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Current and Future Use of the 4 GHz Band

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Contents

1 Definitions of Selected Acronyms

AAS	Adaptive Antenna Systems
ACLR	Adjacent Channel Leakage power Ratio
BEM	Block Edge Mask
BS	Base Station
CEPT	European Conference of Posts & Telecommunications
CPE	Customer Premises Equipment
CSDP	[Europe's] Common Security and Defence Policy
DL	Down Link
EC	European Commission
ECC	CEPT's Electronic Communications Committee
ECS	Electronic Communications Services
EIRP	Equivalent Isotropic Radiated Power
ETSI	European Telecommunications Standard Institute
FAA	Federal Aviation Administration
FDD	Frequency-division duplex
FRMCS	Future Railway Mobile Communication System
FSS	Fixed Satellite Service
FWB	Fixed Wireless Broadband
HS	Harmonized Standard
ICAO	International Civil Aviation Organization
ICCAIA	International Coordinating Council of Aerospace Industries Associations
IEEE	Institute of Electrical and Electronics Engineers
ILS	Instrument Landing System (for aircraft)
IMT	International Mobile Telecommunications (ITU's name for 3GPP technologies)
ITU	International Telecommunication Union
LEO	Low Earth Orbit (160 – 2 000 km above Earth's surface)
LMP	Low/Medium Power
LRTC	Least Restrictive Technical Conditions
MFCN	Mobile/fixed Communication Networks

MOPS Minimum Operational Performance Standards

NATO North Atlantic Treaty Organization

NLOS Non-Line-Of-Sight

NPN Non-Public cellular Network

NR New Radio (5G)

OBUE Operating band unwanted emissions

OJEU Official Journal of the European Union

PFD Power Flux Density

P2MP Point to Multi-Point (alternative: PMP)

PNI-NPN Public Network Integrated Non-Public Network

PT Project team

P2P Point-to-Point (alternative: PTP)

RA Radio Altimeter

RDFT Radio Device Fixed Terminal (DECT-2020 NR specification)

RDPT Radio Device Portable Terminal (DECT-2020 NR specification)

RSC (EU) Radio Spectrum Committee

RSPG (EU) Radio Spectrum Policy Group

SNPN Standalone Non-Public cellular Network

TD Threshold Degradation

TDD Time-Division Duplex

TPC Transmit Power Control

TRP Total radiated power

WAIC Wireless Avionics Intra-Communication

WBB Wireless BroadBand

WG Working Group

WMO World Meteorological Organization

WRC World Radiocommunication Conference

2 Management Summary

In 2016, the EU's Radio Spectrum Policy Group (RSPG) identified 3.4-3.8 GHz as "the primary band suitable for the introduction of 5G use in Europe."[1] Although this band was already harmonized for mobile services[2], it was still mainly used to support Fixed and Fixed Satellite services. So CEPT developed a "a technical toolkit for administrations to manage the coexistence [of Mobile/Fixed Communication Networks (MFCN)] with fixed links in this frequency band."[3] But RSPG also said administrations might consider "promoting a greater spread of 5G by clearing the band in full for mobile network operators."[4] Many EU Member States did that, often shifting FS and FSS systems to 3.8-4.2 GHz where they retained primary allocation status while mobile networks were secondaries.

RSPG hoped that the development of mobile networks at 3.4-3.8 GHz would enable development of "a diverse set of applications and new services in a number of different markets, going beyond the traditional mobile broadband market" especially to support "industrial transformation."[5] But they found that while there was significant industrial interest in 5G's potential for in-plant networking, many production facilities are in areas not well covered by public mobile networks. Furthermore, networks supporting automation or mission-critical data might not need or want interconnection with public networks because of the risks of intrusion or leaks of proprietary information. Finally, some industrial customers simply want full control of in-plant networks. This led RSPG to conclude that "connectivity for vertical industries could be provided by mobile operator's solutions, third-party providers [or] directly by verticals themselves in EU harmonised ECS bands or in dedicated spectrum for verticals."[6] That raised the question: should some spectrum be reserved for non-public cellular networks, to encourage industrial deployments—as Finland, France, Germany, UK, etc. have done—or to put the question differently: should entities that might otherwise be MNO customers be able to get their own licenses for non-public cellular deployments in limited areas?

According to a recent article in *RCR Wireless News*, "Countries where spectrum regulators are providing enterprises with the ability to access spectrum directly, rather than solely through leasing arrangements, are seeing higher numbers of public announcements of private networks."[7]

However, the bands designated by individual administrations for local/non-public 5G (as well as the technical conditions for using those bands) have only recently been harmonized. Before harmonization, the European market for IMT devices for industry was fragmented, and thus unattractive to equipment developers. The resulting limited selection of suitable equipment created another barrier to uptake, prompting efforts toward regional harmonization.

So in 2021, the Radio Spectrum Policy Group recommended that EU Member States "investigate the possible use of the band 3.8-4.2 GHz for local vertical applications (i.e. low/medium power) while protecting receiving satellite earth stations and other existing applications and services."[8] A mandate was issued to:

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[1] RSPG, "Strategic Roadmap towards 5G for Europe: RSPG Opinion on spectrum related aspects for next generation wireless systems (5G)," RSPG16-032 FINAL (9 November 2016) - https://radio-spectrum-policy-group.ec.europa.eu/document/download/7664730c-c5e6-45d1-8fb6-3244c6034a1b_en?filename=RSPG16-032-Opinion_5G.pdf

[2] "ECC/DEC/(11)06 of 9 December 2011 on harmonised frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the band 3400-3800 MHz"

(amended in 2018) - https://docdb.cept.org/document/433

[3] ECC Report 254, *Operational guidelines for spectrum sharing to support the implementation of the current ECC framework in the 3600-3800 MHz range* (18 November 2016) - https://docdb.cept.org/download/1276

[4] RSPG, "Strategic Spectrum Roadmap towards 5G for Europe: RSPG Second Opinion on 5G networks" RSPG18-005 FINAL (30 January 2018) - https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/rspg18-005final-2nd_opinion_on_5g.pdf

[5] RSPG18-005 FINAL.

[6] RSPG, "Opinion on 5G implementation challenges (RSPG 3rd opinion on 5G)" RSPG19-007 FINAL (30 January 2019) - https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-01/RSPG19-007final-3rd_opinion_on_5G.pdf

[7] Kelly Hill, ""Which airwaves for private network spectrum? It's all on the table," *RCR Wireless News* (27 November 2024) - https://www.rcrwireless.com/20241127/private-networks/private-spectrum

[8] "RSPG Opinion on Additional spectrum needs and guidance on the fast rollout of future wireless broadband networks," RSPG21-024 FINAL (16 June 2021) - https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-01/RSPG21-024final_RSPG_Opinion_Additional_Spectrum_Needs.pdf

> "CEPT to assess the technical feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area network connectivity with focus on vertical users and other terrestrial wireless use cases and, on that basis, deliver harmonised technical conditions for the shared use of the band. Those harmonised technical conditions should in particular ensure the protection and the possibility of future evolution and development of incumbent spectrum users in this band (notably receiving satellite earth stations in the fixed satellite service and terrestrial fixed links) and the coexistence with spectrum users in adjacent bands (such as radio altimeters on board aircraft operating in the 4.2-4.4 GHz frequency band)."[9]

ECC Decision (24)01, approved in November 2024 for public consultation (a final draft of which was published on 20 December 2024), proposes the least restrictive technical conditions for harmonizing 3.8-4.2 GHz. The "preferred date for implementation of this Decision" by national administrations is 8 May 2025. "CEPT administrations shall communicate the national measures implementing this Decision to the ECC Chair and the [ECO] when this ECC Decision is nationally implemented."[10]

Technical Conditions for Harmonizing 3.8-4.2. GHz

Decision 24(01) stipulates that CEPT administrations shall:

- "designate the frequency band 3.8-4.2 GHz, or parts of this band, on a non-exclusive basis for the use of low/medium power terrestrial wireless broadband systems (WBB LMP) providing local-area network connectivity;
- "ensure the protection of the incumbent services within the 3.8-4.2 GHz frequency band (FSS receiving earth stations and FS links) where appropriate, taking into account their future evolution and development;
- "ensure the protection of MFCN in the adjacent frequency band 3.4-3.8 GHz;
- "where appropriate, ensure the protection of incumbent services (FSS receiving earth stations and FS links) in the adjacent frequency band 3.4-3.8 GHz;
- "ensure the protection of radio altimeters on board aircraft in the adjacent frequency band 4.2-4.4 GHz;
- "allow the free circulation and use of WBB LMP terminals operating under the control of a terrestrial WBB LMP network…"[11]

The frequency arrangement proposed for WBB LMP networks consists of 5 MHz TDD blocks. Adjacent blocks can be combined to obtain wider channels.

Not included in Decision 24(01) but emerging as a shared measure among administrations that already license WBB LMP networks is to terminate the licenses by 31 December 2040 as "a regulatory means of ensuring that a joint decision can be made on the use of the 3400-3800 MHz band from 2041 onwards."[12]

Decision 24(01) assumes the location of WBB LMP base stations and networks is known, because coordination with other band users might be necessary to avoid interference.[13] However, the Decision does not indicate how precise the location information must be. Some experimentation could be necessary to find the best locations for base stations to provide the coverage needed. Therefore the exactness of the base station location information needed for authorization is for national administrations to determine.

