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Licensing and coexistence of WBB services in the 3.8-4.2 GHz band

A report from Plum Consulting

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An Coimisiún um Rialáil Cumarsáide
Commission for Communications Regulation
1 Lárcheantar na nDugaí, Sráid na nGildeanna, BÁC 1, Éire, D01 E4X0.
One Dockland Central, Guild Street, Dublin 1, Ireland, D01 E4X0.
Teil | Tel +353 1 804 9600 Suíomh | Web www.comreg.ie

Licensing and coexistence of WBB services in the 3.8-4.2 GHz band

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Val Jervis
Selcuk Kirtay
Richard Rudd
Sarongrat Wongsaroj

About Plum

Plum offers strategy, policy and regulatory advice on telecoms, spectrum, online and audio-visual media issues. We draw on economics and engineering, our knowledge of the sector and our clients' understanding and perspective to shape and respond to convergence.

About this study

This study for ComReg examines licensing options and technical coexistence constraints for low and medium power (LMP) wireless Broadband (WBB) networks in the 3.8-4.2 GHz band.

It will provide an input to the proposed consultation on a licensing regime for such networks, set out in ComReg's Radio Spectrum Management Operating Plan for the period 2025-2028.

Plum Consulting
10 Fitzroy Square
London
W1T 5HP

T +44 20 7047 1919
E info@plumconsulting.co.uk

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1 Background

1.1 Introduction

ComReg's 'Radio Spectrum Management Operating Plan' for the period 2025-2028[1] includes an action for ComReg to consult on a licensing regime for Wireless Broadband low- and medium-power (WBB LMP) networks in the 3.8-4.2 GHz band.

To inform proposals for such a regime, ComReg has contracted Plum to provide independent expert advice on the following.

- Benchmarking and analysis of approaches adopted or proposed for licensing of WBB LMP networks in other countries.
- Potential approach(es) for how the band could be "presented" for WBB LMP network licensing in Ireland taking into account the potential use, services and requirements of interested parties.
- Coexistence technical analyses:
  - The coexistence of WBB LMP networks in the band and applicability to Ireland.
  - The coexistence between WBB LMP networks and WBB ECS (MFCN)below 3800 MHz, noting the possibility of deploying equipment that meets the 3GPP or DECT standards.
  - The coexistence between WBB LMP networks and radio altimeters above 4200 MHz.
  - The coexistence between WBB LMP networks and Fixed Satellite Earth stations (FSES).

This report presents Plum's analysis of these issues, to form an input to ComReg's consultation process.

1.2 The 3.4 – 4.4 GHz band in Ireland

The simplified figure below gives an outline of spectrum use in the 3.4 - 4.4 GHz frequency range in Ireland.

It should be noted that this spectrum range is often informally referred to as 'C-band', a term originating with the military. The boundaries of 'C-band' vary with context (satellite, terrestrial, IMT) and may encompass a much wider spectrum range between about 3 GHz to 8 GHz.

[1] ComReg Document 24/99a

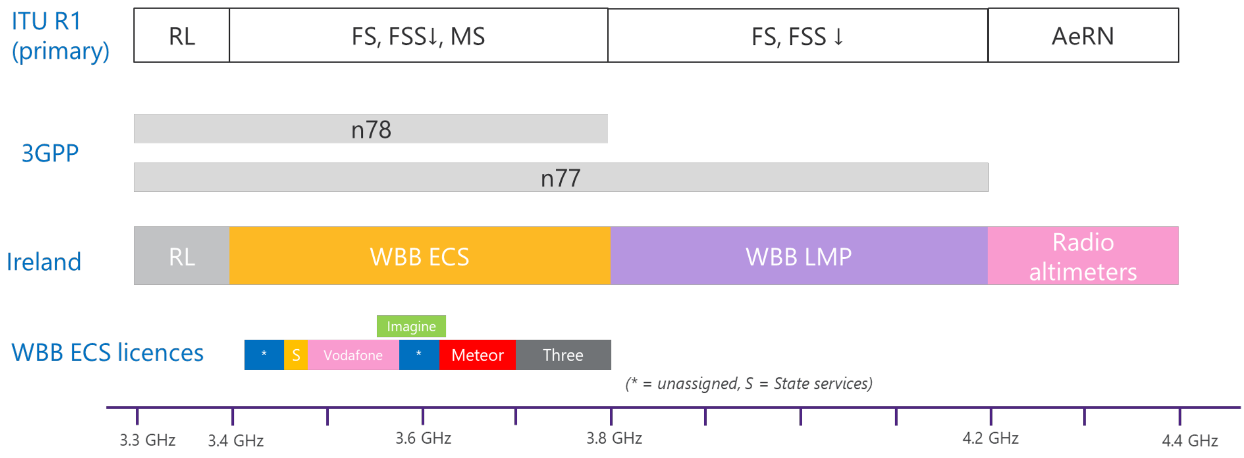

Figure 1.1: Simplified diagram of spectrum allocations and assignments in C-band

It can be seen from Figure 1.1 that, below 3.8 GHz, the band 3.4-3.8 GHz is used for WBB electronic communication services ("ECS"), with Three Ireland licensed and operating services in the upper 100 MHz. The 3.4-3.8 GHz band is for TDD operation and there are inter-licence synchronisation procedures that all the licensees are bound by.

Above 4.2 GHz the band is allocated to Aeronautical Radionavigation and used by radio altimeters.

While the 3.8-4.2 GHz band is being harmonised for WBB LMP services as discussed below, the 3.8 – 4.2 GHz band is allocated to the Fixed Service (FS) and Fixed Satellite Service (FSS) but the fixed links have never been assigned in Ireland and there are currently no licensed satellite Earth stations.

The spectrum at 3.4 to 4.2 GHz has been harmonised for use by systems employing time-division duplex (TDD), where uplink and downlink transmissions occupy alternate time-slots rather than using separate frequencies. If services in adjacent spectrum or adjacent locations are not synchronised, significant interference may result. Synchronisation is discussed in Appendix H.

1.3 WBB LMP harmonisation of the 3.8 - 4.2 GHz band

In November 2024, the ECC published Decision (24)01 [B7], giving harmonised technical conditions for the shared use of the 3.8-4.2 GHz band by WBB LMP. This Decision takes into account the technical studies summarised in CEPT Report 88 [B6] and ECC Reports 358 [B4] and 362 [B5].

These 'Least Restrictive Technical Conditions' are technology neutral and leave the specific details of assignment and licensing to individual administrations. The following technical conditions are specified:

- The band plan is for time-division duplex (TDD) operation
- The channel raster is based on a minimum block size of 5 MHz, which may be combined to obtain wider channels
- Maximum base-station in-block EIRP spectral density shall be 18 dBm/5 MHz (low-power) and 38 dBm/5MHz (medium power) for channel bandwidths greater than 20 MHz. For channel bandwidths less than 20 MHz, an absolute maximum power of 24 dBm/channel (low power) or 44 dBm/channel (medium power) shall apply.

- Unwanted emission levels above 4200 MHz are defined to protect radio altimeter operation. For non-AAS base stations the EIRP limit is 11dBm/5 MHz per cell, falling to 8dBm/5 MHz above 4205 MHz. For AAS base stations, the corresponding TRP limits are 1dBm/5 MHz falling to -3dBm/5 MHz above 4205 MHz.
- Maximum terminal TRP shall be 28 dBm, with mandatory transmission power control.
- For fixed terminals, other limits may be defined at national level, provided that protection of in-band and adjacent band incumbent services and any cross-border obligations are fulfilled.

Other parameters and coordination and assignment strategies are within the remit of individual administrations.

The European Commission is working towards the adoption of an EC Implementing Decision setting out harmonised technical conditions for WBB LMP services in this band. The European Commission Radio Spectrum Committee has discussed a number of drafts with the most recent publicly available draft (Revision 2) [B12] stating that "*by 30 September 2026, Member States shall designate and make available on a non-exclusive basis the 3 800 – 4 200 MHz frequency band for WBB LMP systems in compliance with the harmonised technical conditions set out in the Annex*". The annex of the draft document essentially re-states the technical conditions set out in ECC Decision (24(01) given above.

1.4 Use cases

According to a recently published BEREC report[2], examples of private network deployments according to national regulators include

- automation and digitalisation of underground mining operations;
- seaport terminal and energy-efficient cargo handling;
- a neutral host indoor mobile connectivity network solutions;
- ultra-low latency smart manufacturing;
- secure logistics;
- specific business activities at submarine network landing sites; and
- smart factories and robotics solutions.

Key drivers behind current deployments are specified as improved performance, network flexibility, reliability, service availability, low latency, high data rates and network sovereignty.

There are also many references of use cases published in the literature which can be placed under the following categories.

- Manufacturing and industrial (for example automotive and chemical industries)
- Healthcare

[2] https://www.berec.europa.eu/en/all-documents/berec/reports/berec-report-on-the-evolution-of-private-5g-networks-and-interrelation-with-public-networks-in-europe

- Educational institutions, in particular universities
- Offices and corporate campuses
- Stadiums and arenas
- Utilities
- Defence organisations
- Logistics and warehousing (including ports, airports and railways logistics)
- Hospitality and venues
- Mining
- Agriculture
- Retail

The wide range of potential use cases is also discussed in a companion report by DotEcon.

It should be noted that, regardless of the potential use case scenarios, the adopted licensing approach needs to be sufficiently flexible to accommodate current and future applications that could be deployed in indoor and outdoor environments with varying network configurations.

1.5 Benchmarking of WBB LMP frameworks across Europe

In this section, we give an overview of the approaches adopted by national regulatory authorities across Europe for the licensing of spectrum for private mobile networks and other WBB LMP services. Plum surveyed eleven countries, comprising Belgium, Denmark, Finland, France, Germany, Italy, Norway, Poland, Spain, Sweden and the United Kingdom. One key finding is that European countries are in different stages of development on the licensing of C-band (including the 3.8-4.2 GHz band) for WBB LMP use including for private mobile networks. The countries surveyed can be grouped into the following categories:

1. Countries that have yet to consider the use of the band for private mobile use (Spain);
2. Countries that permit or mandate the use of spectrum awarded to MNOs in the sub-band below 3.8GHz under a wholesale agreement with the MNOs when requested by a private mobile network operator (not obligatory: Italy, obligatory: Denmark and Finland);
3. Countries that are currently consulting on the use of the 3.8-4.2 GHz band for private mobile use (France); and
4. Countries that have in place a spectrum framework for use of the C-band for private mobile networks (Belgium, Germany, Norway, Poland, Sweden and the UK). Note summary information for each of these six countries is set out in Appendix C.

It should be noted that both Denmark and Finland are working towards releasing the 3.8-4.2 GHz band for private mobile use in the long term.

1.5.1 Countries with a regulatory framework in the C-band

Across the six countries that have established a regulatory framework for private mobile networks in the C-band, Belgium, Poland, Norway and the UK have a licensing framework in the 3.8-4.2 GHz band. Germany grants licences to private mobile network operators in the 3.7-3.8 GHz sub-band, while Sweden allows spectrum between 3.72 GHz and 3.8 GHz to be used by private mobile users. An overview of the key findings on the spectrum frameworks are as follows:

- Most or all of the bandwidth of the frequency range is available, except in Belgium, where only 200MHz (from a potential 400 MHz) is planned to be made available for private networks.
- Minimum channel size is generally between 10MHz (UK, Poland, Germany and Sweden) and 20MHz (Norway and Belgium), and the maximum channel bandwidth varies between 40MHz (Belgium) and 100MHz (UK, Poland and Germany). Bandwidths offered increase in increments of 10MHz for countries with a minimum channel size of 10MHz and in increments of 20MHz for countries with a minimum channel size of 20MHz.
- Licences are awarded on a first-come-first-served basis or as applications are made. Four countries (UK, Norway, Germany and Sweden) have a use-it-or-lose-it clause that requires the licensee to use the spectrum within 6 or 12 months of the licence award.
- Application is made by filling out an electronic form which is submitted by email to the regulator. The regulators assess new applications against licences granted to existing licensees, who, thus, have priority, although in Germany a new entrant has to negotiate with affected incumbents to achieve compatibility and where this fails BnetzA will intervene. The assessment is based on technical assessment of coexistence between the new applicant and existing licensees as well as between the new applicant and other users (such as satellite, aeronautical altimeters, and MNOs in the sub-band below 3.8GHz).
- Licence duration varies from 5 years (Sweden), up to 10 years (Norway, Belgium and Germany) and indefinite (the UK). Poland, Sweden and Germany have also set a date where all licences expire, at the end of 2028, end of 2032 and end of 2040, respectively.
- Licences permit both indoor and outdoor uses for all countries, but the UK, Norway and Poland also distinguish between low-power and medium-power licences, with different usage conditions. In the UK and Norway, applicants for low-power licences can state whether usage will be exclusively indoors on the application. However, licences granted for indoor use only cannot be used for outdoor transmission.
- There is no clear band segmentation for different types of licence – i.e. low-power vs medium-power licences. In Norway, Nkom limited the allocation for medium-power outdoor base stations to the lower half of the 3.8-4.2GHz band, while international studies on the risk of interference with radar altimeters in the 4200-4400MHz band were taking place; no change to this limitation has yet been announced. In Poland, only local government is permitted in the 3.8-3.9 GHz band.
- Additional technical conditions apply to some parts of the band in some countries. Norway, Poland and Belgium also state that special technical usage conditions, such as synchronisation requirements, apply in the 40MHz (Norway and Poland) or 60MHz (Belgium) bandwidth above 3800MHz to prevent interference with public mobile networks.
- There is generally no geographic restriction for low-power licences (where they are applicable).
- For medium power licences, there are restrictions on the deployment's geographic area as follows:

- In the UK, an "Exceptions" process is used to assess applications for medium power deployment (for antenna height of up to 10m) in Greater London, and for antenna heights above 10m everywhere in the UK (including Greater London). See Figure 1.2 below.
- In Norway, installation of medium-power base stations is not permitted in geographic areas that fall within a zone of 10 km outside urban settlements with more than 10,000 inhabitants. Nkom may, however, grant exemptions for large industrial sites such as ports, if the benefits of deployment outweigh the disadvantages.
- In Poland, medium power deployment is not permitted in urban areas, and communes defined as urban areas can be found in the ordinance on the frequency management plan for the 3800-4200 MHz band.[3]

- While some countries (UK, Norway and Poland) distinguish between low and medium power licences in the 3.8 – 4.2 GHz band, another (Belgium) does not appear to make this distinction.
- Except in Germany, there is no requirement for coordination between users, but the use of TDD frame synchronisation is encouraged or strongly recommended as a means of interference mitigation for neighbouring networks. In the UK, user-led coordination can be used to overcome potential interference issues identified by Ofcom that led to an application's initial rejection.
- There are limits on EIRP and antenna heights along with other technical conditions of use in the UK, Norway, Belgium, Poland and Sweden to help prevent interference.
- The regulators in Norway and the UK make clear that an existing assignment may be moved to a different part of the band to improve spectrum usage efficiency. Nkom in Norway requires the equipment used by licensees to support the entire 3800-4200 MHz frequency band to facilitate this potential migration.
- The UK are planning to move an existing FWA allocation of 84 MHz held by Three from the middle of the 3.8 – 4.2 GHz band to become adjacent to 3.8 GHz.

