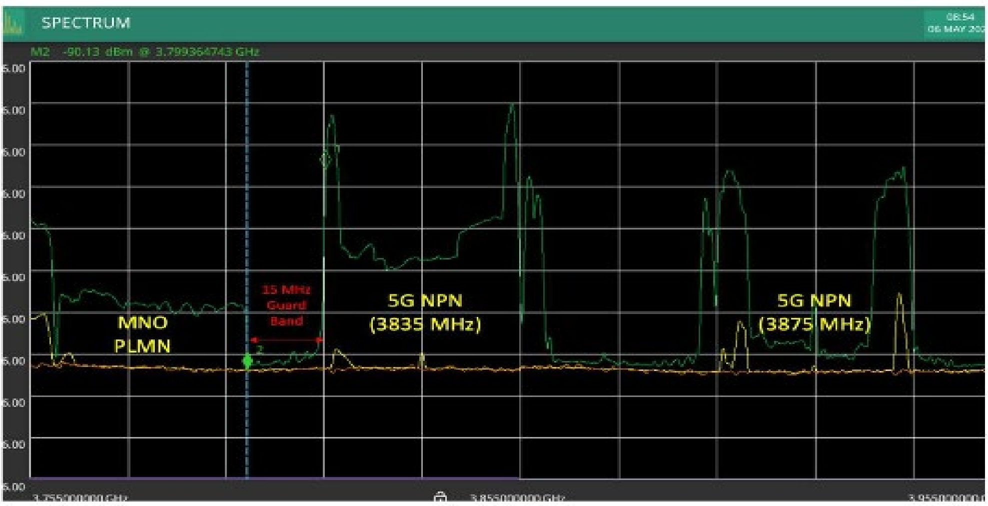

Figure 17: Radio spectrum of 5G NPN and Mobile services measured at Green Park

A1.2.4.4 Network configuration

The network was designed to provide seamless coverage along The Mall, from Admiralty Arch to Buckingham Palace. Four antenna sites were identified to host seven cells, with a classic A/B channel plan used for spectrum reuse. The network was run on a custom-built rack located in the BBC News area of the media compound. To provide hardware redundancy, each site (hosting two cells) was hosted on individual hardware. Cell neighbours were fully specified to enable inter-gNB handover. Each cell used the uplink biased 2:7 TDD frame structure using a 40 MHz channel with SISO transmit. For the uplink, dual channel receive diversity was used to receive and combine both +45° and -45° polarisations simultaneously. Downlink transmission powers were configured within the medium-power licence specification.

The 2:7 TDD frame structure implemented across all cells was capable of supporting 4 bits/s/Hz, resulting in a capacity of 160 Mb/s for each 40 MHz cell. Across the seven cells for the main network, over 1 Gb/s of wireless connectivity was provided along The Mall to the broadcasters, at a time when the public mobile networks were saturated despite the provision of additional temporary cells. We note that, despite this wireless capacity, internet backhaul over the BBC Broadcast Contribution Network (BCN) to New Broadcasting House was limited to 450 Mb/s.

A1.2.4.5 Cell Channel TX power

Table 60: Cells configurations

Cell	Channel	TX power (dBm)	TX gain (dBi)	TX mode	RX gain (dBi)	RX mode
1	C	26	12	SISO	12	2x diversity
2	B	33	17.7	SISO	17.7	2x diversity
3	A	33	12	SISO	12	2x diversity
4	B	33	17.7	SISO	17.7	2x diversity
5	A	33	12	SISO	12	2x diversity
6	B	33	17.7	SISO	17.7	2x diversity
7	A	33	12	SISO	12	2x diversity
LL	A	26	3	2x MIMO	3 + 12	4x diversity

Note: Channels: A – 3815-3855 MHz [ARFCN 655666]; B – 3855-3895 MHz [ARFCN 658334]; and C – 3895-39351 MHz [ARFCN 661000].

An additional network designed to support low latency UHD camera feeds using constant bitrate encoders was deployed at Canada Gate alongside cell 1. This cell was configured to run the lower-latency 1:2 TDD frame structure, which significantly reduces latency and network jitter. This used a low gain omni-directional antenna for downlink transmission, allowing for connectivity within the media compound, with additional receive diversity on a high gain sector antenna facing the area outside the Palace. Since the Sony Xperia mobile handsets and modems used support MIMO, this cell was configured to provide 2x downlink MIMO.

A1.2.4.6 Coverage validation

The coverage was checked by making mobile measurements at ground level using a smart phone running an RSRP logging app and using a 5G modem interfaced to a Raspberry Pi equipped with a GPS receiver. Paddle-type monopoles (~2 dBi) were used on the Raspberry Pi modem which returned signal strength values typically 12 dB greater compared to the phone. This would be consistent with the phone having an effective antenna gain of approximately –10 dBi.