In the UK, which is no longer an EU Member but which has been notably successful in developing local cellular in the 3.8-4.2 GHz band, two types of license are offered: *per area* or *per base station*:

- "Low power licence. This authorises users to deploy as many base stations as they require within a circular area with a radius of 50 metres as well as the associated fixed, nomadic or mobile terminals connected to the base stations operating

[9] European Commission, "Mandate to CEPT on Technical Conditions Regarding the Shared Use of the 3.8-4.2 GHz Frequency Band for Terrestrial Wireless Broadband Systems providing Local-Area Network Connectivity in the Union" (16 December 2021) - https://cept.org/files/6813/Mandate%203_8-4_2GHz.pdf

[10] ECC Decision (24)01, *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* - https://docdb.cept.org/download/4573

[11] Ibid.

[12] Bundesnetzagentur's English translation of "Verwaltungsvorschrift für Frequenzzuteilungen für lokale Frequenznutzungen im Frequenzbereich 3.700-3.800 MHz" (2023) - https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/LokaleNetze/Verwaltungsvorschrift3.7-3.8GHz_pdf.pdf

[13] "To enable administrations to carry out coordination, the least restrictive technical conditions (LRTC) in this Decision are derived on the basis that the location of the WBB LMP network or WBB LMP base station is known. A licensing regime where the location is not known is out of scope for this harmonisation as this situation may create a risk of interference for existing and new MFCN base stations, fixed links and FSS earth stations as well as between WBB LMP networks."

within the area."[14] (Registration of the mobile terminals served by the base station is no longer required.) The power limit is 24 dBm for carriers with signal bandwidths of up to 20 MHz. A 10m height limit applies to outdoor antennas.

- "Medium power licence. This authorises a single base station and the associated fixed, nomadic or mobile terminals connected to the base station."[15] These licenses are generally issued only in rural areas where the risk of interference to neighbouring systems is reduced but exceptions for "urban" deployments can be granted under certain conditions. Licensees are entitled to no more than 100 MHz at a given location. In addition there is a power limit of 42 dBm for carriers with signal bandwidths of up to 20 MHz. No antenna height limit is specified.

In Germany, Bundesnetzagentur has adopted more flexible rules, also with notable success: The English translation of their "Administrative rules for spectrum assignments for local spectrum usages in the 3700-3800 MHz band" says:

> "Assignment holders are free in the planning of their networks within the premises… it is sufficient for the purposes of the application to give just one reference base station. This must be the base station with the highest transmit power. The application must also give the planned maximum indoor antenna height. The coordinates of the centre of the building must be given. This enables flexible use of the base stations within the building."[16]

While that passage assumes deployment will be indoors, the definition of "premises" does not have that limitation:

> "[Premises] mean a section of the surface of the Earth that forms a unit because of the nature of its economic use or its external appearance, even if it comprises more than one plot in real estate terms. This definition therefore covers, for example, industrial parks and exhibition venues as well as agricultural and forestry land.
>
> "Eligibility to apply can ensue from a premises ownership right or another right to use premises (such as a lease), or from relevant authorisation by the holder of such a right. In this context, it is also conceivable for several owners of premises, for example in an industrial park, to make a joint application for spectrum assignment for the whole area."

Bnetz's relaxed approach to base station location is mirrored in their decision not to set field strength limits at the boundary of the local authorized service area:

> "The Bundesnetzagentur will not generally define a maximum permissible field strength at the assignment area border. Assignment holders are, however, required to ensure efficient and interference-free use of their networks… Operators of geographically adjacent wireless networks are subject to a negotiation requirement for operator agreements. The operators have the best overview of the local conditions (such as topography and buildings) relevant to radio wave propagation. Optimal spectrum planning taking account of these conditions can be carried out and agreed among the operators on location. The Bundesnetzagentur assumes that the operators will find an appropriate solution among themselves. The relevant operator agreements… must be submitted to the Bundesnetzagentur."[17]

These two examples of national implementations preceded the adoption of regionally harmonized power limits, but their license conditions can otherwise persist.

The following tables are copied from Decision 24(01):

[14] Ofcom UK, "Shared Access Licences" (2024) - https://www.ofcom.org.uk/spectrum/frequencies/shared-access

[15] Ibid.

[16] Bundesnetzagentur, "Administrative rules for spectrum assignments for local spectrum usages in the 3700-3800 MHz band" (2023) - https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/FrequencyAssignment/LocalBroadband3,7GHz.pdf

[17] Ibid.

Table 1: Maximum in-block e.i.r.p. per cell for base stations operating in 3800-4200 MHz[18]

Cathegory	e.i.r.p. per cell (Note1 and Note 2)
Low power base station	≤ 24 dBm/channel for BW ≤ 20 MHz ≤ 18 dBm/5MHz 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.	

Source: ECC Decision 24(01)

Table 2: Maximum unwanted emission levels above 4200 MHz for WBB LMP base stations [19]

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.		

Source: ECC Decision 24(01)

In this Decision, the spurious domain for a base station operating in the 3800-4200 MHz range starts 40 MHz from the band edge and the corresponding spurious emission limits are defined in ERC Recommendation 74-01[20].

The Decision additionally limits the maximum in-block power for WBB LMP terminals to 28 dBm t.r.p. For fixed terminals, an in-block e.i.r.p. limit may be defined at the national level, provided that protection of in-band and adjacent-band incumbent services and cross-border obligations are fulfilled. Transmission power control is mandatory and shall be activated. On the other hand, the Decision also notes that "the use of WBB LMP in the frequency band 3.8-4.2 GHz for connectivity to aerial terminal stations [e.g. drones] was not studied, and that further studies are required in order to identify relevant technical and operational conditions for the usage of aerial terminal stations in this frequency band…"

More generally, the explanatory memorandum accompanying the Decision points out that:

> "ECC Report 358 concludes that it is not possible to define generic technical conditions that guarantee the protection of fixed service (FS) and fixed satellite service (FSS) in all scenarios across all CEPT administrations. Instead, a case-by-case analysis is needed, in combination of considering appropriate mitigation techniques, to ensure satisfactory coexistence…
>
> "For the protection of MFCN operating below 3.8 GHz, ECC Report 358 concludes that for unsynchronised WBB LMP operation in the lower part of the 3.8-4.2 GHz frequency band, coordination may be needed." [21]

[18] Table copied from ECC Decision (24)01 FINAL (8 November 2024) - https://docdb.cept.org/download/4573

[19] Ibid.

[20] ERC Recommendation 74-01: *Unwanted emissions in the spurious domain* (1998, 2022) - https://docdb.cept.org/download/4014

[21] https://docdb.cept.org/download/4573

To assist administrations in addressing the various coexistence situations that may arise in the vicinity of 4 GHz, CEPT promises to issue a set of additional recommendations which take into account issues not resolved by the regionally harmonized technical conditions as well as issues specific to various combinations of systems:

- Coexistence among WBB LMP stations (national planning of WBB LMP networks);
- Coexistence between WBB LMP stations and FS links;
- Coexistence between WBB LMP stations and FSS receiving earth stations;
- Coexistence between WBB LMP stations and radio altimeters operating above 4200 MHz;
- Coexistence between WBB LMP stations operating in the 3800-4200 MHz band and MFCN operating below 3800 MHz (including MFCN in neighbouring countries).

CEPT's FM60 working group has been tasked with developing these recommendations. They emphasize that the recommendations will not be "mandatory for administrations to follow. They are guidelines, with the intention to help administrations by describing method/methods to ensure protection of incumbent services, and have efficient in-band LMP vs LMP sharing."[22] Work on the recommendations began at a meeting from 18 to 20 November 2024 in Norway. The CEPT website says that the due date for delivering the draft recommendations for public consultation is 22-23 May 2025, with adoption of the recommendations expected by 1-3 October 2025.[23]

Preliminary notes from the recent meeting of FM60 have already been made public. Some highlights:

- With regard to radio altimeters, a few EU members had implemented exclusion zones for IMT base stations near airports after instances of harmful interference were reported in the US. But FM60 seems to be taking a softer line, because field studies, modelling and measurements in Europe have found the risk of interference to altimeters to be low except when aircraft are within a few hundred meters of the ground (that is to say, during take-offs and landings; altimeter performance degradation during take-offs generally implies limited safety risk but the implications are more serious during landings, especially in low visibility conditions). One FM60 meeting participant recommended "coordination zones" rather than "exclusion zones" near runways as there are ways to mitigate risk other than by simply forbidding base stations – requiring antenna downtilt, for example, or by aiming an AAS beam null toward detected nearby aircraft, by setting a reduced base station power limit in the zone, etc. While there seems to be no need for panic or radical changes in the conditions being discussed for WBB LMP deployment, given the demonstrated robustness of currently deployed altimeters, new compatibility standards for altimeters are expected to be issued in a few months for implementation during the coming decade. These could reduce or eliminate the need for special restrictions on base stations near airports.
- With regard to Fixed Service links, several meeting participants asked how should "future developments" be taken into account when the locations of future stations are not known? The short answer is that such stations are outside the scope of CEPT's mandate to develop the recommendations (despite the explicit reference in the mandate to protect those "future developments," because the locations are unknown, so that requirement might not be harmonizable. Nationally specific or case-by-case resolutions may be the only practical options. (See the body of this report for a more detailed discussion of this issue.)
- Finally, the discussion of WBB LMP/MFCN interference revealed two deficiencies in the already concluded technical studies:
    - WBB LMP as a victim of interference from MFCN was not considered, only the reverse case.
    - Also, some studies used an interference/noise ratio of -6dB to define protection criteria, but other studies used throughput loss, yielding different criteria. This is not just a problem for national recommendations, it is an inconsistency in the proposed harmonization.