[3] https://edziennik.uke.gov.pl/DU_UKE/2023/12/akt.pdf, Pages 13-23

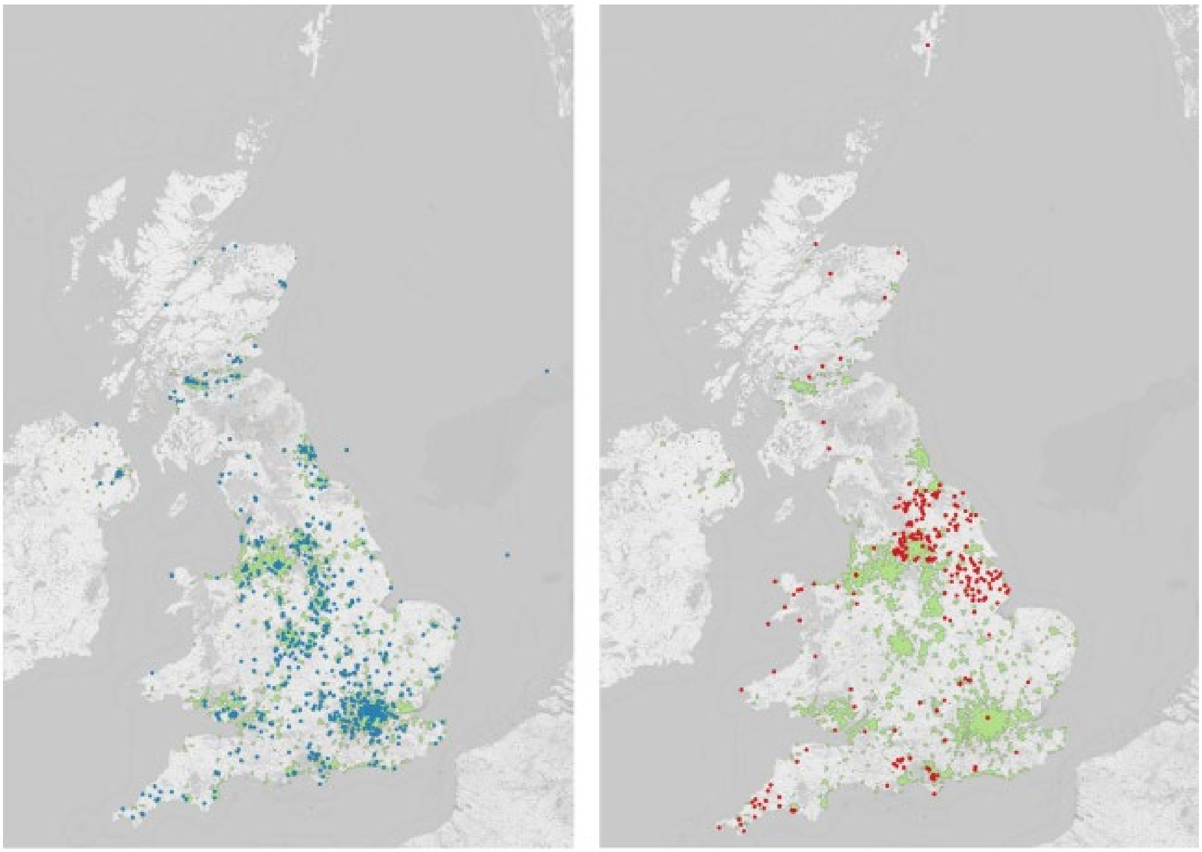

Figure 1.2: Shared Access Licence Locations, Low Power (blue dots) and medium power (red dots). Urban areas highlighted in green (Source: Ofcom)

Appendix C provides details of the spectrum frameworks for countries that have licensing frameworks (on a shared basis) in C-band spectrum for private mobile and other WBB LMP use.

2 Coexistence constraints

2.1 Introduction

This study has examined and quantified the technical constraints relating to both in-band and adjacent band coexistence that must be accounted for in any arrangement for licensing the spectrum at 3.8 – 4.2 GHz in Ireland given the obligations to appropriately protect such systems in line with the draft Commission Implementing Decision [B12].

Four distinct coexistence scenarios need to be considered:

- Coexistence between different WBB LMP networks operating within the 3.8-4.2 GHz band.
- Coexistence between WBB LMP networks and Earth stations of the Fixed Satellite Service (FSS) operating within the 3.8-4.2 GHz band.
- Coexistence between WBB LMP networks above 3.8 GHz and WBB ECS (i.e. public cellular networks) below 3.8 GHz.
- The impact of WBB LMP networks in the 3.8-4.2 GHz band on aircraft radio altimeters operating above 4.2 GHz.

Each of these scenarios is addressed in the sections below, with detailed technical analysis in Annexes D-G.

Other potential sharing scenarios, referenced in the draft Commission Implementing Decision [B12] include:

- Microwave links in the Fixed Service (FS). FS links are not licensed in Ireland, so this scenario has not been considered.
- Radio astronomy receivers forming part of a very long baseline interferometer network within the VGOS framework (Very Large Baseline Interferometry Global Observing System). This is a global network of sites that uses astronomical sources to make precise measurements of geodesy (i.e. the shape and deformation of the Earth). The wideband observations use frequencies between 2-14 GHz. There are no VGOS sites in Ireland (the nearest are in Germany and Portugal), so this scenario has not been considered.

2.1.1 Previous studies and current work-in-progress

In December 2021, the EU Commission issued a Mandate to CEPT to study the feasibility of using the 3.8-4.2 GHz band by terrestrial wireless broadband systems providing local-area network connectivity in a shared manner. The Mandate also requested development of relevant harmonised technical conditions suitable for 5G technology use and protection and future evolution and development of incumbent spectrum users within the band and in adjacent bands.

Specifically, CEPT was mandated to

- study the technical feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area (i.e. low/medium power) network connectivity by taking account of in-band incumbent users (including satellite earth station receivers and fixed links) and adjacent band use by terrestrial systems providing wireless broadband electronic communications services in the 3.4-3.8 GHz frequency band and radio altimeters on board aircraft in the 4.2-4.4 GHz frequency band; and

- develop the least restrictive harmonised technical conditions for the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area connectivity.

In response, CEPT developed

- **ECC Report 358** [B4] which summarises sharing studies between WBB LMP networks and other in-band users (FS and FSS) and adjacent band MFCN below 3.8 GHz (June 2024).
- **ECC Report 362** [B5] describing adjacent band studies between WBB LMP in the 3.8-4.2 GHz band and Radio Altimeters above 4.2 GHz (November 2024).
- **CEPT Report 88** [B6] which assesses the technical feasibility of the shared use of the 3800-4200 MHz frequency band by low/medium power terrestrial wireless broadband systems (WBB LMP) providing local-area network connectivity (November 2024)
- **ECC Decision (24)01** [B7] which describes harmonised technical conditions for the shared use of the 3800-4200 MHz frequency band by low/medium power terrestrial wireless broadband systems (WBB LMP) providing local-area network connectivity. (November 2024)

ECC Decision (24)01 also notes that CEPT is developing ECC Recommendations to provide administrations relevant mechanisms/solutions for implementation at national and bilateral/multilateral level to manage coexistence among WBB LMP deployments, and between WBB LMP and in-band and adjacent band incumbent services. The work is undertaken by CEPT FM60.

After ECC PT1 performed studies (ECC Report 358) the ECC group responsible for the regulatory implementation of the shared use of the 3.8-4.2 GHz frequency band is FM60[4]. This group have held a number of physical and online meetings in the last year, culminating in CEPT producing a Decision ((24)01) and CEPT Report 88 in reply to the EU Commission. In January 2025, FM 60 started work on the Guidelines for the implementation of WBB LMP with its most recent meeting from 22-23 May. They are preparing three new Recommendations:

- Recommendation 1: In-band planning and co-existence between WBB LMP networks and MFCN below 3 800 MHz
- Recommendation 2: Protection of Radio altimeters above 4 200 MHz
- Recommendation 3: Coordination between WBB LMP and in-band FSS & FS

A draft of Recommendation 3 was approved for public consultation at the June meeting of WG FM, while the others are expected to be submitted to the October meeting of WG FM and finalised in Q1 of 2026.

It is noted that the issue of the coexistence of MFCN with *unsynchronised* WBB LMP is an important issue but had been relatively little studied.

[4] ECC - ECC - WG FM - FM 60

2.2 Coexistence between WBB networks

The fundamental source of information, within the CEPT, on the mutual compatibility of WBB LMP networks is Section 6.1 of ECC Report 358 which reports two sets of studies undertaken to quantify the issue. The results from these two studies are used in Report 88 and underpin current discussions within FM 60.

Noting that these studies used rather different methodologies, Plum have undertaken additional modelling intended to represent potential WBB LMP deployment in Ireland. The technical assumptions for this modelling are set out in Appendix I.

The following tables, reproduced from Appendix D of this report, present indicative re-use distances for the various potential interference paths. The distances are calculated on the basis of the assumed receiver parameters and interference thresholds set out in Appendix I of this report.

Unsynchronised		MP	LP	Indoor
Interferer (BS)	MP	22 km	9 km	1.5 km
	LP	6 km	3 km	0.5 km
	Indoor	1.5 km	0.5 km	<0.3 km

Table 2.1: Indicative re-use distances (BS-BS, unsynchronised operation)

For the unsynchronised base, it is reasonable to assume that reuse distances will be determined by BS-BS coupling and that BS-UE interference can reasonably be ignored.

Synchronised		MP	LP	Indoor
Interferer (BS)	MP	4 km	4 km	<0.2 km
	LP	0.4 km	0.4 km	<0.2 km
	Indoor	<0.2 km	<0.2 km	<0.1 km

Table 2.2: Indicative re-use distances (BS-UE, synchronised operation)

Adjacent channel coexistence will also need to be considered in a final assignment methodology (see Appendix D Section 6.1).

As work on the mutual compatibility of WBB LMP systems is ongoing in FM 60, these indicative distances may be subject to refinement.

2.3 Coexistence with FSS Earth stations

The co-ordination of satellite Earth station receivers with terrestrial transmitters is a well-understood process. The formal protection requirements for licensed Earth stations can imply coordination distances of hundreds of kilometres where services requiring high-availability must be protected, to allow for tropospheric enhancement.

C-band satellite use in Europe is relatively modest (compared with Ku-band at 10.7-12.7 GHz) and the majority of receivers in the band are likely to be used for television reception. The work in FM60 has been focussed on the protection of larger, gateway, Earth stations and in this context, FM 60 have recommended that co-ordination zones should be calculated using the actual parameters of FSS ES and WBB LMP base stations. FM 60 also refer to a generic coordination radius of 40 km and this figure aligns broadly with the modelling results in Appendix E.

The actual constraints on sharing will vary significantly depending on the satellite in use, as this will determine the horizon gain and pointing of the Earth station antenna, and on the specific satellite transponder(s) in use and any mitigating actions that the satellite ES has taken to protect itself, such as shielding.

2.4 Coexistence with public mobile networks below 3.8 GHz

While ECC Report 358 and ECC Decision (24)01 only state that synchronisation (of WBB LMP networks with MFCN ECS below 3800 MHz) *may* be necessary, the current working text in FM60 would mandate the use of synchronisation in the lower 20 MHz in all cases and require synchronisation for medium power stations up to 3860 MHz.

Information on the mutual impact of unsynchronised networks in the real-world is sparse and anecdotal, and it is hard to prove a negative (that no interference currently occurs between unsynchronised networks). The absence of reported issues in the UK (where synchronisation is not required) may also be attributable to the fact that most WBB LMP assignments are low power and to the likelihood that many such systems are, by default, synchronised with the same frame structure as users below 3.8 GHz.

2.5 Coexistence with radio altimeters above 4.2 GHz

The conclusion of the work within the ECC (detailed in Appendix G) is that there is no risk of interference to radio altimeters from WBB LMP systems deployed in spectrum below 4.1 GHz.

Above 4.1 GHz, the only risk of interference is from WBB medium power systems using certain beamforming (AAS) antennas, located at a distance from the runway threshold where the antenna height is limited by the Obstacle Limiting Surface (OLS). This interference risk can be mitigated by ensuring that base stations are located more than 1200 m from the runway threshold or 40 m laterally (see Figure G.2 in Appendix G) or, alternatively, by enhancing the suppression of out-of-band emissions.

It should be noted that the area of Figure G.2 only covers the coordination zone required by the interference to an aircraft on an ideal landing path. In practice, aircraft may deviate from this path and proposals are currently being considered to extend the coordination zone by the addition of a trapezoidal area extending some 700m from the runway threshold and with a maximum width of 240m.

Although the details are still being agreed within FM 60, the overall coordination zone around any runway would remain small and will not impose a significant constraint on WBB LMP deployment.

3 Technical conditions and licensing guidelines

3.1 Bandwidth

Benchmarking has indicated that channel bandwidths may vary between 10 MHz and a maximum of 80 MHz (Norway and Sweden) or 100 MHz (UK, Poland, Germany). Bandwidths are generally based on multiples of 10 or 20 MHz. Although ECC Decision (24)01 specifies a 5 MHz *raster* for the band, to allow a 5 MHz channel bandwidth might result in excessive fragmentation with consequent constraints on assignment.

It will clearly be important to ensure that users do not demand more bandwidth than is required for a particular application. Potential options to ensure this include:

- Require applicants to provide detailed rationale and plans for requested bandwidth, based on service, coverage area, capacity requirement, number of users/connected equipment, etc, and
- Impose requirements on holders of licences to periodically report actual usage. The regulator should also have the ability to be able to change the licensed channel size if actual usage falls below the original bandwidth requested or withdraw if there is no use.

There may also be justified cases where higher bandwidths is required. For example, for an uplink heavy LMP network where synchronisation is required (either towards MFCN, another LMP network or both) additional bandwidth may be required to meet the capacity requirements of the LMP network given its requirement for synchronisation.

It is anticipated that video applications and also deployments at ports and airports would likely to require higher bandwidths. It might also be worth considering allowing higher bandwidths if users are willing to synchronise.

A companion report by DotEcon also notes the wide range of potential bandwidth requirements.

3.2 Protection of FSS receivers

Protection of FSS receivers is very case specific and will depend on the exact deployments of the FSS receiver and the WBB LMP systems. The work of FM 60 identifies a 'compromise' figure of a 40km co-ordination zone for the protection of FSS receivers and this seems an appropriate pragmatic value.