Due to logistical complications onsite, the position of site 3 was moved from the intended camera platform to a BBC radio booth located nearby. In addition, the omni-directional antenna used for cell 1 at Canada Gate, which provided blanket coverage over the media compound during testing, was changed to a sector antenna the day before the event, as the coverage overlap with cell 2 was interfering with cell handover. RF simulations were repeated to model coverage on Coronation Day itself.

Figure 18 shows the predicted downlink signal strength, with logging data collected on a mobile handset overlaid. The agreement between the predictions and on-the-ground measurements is excellent, taking into account the gain of the handset.

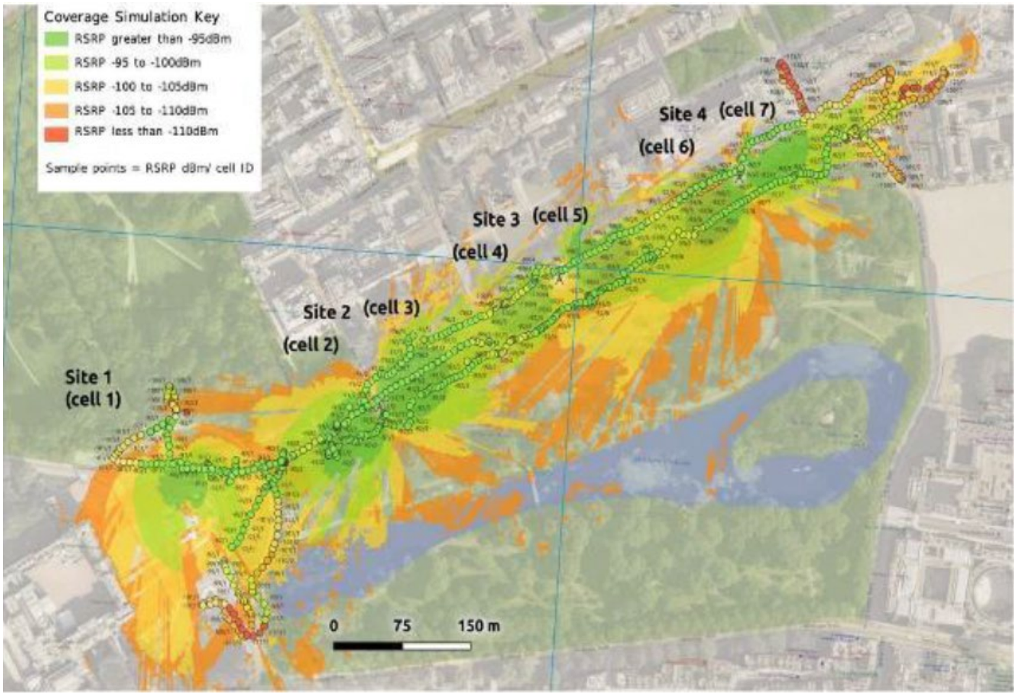

Figure 18: Predicted and measured RSRP values for the 5G network

A1.2.4.7 Observed performance and throughput

In the days leading up to the Coronation, bonded cellular units started live news contributions. These devices were loaded with two SIM cards for the NPN, but also various SIMs for the public MNOs. The devices worked as expected, evenly splitting the stream bitrate over the public and private networks. However, as the crowds gathered and the public networks became congested, the device adapted to push the majority of the data over the private network.

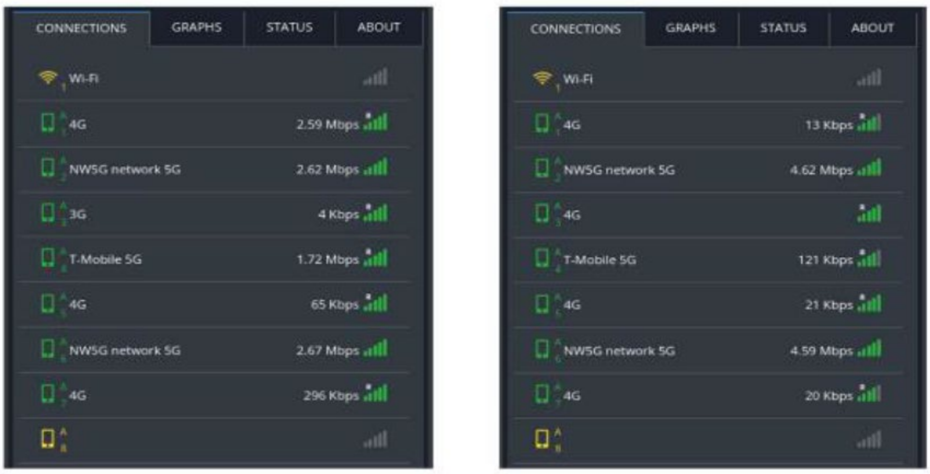

Figure 19: Monitoring screens from typical bonded cellular equipment

While low latency was not the design goal for the newsgathering contribution network, one vendor reported a packet round trip time (RTT) of 37 ms from their encoder on The Mall to their data centre located in France; the transit time of 19 ms includes the 5G network (not optimised for latency), fibre backhaul and public internet connectivity and is impressive.