While we wait for CEPT to draft its recommendations, it is important to note that guidance for managing the coexistence of these services in this frequency range is already available from the ITU and could be adapted to 5G:

- Report ITU-R S.2199 (2010): Studies on compatibility of broadband wireless access systems and fixed-satellite service networks in the 3 400-4 200 MHz band - https://www.itu.int/pub/R-REP-S.2199-2010
- Recommendation ITU-R F.1671 (2004): Guidelines for a process to address the deployment of area-licensed fixed wireless systems operating in neighbouring countries - https://www.itu.int/rec/R-REC-F.1671/en
- Report ITU-R F.2328-0 (2014): Sharing and compatibility between international mobile telecommunication systems and fixed service systems in the 3 400-4 200 MHz frequency range - https://www.itu.int/pub/R-REP-F.2328

[22] "TEMP 2 – high level generic discussion on recommendation framework" (19 November 2024) - https://api.cept.org/documents/fm-60/86328/temp-2_high-level-generic-discussion-on-recommendation-framework

[23] "FM60 #13 Meeting Kristiansand 18 to 20 November 2024: Result of the Meeting" - https://www.cept.org/ecc/groups/ecc/wg-fm/fm-60/news/fm60-13-meeting-kristiansand-18-to-20-november-2024

- Report ITU-R M.2109 (2007): Sharing studies between IMT Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 and 4 500-4 800 MHz frequency bands - https://www.itu.int/pub/R-REP-M.2109
- Recommendation ITU-R M.2059-0 (2014): Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4 200-4 400 MHz - https://www.itu.int/dms_pubrec/itu-r/rec/m/r-rec-m.2059-0-201402-i!!pdf-e.pdf
- Recommendation ITU-R M.2085-0 (2015): Technical conditions for the use of wireless avionics intra-communication systems operating in the aeronautical mobile (R) service in the frequency band 4 200-4 400 MHz - https://www.itu.int/rec/R-REC-M.2085/en

In this study we try to extract the most useful suggestions and ideas from those (and other) documents. However, that requires more discussion than can be fit into this initial summary so it is found later in the document.

To sum up, CEPT's recent proposal of harmonized conditions for shared use of the 3.8-4.2 GHz band in Decision (24)01 provides essential guidance to national administrations. But because it offers the "least restrictive" technical conditions, some issues are left for national regulatory authorities to decide. The requirement for knowing the location of WBB LMP base stations to ensure that there is an adequate separation distance from stations that could suffer interference implies an authorization regime based on individual licenses. However, it is left to regulators to decide how precise the location information must be. There are successful examples in Europe of both "area" licenses and "per base station" licenses (license exemption, as is presently common with industrial RLANs, is implicitly rejected). Taking the cue from Ofcom UK, low-power systems could require area licenses while medium-power systems are governed by per-base station licenses. The pricing and duration of licenses, and appropriate bandwidth entitlement "caps" (if any) are also left to national discretion, as they should be, although an ultimate end date of 31 December 2040 seems to be emerging as a consensus decision among regulators in Europe, so that a band review can be conducted regionally in 2041. The issue of "exclusion" or "coordination" zones near airports is left open, pending publication of updated altimeter performance requirements in 2025. And the question of how to protect "future development" of incumbent services in the 3.8-4.2 GHz band is set aside for now, although there are some national level options that seem practical.

3 Recommendations

In November 2024, CEPT's Electronic Communications Committee approved a group of documents concerning the 3800-4200 MHz band:

- ECC Report 358: "In-band and adjacent bands sharing studies to assess the feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area (i.e. low/medium power) network connectivity"
- ECC Report 362: "Compatibility between mobile or fixed communications networks (MFCN) operating in 3400-3800 MHz and wireless broadband systems in low/medium power (WBB LMP) operating in the frequency band 3800-4200 MHz with Radio Altimeters (RA) operating in 4200-4400 MHz"
- CEPT Report 088: "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"
- ECC Decision (24)01: "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"

Together these documents outline a framework for the introduction of low- and medium-power wireless broadband (WBB LMP) systems on a regionally harmonized basis in a frequency range already allocated to Fixed and Fixed-Satellite Services (FS and FSS). Thus, new authorization and management policies are needed at the national level to ensure that equitable band-sharing and sustainable coexistence develops between new and incumbent users of the 3800-4200 MHz band, while interference into and from adjacent bands (3600-3800 MHz and 4200-4400 MHz) is minimized.

CEPT Report 088 notes an important finding of the studies performed to support ECC Decision (24)01:

> "It has not been possible to define generic technical conditions that alone guarantee the protection of all incumbent services. Careful planning and case-by-case analysis is needed, in combination of considering appropriate mitigation techniques. In order to facilitate and maximise the opportunities for the deployment of WBB LMP and to manage remaining coordination cases that may not be addressed by the harmonised technical conditions, administrations may want to complement certain aspects of their use of the frequency band 3.8-4.2 GHz at the national and/or the local level circumstances, for example on synchronisation, pfd limits, separation distance and/or frequency separation requirements. CEPT intends to develop relevant recommendations in order to support administrations as appropriate."

ECC Decision (24)01 indicated that CEPT will draft up to five Recommendations to help regulators implement "national measures" regarding WBB LMP coexistence with

- Other WBB LMP networks
- FSS earth stations;
- FS links;
- Radio Altimeters (RA) and Wireless Avionics Intra-Communication (WAIC) systems in the adjacent 4200-4400 MHz band; and
- WBB LMP and MFCN in the adjacent 3400-3800 MHz band.

However, those recommendations are not due until October 2025 and they are not expected to be mandatory. They will be guidelines intended "to help administrations by describing method/methods to ensure protection of incumbent services, and have efficient in-band LMP vs LMP sharing." Since the "preferred date" for national administrations to implement this Decision is 8 May 2025, there is a need for interim recommendations, to which this report aims to contribute.

But because these are only interim recommendations, and the European Commission has been clear about the need to protect existing uses, no changes to the license conditions, locations or frequencies of existing stations are considered—only ways to make the addition of WBB LMP networks minimally disruptive and maximally useful.

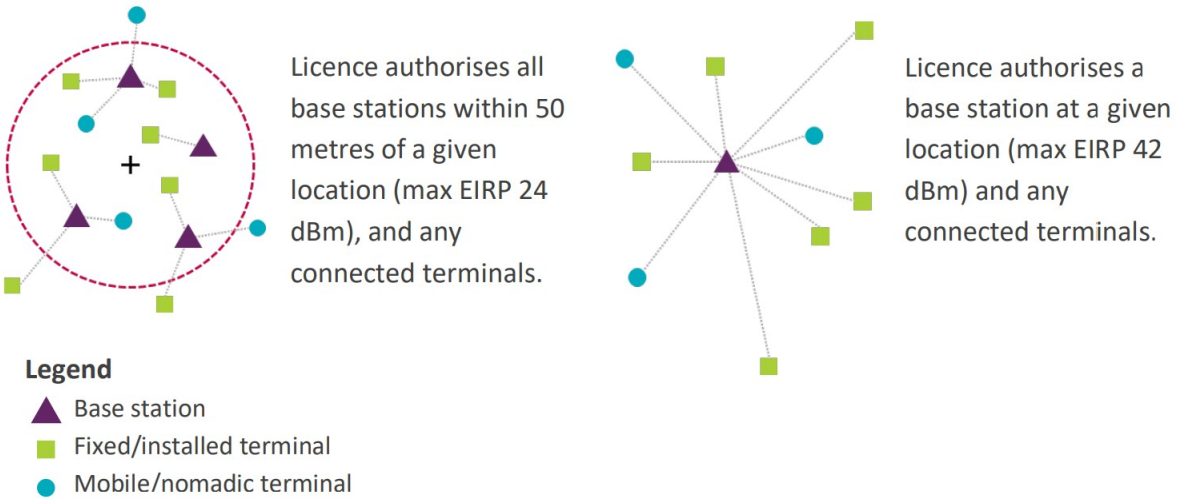
WBB LMP authorizations

Decision 24(01) assumes the locations and operating frequencies of WBB LMP base stations and networks are known, because coordination with other band users could prove necessary to prevent interference. Coordination requires that the distances between potential sources and victims of interference are known, along with the inhibiting and enhancing parameters of the propagation paths. But the Decision does not indicate how precise the location information must be for new WBB LMP stations. That is left for national administrations to decide.