Given, however, the absence of any currently-licensed Earth stations in this band, that there have been no licensed FSS systems in the band over the past 10 years, that demand for FSS receivers tends to be in the Ku-band at 10.7-12.7 GHz and the potential for large coordination areas between FSS and WBB LMP, we would suggest that no protection for FSS ES receivers is offered and that ComReg amends its satellite guidelines accordingly.

Satisfactory reception of satellite services is likely to be possible in most cases but might require careful positioning of the FSS receive antenna behind buildings, or the use of a larger aperture antenna to reject interference.

3.3 Protection of Radio Altimeters above 4200 MHz

The draft EC implementing Decision [B12] states:

"*Member States should ensure the protection of radio altimeters operating in the 4 200 –4 400 MHz frequency band from WBB LMP systems operating in the 3 800 –4 200 MHz frequency band, based on the results set out in the ECC Report 362 and potential measures that could be established by the Member States' civil aviation authorities and the European Aviation Safety Agency (EASA). Particular attention at national level should be given to the protection of radio altimeters from medium power AAS base stations that are located in close proximity to airports and operate within the 4 100 – 4 200 MHz frequency sub-band.*"

Given the very limited geographic areas and frequency range affected by the protection measures set out in ECC Decision (24)01, it is not expected that the protection of radio altimeters will represent a significant constraint on licensing of WBB LMP services.

3.4 Protection of WBB ECS below 3800 MHz

To minimise interference to adjacent WBB-ECS systems in spectrum below 3800 MHz, it may be necessary to consider synchronisation of WBB LMP networks in the spectrum immediately above 3800 MHz with WBB-ECS below 3800 MHz. Our benchmarking has noted a number of different approaches in relation to this sub-band and synchronisation with MFCN below 3800 MHz:

- Germany does not require a guard band if synchronisation is used:
- Norway and Poland require synchronisation for the 40 MHz wide sub-band 3800 – 3840 MHz
- Belgium requires synchronisation for the 60 MHz wide sub band 3800-3860 MHz.
- The UK requires a guard band of 5 MHz but does not require synchronisation (but notes that unsynchronised networks may experience some interference, presumably implying that interference in the reverse direction is possible).
- Sweden does not require synchronisation '*unless necessary*'

While ECC Report 358 and ECC Decision (24)01 only state that synchronisation (of WBB LMP networks with MFCN ECS below 3800 MHz) may be necessary, the current working text in FM60 would mandate the use of synchronisation in the lower 20 MHz in all cases and require synchronisation for medium power stations up to 3860 MHz.

Rather than mandate synchronisation, a light-touch approach would be to assign WBB LMP systems that intend to adopt the standard frame structure at the lower end of the band, with other systems assigned from the top down. This would lead to a 'soft' band segmentation that would reflect demand.

3.4.1 Blocking

For unsynchronised ECS and LMP base stations operating in close proximity, regardless of frequency separation, there is a risk of blocking due to overload of receiver front-ends, which generally will have limited rejection of out-of-band power.

A recent example of this was at the Paris Olympics of 2024, where (temporary) WBB LMP base stations were overloaded by downlink transmissions from a nearby (temporary) WBB ECS base station. The problem was resolved by (i) increasing the physical separation between base stations and (ii) fitting the WBB LMP receiver with a RF bandpass filter. No blocking of the WBB ECS site was reported, presumably due to the low-power of the WBB LMP transmitter. It should be noted that it would not be possible to retrofit such filters to sites that use AAS antennas.

The issue of ECS and LMP compatibility is referenced in the draft ECC Recommendation, which also notes the potential need to limit WBB LMP out-of-band emissions to a level below the standard 3GPP specification when they operate close in frequency or space to an unsynchronised WBB ECS network. Depending on the deployment density of WBB LMP sites, it may be preferable to avoid such a requirement by careful consideration of assignments by ComReg.

3.5 Licensing and planning of WBB LMP networks

In FM60 documents[5] that consider licensing and planning of WBB LMP networks between themselves, there are two main principles for the methodologies that a national regulator can use:

- Case-by-case planning where the regulator undertakes the necessary planning to ensure an interference-free co-existence between WBB LMP networks, using the network parameters (output power, antenna placement etc) in the licence conditions.
- Licence conditions include requirements on maximum field strength levels, for example at the border of the licence area[6]. This may allow for a less complicated, and more generic planning by the national regulator.

The FM 60 document does not pursue the latter option. Plum considers that the requirement to define a service area and to determine field strength values at the boundary of that area may be a disproportionate complexity for the majority of applications, certainly in the low-power case. To define an appropriate field strength value would also require assumptions to be made about the technical characteristics of the (unknown) services to be protected. It would be worthwhile asking, in the proposed consultations, for stakeholder views on this issue.

Our benchmarking noted that in Germany there is a requirement for operators of geographically adjacent networks to negotiate, and it is assumed that operators will find an appropriate solution among themselves. For licensing purposes, submissions should be provided with details of the agreement from other operators on interference mitigation measures.

In the UK user-led coordination is also possible if an application does not pass Ofcom's initial assessment, but this is only available for deployments that adhere to the technical terms specified in Ofcom's standard Shared Access licence templates (i.e. transmit powers and heights of Ofcom's core products).

In the ECC recommendation currently being drafted by FM60[7], in the context of coexistence among 3GPP based WBB LMP networks, FM60 suggest a series of coexistence limits, based on predicting the interference power present at the output port of a victim antenna of representative gain. The levels currently being considered in FM60 are summarised below in Table 3.1. These levels, although still in draft form, appear to consider all interference scenarios. While they may be refined over the course of the work of FM60 they appear to be an appropriate approach, and follow a similar approach to that used by Plum in developing the example separation distances of Table 2.1 and Table 2.2.

[5] Initial draft ECC Recommendation on WBB LMP vs WBB LMP
[6] E.g. the French proposal to FM60 (document 27) of a field strength level at the WBB local area network coverage edge of 32 dBuV/m/5 MHz at 3m with omni antenna of 0 dBi gain. This value is taken from Report 358. The association with an antenna gain is not necessary for a field strength.
[7] https://www.cept.org/ecc/groups/ecc/wg-fm/fm-60/client/meeting-documents/file-history?fid=89145, Draft ECC Recommendation for MFCN and LMP vs LMP, FM60#17, 23 May 2025,

Interference scenario		Low power (Imax)	Medium Power (Imax)
Unsynchronised	Co-channel (BS-BS)	-100dBm/5MHz	-103dBm/5MHz
	Co Channel (BS-UE)	-98dBm/5MHz	
	Adjacent channel (BS-BS)	<20MHz: -57dBm/5MHz >=20 MHz: -48dBm/5MHz	<20MHz: -57dBm/5MHz >=20 MHz: -48dBm/5MHz
	Adjacent channel (BS-UE)	Typically not an issue	
Synchronised	Co Channel (BS-UE)	-98dBm/5MHz	
	Adjacent channel	Typically not an issue for 3GPP systems	

Table 3.1: FM60 draft coexistence limits

3.5.1 Definition of geographic area

In Norway, in the case of low-power deployment, the licences allow an unlimited number of base stations within a 50-metre radius geographic area, while user equipment can operate both inside and outside this area. The maximum permitted antenna height for outdoor low-power antennas is 10 metres above the ground, while indoors there is no height restriction. Medium power licences are for a single base station transmitter with a maximum spectral density of 36 dBm/5 MHz (EIRP) and a 10 km separation from areas with more than 10,000 inhabitants[8]. There are no restrictions to the antenna height for medium-power, but Nkom engages in dialogue with the applicant in cases where it considers the location or height of the antenna applied for to be problematic for the efficient reuse of frequency resources.

[8] This relates to the different geographic areas and defines rural areas which are considered to need to be 10 kms away from populated areas to avoid interference to any low power transmitters deployed there.

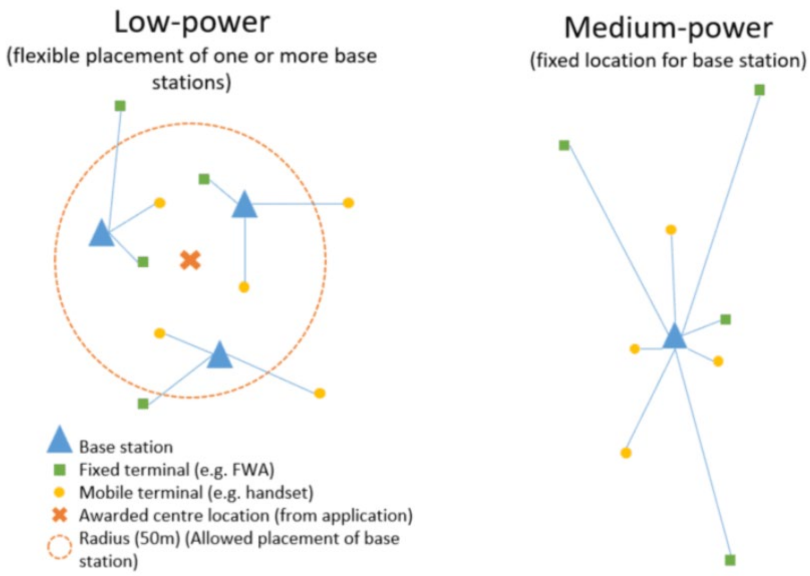

Figure 3.1: 3.8 GHz private network deployment options (Nkom)

A similar approach has been adopted in the UK and would seem to provide an appropriate balance between operational flexibility and technical assurance. The suggested process would be as follows:

A **Low power** licence would allow flexible base station deployment within a circle of 50m radius. The maximum permitted antenna height outdoors would be 10 metres above the ground while indoors there would be no height restriction. The service area where user equipment operates might extend beyond that radius. If a licensee requires a greater base station deployment area they may apply for multiple circles, contiguous or otherwise. The licensing framework for low-power sites would follow the following process:

1. Initial licence(s) issued and ComReg makes available relevant details of these licences on its website.

2. For subsequent applicants, it would be prudent that new applicants consider the existing licences issued in the band and submit its application to ComReg following coordination with existing licensees. Co-channel deployment would likely be permitted if beyond a fixed distance (e.g. using Table 2.1 this would be 0.5 km for LP to indoor, 3 km for LP to LP and 6 km for LP to MP).

3. If within the above distance, and if no non-overlapping assignments are available for the bandwidth requested, ComReg may conduct an assessment using modelling that takes into account terrain and clutter (e.g. Recommendation ITU-R P.1812, [A10]) to determine whether the signal is below an appropriate threshold (this could be the thresholds currently under discussion in FM60 as per Table 3.1 above or other limits deemed representative (e.g. those used by Plum and detailed in Appendix I)) , and whether the application could be licensed. The assessment would be made between the nominal locations of base stations and, in the general case, would assume a victim receive antenna at base station height (i.e. 10m for the LP case). Where synchronisation was known to exist, the calculation would be made to the nominal UE height (e.g. 1.5m).

4. If the level is predicted to be above the threshold, ComReg would not be able to issue the licence unless prior agreement had been reached between the applicant and licensees to resolve the co-existence issue, and this has been submitted to ComReg.

A **Medium power** licence would be granted on the basis of detailed base station deployment characteristics (antenna pattern and pointing, antenna height, radiated power, etc…) for medium power deployments (proposed and existing), and generic characteristics for low-power licences. These calculations might apply the limits currently under discussion in FM60 (see Table 3.1), or other limits deemed representative (e.g. those used by Plum and detailed in Appendix I).

The example interference contours shown in Appendix D show that there is limited scope for co-channel frequency re-use in urban areas. As it is likely that a majority of urban use cases can be addressed by low-power base stations, with antennas below the average clutter height, we would suggest that medium-power licences should not be made generally available in city areas. This should not be an inflexible rule, as some compelling use cases may require wider coverage, and some exceptions should be possible, following consultation between prospective licensees and ComReg.

3.5.2 Band segmentation

Band segmentation may be considered where it could improve overall spectrum efficiency.

For example, to allow for unsynchronised operation in a specific section of the band thereby providing greater flexibility regarding up-link and down-link capacity, albeit unsynchronised operation has greater indicative re-use distances between WBB LMP deployments than synchronised operation (see Table 2.1 and Table 2.2). This may provide a fast-entry route for users with simple requirements and no technical skills.

Band segmentation may be appropriate if:

- There is a difference across the band due to the potential for interference into other services that are co- and adjacent-channel, or
- Parts of the band would be subject to different licensing requirements, e.g. There is a need for easy access to spectrum to be provided with no detailed technical co-ordination process and on the basis there may be an indeterminate QoS and a risk of interference.

The current FM60 proposal for band segmentation is sketched below.

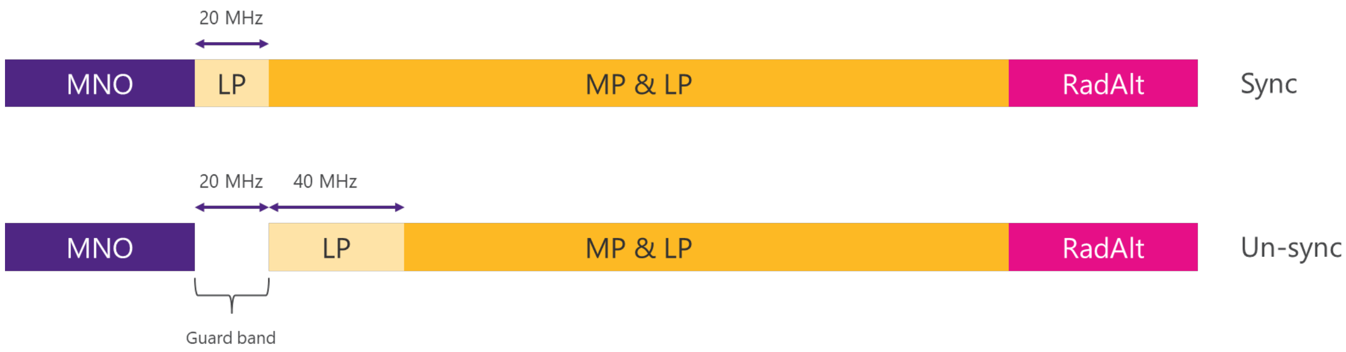

Figure 3.2: FM60 proposal for band segmentation for unsynchronised operation (Plum)

For many users, the default frame structure, TD-LTE frame configuration 2 (Downlink: Uplink, 3:1), is likely to be acceptable and may be configured in the equipment by default.

Plum have given some consideration to the idea that the band might be segmented to ease coexistence between users with different, specific, frame structures or power levels. There is a significant danger, however, that given the uncertainty regarding the balance between different use-cases and the overall demand for licences, such segmentation might enshrine an inefficient pattern of use.