Users reported uninterrupted handover and continuous bitrate when walking the length of The Mall, with usable coverage found in unexpected and unplanned locations, such as Duke of York Steps and outside Horse Guards. The response from broadcasters was unanimously positive.

Over the course of the week, over 60 devices accessed the NPN.

The 5G SA network carried 54.4 GB of uplink video, with the majority being on Friday 5 May and Saturday 6 May. On Coronation Day itself, 24.8 GB of video data were streamed – over 6 hours 50 minutes of continuous video at an average of 8 Mb/s. Since live news contributions typically do not air at the same time across broadcasters, the peak uplink was only 80 Mb/s, well within the capabilities of the network (see Figure 20). In addition, over 2.3 GB of downlink (return audio communications and radio contributions) were delivered to devices.

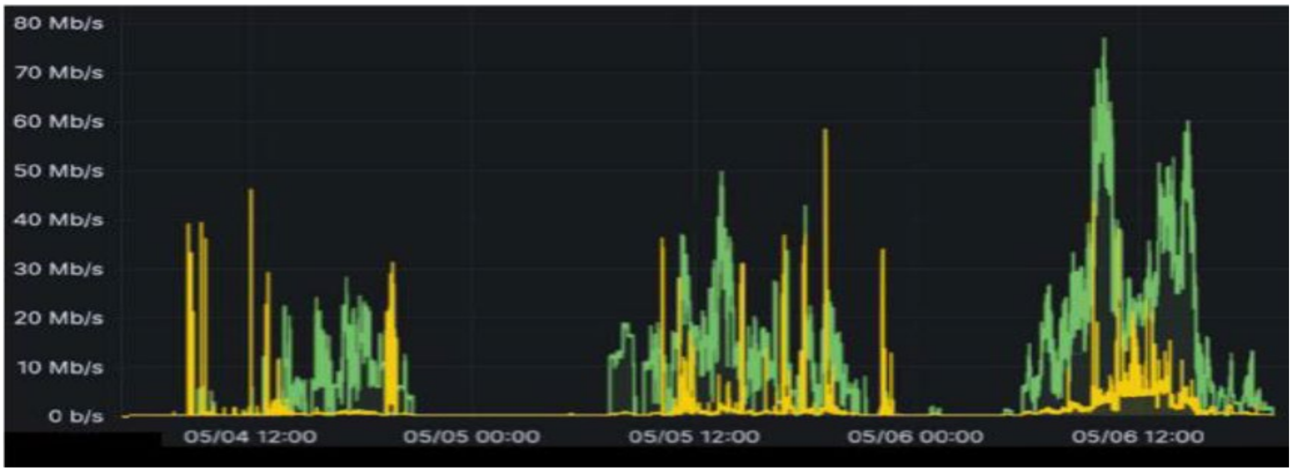

Figure 20: Network traffic from 5G network to backhaul

Testing of the complementary low-latency cell within the media compound resulted in excellent performance. An experimental low latency UHD camera operating at 55 Mb/s (CBR) was attached to the network using a handset configured as a USB connected 5G modem with HD return video. A novel core was used with dynamic on-the-fly QoS reconfiguration using the Network Exposure Function to alter bearers and priority on a per SIM basis.

The collocation of antennas for networks running different TDD configurations led to poor performance of the low-latency cell in front of the Palace which was affecting handover with cell 2. The decision was taken to match the 2:7 TDD structure and GPS lock the two networks. The cell performed as expected, providing an additional 160 Mb/s connectivity for low-latency devices, including a BBC R&D prototype. The increased network latency and jitter required increased data buffers to facilitate stable performance, with the UHD camera reporting a glass-to-glass latency of 115 ms.

A1.2.5 Conclusions

A 5G NPN was successfully deployed for the Coronation of King Charles III. The network was used to support news teams sending 1080i and 1080p streams from The Mall at bitrates in the range 6-12 Mb/s, typically using H.265 compression. Radio spectrum around 3.9 GHz was used in two 40 MHz channels to implement a multicell network covering the procession route of 1 km. Over 20 broadcast camera crews successfully shared this network and reported stable performance. The reported experience was positive, and the network allowed for the delivery of live content that could not have otherwise been broadcast. The sharing of a single non-public network to support a number of international broadcast contributions is considered a very efficient use of radio spectrum, particularly for a major national event where other PMSE spectrum was fully utilised for the main event coverage.