Our review of measures adopted by European countries to enable enterprises to deploy non-public/local cellular networks use shows a wide variety of practices in specifying location. A few examples:

- The United Kingdom offers two types of WBB LMP license:[24]
    - A *low-power license* limits the base station power density to 27 dBm / carrier e.i.r.p. per cell for carriers ≤ 20 MHz or 21dBm / 5 MHz e.i.r.p. per cell for carriers > 20 MHz. This is a "per area" license: any number of base stations and terminals can be deployed in a circular area with a radius of 50 meters (see diagram below; applicants must specify the coordinates of the circle's centerpoint). Licensees can re-position the transmitters within the licensed area without seeking re-coordination by the regulator.They are also able to apply for additional low-power licenses if they want to be able to re-locate transmitters within a larger area. Outdoor antennas are limited to 10 m height above ground.
    - A *medium-power license* authorizes a single base station whose power density is limited to 42 dBm / carrier e.i.r.p. per cell for carriers ≤ 20 MHz; or 36 dBm / 5 MHz e.i.r.p. per cell for carriers > 20 MHz. This is a "per base station" license and the coordinates of the base station must be specified in the application.

Figure 1: What low-power (left) and medium-power (right) licenses authorize



Source: Ofcom UK[25]

- Germany does not impose in-block e.i.r.p. limits on base stations or define a maximum permissible field strength at the edge of the authorized service area. But networks must be designed and built "to minimize the interference ranges of their spectrum usages." Because the right to apply for WBB LMP authorization is based on the owner's or renter's rights to use a "premises," the size and shape of the "premises" establish the outer limits of the service area.[26] If the network has more

[24] Note that the power density limits for WBB LMP base stations in the UK differ from the harmonized standards in ECC Decision (12)01.

[25] "Shared Access Licence: Guidance Document" (2022) - https://www.ofcom.org.uk/siteassets/resources/documents/consultations/category-1-10-weeks/129951--enabling-opportunities-for-innovation/associated-documents/shared-access-licence-guidance.pdf?v=381313

[26] "Premises are also taken to mean a section of the surface of the Earth that forms a unit because of the nature of its economic use or its external appearance, even if it comprises more than one plot in real estate terms. This definition therefore covers, for example, industrial parks and exhibition venues as well as agricultural and forestry land… In this context, it is also conceivable for several owners of premises, for example in an industrial park, to make a joint application for spectrum assignment for the whole area." Quoted from Bundesnetzagentur, *Administrative rules for spectrum assignments for local spectrum usages in the 3700-3800 MHz band* - https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/

than one base station, the coordinates of the base station with the highest transmit power must be given. And if it is inside a building, the coordinates of the centre of the building must be given. The application must also give the planned maximum indoor antenna height. LMP licenses do not include non-interference rights guaranteed by the regulator. Conflicts that arise with the operation of a "geographically adjacent wireless network" should be resolved through negotiation. If agreement cannot be reached, "Bundesnetzagentur will define a field strength limit of 32 dBµV/m/5 MHz at a height of three metres at and beyond the border of the assignment area..."

- Belgium asks applicants to diagram the proposed service area of their WBB LMP system as a polygon. Each corner of the polygon is considered a test point on the service area's perimeter. The test points cannot be more than 50 m apart. To assess the compatibility of the proposed service area for "network A" with the nearest neighboring WBB LMP system ("network B," also represented by a polygon whose corners are test points), the RF field produced by base stations in network A (which are assumed to have the maximum antenna height and operate with the maximum allowed e.i.r.p.) is calculated at each test point of network B. For synchronized networks, interfering signals from the network A base stations into the terminals of network B must be less than 61 dBµV/m/5 MHz at 3 m above ground level. For non-synchronized networks, the interference threshold is 55 dBµV/m/5 MHz at 10 m above ground level.

Our recommendation is for ČTÚ to apply many aspects of Ofcom UK's implementation plan but using the power density limits of ECC Decision (12)01:[27]

Figure 2: The power density limits of ECC Decision (12)01

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.	

Source: *ECC*

Not every detail of Ofcom's plan (e.g. license fees, relying on national equipment standards instead of the EU Radio Equipment Directive, etc.) is compatible with the situation in the Czech Republic, but we believe that the following rules are:[28]

- The regulator decides which frequencies to assign given the location of the proposed network and the availability of unused channels at that location.
- Licenses are issued on a "first come, first served" basis, but with a "beauty contest" dimension. That is to say, applicants must describe the network's intended purpose so the regulator can evaluate its merits and confirm that the proposed design is "fit for purpose." If the application is accepted, the regulator will coordinate the frequency assignment to avoid interference to already deployed systems.
- Applicants can request a license of any duration for bandwidths of 10, 20, 30, 40, 50, 60, 80 or 100 MHz, with a 100 MHz cap on the assignment of spectrum to the applicant within 500 m of a medium-power WBB network already authorized to the applicant.
- Germany adds that an LMP license cannot be used to offer telecommunication services to the public. We recommend that ČTÚ adopts a similar policy.

FrequencyManagement/FrequencyAssignment/LocalBroadband3,7GHz.pdf

[27] When considering the feasibility of sharing between WBB LPM and incumbent services, CEPT Report 088 had set the maximum low power base station power level at 31 dBm/100 MHz e.i.r.p. and the maximum medium power base station power level at 51 dBm/100 MHz e.i.r.p. Those values are equivalent to the 24 dBm/20 MHz and 44 dBm/20 levels adopted in ECC Decision (24)01.

[28] These recommendations are adapted from Ofcom UK, "Enhancing the Shared Access framework: Statement on further measures to support licensees and enable new use cases" (2 December 2024) - https://www.ofcom.org.uk/siteassets/resources/documents/consultations/category-1-10-weeks/consultation-supporting-increased-use-of-shared-spectrum/associated-documents/statement-enhancing-the-shared-access-framework.pdf

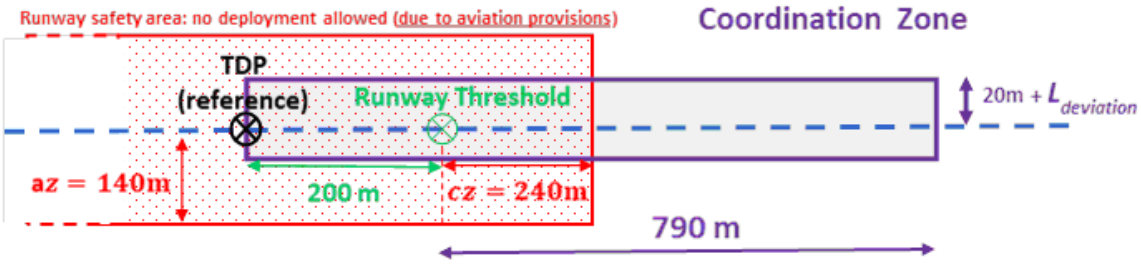
- ČTÚ may want to consider higher license fees or more restrictive rules for medium-power WBB deployments in Prague, to enhance the availability of frequencies for low-power deployments within the city limits (in order to supply more facilities with connectivity).
- The location, power, antenna height and other details of terminals in low-power deployments need not be reported to ČTÚ or recorded in the system log book.
- Licensees must install and begin using their WBB LMP equipment consistent with the terms of the license within 6 months of the license issue date. (In Germany, licensees have one year to begin using their network.)
- Any change in the licensee's name or address on a Low or Medium Power license must be notified in advance to ČTÚ in writing. The license may be transferred but only with prior notice to and permission from ČTÚ.
- Any proposed amendment to or change in the license specifications must be agreed in advance with ČTÚ and implemented only after ČTÚ has modified or reissued the license.
- The licensee agrees to accept notifications and other documents related to their WBB LMP license via the email address registered on their license. The licensee must promptly inform ČTÚ about any change to their email address.
- The licensee shall permit any person authorized by ČTÚ to inspect the license and have access to, inspect or test the WBB LMP radio equipment, at any reasonable time, when in the opinion of that person an urgent situation exists, to ensure that the radio equipment is being used according to the terms of the license.
- Any person authorized by ČTÚ may require the WBB LMP radio equipment to be modified or restricted in use immediately, temporarily or permanently, if, in the opinion of the authorized person, a breach of the license has occurred or use of the radio equipment is or may be causing or contributing to undue interference to other authorized radio equipment.
- ČTÚ may require any deployed WBB LMP radio equipment to be modified or restricted in use or temporarily closed down in the event of a declared national or local state of emergency. ČTÚ may only exercise this power after written notice has been served on the licensee or a general notice to all WBB LMP licensees has been published.
- The licensee must comply with any technical conditions or requirements relating to synchronization notified to it by ČTÚ. The licensee accepts the obligation to alter or replace radio equipment in order to comply with a notified synchronization requirement. If synchronization requirements are included in the terms of the license, the licensee must transmit within the limits specified. Where synchronization requirements have not been specified, in the event that harmful interference occurs, the licensee shall discuss and agree with the other licensee(s) how to coordinate their use. If agreement between the licensees cannot be reached, ČTÚ may direct the licensee to comply with additional technical requirements related to synchronization.
- Like Ofcom, we recommend the operating frequency range for WBB LMP stations to be 3805–4195 MHz.[29] The deployed equipment should be capable of operating anywhere within that range as ČTÚ may require frequency changes to resolve interference problems.
- ECC Decision (24)01 requires all WBB LMP terminal equipment to have transmit power control and to have it activated.
- Because there is some risk of interference into WBB LMP networks from MFCN networks operating below 3800 MHz and some risk of interference from AAS-equipped medium-power WBB LMP base stations into altimeters operating above 4200 MHz, ČTÚ might start assigning medium-power networks below 4000 MHz and low-power networks above 4000 MHz. We suggest starting to assign frequencies for AAS-equipped medium-power networks near 4000 MHz, serially adding new assignments down-band toward 3805 MHz (while avoiding the location and frequencies of existing FS links). When this part of the band is full, additional medium-power base stations can be assigned available frequencies above 4000 MHz. Above 4100 MHz there could be geographical restrictions on AAS-equipped medium-power base stations near airports that support automatic landing procedures (see below). We also suggest starting to assign frequencies for low-power WBB networks near 4000 MHz then serially adding new assignments up-band toward 4195 MHz (taking into account and avoiding the location and frequencies of existing FS links).
- Synchronization may prove necessary for WBB LMP networks operating below 3900 MHz, so recommending that equipment to be used in that part of the spectrum has that capability seems wise.
- It is hard to tell how much demand there might be for WBB LMP networks in the Czech Republic, or what ratio of medium- to low-power networks will emerge, or the proportion of networks deploying LTE vs 5G technology.[30] Germany and the UK have authorized many hundreds of non-public cellular networks, but other European countries have authorized far fewer.