Rather than mandate synchronisation, or impose a rigid band segmentation, a light-touch approach would be to allocate WBB LMP systems that intend to adopt the standard frame structure at the lower end of the band, with other systems assigned from the top down. This would lead to a ‘soft’ band segmentation that would reflect demand.

4 Conclusions

This report has summarised the technical compatibility issues associated with the deployment of WBB LMP services in the 3.8-4.2 GHz band and provides a benchmarking summary of licensing approaches adopted by other administrations as well as advice on potential technical conditions and licensing guidelines for co-existence with in-band and adjacent band services.

It seems clear from this benchmarking, and from separate studies carried out for ComReg, that use cases, deployment scenarios and the technical characteristics of WBB LMP systems are likely to be very diverse.

While harmonisation studies are still ongoing within FM60 and the advice in this report would be updated accordingly in ComReg's consultation process, some of the key technical considerations set out in this report include that:

- Applicants would need to justify their application request, e.g. provide detailed rationale and plans for their requested bandwidth, service area, etc. Benchmarking indicates a maximum bandwidth of 80-100 MHz per licence, although there may also be justified cases where higher bandwidths could be considered.

- Licensees would need to report periodically on actual usage. To ensure that the spectrum is efficiently used, the regulator should also have the ability to be able to change the licensed channel size and service area if actual usage falls below the original bandwidth requested or withdraw if there is no use.

- For the reasons set out in this paper we suggest that no protection of FSS receivers in the 3.8-4.2 GHz band is provided in the future and ComReg amends its satellite guidelines accordingly. Licence-exempt FSS receivers could still be used in the 3.8 – 4.2 GHz band, noting that satisfactory reception of satellite services is likely to be possible in most cases but might require careful positioning of the FSS receive antenna behind buildings, and/or the use of a larger aperture antenna to reject interference.

- The protection of Radio Altimeters above 4200 MHz is not expected to represent a significant constraint on the licensing of WBB LMP services, given the very limited geographic areas and frequency range affected by the protection measures set out in ECC Decision (24)01. Although discussions on the precise coordination area required around runways are continuing in FM60 and will be monitored by ComReg, this conclusion is not expected to change.

- Protection of WBB ECS below 3800 MHz may require WBB LMP deployments in the lower part of the band to be synchronised with WBB-ECS or separated by a guard band. Rather than mandate synchronisation, a light-touch approach would be to assign WBB LMP systems that intend to adopt the standard frame structure at the lower end of the band, with other systems assigned from the top down. This would lead to a 'soft' band segmentation that would reflect demand.

- There are two generic methodologies for the licensing and planning of WBB LMP networks with the suitability of each methodology depending on factors such as the power of the WBB LMP system, the number of base stations to be deployed etc.

- The first methodology is a case-by-case assessment of each application where the regulator, using the network parameters (output power, antenna placement etc.) in the licence, undertakes the necessary assessment and planning to ensure co-existence between WBB LMP networks operating in the same or adjacent channels.

  - This could be appropriate for MP deployments of a single base station and has been used by Ofcom (the UK) and Nkom (Norway) for MP deployments.
  - A variant of this approach for low power deployments is to allow a licensee to deploy low power base stations within a small defined area (e.g. a circle with 50m radius). Assessment could be calculated initially assuming deployment from the centre of the circle, although more detailed planning could be conducted using actual site deployments as required. Both Ofcom (the UK) and Nkom Norway) use a 50m circle within which the licensee can deploy multiple LP base stations, while users may be located both inside and outside the circle. The maximum permitted antenna height outdoors is 10 metres above the ground while indoors there is no height restriction.
- The second method would use licence conditions to set maximum field strength level requirements, for example at the border of the licence area, or the setting of a base station deployment area.
  - Such a licensed service area could be appropriate for larger WBB LMP deployments or campus network deployments where multiple base stations are deployed within the service area. The licensee would need a technical expert that is capable of designing the system to meet maximum field strength requirements at the border of the area or at some distance from the border, and its subsequent monitoring and reporting.
  - The definition of appropriate field strength values requires assumptions to be made regarding the technical characteristics representative of all other services and may lead to inefficient planning.

Experience in other countries (e.g. the UK) has shown the importance of a well-designed licensing system that best meets the needs of the innovative use cases for the band while also ensuring that the band is efficiently managed and used.

While non-essential technical conditions should be avoided where possible, any licensing approach should maintain the flexibility to alter technical conditions for licensees should this become necessary, for example, to ensure the efficient use of spectrum due to a high demand in a particular area. This flexibility might include the requirement for licensees to change frequency within the band or to implement a particular synchronisation strategy.

Appendix A Glossary

3GPP	'3rd generation Partnership Project' (mobile broadband standards group)
AAS	Active Antenna System
AGL	Above Ground Level
ARCEP	l'Autorité de régulation des communications électroniques, des postes et de la distribution de la presse (French telecommunications regulator)
ASL	Above Sea Level
BEL	Building Entry Loss
BT	British Telecom
CEPT	Conférence Européenne des Postes et Télécommunications
CWN	City-wide network
DL	Downlink (i.e. from base station to user)
EASA	European Air Safety Agency
ECC	Electronic Communications Committee (of CEPT, q.v.)
EIRP	Effective Isotropic Radiated Power
EMEA	Europe, Middle-East and Africa
ES	Earth Station
ETSI	European Telecommunications Standards Institute
FCFS	'First-come, first-served'
FR1	Frequency Range 1 of the 5G standard (i.e. below 6 GHz)
FR2	Frequency Range 2 of the 5G standard (i.e. above 24 GHz)
FS	Fixed Service
FWA	Fixed Wireless Access
GSA	Global mobile Suppliers Association (trade body)
GUI	Graphical User Interface
I/N	Interference to noise ratio
ITU-R	International Telecommunication Union, Radiocommunications Sector
LoS	Line-of-Sight
LP	Low-power (used in this report to indicate base stations below rooftop level)

MCL	Minimum Coupling Loss
MFCN	Mobile or Fixed Communications Networks
MP	Medium-power (used in this report to indicate base stations above rooftop level)
MIMO	Multiple-Input, multiple-output (refers to antennas in a radio system)
NKom	Norwegian Communications Authority
NLoS	Non-Line-of-Sight
OFCOM	Office of Communications (UK spectrum regulator. NB: Swiss regulator has same name)
PFD	Power Flux Density
PTS	Swedish Post and Telecom Authority
QoS	Quality of Service
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool (Software)
SUTP	Single user throughput
TRP	Total Radiated Power
UE	User equipment
UL	Uplink (i.e. from user to base station)
WBB LMP	Wireless Broadband low-and medium-power networks

Appendix B References

B.1 ITU documents

[A1] "*Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications in the bands identified for IMT in the Radio Regulations*" Recommendation ITU-R **M.1036-6**, October 2019. Link.

[A2] "*Prediction of clutter loss*", Recommendation ITU-R **P.2108-1**, September 2021. Link.

[A3] "*Prediction of building entry loss*", Recommendation ITU-R **P.2109-2**, August 2023. Link.

[A4] "*Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses*", Report ITU-R **M.2292-0**, December 2013. Link.

[A5] "*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*", Recommendation ITU-R **F.1336-4**, January 2019. Link.

[A6] "*Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz*", Recommendation ITU-R **P.452-17**, September 2021. Link.

[A7] "*Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4 200-4 400 MHz*", Recommendation ITU-R **M.2059-0**, February 2015. Link

[A8] "*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*", Recommendation ITU-R **S.465-6**, January 2010. Link.

[A10] "A path-specific propagation prediction method for point-to-area terrestrial services in the frequency range 30 MHz to 6 GHz", Recommendation ITU-R **P.1812-7**, August 2023, Link.

B.2 CEPT & EC documents

[B1] "*Harmonised frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the band 3400-3800 MHz*", **ECC Decision (11)06**, December 2011, amended 2018. Link.

[B2] "*Analysis of the suitability of the regulatory technical conditions for 5G MFCN operation in the 3400-3800 MHz band*", **ECC Report 281**, July 2018. Link.

[B3] "*National synchronization regulatory framework options in 3400-3800 MHz: a toolbox for coexistence* [...]", **ECC Report 296**, March 2019. Link.

[B4] "*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*", **ECC Report 358**, June 2024 corrected March 2025). Link.

[B5] "*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*", ECC Report 362, October 2024, Link.

[B6] "*Report from CEPT to the European Commission in response to the Mandate on shared use of the 3800-4200 MHz frequency band by low/medium power terrestrial wireless broadband systems (WBB LMP) providing local area network connectivity*", CEPT Report 88, November 2024. Link.

[B7] "Harmonised technical conditions for the shared use of the 3800-4200 MHz frequency band by low/medium power terrestrial wireless broadband systems (WBB LMP) providing local-area network connectivity", ECC Decision (24)01, November 2024. Link.

[B8] "*Operational guidelines for spectrum sharing to support the implementation of the current ECC framework in the 3600-3800 MHz range*", ECC Report 254, November 2016. Link

[B9] "*Roadmap For Ensuring Safe Coexistence Between Mobile Networks and Aircraft Radio Altimeters Within the Frequency Range 3.4-4.4 GHz in the Union*", European Commission, 30 April 2025. Link.

[B10] "*Analysis of the suitability of the regulatory technical conditions for 5G MFCN operation in the 3400-3800 MHz band*", ECC Report 281, July 2018. Link.

[B11] "*National synchronization regulatory framework options in 3400-3800 MHz: a toolbox for coexistence* […]", ECC Report 296, March 2019. Link.

[B12] "*Commission implementing decision on the harmonisation of the 3 800-4 200 MHz frequency band for the shared use by terrestrial wireless broadband systems capable of providing local-area network connectivity in the Union*", Draft document 'RSCOM24-43rev2_clean', 19 March 2025. Link

[B13] "*EU Roadmap For Ensuring Safe Coexistence Between Mobile Networks and Aircraft Radio altimeters Within the Frequency Range 3.4-4.4 GHz in the Union*", Draft document, March 20th 2025. Link.

B.3 ETSI/3GPP documents

[C1] "*5G;NR; Base Station (BS) radio transmission and reception*", ETSI Technical Specification TS 138 104, version 16.6.0, January 2021. Link.

[C2] "*5G;NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone*", ETSI Technical Specification TS 138 101-1 version 17.5.0, May 2022. Link.

B.4 National regulators

[D1] "*Results of the 3.6 GHz Band Spectrum Award*", ComReg Information Notice, May 2017. Link.

[D2] "*Regulation of local networks in 3.8-4.2 GHz*", Nkom statement, January 2023. Link.

[D3] "*Shared Access Licence guidance document*", Ofcom, September 2022. Link.

[D4] "*Technical Frequency Assignment Criteria for Shared Access Radio Services*", Ofcom Document OfW 590, September 2022. Link.

[D5] "*Evolution of the Shared Access Licence Framework*", Ofcom 'call for input', March 2023. Link.

[D6] "*Shared Access Licence – guidance document*", Ofcom, January 2025. Link.

B.5 Other documents

[E1] "*Spectrum for future IMT system in Myanmar*", Asia Pacific Telecommunity (APT) expert mission report, October 2019. Link.

[E2] "*Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations*", RTCA Paper No. 274-20/PMC-2073, October 2020. Link.

[E3] "*Private Mobile Networks*", GSA Member Report, May 2023. Link.

[E4] "*5G Standalone Non-Public Networks: Modernising wireless production*", BBC Research & Development White Paper 410, October 2023, Link.

Appendix C Benchmarking Summary Table

Feature	UK	Norway	Belgium	Poland	Germany	Sweden
Spectrum band	• 3800-4200 MHz	• 3800-4200 MHz	• 3800-4200 MHz	• 3800-4200 MHz (divided into 2 sub-bands namely 3800-3900 MHz & 3900-4200 MHz)	• 3700-3800 MHz	• 3720-3800 MHz
Total bandwidth available	• 390 MHz (5 MHz at top and bottom of 3800 – 4200 MHz range not available)	• 360 MHz (40 MHz protection band 3800-3840 MHz for mobile networks)	• 200 MHz (to be identified through a phased approach)	• Potentially 400 MHz (under no synchronisation, 3800-3840 MHz will be guard band.)	• 100 MHz	• 80 MHz
Channel size	• 10 MHz to 100 MHz in increments of 10 MHz	• 20 MHz to 80 MHz in increments of 20 MHz	• 20 MHz and 40 MHz (maximum channel size)	• 10 MHz to 100 MHz in increments of 10 MHz	• 10 MHz to 100 MHz (with no guard band) in increments of 10 MHz	• 10 MHz to 80 MHz in increments of 10 MHz
Licence award basis	• First-come, first-served • Database in the form of searchable map of spectrum available in an area is available on Ofcom's website to provide guidance on how much spectrum may be available	• On-going basis (new applications will be assessed against existing licences)	• First-come, first-served	• First-come, first-served • 3800-3900 MHz is for government use. • 3900-4200 MHz is for private use.	• On-going (dependent on outcome of coordination negotiation with neighbouring users in the band)	• On-going (but existing licensees have priority over new applicants)

Feature	UK	Norway	Belgium	Poland	Germany	Sweden
Licence duration	• Indefinite, contingent on payment of annual fees and licence compliance • Transmission must start within 6 months of licence usance and continue thereafter.	• Licences are granted for a duration of up to 10 years. • Network must be deployed within 12 months of licence start date.	• Up to 10 years	• Until 31 December 2028.	• Licence is valid for up to 10 years. All licences to expire on 31 Dec. 2040 at the latest. • Spectrum must be used within one year of assignment.	• Up to 5 years, with the latest licence expiry date of 31 December 2032 • Use of spectrum must commence no later than 6 months from state date of permit.
Types of licences	• Lower power licence available for multiple base stations in a circular area with a radius of 50m, with flexibility to move the base stations within the area. • Medium power authorises a single base station, whose location is not expected to change. • Medium power in Greater London is available via exceptions process only.	• Lower power licence permits deployment of multiple base stations in a circular licence area of 50m. Indoor and outdoor uses are permitted with outdoor use defined as at least one base station placed outdoors. • Medium power licence is for a single base station only, and user must state whether each base station is indoor or outdoor. Medium power is only restricted to areas within a zone of 10 km outside urban settlements with more than 10,000 inhabitants. Exemptions may be granted for large industrial sites such as ports, if the benefits of deployment outweigh the disadvantages	• Licences permit indoor and outdoor networks.	• Low power licence available for base stations within a circular area with a 50m radius. • Medium power licences are not available in 3900-4200 MHz for exclusion zones listed found in the decision document. ((https://edziennik.uke.gov.pl/legalact/2023/12/)	• Licences are for a geographic area and can permit indoor or outdoor use.	• Indoor and outdoor uses are permitted.