This trial of 5G NPN technology in standalone mode demonstrates a useful application of the Shared Licence Access scheme developed by Ofcom. Modems that can access the 5G n77 band are readily available and vendor equipment using Software Defined Radios running on commodity computers provide cost effective infrastructure.

The 5G standalone network technology is relatively new and has not been widely deployed by Mobile Network Operators (MNOs). Some issues with modem attachment delays were encountered, which appear to depend upon the firmware release used by the modem vendor. The cell handover characteristics of mobile are generally inferior to existing COFDM diversity receiver installs using maximum ratio combining but are fine for News feeds and will improve as the technology develops. Modems operation in MIMO is not yet available and early implementations do not appear to be sufficiently stable to support video streaming. Enhancements to the implementations are anticipated to address these short comings and further improve spectrum efficiency.

As 5G develops further, it is anticipated that the PMSE use case will continue to expand, limited only by achieving timely access to suitable spectrum, particularly in 3.8-4.2 GHz. This will facilitate the transition from traditional broadcast technology to IP operation supported by cloud services.

ANNEX 2: LIST OF REFERENCES

[1] ECC Report 362: “Compatibility between mobile or fixed communications networks (MFCN) operating in 3400-3800 MHz and wireless broadband systems in low/medium power (WBB LMP) operating in the frequency band 3800-4200 MHz with Radio Altimeters (RA) operating in 4200-4400 MHz”

[2] ECC Recommendation (20)03: "Frame structures to facilitate cross-border coordination of TDD MFCN in the frequency band 3400-3800 MHz" approved October 2020

[3] ERC Report 025: "The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz", approved June 1994, latest editorial update March 2024

[4] ECC Decision (11)06: "Harmonised frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the band 3400-3800 MHz", approved December 2011, latest amended October 2018

[5] ERC Recommendation 12-08: "Harmonised radio frequency channel arrangements and block allocations for low, medium and high capacity systems in the band 3600 MHz to 4200 MHz" approved 1997, revised on 14 May 1998, latest amended May 2024

[6] Recommendation ITU-R F.382: "Radio-frequency channel arrangements for fixed wireless systems operating in the 2 and 4 GHz bands"

[7] Report ITU-R RA.2507: "Technical and operational characteristics of the existing and planned Geodetic Very Long Baseline Interferometry"

[8] Commission Implementing Decision (EU) 2019/235 of 24 January 2019 on amending Decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3400-3800 MHz frequency band

[9] ECO Report 03: "The Licensing of "Mobile Bands" in CEPT", version of 19 February 2024

[10] EU 5G Observatory Report, https://5gobservatory.eu/report-19-october-2023

[11] Report ITU-R M.2039: "Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses"

[12] ETSI TS 103 636-2 (V1.4.1, 2023-01): "DECT-2020 New Radio (NR); Part 2: Radio reception and transmission requirements; Release 1"

[13] ETSI TR 103 943 V1.1.1 (2024-01): “System Reference document (SRdoc); DECT-2020 NR technology operating in frequency bands below 6 GHz”

[14] Recommendation ITU-R P.2108: “Prediction of clutter loss”

[15] Recommendation ITU-R P.1546: “Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 4 000 MHz”

[16] Recommendation ITU-R P.1238: “Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 450 GHz”

[17] Recommendation ITU-R P.2109-2 (08/2023): “Prediction of building entry loss”

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

[19] Recommendation ITU-R F.758-7: “System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference”

[20] Report ITU-R M.2292-0 (12/2013): “Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses”

[21] Recommendation ITU-R P.2001-4 (09/2021): “A general purpose wide-range terrestrial propagation model in the frequency range 30 MHz to 50 GHz”

[22] Ofcom, United Kingdom: “Enabling opportunities for innovation”

[23] Recommendation ITU-R M.2101: “Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies”

[24] 3GPP TR 38.803: “Study on new radio access technology: Radio Frequency (RF) and co-existence aspects”

[25] Recommendation ITU-R F.1336: “Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz”

[26] Recommendation ITU-R F.635: “Radio-frequency channel arrangements based on a homogeneous pattern for fixed wireless systems operating in the 4 GHz (3 400-4 200 MHz) band”

[27] Recommendation ITU-R P.382: “Radio-frequency channel arrangements for fixed wireless systems operating in the 2 and 4 GHz bands”

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