[29] Although the protection requirements of radio altimeters is not yet adequately defined and could change with the new performance standards expected from the aviation industry in the next few months.

Demand in the Czech Republic might be satisfied before the frequencies above 4150 or below 3850 MHz are assigned. By retaining them for later assignment, ČTÚ will be able to accumulate experience managing the coexistence of the incumbents with the new band entrants under more favorable conditions.

- ECC Report 362 found that for "the frequency band 4.1-4.2 GHz, all studies show sufficient [interference protection margins for radio altimeters operating above 4.2 GHz] except for some types of medium power beamforming base station and radio altimeter scenarios (below 200 feet [where an automatic landing procedure can be activated and incorrect height measurements can create life-threatening situations for aircraft passengers])." ECC Report 362 identified two ways to mitigate this risk:

Figure 3: Airport coordination zone for medium-power WBB with AAS



(Figure not scaled)

Source: ECC Report 362, page 85

1. Create a coordination zone defined by a rectangle extending 790 m from the aircraft touchdown point toward the direction of arrival and 20 m in both directions perpendicular to that axis (see diagram). Within this zone no AAS-equipped medium-power WBB base station should be permitted to transmit between 4100 MHz and 4200 MHz; or
2. Require medium-power WBB base stations to implement the power limits in this table from page 76 of ECC Report 362:

[30] Reports in the trade press indicate that there many more non-public and industrial deployments based on LTE technology than 5G, because LTE is less expensive and easier to configure and maintain. Of course, there other wireless network technologies even more widely used in industry, based on license exempt spectrum. See Paige West, "Low-power radio options for harsh industrial environments," *Electronic Specifier* (16 December 2024) - https://www.electronicspecifier.com/industries/wireless/low-power-radio-options-for-harsh-industrial-environments

Figure 4: Block edge mask based on ECC Decision (11)06, to be applied above 4200 MHz for AAS WBB LMP base stations to protect radio altimeters

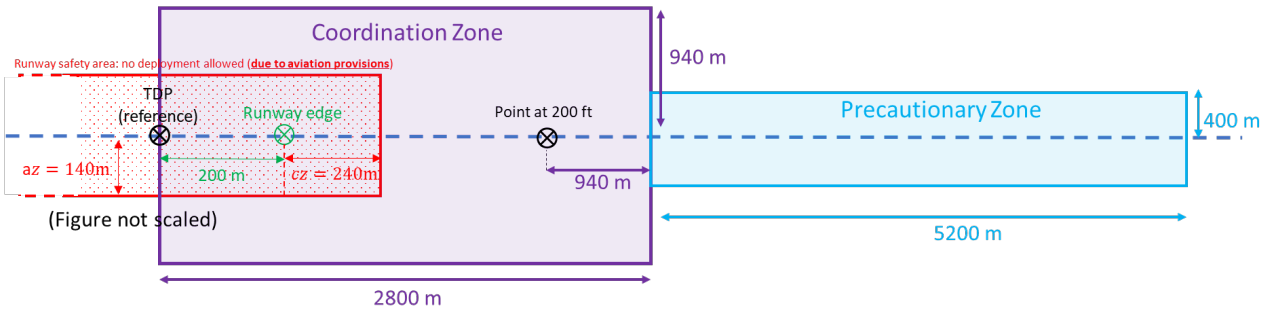
Frequency range (MHz)	Notation	AAS TRP limit in dBm/MHz per cell (Note 1)	AAS TRP limit in dBm/MHz per cell (Note 1) applied for 4x4 AAS	AAS TRP limit in dBm/MHz per cell (Note 1) applied for 8x8 AAS
4200-4205	P_{OOB1} (dBm/MHz)	TRP -47	-14.4	-20.4
4205-4240	P_{OOB2} (dBm/MHz)	TRP -52	-19.4	-25.4
Above 4240	P_{OOB3} (dBm/ MHz)	-30	-30	-30
Note 1: In a multi-sector base station, the radiated power limit applies to each one of the individual sectors				

MFCN out-of-band emissions

ECC Report 362 also found that there are some situations in which the interference tolerance threshold of the most susceptible altimeters are exceeded by MFCN base stations operating in the 3400-3800 MHz band if they deviate from the characteristics given in a report prepared for WRC-23[31] (the specific deviations being a 0° mechanical downtilt or the electrical steering range extended beyond the typical setup). So a narrowly tailored mitigation might be to require the antennas of MFCN base stations deployed in the 3400-3800 MHz band to have a mechanical downtilt ≥3° (the figure cited in the report to WRC-23) and an electrical steering range less than or equal to "the typical setup."

ECC Report 362 identifies another mitigation strategy based on geographic separation. Like the proposal for AAS-equipped WBB medium-power base stations, Annex 3 of the Report proposes a "coordination zone defined by a rectangle of width 2800 m, half-height 940 m, where the [MFCN] base station cannot be deployed if its transmitted power is not reduced below 78 dBm." In addition, the Annex suggests a "precautionary zone defined by a rectangle of width 5200 m, half-height 400 m, where the [MFCN] base can be deployed only if the AAS grating lobes do not cause harmful interference to Radio Altimeters…" This suggestion is a result of uncertainty about the actual profile of the terrain near the airport. That information would certainly be available to national regulatory authorities, who can decide if such a precautionary zone is actually necessary, taking into account the shielding effect (if any) of clutter in the actual terrain.

Figure 5: Deployment conditions near airport runway for MFCN base station operating in the 3400-3800 MHz band



Source: ECC Report 362, page 65

[31] 3GPP response to ITU-R Working Party 5D Chairman's Report, "Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23," Annex 4.4 to Document 5D/716-E

We must note that Report 362 Annex 3's conclusions about the dimensions of the MFCN coordination zone and the need for a precautionary zone were based on the assumption that base station e.i.r.p. is limited to 78 dBm. However, the Report notes on page 13 that the ECC requested updates from CEPT administrations in September 2024 concerning the maximum Base Station transmit power in operation in the 3400-3800 MHz band and found that 78 to 82 dBm/100 MHz is more representative of the base stations now deployed in CEPT countries. Increasing the assumed power by 4 dB would justify a larger coordination zone and strengthen the case for a precautionary zone.

A much broader mitigation (not limited to altimeter protection) was proposed in the Annex to Commission Implementing Decision (EU) 2019/235 of 24 January 2019:

> "additional baseline power limits are applied at the 3800 MHz band edge to support the coordination process [to protect incumbent FS to be carried out at national level [above 3800 MHz]. … A coordination zone…based on AAS TRP limit of –52 dBm/MHz per cell, may be required. Such coordination is under responsibility of the relevant Member State. Other mitigation measures like geographical separation, coordination on a case-by-case basis or an additional guard band may be necessary."[32]

The following table reproduces the data from Table 7 of the Annex to Implementing Decision (EU) 2019/235:

Figure 6: Additional baseline power limits above 3800 MHz for MFCN base stations to coexist with FSS and FS

BEM element	Frequency range (MHz)	Non-AAS e.i.r.p limit P_{Max} is the maximum mean carrier power in dBm for the base station measured as e.i.r.p. per carrier per antenna	AAS TRP power limit $P_{Max'}$ is the maximum mean carrier power in dBm for the base station measured as TRP per carrier in a given cell. In a multi-sector base station, the radiated power limit refers to the level corresponding to each one of the individual sectors
Additional baseline	3800-3805	Min(P_{Max} –40, 21) dBm/(5 MHz) per antenna	Min($P_{Max'}$ –40, 16) dBm/(5 MHz) per cell
	3805-3810	Min(P_{Max} –43, 15) dBm/(5 MHz) per antenna	Min($P_{Max'}$ –43, 12) dBm/(5 MHz) per cell
	3810-3840	Min(P_{Max} –43, 13) dBm/(5 MHz) per antenna	Min($P_{Max'}$ –43, 1) dBm/(5 MHz) per cell
	>3840	–2 dBm/(5 MHz) per antenna	–14 dBm/(5 MHz) per cell