Feature	UK	Norway	Belgium	Poland	Germany	Sweden
Application process & requirements	• Application through an electronic application form, after which a coordination assessment will be caried out by Ofcom	• Application will be considered following Nkom's coexistence assessment between local mobile networks and satellite earth stations as well as with aeronautical altimeters above 4200 MHz, to ensure adequate protection.	• Application can be filed using a form in BIPT's decision on private network use in 3800-4200 MHz band. • Applicant must demonstrate link to the area for which the licence is requested. • ASCII file with requested service area must be attached to the application form.	• N/A	• Application can be made via email. • Key information for application are coordinates of licence area requested, technical parameters of base stations to be used (such as highest transmit power and maximum antenna height for indoor base station) and agreement from other operators on interference mitigation measures.	• Application through an electronic form • Centre point for the geographical area applied for must be specified. • Map with clear indication of the requested licence area must be included.
Role of regulator in assessing applications & ability to modify licence details	• Ofcom carries out a technical assessment to ensure that there is no interference from or into the applicant's deployment, the outcome of which will determine success of the application. • Ofcom may request a change of frequency from time to time to accommodate new users in the same area or frequency or to deal with interference.	• Nkom may move a licence holder's allocation to a different part of the band to accommodate new users.	• BIPT assesses an application based on compatibility criteria and calculations to ensure 1) compatibility between private local networks, 2) compatibility with other services, and 3) protection of satellite earth stations.	• N/A	• Assessment of applications based on compatibility with FSS earth stations and other services in the band before licence award. • BNetzA can set out measures to ensure efficient user of spectrum if licence holders cannot reach an agreement on interference mitigation themselves through commercial negotiations. • .	• Assessment of application

Feature	UK	Norway	Belgium	Poland	Germany	Sweden
Coordination between users	• If application did not pass the initial assessment, user-led coordination is also possible, but this is only available for deployments that adhere to technical terms on transmit powers and heights of core products specified in Ofcom's standard Shared Access licence templates.	• N/A	• N/A	• N/A	• Negotiation requirement for operators of geographically adjacent networks, and it is assumed that operators will find an appropriate solution among themselves.	• No requirement on coordination but synchronisation is recommended to avoid interference

Feature	UK	Norway	Belgium	Poland	Germany	Sweden
Conditions of use	• Wide-area mobile network not allowed. • For low power licences indoor and outdoor deployment permitted with outdoor antennas limited to 10m above ground • For medium power in Urban areas antenna heights above 10m would only be considered as exceptions • Technical conditions (including. EIRP and emission limits) can be found on Ofcom's website[9]	• Maximum low-power antenna height of 10m above ground for outdoor use, no formal height restriction for indoor use. • Lower power licence permits a maximum power spectral density of 18 dBm/5 MHz ERP. • No height restriction for medium-power use, but operator must state the antenna gain, with the maximum permitted being 16 dBi. • Maximum EIRP for connected devices of 28 dBm TRP. • Roaming devices are not permitted in the band, and operator must maintain an updated overview and location of all registered devices.	• Synchronisation allows for better coexistence between networks and therefore potentially higher power. • For unsynchronised outdoor networks, EIRP limit is 18 dBm/5 MHz, with a height limit of 10m. • For synchronised outdoor networks, EIRP limit is 30 dBm/5 MHz with an antenna height limit of 10m • For synchronised indoor networks, the EIRP limit is 24 dBm/5 MHz, while for unsynchronised indoor networks, the limit is 30 dBm/5 MHz. • Exceptions may be granted where coverage area required is large, and BIPT will examine such requests on a case-by-case basis. • EIRP limit outside the assigned block is between 40 dB and 43 dB per antenna.	• Government deployment is permitted in an area no larger than 20 communes • Not permitted for provision of public telecoms network. • Only permitted for standalone isolated network. • For outdoor, low-power use, the antenna height limit is 10m. • For outdoor, medium-power use, the antenna height limit is 20m. • No medium power radio device with outdoor antenna in 4000-4200 MHz sub-band due to presence of radio altimeters. • Permissible gain, polarisation and radiation characteristics of antennas, EIRP limit for base station, maximum average EIRP density for base station antenna for adjacent channel emissions, EIRP density for out-of-band emission and maximum power of terminal devices can be found in decision document.	• No prescription of maximum permissible field strength at border areas, but licence holders are expected to ensure efficient and interference-free use of their networks through appropriate technical means. • No in-block EIRP limits have been defined for base stations. • Out-of-band emission limits can be found in Annex 2 of https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/FrequencyAssignment/LocalBroadband3,7GHz.pdf?__blob=publicationFile&v=1	• Use for terrestrial electronic communication in a local area only • On Onsala Peninsula, spectrum power density limit is 112 dBW/m2/MHz • Avoidance of harmful unauthorised harmful interference of existing local licensees in the band. • Average radiated power from base stations may not exceed 38 dBm TRP2 per cell. • Radiated power of terminals is limited to 28 dBm TRP. • Technical conditions for different sub-bands and synchronisation approaches as well as maximum field strength outside permit area • can be found here: https://www.pts.se/contentassets/4bf2aa62c41c49c394e40cdc9a306829/bilaga-2-tillstandsvillkor-for-3720-3800-mhz.pdf

Feature	UK	Norway	Belgium	Poland	Germany	Sweden
Requirements on synchronisation	• No synchronisation requirement, but Ofcom reserves the right to impose local level interference management measures.	• No synchronisation requirements but a 40 MHz protection band (3800-4200 MHz) is required to prevent interference with public mobile networks.	• For the 3800-3860 MHz sub-band, there is a requirement to use DDDSU frame structure (with the possibility of replacing D slots/symbols in the DDDSU frame with U slots/symbols, as for the 3400-3800 MHz band). • No requirement on other parts of the band.	• Only for use of 3800-3840 MHz for low-power radio equipment requires synchronisation with public networks in the 3700-3800 MHz band. This band is otherwise kept as guard band. • If there is a possibility of interference in the 3900-4200 MHz sub-band, synchronisation with existing devices may be necessary.	• If synchronisation is enabled, no guard band is necessary between MNO and local licence holders above 3700 MHz. • No synchronisation requirement but considered to be sensible for efficient use of spectrum and interference free transmission of geographically adjacent users.	• If necessary to mitigate interference, synchronisation with licensees in the 3400-3720 MHz band, or with others in the 3720-3800 MHz band shall be implemented. • Synchronisation may be avoided if other mitigating measures are sufficient (frequency separation, building loss).

[9] https://www.ofcom.org.uk/siteassets/resources/documents/consultations/category-1-10-weeks/consultation-supporting-increased-use-of-shared-spectrum/associated-documents/shared-access-licence-guidance-document-2024.pdf?v=388817)

Appendix D Coexistence between WBB LMP networks

D.1 Background

This Appendix provides an overview of the CEPT work related to coexistence among WBB LMP deployments in the 3800 – 4200 MHz band.

D.2 ECC Report 358

This Report [B4] includes in-band and adjacent band co-existence studies for the shared use of 3.8 – 4.2 GHz band. For in-band sharing among WBB LMP networks, the key points to consider include the following.

- Two WBB LMP network technologies have been considered: 3GPP 5G NR and DECT-2020 NR. Assumed parameter values for both technologies are described.
- For 3GPP 5G NR, these include in-band parameters (eirp, bandwidth, antenna heights) for low power and medium power base stations, out-of-block emission limits with reference to frequency offsets from lower/upper channel edges (based on ECC Decision (11)06), and other parameters (including cell size, frequency reuse, activity factor, antenna gain, MIMO, noise figure, interference criteria, antenna heights and antenna characteristics for AAS and non-AAS assumptions) as well as base station receiver characteristics (ACS and blocking levels).
- For DECT-2020 NR, assumed parameters are mainly based on ETSI TS 103 636-2 v1.4.1 where a single set of parameters is assumed for network equipment as no distinction is made between base station and user terminals.
- It is important to note that networks using the above two technologies (3GPP 5G NR and DECT-2020 NR) cannot synchronise with each other due to different operational principles.
- Propagation models are chosen depending on the scenario modelled (i.e. below/above clutter, indoor/outdoor) and include ITU-R Recommendations P.452, P.2001, P.2108, P.1238 and P.2109. Interference scenarios comprise WBB LP (outdoor) vs. WBB LP (outdoor); WBB LP (indoor) vs. WBB LP (outdoor); WBB LP (outdoor) vs. WBB LP (indoor); WBB MP vs WBB MP; WBB MP vs WBB LP (indoor); and WBB MP vs WBB LP (outdoor).
- For coexistence analysis among 3GPP WBB LMP networks, Monte Carlo (MCL) simulations were performed. To satisfy the assumed I/N of -6 dB criterion, required minimum separation distances were determined for two unsynchronised networks operating co-channel and outdoors in urban, suburban and rural deployments. **Calculated distances are range from a couple of hundred metres for two urban low power deployments to 23 km for two rural medium power deployments**. A further study included in the report on the same topic uses 'throughput loss' as an interference criterion and models co-channel and adjacent channel coexistence between two neighbouring WBB LMP networks by using Monte Carlo simulations. The method is based on determining the minimum separation distance between two base stations satisfying an assumed throughput loss criterion and the calculating the field strength at mid-point for synchronised and unsynchronised operation with AAS and non-AAS antennas. Similar to the first study, the calculated distances range from a couple of hundred metres to 27 km depending on the scenario simulated.

- For coexistence analysis among DECT-2020 NR networks, it is noted that protocols used for interference management between DECT-2020 NR devices should be sufficient to manage coexistence among these networks. For completeness MCL calculations were undertaken and results show that required distances are between 250 – 600 metres for co-channel operation and 30 m for immediate adjacent channel deployments.

- For DECT-2020 NR interfering with 3GPP WBB LMP networks, co-channel separations of up to 3 km are calculated with clutter and up to 33 km without clutter. Adjacent channel separations are up to 5 km. It is noted that polite protocols based on LBT used by DECT-2020 NR can help to enhance spectrum sharing and this is not taken into consideration in the MCL analysis.

- 3GPP WBB LMP interfering with DECT-2020 NR, co-channel separation distances range from 250 metres to 3.6 km depending on clutter assumptions. In the case of adjacent channel sharing, separations are less than 100 metres. These results are for medium power 3GPP WBB interferers.

The two studies relevant to coexistence between WBB networks are summarised in Section 6.1 of the Report (with detailed descriptions in Attachments 1 and 2). Both studies use Monte Carlo models

- Low-power sites are assumed to have an antenna height of 10m with EIRP of up to 31 dBm/100 MHz

- Medium power sites are assumed to have an antenna height of up to 30m with EIRP of up to 51 dBm/100 MHz

The first study considers low and medium-power, outdoor stations and assumes unsynchronised operation. Loss is modelled using P.452 with P.2108 for clutter. Interference is assessed using an I/N=-6dB criterion.

Low-power sites are at 10m with EIRP of 31 dBm/100 MHz, while medium power sites are at 12m with 49dBm/100 MHz or 15m with 51 dBm/100 MHz.

Unsynchronised		Victim		
		LP	MP (dense suburban)	MP (rural)
Interferer (BS)	LP	<250m (urban) ~600m (rural)	~300m	?
	LP		~ 500m	?
	Indoor			22-23 km

Table D.1: Summary of separation distances in ECC Report 358 (first study)

The second study also considered LP and MP outdoor sites but included both synchronised and unsynchronised operation and assessed interference using throughput loss (of 5%, 10%, 20% and 30%).

This study also assumed P.452 with P.2108 for modelling interference between low-power sites (at 10m) with EIRP of 31 dBm/100 MHz.

For medium-power sites, however, P.452 was used in urban areas but P.1546 in rural cases. Medium-power sites were assumed to have an EIRP of 49 dBm/100 MHz and antennas at 20m (urban), 25m (suburban) and 30m (rural).

In the unsynchronised case, for the chosen throughput loss, the 3m field strength at the mid-point between is determined. Rather oddly, this is then referred to as the 'local area network coverage border', although the extent of the service coverage will, presumably, be significantly less.

If there is a frequency overlap with a neighbour, an MP station cannot be assigned, while an LP station must meet a field strength limit of 32 dBuV/m. For non-overlapping frequencies (preferential) field strengths of 48 dBuV/m and 26 dBuV/m must be met for LP and MP cases (if an MP site uses AAS, the latter can be relaxed to 48 dBuV/m..

In the synchronised case, the 3m field strength is defined at the cell coverage edge and is 61 dBuV/m.

D.3 CEPT Report 88

CEPT Report 88 [B6] refers to ECC Reports 358 and ECC Report 362 (which examines adjacent band sharing with radio altimeters[10]) for coexistence studies. The following key points are noted in the context of sharing among WBB LMP networks.

- It is assumed that adjacent channel coexistence among 3GPP synchronised WBB LMP networks is covered by 3GPP/ETSI standardisation. This assumption also accounts for adjacent band operation of 3GPP WBB LMP networks in the frequency band 3800-4200 MHz synchronised with WBB ECS below 3800 MHz. Such synchronised coexistence between WBB ECS below 3800 MHz and WBB LMP above 3800 MHz, or among WBB LMP networks in the 3800-4200 MHz frequency band, could be a possible coordination solution for WBB LMP networks based on 3GPP technical specifications.
- Synchronisation, PFD limits, separation distances and/or guard bands could be considered for facilitating deployment of WBB LMP and coexistence with WBB ECS below 3800 MHz.
- CEPT will develop ECC Recommendations providing guidance to administrations on relevant mechanisms/solutions to be further implemented at national and bilateral/multilateral level to manage in-band and adjacent band coexistence.
- Assumed modelling parameters and outcomes of modelling are based on repetition of ECC Report 358.
- A set of harmonised technical conditions are proposed on the basis of analyses presented in ECC Reports 358 and 362. These conditions include in-block eirp limits for low and medium power WBB base stations and adopted in EC Decision 24(01).

D.4 ECC Decision 24(01)

ECC Decision (24)01 [B7] provides least restrictive technical conditions for the shared use of the 3.8-4.2 GHz frequency band by WBB LMP providing local-area network connectivity. The conditions are based on the assumption that the location of the WBB LMP network or base station is known.

The frequency arrangement is based on a TDD deployment in 5 MHz block sizes. AAS and non-AAS deployments are considered.

[10] See Appendix G

The maximum in-block EIRP per cell for base stations operating in the 3.8-4.2 GHz frequency band is described as follows.

Category	e.i.r.p. per cell (Note1 and Note 2)
Low power base station	≤ 24 dBm/channel for BW ≤ 20 MHz ≤ 18 dBm/5 MHz for BW > 20 MHz
Medium power base station	≤ 44 dBm/channel for BW ≤ 20 MHz ≤ 38 dBm/5MHz for BW > 20 MHz
Note 1: In a multi-sector site, the value per 'cell' corresponds to the value for one of the sectors. Note 2: Higher e.i.r.p. levels may be authorised by national administrations in exceptional and duly justified cases, provided that protection of FSS receiving earth stations and FS links (where appropriate nationally) in the band as well as MFCN below 3.8 GHz and radio altimeters above 4.2 GHz is ensured, taking into account their future development, including in the neighbouring countries. Coverage shall remain local, i.e. no nationwide networks.	

Table D.2: Base station EIRP levels (ECC Decision 24(01))

The maximum terminal station in-block power is 28 dBm TRP including a 2 dB tolerance and transmission power control is mandatory and needs to be activated. For fixed terminals an in-block EIRP limit may be defined at national level, provided that protection of in-band and adjacent band incumbent services and cross-border obligations are fulfilled.

The stipulations of the Decision which relate to the protection of MFCN below 3.8 GHz and radio altimeters above 4.2 GHz are summarised in Appendices F and G respectively.

It is important to note that the Decision does not include

- Out-of-block emission limits for coexistence among WBB LMP deployments;
- Out-of-block emission limits for coexistence with FSS and FS deployments; and
- Unwanted emission limits for coexistence with MFCN operating below 3800 MHz.

It is stated that, for all three cases, national coordination may be required.

D.5 FM60 work on development of ECC Recommendation for WBB LMP coexistence

Recent FM60 meeting documents relating to the development of ECC Recommendation for coexistence among WBB LMP deployments have been discussing the following points.

- *Licencing approach* – Options presented include case-by-case analysis implemented by the national regulator using network parameters specified in licence conditions; or simplified planning based on satisfying a maximum field strength at the edge of licensed area. The main assumption seems to be licences are granted on a first-come-first-served basis.
- *Protection requirements* – Current discussions focus on whether interference limits should be defined at a base station location and/or an edge/inside of WBB LMP coverage area. Some arguments are related

to avoiding introduction of additional constraints on top of the least restrictive technical conditions defined in the ECC Decision (24)01 as well as definition of 'coverage area' and 'edge of coverage area'.

- *Co-channel separation distances* – Minimum coupling loss separation distances from a few hundred metres to a couple of kilometres are calculated for low and medium power deployments assuming I/N of -6 dB which corresponds to field strength requirement of 49 dBuV/m/5MHz.
- *Adjacent channel separation distances* – For low power deployments distances vary up to 150 m and for medium power deployments distances are up to 1 km depending on assumed frequency separations.
- *Overlapping coverage areas* – It is argued that for those scenarios where calculated distances are comparable to WBB LMP coverage areas, coexistence should be possible by avoiding overlapping coverage areas.
- *Synchronisation* – The main issue appears to be if synchronisation should be imposed or should be considered as a tool when interference occurs. Arguments presented include allowing WBB LMP operators to resolve interference among themselves and letting the regulator interfere if no agreement can be reached; and applying other mitigations (power and antenna) before imposing a common frame structure or asking a new WBB LMP operator to synchronise with existing nearby deployments. It is important to consider trade-off between flexibility in choosing different frame structures and potential for interference.
- *Specification of interference limits* – In the most recent meeting of FM60, it was suggested that recommended limits for victim base station interference levels should be in dBm and should be defined at the antenna connector so as to include antenna gain.

D.6 Example interference contours

The following plots indicate the areas around a hypothetical base station in central Dublin which would be 'sterilised' for use by other WBB LMP networks.

Figure D.1 shows the areas around a medium power site within which another medium-power site could not be assigned co-channel. The use of synchronisation implies that the dominant interference path is now between the base station and a victim terminal. As the latter is below clutter height and has a low-gain antenna, it is far less vulnerable to interference, with exclusion distances of less than 2km.

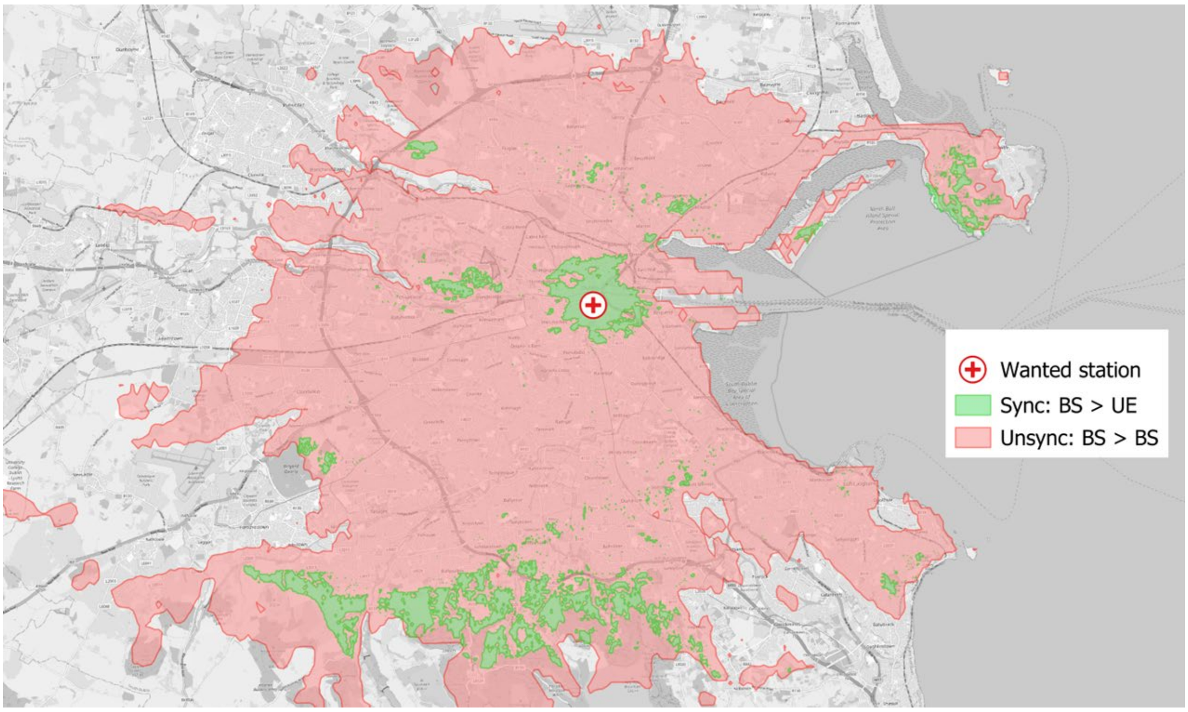

Figure D.1: MP – MP case: impact of synchronisation

The extent of potential interference for the unsynchronised MP-MP, MP-LP and LP-LP cases is indicated in Figure D.2.

The maximum exclusion distance of around 22km for the MP-MP case is comparable with those determined in Report 358

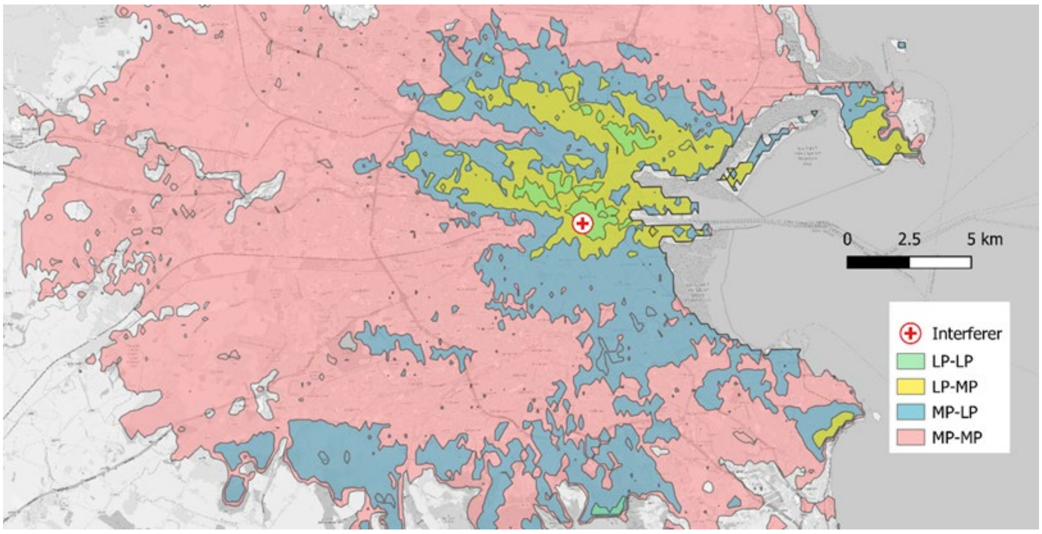

Figure D.2: Unsynchronised interference contours

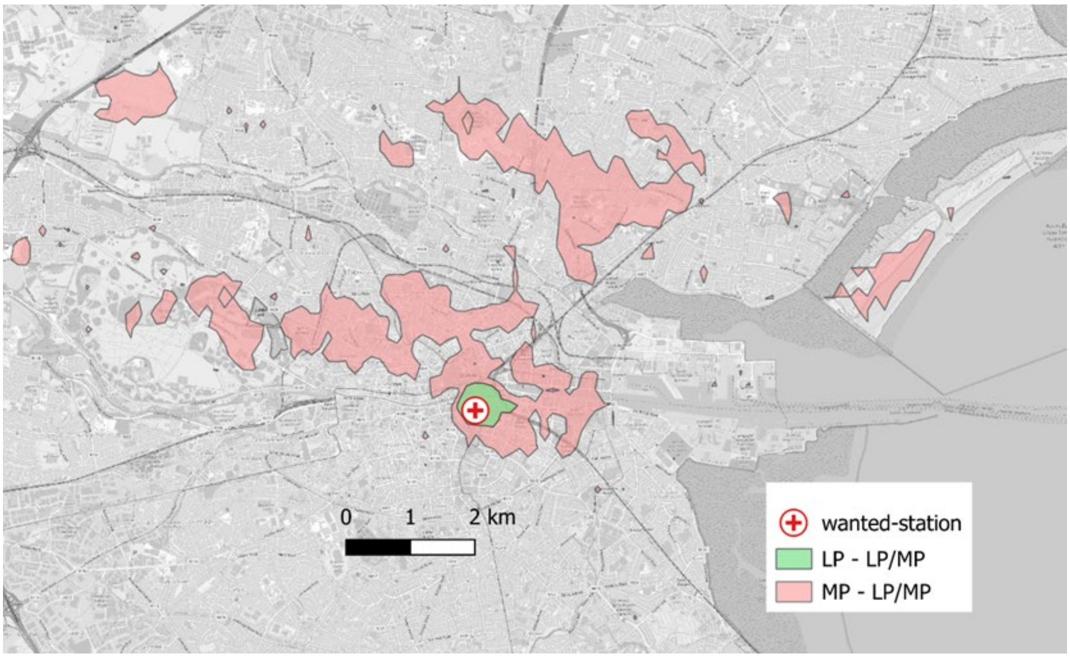

Figure D.3: Synchronised interference contours

D.6.1 Adjacent channel interference

In-band coexistence between WBB LMP systems will be dominated by co-channel constraints, but any planning process will need to take adjacent-channel interference into account as well.

In ECC Report 358 the adjacent-channel case was examined only in 'Study 2' and is not reported in the main body of the report except to say that "*Adjacent channel operation between neighbouring WBB Medium Power BSs is more feasible than co-channel based on the simulation results*" (p.37). In Attachment 2, the results of the SEAMCAT modelling seem to show MP-MP separation distances of 12.6km (urban, non-AAS) and 2km (urban, AAS).

Report 88 repeats the '*more feasible*' phrase and gives the following field strength values for planning of unsynchronised systems:

Environment	WBB low power base station Urban/Suburban/Rural dBμV/m/5 MHz at 3 m height	WBB medium power base station Urban/Suburban/Rural dBμV/m/5 MHz at 3 m height
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 D.3: Adjacent-channel field strength limits (ECC Report 88)

For synchronised operation, the value is a flat 61dBμV/m.

Previous work by Plum (a study for a European regulator) compared separation distances for the co- and adjacent-channel cases. The figures in the table below illustrate the constraints imposed in the two cases.

Separation distance (km)	MP-MP	MP-LP	MP-Ind	LP-MP	LP-LP	Ind-MP	Ind-LP
Co-channel	17.1	12.3	0.9	15.1	5.8	1.7	0.4
Adjacent-channel	1.2	0.5	-	0.5	0.3	0.2	0.2

Table D.4: Sample separation distances for unsynchronised networks (Plum)

D.7 Summary of technical issues

The modelling described in Report 358 used two different methods for the assessment of interference to WBB LMP networks (an I/N threshold and throughput degradation) and applied a variety of assumptions regarding clutter (urban, dense suburban, suburban, rural) and antenna gain and downtilt. Some of the transmit powers assumed do not align exactly with the maximum values subsequently identified in ECC Decision (24)01.

Nevertheless, the broad conclusions relating to necessary separation distances are clear and align with the independent modelling reported in the section above. The tables below provide indicative separation distances for different system combinations where system parameters are as given in Appendix I.

Unsynchronised		MP	LP	Indoor
Interferer (BS)	MP	22 km	9 km	1.5 km
	LP	6 km	3 km	0.5 km
	Indoor	1.5 km	0.5 km	<0.3 km

Table D.5: Indicative re-use distances.

For the synchronised case, distances are greatly reduced

Synchronised		MP	LP	Indoor
Interferer (BS)	MP	4 km	4 km	<0.2 km
	LP	0.4 km	0.4 km	<0.2 km
	Indoor	<0.2 km	<0.2 km	<0.1 km

Table D.6: Indicative re-use distances

Appendix E Coexistence with FSS Earth stations

E.1 Background

In ITU-R Region 1, the band 3.4-4.2 GHz has a primary allocation to the Fixed Satellite Service (FSS) in the space-Earth direction. Globally, the band has been intensively used for both direct-to-home broadcast and Very Small Aperture Terminal (VSAT) data links, but in Europe, where rain-margins are modest, such applications have generally migrated to higher frequency bands.

E.2 FM60 draft annex – Technical toolkit: WBB LMP and Fixed Satellite Service Earth Station in 3800-4200 MHz band

The current FM60 draft annex that addresses WBB LMP and FSS in the 3800-4200 MHz band, following the on-line meeting 28 - 29 April, notes that compatibility between the two services can be achieved by the use of "*coordination measures to be applied within coordination zones evaluated around FSS earth station receivers*".

The possibility of adopting exclusion zones around FSS Earth Stations (ES) , smaller than coordination zones, in the same way as in ECC Report 254 [B8] is also mentioned.

It is noted that separation distances could range up to several tens of kilometres and highlight the importance of considering site-specific terrain data. It is proposed that the exact shape of the coordination/exclusion zones should be calculated on a case-by-case, mainly depending on the terrain profile around the specific FSS system, and the type/characteristics of the specific FSS system.

Two different approaches to define the coordination zone, within which base stations will have to be coordinated[11], are proposed:

- Define by using generic parameters that can be exchanged for the real ones, or
- Define as a circle based on typical distances calculated from previous studies.