Source: Implementing Decision (EU) 2019/235

Protection of the interferometry stations at Wettzell, Germany

Section 5.1 of ITU-R Report RA.2507-0[33] discusses the levels of interference detrimental to Very Long Baseline Interferometry Global Observing Systems like the twin radiotelescopes at Wettzell. Two scenarios are considered -- "continuum calibration mode" and "VLBI interferometry mode" -- because their interference tolerance thresholds are very different. The data in the following table is taken from from Tables A1 and A2 in ITU-R Report RA.2507-0:

Figure 7: Threshold levels of interference detrimental to VLBI observations for VGOS radiotelescopes

Mode	Frequency range (MHz)	Input power (dBW)	pfd (dB(W/m^2))	Spectral pfd (dB(W/(m^2 · Hz)))
Continuum calibration	3832.4 - 3896.4	-198	−164	-239

[32] Annex, Commission Implementing Decision (EU) 2019/235 of 24 January 2019 on amending Decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3400-3800 MHz frequency band - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019D0235

[33] "Technical and operational characteristics of the existing and planned Geodetic Very Long Baseline Interferometry" (2022) - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-RA.2507-2022-PDF-E.pdf

VLBI interferometry	4024.4 - 4120.4	-235	−126	−202

Source: Report ITU-R RA.2507-0

Without knowing more about the terrain which separates Wettzell from transmitters in the Czech Republic it is not possible to estimate the size of the coordination zone on this side of the border or the maximum tolerable e.i.r.p.

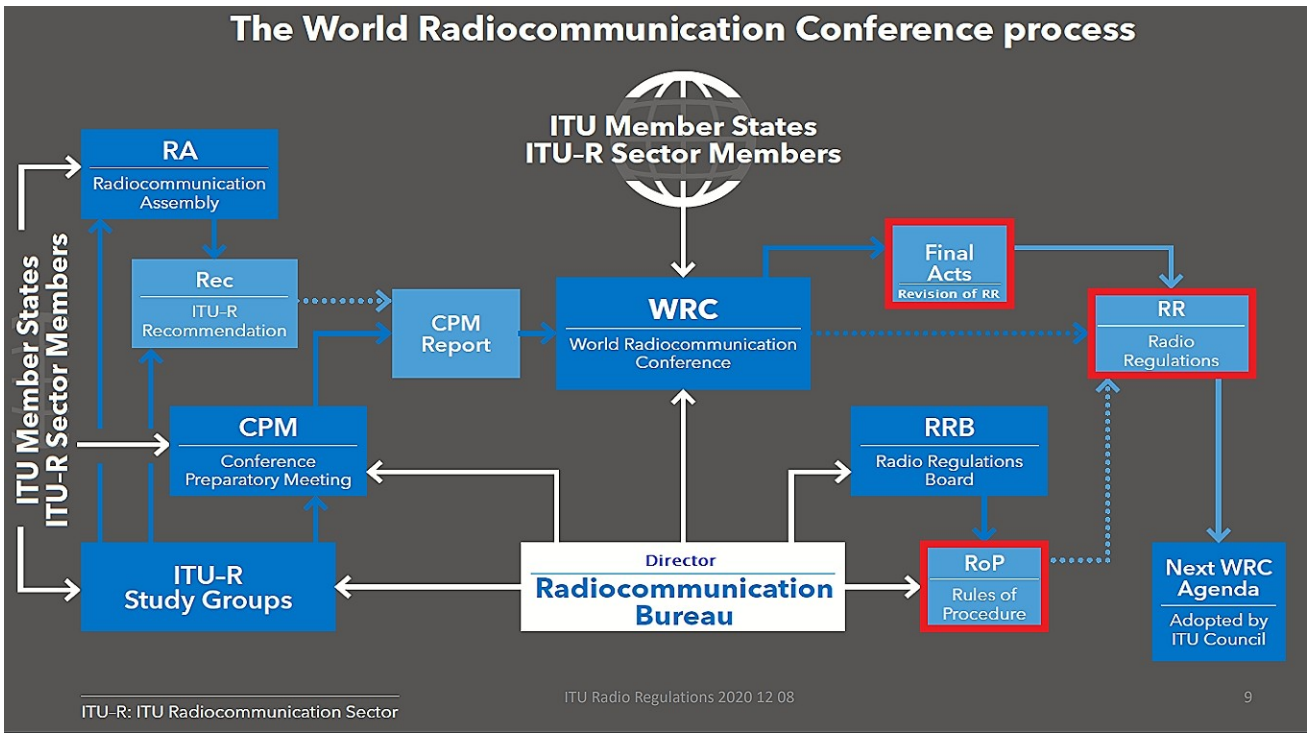
4 Analysis of the Current State of 4 GHz Band Usage

4.1 The Existing Legal and Regulatory Framework

4.1.1 International Telecommunication Union (ITU)

Certain discussions and decisions at World Radiocommunication Conferences (WRCs) convened by the ITU are essential background for the topics addressed in this report, as are many reports and recommendations from the ITU-R Study Groups.[34]

Figure 1: Decision-making process of ITU-WRC



Source: V. Glaude (ITU, 2020)[35]

[34] Recommendations and Reports record the conclusions of studies undertaken by the ITU-R Study Groups. Although they lack the treaty status of Regulations, each Recommendation must be approved by all administrations in the ITU-R before they come into force, so published Recommendations are considered authoritative advice.

[35] Veronique Glaude, "International Regulation of Radio Frequencies and Associated Orbits," presented at the UN Conference on Space Law & Policy, 8 December 2020 - https://www.unoosa.org/documents/pdf/spacelaw/activities/2020/SLC2020Presentations/SLC2020PDFPresentations/F._Glaude_-_8_Dec_2020_-_UN_Space_Law_Conference_-_ITU_Frequency_Regulations_20201208_v0.pdf

For example, WRC-12 adopted Resolution 154[36], which asked ITU-R "to study possible technical and regulatory measures in some countries in Region 1 to support the existing and future FSS earth stations in the 3 400-4 200 MHz band used for satellite communications related to safe operation of aircraft and reliable distribution of meteorological information" and report its findings to WRC-15. WRC-15 revised Resolution 154[37], stating that "ITU R conducted comprehensive studies of compatibility between FSS on the one hand and fixed wireless access systems and IMT applications on the other hand in the frequency band 3 400-4 200 MHz, and summarized the results of the studies in Recommendation ITU R SF.1486[38] as well as Reports ITU R S.2199[39], ITU R M.2109[40] and ITU R S.2368[41]; [these] offer a set of interference mitigation techniques that could be employed for international coordination and at a national level and to facilitate coexistence of FSS, fixed service and mobile service systems…"[42]

However, Recommendation SF.1486 was issued before the development of 5G, which has operational features different from earlier generations of IMT— the use of active antenna systems, for example. So SF.1486 and the other listed reports (as well as Report F.2328-0[43]) must be re-evaluated. Resolution 73,[44] adopted at WRC-23, mandates that re-evaluation, the findings of which are to be made available in time for WRC-27.

4.1.1.1 World Radiocommunication Conferences (WRCs)

Three items on the agenda of the WRC-23 conference in Dubai (20 November – 15 December 2023) were especially relevant to topics discussed here:

- *Agenda Item 1.3* concerned an upgrade from secondary to primary status of the Mobile (except Aeronautical Mobile) Service in the 3600-3800 MHz band in ITU Region 1. WRC-23 approved that change. However, for Region 1 the band is not identified for IMT. CEPT had supported this proposal "subject to the conditions that the current use in the frequency bands 3400-3800 MHz and the protection of primary services, under the existing CEPT regulatory framework, can be continued, and that no undue constraints are imposed on the existing services and their future development. In consequence, CEPT supports that the technical and regulatory conditions applicable to the band 3400-3600 MHz [should also apply to 3600-3800 MHz], in particular the pfd limit of -154.5 dBW/m²/4 kHz not to be exceeded for more than 20% of time 3 m above ground at the border to protect the neighbouring countries…"[45] These conditions are written into footnote 5.434A, attached to the 3600-3800 MHz band in the International Table of Frequency Allocations.