The second approach is considered to be simpler but the coordination zones will be larger, so more WBB LMP networks need to be coordinated.

It is proposed where there are a limited number of FSS ES or the WBB LMP base stations are not expected to be deployed in the immediate vicinity of an existing FSS antenna a coordination radius of 40 km might be used as a good compromise. As noted in the draft FM60 document "*this corresponds to results for Medium Power BS limited to Ptx = 35 dBm/40 MHz (which corresponds EIRP = 49 dBm/100 MHz with a 10 dBi antenna gain), model P.452-16, no clutter, FSS ES antenna diameter of 4.5 m, azimuth discrimination of 0°, and FSS ES elevation angle of 10°*". It is however noted that larger distances could be used, such as the 287 km used in the UK, corresponding to a worst case MCL calculation, but this obviously increases the number of WBB LMP networks that would need to be individually coordinated.

There are no proposals for calculating the aggregated effect of WBB LMP base stations as it is expected to be low.

[11] User equipment is not considered as likely to be indoors or shielded by clutter

E.3 Irish use cases

No licensed FSS use is known to exist in Ireland, although it is believed that some FSS terminals may be deployed in the Dublin area, presumably for receive-only use.

To illustrate the size and variability of the exclusion zone required for FSS receiver protection, predictions have been made for two hypothetical ES locations in the Dublin area, distinguished by the difference in height above sea level. In each case, contours were drawn for a ground-based FSS antenna and one assumed to be mounted on a building roof, above clutter.

	Site 1	Site 2
Terminal location	53.346589° N, -6.272209° E	53.361678° N, -6.275037° E
Location height	4m ASL	31m ASL
Target satellite	SES 5 (5° E)	
Target satellite azimuth, elevation	166°, 28.3°	
Antenna diameter	1.5m	
Antenna gain	33.7 dBi	
Antenna height	2m or 12m	

Table E.1: Parameters of hypothetical C-band satellite terminals in Dublin

For modelling purposes, it is assumed that the antenna patterns are represented by Recommendation ITU-R S.465 [A8].

Predictions have been made of the area within which interference to these FSS receivers might occur from a co-channel WBB assignment, on the basis of an interference-to-noise (I/N) criterion of -10dB (the assumption made in ECC Report 254 [B8].

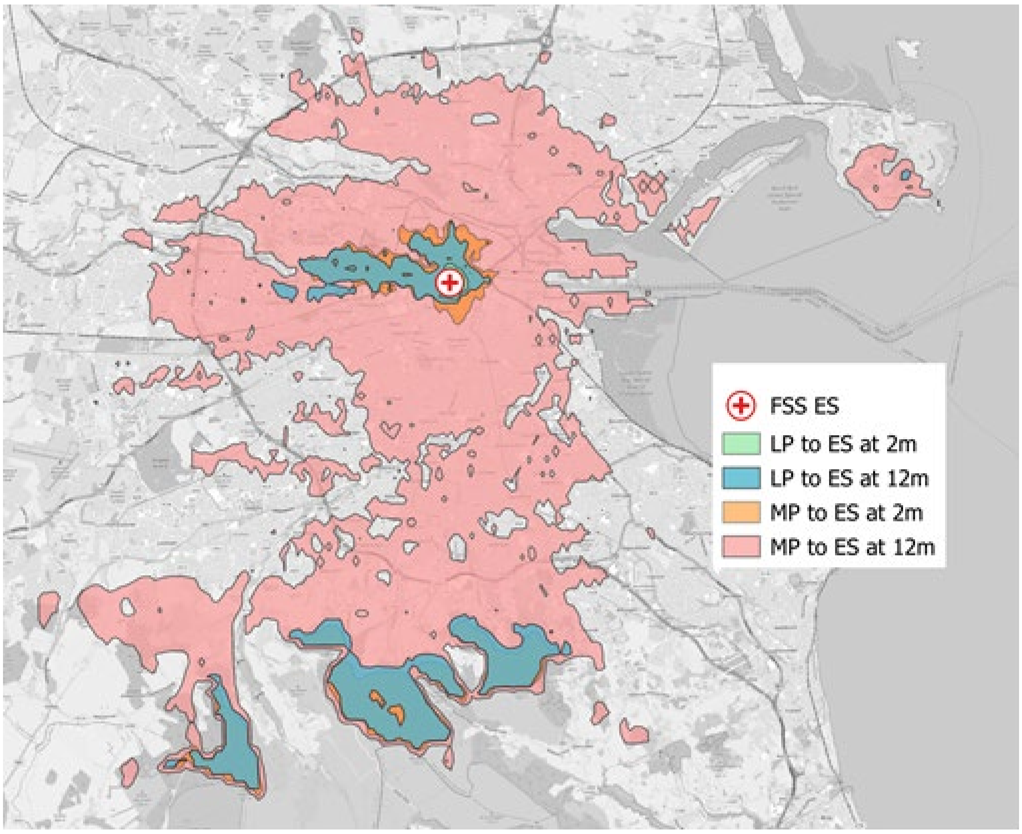

Figure E.1: FSS Coordination areas for 'Site 1' (4m ASL)

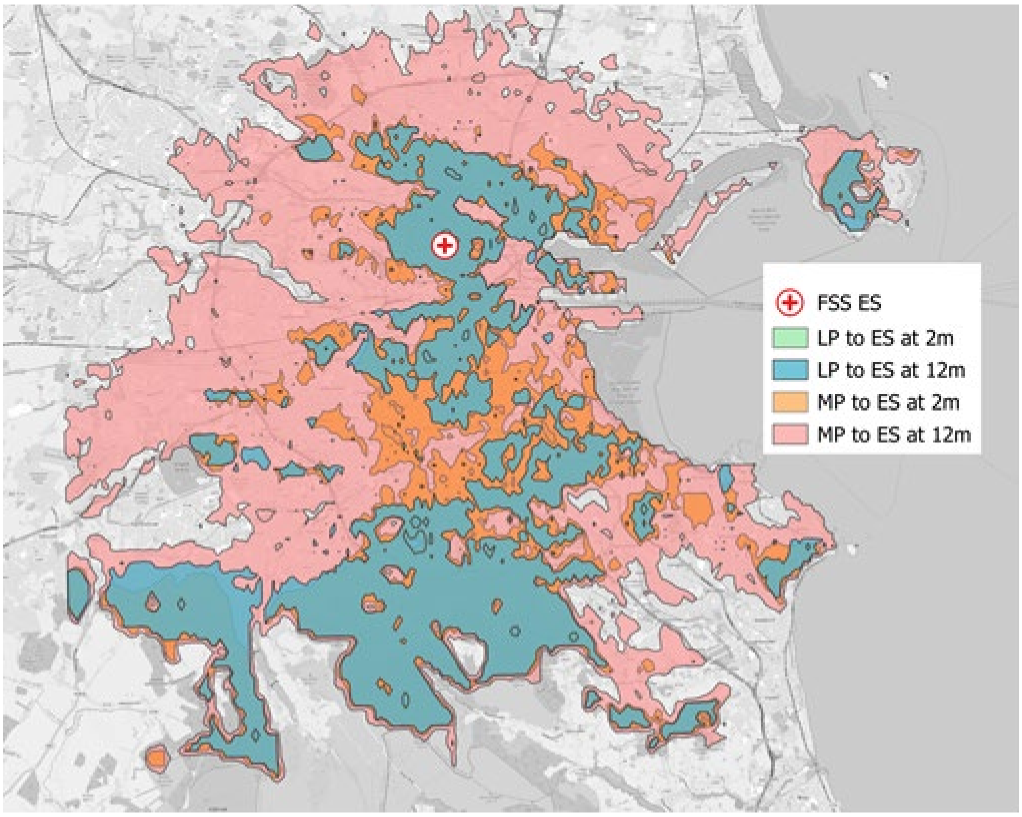

Figure E.2: FSS Coordination areas for 'Site 2' (31m ASL)

The variation in the areas within which WBB sites may cause interference is striking; this is primarily due to the higher location of Site 2 and the differences in Earth station antenna height.

In both cases, indoor, low-power use has a negligible impact.

Appendix F Coexistence with public mobile networks below 3.8 GHz

F.1 Introduction

A substantial amount of technical modelling work was undertaken within ECC PT1 to define the regulatory technical conditions for WBB LMP under condition that the adjacent band 5G MFCN and several other in-band and adjacent band systems are properly protected.

The results of these studies are summarised in ECC Report 358, which has been used to inform EC Decision 24(01) and the current work withing ECC FM60.

F.2 ECC Report 358

ECC Report 358 [Ref] considers compatibility of WBB with MFCN below 3800 MHz in Section 7.12. Seven technical studies of unsynchronised operation are reported, and the following findings noted:

- Low power WBB operation may be possible down to 3800 MHz if an additional out-of-band emissions limit of -45dBm/MHz (conducted) is applied.
- Frequency separation of 20 MHz (low power) and 60 MHz (medium power) may be needed to avoid MFCN receiver blocking.
- WBB LMP receivers may need to have an improved blocking performance with respect to MFCN below 3800 MHz
- WBB LMP terminal EIRP may need to be limited to 28 dBm

Some studies investigated if stricter out of band emission and receiver blocking levels of WBB 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 base stations;
- synchronisation or semi-synchronisation between MFCN and WBB LMP networks

F.3 ECC Decision (24)01

ECC Decision (24)01 [B7] notes that, to protect MFCN operating below 3.8 GHz, coordination may be required at national level where examples include:

- Geographical or frequency separation.
- Defining a maximum allowed PFD at the border of the WBB LMP licensed area.
- Synchronised operation.
- Specific sub-cases of semi-synchronised operation which only allow DL to UL modifications to the WBB LMP network compared to the frame structure of the MFCN.
- Defining the maximum unwanted emissions below 3.8 GHz depending on location of WBB LMP in relation to MFCN.

F.4 Draft Recommendation (FM60)

The draft Recommendation from FM60[12] notes that 3GPP standards will ensure that, when synchronisation is implemented, co-existence is not an issue.

Semi-synchronised WBB operation may be used to protect MFCN uplink (but in this case, WBB may still be degraded).

Unsynchronised operation should <u>not be permitted</u> below 3820 MHz and <u>only permitted at low power</u> between 3820-3860 MHz.

There is ongoing discussion in FM60 regarding the interference criterion for base-station-to-base-station analysis. In some administrations (Norway, UK) an interference criterion of I/N=-6dB is applied, while elsewhere, throughput loss is estimated. These approaches can lead to very different results.

F.5 Summary

While ECC Report 358 and ECC Decision (24)01 only state that synchronisation (of WBB LMP networks with MFCN ECS below 3800 MHz) <u>may</u> be necessary, the current working text in FM60 would mandate the use of synchronisation in the lower 20 MHz in all cases and require synchronisation for medium power stations up to 3860 MHz.

Information on the mutual impact of unsynchronised networks in the real-world is sparse and anecdotal, and it is hard to prove a negative (that no interference occurs between unsynchronised networks). Two recent

[12] "*Guidance on planning Low and Medium power terrestrial wireless broadband systems (WBB LMP) in the band 3800-4200 MHz, and the co-existence with MFCN below 3800 MHz*", Draft report under development in FM60.

examples involved the use of private WBB networks for video broadcast contributions and used uplink-centric frame structures unsynchronised with MNO networks below 3800 MHz.

The first case was in central London for the coronation of King Charles III in 2023 and the second for the Paris Olympics in 2024. In the former case, some of the nodes operated only 15 MHz from the lower band edge and no issues of interference were reported. In the second case, the private WBB network suffered significant interference from the public network below 3800 MHz, and it was necessary to fit FR bandpass filters to prevent overload in the front-end amplifier. Again, no interference to the public network was reported.

It is quite likely that any interference from the private network was not noticed simply because the MNO public networks would have been highly congested in any case. The absence of reported issues in the UK may also be attributable to the fact that most assignments are low power and the likelihood that many devices are, by default, synchronised with the same frame structure as users below 3.8 GHz.

Appendix G Coexistence with radio altimeters above 4.2 GHz

G.1 Introduction

Most aircraft, both fixed-wing and helicopters, use radar altimeters operating in the 4.2-4.4 GHz band. In most commercial aircraft, these altimeters are integrated into overall safety and warning systems and any disruption may cause operational delays, at best and catastrophic accidents, at worst.

This band has been in a relatively quiet part of the spectrum until recently, with adjacent use mostly by terrestrial fixed links and satellite Earth station receivers. This has changed recently with the international roll-out of new 5G mobile networks using C-band spectrum from 3.6 – 4.0 GHz, and on frequencies above 4.4 GHz.

This creates the possibility of interference from these networks to radar altimeters, either due to overload of the radar receiver by the transmissions in the adjacent band, or by out-of-band emissions from the MFCN transmitters falling in the bandwidth of the radar receivers.

This topic has received a great deal of attention and publicity over the last few years, but there is, as yet, no consensus on the best approach to manage the interference risk. This is partly due to the different spectrum allocation status in different countries and partly due to the difficulty in extrapolating the statistics from a relatively small number of equipment performance measurements to represent the entirety of installed radio altimeter systems.

G.1.2 Radio Altimeter Systems

Radio altimeters are specialised, low-power radars, the sole purpose of which is to determine the range from an aircraft to the ground beneath. They are relatively simple systems, as no scanning or imaging is required – unlike 'normal' radar systems, the antennas must have a very broad beamwidth so that a consistent 'view' of the ground is obtained even when the aircraft rolls or pitches in flight.

As noted, radio altimeters are used in all aircraft types, but can be seen to fall, broadly, into two classes. Units for use in large airliners and similar commercial aircraft will measure altitudes up to around 5,500'-7,500', while the smaller, cheaper units intended for smaller aircraft, including helicopters, are typically limited to around 2,500'. Transmitter powers are typically in the 100mW to 5W range.

Most civilian radar altimeters use the 'FMCW'[13] approach, where the transmitted carrier is swept across the spectrum in a regular fashion (generally in a linear, triangular, sweep up and down, in frequency). This signal will travel to the ground, be reflected and return to the aircraft. By the time the signal returns to the aircraft, the transmitted frequency will have changed, by an amount depending on the sweep rate and the overall path length to the ground and back. The difference between the frequencies can then be used to determine the height. In most systems, this is a simple matter of measuring the beat frequency between the transmitted and received signals, which may be done in an analogue domain or with quite sophisticated digital signal processing (DSP).

A few altimeters use a traditional pulsed-radar approach, where the delay between a transmitted and return pulse is measured directly and multiplied by the speed of light to give distance.

[13] Frequency modulated continuous wave

As with most radio systems, two potential coupling mechanisms for interference must be considered.

- A victim radio altimeter may have an undesired response to energy in the main carrier of the 5G transmission, as a result of limited receiver filtering. The reports reviewed here refer to this variously as 'fundamental' or 'blocking' interference.
- A 5G transmitter may, unintentionally, radiate energy falling in the bandwidth of the radio altimeter receiver due to limitations in transmitter filtering. The reports reviewed here refer to this interference as being due to 'spurious emissions', 'unwanted emissions', 'out-of-band emissions' or 'desensitisation' interference .

In terms of determining spectrum compatibility, the crucial parameters of the altimeter are:

- The antenna pattern and gain (broadly hemispherical, typically ~10dBi)
- The system noise figure (typically 5dB)
- The effective bandwidth (generally an intermediate frequency (IF) bandwidth of 0.1-2 MHz)
- The overload characteristics of the receiver front-end (varies very widely)
- The front-end filter response of the receiver

The primary document relating to protection requirements for radio altimeters is ITU-R Recommendation M.2059 [A7], dating from 2014, which gives parameters for ten (anonymised) radio altimeter types.

G.1.3 Previous studies

A substantial report [E2] was published in 2020 by the RTCA[14] and describes laboratory tests on nine (anonymised) altimeters and a series of detailed compatibility analyses reflecting operational scenarios. The Report was developed in the context of the release of spectrum in the USA at 3.70-3.98 GHz.

The primary findings of the report were that in a few operational scenarios a risk of interference to the worst-performing altimeters existed. It was also highlighted that the use of active antenna systems by MFCN base stations could give rise to 'grating lobes' which direct unintended energy skywards. A major problem for regulators was that there was no record of the aircraft fitted with poorly-performing altimeters and no standard for altimeter front-end filter performance.

This situation led to a high-profile dispute between the aviation and telecommunications communities, and a voluntary agreement was to restrict 5G rollout near airports until February 2024, pending investigations, testing and filter retrofitting.

[14] Founded in 1935 as the 'Radio Technical Commission for Aeronautics', this US non-governmental, non-profit organisation develops Minimum Operating Performance Standards (MOPS) for avionics and aeronautical procedures.

The topic of radio altimeter protection has recently been raised within ITU-R WP5D and WP5B in relation to studies for WRC-27 Agenda Item 1.7, which concerns the possible identification of the band above 4.4-4.8 GHz) for IMT. This work is not expected to have any relevance for the present study.

G.2 Coexistence measures

In France, licences in the 3.4-3.8 GHz band were issued very shortly after the publication of the RTCA report. As an immediate response to the latter, 'phase 1' restrictions on 5G deployment near airports were defined in November 2020. A similar approach was also adopted in Canada.

These restrictions[15] stated that antennas must only tilt below the horizon, and that AAS shall 'avoid grating lobes as far as practicable'. In addition, two zones were defined around those airport runways where IFR[16] approaches are allowed, and around some helicopter platforms. No stations may operate within 'zones de sécurité' while stations in a 'zone de precaution' require individual coordination.

The exact dimensions of the zones depend on the maximum eirp assumed for base stations. For the case of a 78dBm eirp, the dimensions are:

- **zones de sécurité** extend 910 metres on either side of the runway edge and 2100 metres from the runway thresholds
- **zones de precaution** are 800m wide and extend 6.1km from either end of a zone de sécurité

An illustration of the zones is reproduced below.

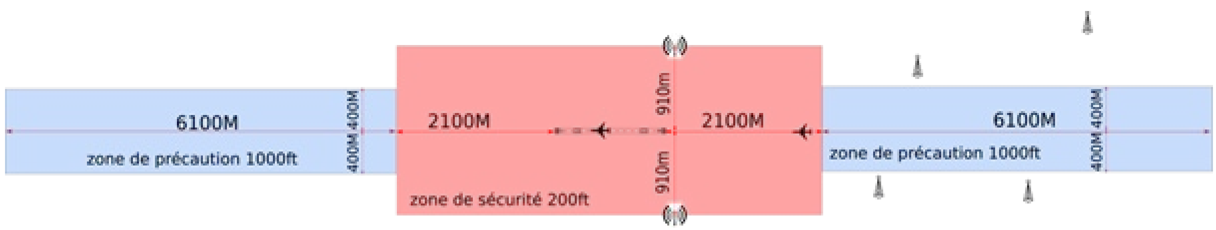

Figure G.1: French protection zones

The zones are explicitly determined using parameters given in the RTCA report to protect category 1 altimeters (the best-performing case, associated with large commercial airlines.

The RTCA report found that the (worst case) performance of category 2 and 3 altimeters was so much worse than for category 1, that to apply the rules above would prevent the deployment of 5G anywhere in France. The only mitigation measure possible was therefore to limit above-horizon antenna tilt.

The French civil aviation authority, the DGAC[17] , has therefore invested significant effort in identifying the radio altimeters with the poorest selectivity and ascertained that these were fitted to about 100 French-registered regional or business jet aircraft. The DGAC were clearly frustrated [13] that this data had not been made public.

In 'phase 2' (from February 2021), noting the lack of evidence of any actual issues with 5G interference, and the fact that France was the only European county to adopt preventative measures, the restrictions were relaxed.

[15] https://www.anfr.fr/fileadmin/mediatheque/documents/N%C3%A9gociations/Note-technique-zones-securite-precaution.pdf
[16] Instrument Flight Rules
[17] Direction générale de l'aviation civile

The measures listed above are now only applied to CAT II and CAT III runways and the heliports already identified. In March 2021, flight tests and other European studies were being planned to quantify interference issues.

G.3 ECC Report 362

This very substantial, 362-page ECC report [B5], published in November 2024, concerns the compatibility of radio altimeters with both MFCN below 3.8 GHz and WBB LMP at 3.8-4.2 GHz.

Measurements on Radio altimeters revealed a very wide range of susceptibilities to interference, and this was reflected in the use of two parameters sets to represent altimeters in the technical studies.

For WBB LMP, no issues were identified except for sites operating above 4.1 GHz and also using active antenna systems (AAS). In this case, if the most vulnerable receiver parameters were assumed, there was a possibility that the required 6dB ICAO safety margin would not be achieved. This could be addressed either by ensuring that base stations were located more than 1200 m from the runway threshold or 40 m laterally or, alternatively, by enhancing the suppression of out-of-band emissions.

G.4 ECC Decision 24(01)

This ECC Decision [B7] defines the maximum unwanted emissions above 4200 MHz for general protection of radio altimeters as follows.

Frequency range	Non-AAS base station e.i.r.p. limit dBm/5 MHz per cell (Note 1)	AAS MP base station t.r.p. limit dBm/5 MHz per cell
4200-4205 MHz	11	1
4205-4240 MHz	8	-3
Note 1: In a multi-sector site, the value per 'cell' corresponds to the value for one of the sectors.		

Table G.1: Unwanted emission levels for radio altimeter protection (ECC Decision 24(01)

For AAS medium power base station in 4.1-4.2 GHz deployed in close proximity to those airports which support precision approach procedures, coordination may be needed. Examples include:

- no AAS medium power base station deployment closer than 1200 m from the runway threshold and 40 m laterally from the edge of the runway,
- AAS medium power base stations in compliance with emission levels meeting the spurious emission limit between 4200 and 4240 MHz. The spurious domain for a base station operating in 3.8-4.2 GHz starts 40 MHz from the band edge and the corresponding spurious emission limits are defined in ERC Recommendation 74-01.

The same constraints are specified in the draft EC Implementing Decision [B12] of March 2025.

G.5 Draft Recommendation (FM60)

This draft Recommendation from FM60 uses the findings of ECC Report 362 to set out the measures that administrations should take to ensure coexistence with radio altimeters. It is stressed that coexistence issues only arise for the case of base stations that (i) use AAS and (ii) operate above 4.1 GHz.

Annex 1.1 details the use of site-specific parameter tuning (power, antenna pointing) to meet the coexistence requirements.

Annex 1.2 describes the exclusion zone around a runway required to avoid any coexistence issues with AAS sites operating above 4.1 GHz (1200 m from the runway threshold or 40 m laterally)

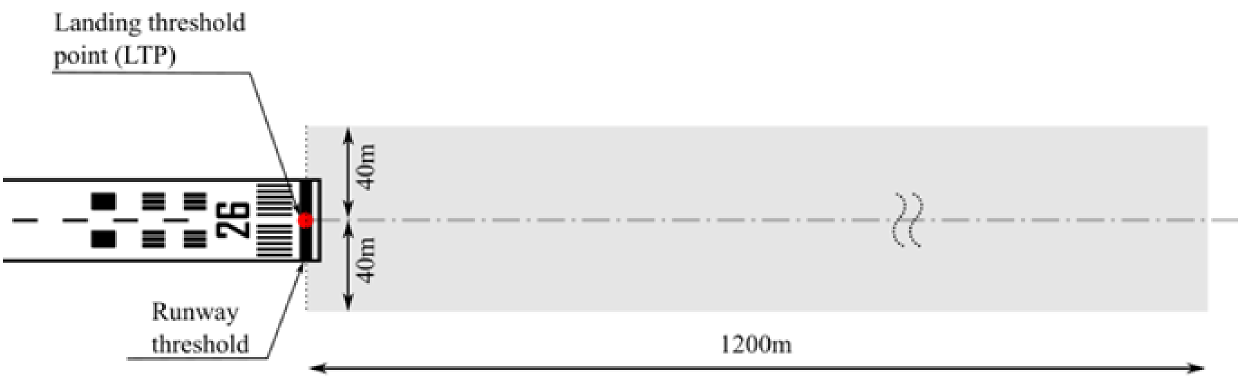

Figure G.2: Draft recommended exclusion area for AAS base stations operating above 4.1 GHz

G.6 EU Roadmap

The European Commission has recently (30 April 2025) published a '*Roadmap for Ensuring Safe Coexistence Between Mobile Networks and Aircraft Radio Altimeters Within the Frequency Range 3.4-4.4 GHz in the Union'*. The document [B13] notes:

"*Particular focus should be given to orderly transition that needs to be organised well in advance to ensure that the use of the 3.8-4.2 GHz frequency band by LMP WBB networks in Europe will not cause an unsafe condition in aviation and that it won't introduce undue delays in the deployment of mobile networks. Considering lessons learnt from developments in the US, if no coordination takes place and any necessary limitations are not applied, EASA may have to issue an Airworthiness Directive addressing all the fleet, which will result in an unorderly, disruptive, and expensive retrofit of the entire fleet.*"

Appendix H Synchronisation in TDD networks

Where spectrum is assigned with TDD duplexing, synchronisation between licensees minimises the potential for co- and adjacent-channel interference and maximises spectrum efficiency.

Synchronisation requires the establishment of fixed uplink (UL) and downlink (DL) ratios as well as having a common reference phase clock to synchronise the beginning of frames across all networks. While this avoids the risk of base station to base station interference from unsynchronised transmissions, it removes the flexibility of operators to tailor their UL/DL ratios to their particular use-cases.

Alternatively, networks can be semi-synchronised or unsynchronised.

Unsynchronised time-division duplex (TDD) deployments can lead to high levels of interference, even if the frequency use in networks deployed in adjacent geographic areas is for the same services and the same technologies. The potential interference paths in the case of unsynchronised TDD operation includes base station to base station, base station to user terminal, user terminal to user terminal, and user terminal to base station interference paths.

In unsynchronised deployment scenarios, the most significant impact is mutual base-station interference, as the height and EIRP of base stations are greater than those of user terminals. Also, base stations are at fixed locations so the potential for the interference is always present. Any co-ordination thresholds that are developed to limit such base-station-to-base-station interference will also cover, by proxy, the coordination threshold requirements of base-station-to-user-terminal, user-terminal-to-base-station and user-terminal-to-user-terminal interference paths.

ECC Report 281 [B10] provides definitions of synchronised, unsynchronised and semi-synchronised operation:

Synchronised operation *"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 synchronising the beginning of the frame across all networks"*.

Unsynchronised operation *"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 "*

"*Semi-synchronised operation corresponds to the case where 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*".

According to ECC Report 307, semi-synchronised operation requires the adoption of a default frame structure (for which UL/DL directions are defined across the whole frame) and at the same time the definition of the part of the frame where each operator is allowed to reverse the default transmission direction (flexible part). As a consequence, for semi-synchronised operations two possible modifications compared to the default frame structure are possible:

- DL to UL modifications: in case an operator selects the UL direction in the flexible part while the default frame structure adopts the DL direction; This has been the option considered in sharing studies in ECC PT1 where the modification is allowed in the WBB LMP network.

- UL to DL modifications: in case an operator selects the DL direction in the flexible part while the default frame structure adopts UL direction.

In ECC Report 296 [B11] the differences and commonalities between these modes of operation are further elaborated. In addition, this Report discusses the implications on clock and frame structure alignment as well as the out-of-block power limits.

In Ireland, Statutory Instrument 532/2016[18] specifies that networks operating in the 3.4-3.8 GHz band shall use TD-LTE frame configuration 2 (Downlink: Uplink, 3:1), the structure of which is indicated in Figure H.1.

DL/UL ratio	**Timeslot or Subframe number**									
	0	1	2	3	4	5	6	7	8	9
3:1	D	S	U	D	D	D	S	U	D	D

Figure H.1: Structure of TD-LTE frame configuration 2 (Downlink: Uplink, 3:1)

While this downlink-focussed structure is appropriate for many applications, particularly in the consumer sphere, some envisaged industrial and broadcast operation will have a more uplink-heavy distribution of traffic. The use of private 5G networks for high-definition video uplink (e.g. from broadcast radio cameras) has received considerable attention, and is well described in a recent BBC White Paper [E4]. For such use, not only must the choice of frame structure be flexible, but the licensing process also needs to accommodate temporary requirements at short-notice.

[18] S.I. No. 532/2016 - Wireless Telegraphy (3.6 GHz Band Licences) Regulations 2016.

Appendix I Technical parameters assumed in modelling

The following parameters were assumed in developing the plots of interference in this report.

	Local MP (above clutter)	Local LP (below clutter)	Indoor
Power (EIRP)	51 dBm	31 dBm	27 dBm
Bandwidth	100 MHz	100 MHz	100 MHz
Antenna height	17m	6m	3m
Antenna gain	16 dBi	7 dBi	3 dBi
Antenna HRP	Omnidirectional	Omnidirectional	Omnidirectional
Antenna VRP	F.1336	F.1336	Omnidirectional
Antenna downtilt	0°, 3°, 6°	0°, 3°, 6°	-
BS noise figure	5 dB	5 dB	5 dB
I/N criterion	-6 dB	-6 dB	-6 dB
ACLR	45 dB	45 dB	45 dB
ACS	37.6 dB	37.6 dB	37.6 dB
ACIR	36.9 dB	36.9 dB	36.9 dB

Table I.1: Modelling parameters assumed by Plum

Propagation loss was determined using Recommendation ITU-R P.1812-7, with SRTM[19] terrain data and ESA 'Worldcover' clutter data.

[19] NASA's 'Shuttle Radar Topography Miussion'