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[36] RESOLUTION 154 (WRC-12): "Consideration of technical and regulatory actions in order to support existing and future operation of fixed-satellite service earth stations within the band 3 400-4 200 MHz, as an aid to the safe operation of aircraft and reliable distribution of meteorological information in some countries in Region 1" – *Final Acts, WRC-12*, pages 231-232 - https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/4.133.43.en.100.pdf

[37] RESOLUTION 154 (REV.WRC-15): "Consideration of technical and regulatory actions in order to support existing and future operation of fixed-satellite service earth stations within the frequency band 3 400-4 200 MHz, as an aid to the safe operation of aircraft and reliable distribution of meteorological information in some countries in Region 1" - https://www.itu.int/dms_pub/itu-r/oth/0C/0A/R0C0A00000F0045PDFE.pdf

[38] "Sharing methodology between fixed wireless access systems in the fixed service and very small aperture terminals in the fixed-satellite service in the 3 400-3 700 MHz band" (2000) - https://www.itu.int/dms_pubrec/itu-r/rec/sf/R-REC-SF.1486-0-200005-I!!PDF-E.pdf

[39] "Studies on compatibility of broadband wireless access systems and fixed-satellite service networks in the 3 400-4 200 MHz band" (2010) - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-S.2199-2010-PDF-E.pdf

[40] "Sharing studies between IMT Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 and 4 500-4 800 MHz frequency bands" (2007) - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2109-2007-PDF-E.pdf

[41] "Sharing studies between International Mobile Telecommunication-Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15" (2015) - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-S.2368-2015-PDF-E.pdf

[42] "Consideration of technical and regulatory actions in order to support existing and future operation of fixed-satellite service earth stations within the frequency band 3 400-4 200 MHz, as an aid to the safe operation of aircraft and reliable distribution of meteorological information in some countries in Region 1" - https://www.itu.int/dms_pub/itu-r/oth/0C/0A/R0C0A00000F0045PDFE.pdf

[43] ITU-R Report F.2328-0: "Sharing and compatibility between international mobile telecommunication systems and fixed service systems in the 3 400-4 200 MHz frequency range" (2014) - https://www.itu.int/pub/publications.aspx?lang=en&parent=R-REP-F.2328-2014

[44]RESOLUTION ITU-R 73: "Use of International Mobile Telecommunications technologies for fixed wireless broadband in the frequency bands allocated to the fixed service on a primary basis" (2023) - https://www.itu.int/dms_pub/itu-r/opb/res/R-RES-R.73-2023-PDF-E.pdf

[45] CEPT-ECC, "Report of the Fourth Week of the WRC-23" (15 December 2023) - https://cept.org/files/130712/wrc-23%20report%20from%20week%204_83hd536dza.pdf

ČTÚ's "Radio Spectrum Utilization Plan for the Frequency Band 2700-4200 MHz" (PV-P/7/02.2022-3) notes that: "The mobile service is already primary in the Czech Republic and this item of the agenda will not affect the use of the radio spectrum in the Czech Republic."[46] In addition, radio frequency allocations have been granted.

- *Agenda Item 1.2* considered "identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 245 (WRC 19)." The results of this agenda item were best summarized by the EU's Radio Spectrum Policy Group:

  a) 3 600-3 800 MHz (Region 2)

  There was no EU position for this frequency band in Region 2… Administrations wishing to implement IMT shall obtain the agreement of neighbouring countries to ensure the protection of the fixed-satellite service (space-to-Earth). [47]

  b) 3 300-3 400 MHz (Region 2)

  The EU position requested the Member States to "oppose any change of regulatory provisions applicable to stations of International Mobile Telecommunications (IMT) in the frequency band 3 300 – 3 400 MHz in the ITU Region 2, in particular any relaxation of these provisions regarding the radiolocation services.

  WRC-23 decided to identify this frequency band for IMT, previously limited to few countries in Region 2, to the whole Region 2, but kept unchanged the provisions applicable to IMT regarding the coexistence with the radiolocation service.

  c) 3 300-3 400 MHz

  The frequency band 3 300-3 400 MHz is a NATO harmonised band used by military radars, including onboard ships and aircraft, and therefore relevant to the Common Security and Defence Policy (CSDP). The EU Position requested the Member States to:

  - Oppose any change in the existing IMT identification in the frequency band 3 300 – 3 400 MHz in the ITU Region 1 that would result in the extension of the IMT identification to the entire ITU Region 1.
  - Oppose any change of regulatory provisions applicable to IMT stations in the band, in particular any relaxation of these provisions regarding the radiolocation services.

  WRC-23 confirmed a general No Change position. However, offline discussions on the inclusion of certain countries' footnotes Nos. 5.429A and 5.429B for the mobile service and IMT identification respectively took place, but did not reach consensus due to concerns regarding the protection of the critical radiolocation service in the band, used nationally as well as in international waters and air space by NATO countries. In particular it is ensured, that any national implementation of IMT stations shall not cause harmful interference to, or claim protection from, systems in the radiolocation service outside the territories of those countries and are subject to agreement of neighbouring countries…

  Summary for Agenda item 1.2

  In summary, negotiations were especially difficult and complex for this Agenda item …[48]

Other Resolutions and a Recommendation approved at WRC-23 affect 3800-4200 MHz and adjacent frequency bands. For additional source texts, see the altimeter chapter, below.

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[46] https://ctu.gov.cz/sites/default/files/obsah/ctu/sdeleni-o-vydani-opatreni-obecne-povahy-casti-planu-vyuziti-radioveho-spektra-c.pv-p/7/02.2022-3-pro-kmitoctove-pasmo-2700-4200-mhz/obrazky/pvrs7p.pdf

[47] Remarks elsewhere in RSPG's report indicate that this assertion ("Administrations wishing to implement IMT shall obtain the agreement of neighbouring countries") applies to any band that IMT would share with other radio services granted equivalent rights of use.

[48] "Report RSPG on the result of the WRC 2023," RSPG24-017 FINAL (June 2024) - https://radio-spectrum-policy-group.ec.europa.eu/document/download/3d8d393b-2067-48c4-98f9-b95f4d8ed960_en?filename=RSPG24-017final-RSPG_Report_%20WRC23.pdf

- Resolution 683 (WRC-23): “Study of technical and operational issues and regulatory provisions to support inter-satellite service transmissions in the frequency bands 3 700-4 200 MHz and 5 925-6 425 MHz for non-geostationary-satellite space stations communicating with geostationary-satellite space stations…the ITU Radiocommunication Sector to complete [these studies] in time for the 2031 World Radiocommunication Conference…”[49]

4.1.1.2 International Radio Regulations

A post-WRC-23 update of the International Radio Regulations[50] comes into effect on 1 January 2025. The Table of Frequency Allocations in these revised Regulations shows that the Fixed Service (FS) and space-to-Earth downlinks of the Fixed-Satellite Service (FSS) are co-primary services sharing the 3800-4200 MHz band globally. The Mobile Service shares these frequencies as a secondary use in ITU Region 1. The absence of footnotes attached to the allocation table entry for 3800-4200 MHz (which would indicate special conditions, exceptions, exemptions or derogations) suggests there is little disagreement with the current allocations in this band.

However, several footnotes are attached to the bands adjacent to 3800-4200 MHz. These deserve attention because they identify services and applications that could be affected by new spurious and out-of-band emissions from 3800-4200 MHz. The European Commission is aware of these risks and has mandated studies by CEPT and the ECC to identify conditions for satisfactory co-existence before any allocation changes are authorized for 3800-4200 MHz. The footnotes in adjacent bands also suggest conditions that could be attached to 3800-4200 MHz in the future, if that band is made consistent with 3600-3800 MHz in order to create a wider continuous span for identified services.

The following footnotes apply to the bands adjacent to 3800-4200 MHz in the new edition of the International Radio Regulations:

> „**5.434A** The use of the frequency band 3 600-3 800 MHz by the mobile, except aeronautical mobile, service on a primary basis in Region 1 is subject to agreement obtained under No. **9.21**[51] if the power flux-density (pfd) limit below is exceeded. The provisions of Nos. **9.17** and **9.18** shall also apply in the coordination phase. Before an administration in Region 1 brings into use a station in the mobile service in the frequency band 3 600-3 800 MHz, for the protection of stations in the fixed and fixed-satellite services, it shall ensure that the pfd produced at 3 m above ground does not exceed −154.5 dB(W/(m2 x 4 kHz) for more than 20% of the time at the border of the territory of any other administration. Stations in the mobile service operating in the frequency band 3 600-3 800 MHz shall not claim more protection from space stations than that provided in Table 21-4 of the Radio Regulations (WRC 23)“.

[49] This proposal appears to have originated with Luxembourg: “Proposal for a WRC-27 Agenda Item Spectrum allocation and associated regulatory provisions to support use of the 3700-4200 MHz and 5925-6425 MHz frequency bands for inter-satellite links between non-GSO user space stations and GSO space stations,” CPG23 PTA#8, Doc. PTA(23)063, 24 April 2023 - https://cept.org/Documents/cpg-pta/77156/pta-23-063_input-on-ai-10-c-band-isl

[50] https://www.itu.int/hub/publication/r-reg-rr-2024/

[51] This refers to Sub-Section IIA of the International Radio Regulations**: “Requirement and request for coordination**… Before an administration notifies to the Bureau or brings into use a frequency assignment in any of the cases listed below, it shall affect coordination, as required, with other administrations identified under No. 9.27… [**9.17**] for any specific earth station or typical mobile earth station in frequency bands above 100 MHz allocated with equal rights to space and terrestrial services… where the coordination area of the earth station includes the territory of another country… [**9.18**] for any transmitting station of a terrestrial service in the bands referred to in No. 9.17 within the coordination area of an earth station… [**9.21**] for any station of a service for which the requirement to seek the agreement of other administrations is included in a footnote to the Table of Frequency Allocations referring to this provision... [**9.27**] Frequency assignments to be taken into account in effecting coordination are identified using **Appendix 5**…”

Table 3: Relevant part of Table 21-4 of the Radio Regulations

TABLE **21-4** (Rev.WRC-23)

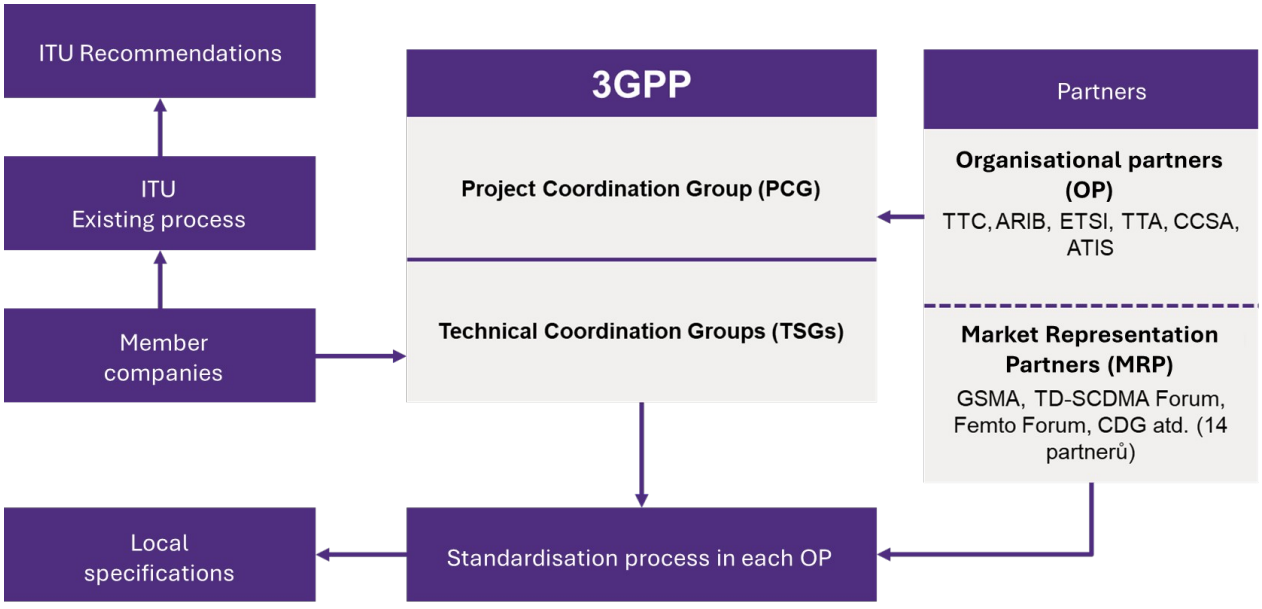
Frequency band	Service*	Limit in dB(W/m²) for angles of arrival (δ) above the horizontal plane			Reference bandwidth
		0°-5°	5°-25°	25°-90°	
3 400-4 200 MHz	Fixed-satellite (space-to-Earth) (geostationary-satellite orbit)	−152	−152 + 0.5(δ − 5)	−142	4 kHz

Source: Radio Regulations (WRC 23)

4.1.2 3rd Generation Partnership Project (3GPP)

3GPP is not a regulatory authority. However, its influence is global because it is the principal standards development organization for mobile telecommunications now. It works closely with the ITU, network operators and large manufacturers of mobile equipment.[52]

Figure 2: 3GPP's external relationships in standards development



Source: Nakamura/3GPP (2009)[53]

[52] IEEE had also been active in this field as a rival standards organization (most notably developing WiFi and WiMAX) until signing a cooperation agreement with 3GPP in 2016. In 2017 IEEE agreed to let "3GPP act as a control channel/system for all wireless systems available globally." See "IEEE 5G and Beyond Technology Roadmap White Paper" (2017), p. 13 - https://futurenetworks.ieee.org/images/files/pdf/ieee-5g-roadmap-white-paper.pdf

[53] Takehiro Nakamura, "Proposal for Candidate Radio Interface Technologies for IMT-Advanced Based on LTE Release 10 and Beyond (LTE-Advanced)," presented at ITU-R WP 5D's 3rd Workshop on IMT-Advanced, 15th October 2009 - https://www.slideshare.net/slideshow/3gpp/5330111#5

ETSI originated the GSM suite of technical standards that made mobile telephony a global success, then it helped create 3GPP in 1998 to continue the development of standards for mobile networking beyond Europe. ETSI still provides 3GPP with support services at its headquarters in Sophia Antipolis, France. So although 3GPP is a global organization, it is rooted in Europe. Consequently, harmonized technical standards developed by CEPT and ETSI for Europe are often transposed by 3GPP into its standards, while CEPT and ETSI regularly defer to 3GPP in developing standards for Europe.

Like CEPT, 3GPP conducts its work with a high degree of transparency, with most of its working documents and outputs freely accessible online. However, it's output is enormous— typically, over 40,000 documents per year. So while close study of the standards is essential for studies of compatibility, in this section we simply list a few documents and reports relevant to the frequencies discussed in this report, without attempting to extract or summarize their content:

- 3GPP TR 37.840 V12.1.0 (2014-01): "Technical Specification Group Radio Access Network: Study of Radio Frequency (RF) and Electromagnetic Compatibility (EMC) requirements for Active Antenna Array System (AAS) base station (Release 12)" - https://www.3gpp.org/ftp/Specs/archive/37_series/37.840/37840-c10.zip
- 3GPP TS 37.105 V18.5.0 (2024-06): "Active Antenna System (AAS) Base Station (BS) transmission and reception (Release 18)" - https://www.3gpp.org/ftp/Specs/archive/37_series/37.105/37105-i50.zip
- 3GPP TS 38.101-1 V18.7.0 (2024-09): "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone (Release 18) - https://www.3gpp.org/ftp/Specs/archive/38_series/38.101-1/38101-1-i70.zip
- 3GPP TS 38.104 V18.6.0 (2024-06): "NR; Base Station (BS) radio transmission and reception (Release 18)" - https://www.3gpp.org/ftp/specs/archive/38_series/38.104/38104-i60.zip
- 3GPP TS 38.113 V18.3.0 (2024-06): "NR; Base Station (BS) ElectroMagnetic Compatibility (EMC) (Release 18) - https://www.3gpp.org/ftp/Specs/archive/38_series/38.113/38113-i30.zip
- 3GPP TS 38.124 V18.1.0 (2023-12): "NR; ElectroMagnetic Compatibility (EMC) requirements for mobile terminals and ancillary equipment (Release 18)" - https://www.3gpp.org/ftp/Specs/archive/38_series/38.124/38124-i10.zip
- 3GPP TR 38.813 V15.0.0 (2018-03): "Technical Report: New frequency range for NR (3.3-4.2 GHz) (Release 15)" - https://www.3gpp.org/ftp//Specs/archive/38_series/38.813/38813-f00.zip This report contains band masks for handsets and base stations.

3GPP uses its own numbering system to refer to the frequency bands discussed in this report. These can be helpful in searching for relevant standards and reports.

Table 4: 5G New Radio (NR) Operating Bands

5G New Radio (NR) Operating Bands	
n48 (3550-3700 MHz)	42 (3400-3600 MHz)
n77 (3300-4200 MHz)	43 (3600-3800 MHz)
n78 (3300-3800 MHz)	48 (3550-3700 MHz)
n79 (4400-5000 MHz)	49 (3550-3700 MHz, Licensed Assisted Access)

Source: Based on 3GPP, processed by GTA

4.2 The Regional Legal and Regulatory Framework

As the top tier of regional governance, the **European Commission** (EC) has both administrative and legislative powers. In its administrative capacity, it oversees the implementation of EU law. In addition, the "Commission is responsible for planning, preparing and proposing new European legislation. This is called the 'right of initiative'."[54]

However, it is important to note that when "General Guidelines for the Cooperation between CEN, Cenelec and ETSI and the European Commission and the European Free Trade Association" were agreed in 2003, the EC agreed to "Refrain from drawing up technical regulations on subjects covered by mandates assigned to the European Standards Organisations, except where considered necessary in the public interest."[55] That agreement became more consequential in 2016, when the European Court of Justice found that harmonized standards form "part of EU law."[56] (Despite that court ruling, the European standards organizations

[54] European Commission, "Planning and proposing law" - https://commission.europa.eu/law/law-making-process/planning-and-proposing-law_en

[55] *Official Journal* C 091, 16/04/2003 pages 0007 – 0011 - https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52003XC0416(03)

[56] European Court of Justice, "Judgment of the Court (Third Chamber) 27 October 2016 in Case C-613/14: James Elliott Construction Limited v. Irish Asphalt Limited," ECLI:EU:C:2016:821, paragraph 40 - https://curia.europa.eu/juris/document/document.jsf;jsessionid=70DFACDB8DAD27253E8E3D19DA468AC8?text=&docid=184891&pageIndex=0&doclang=en&mode=lst&dir=&occ=first&part=1&cid=361875 . See also Kathrin Dingemann and Dr. Matthias

still describe their standards as voluntary and the European Commission's website says "Technical requirements given in EU legislation are mandatory, while the use of harmonised standards is usually voluntary."[57])

The **Radio Spectrum Policy unit** of the EC's **Directorate General for Communications Networks, Content and Technology (CNECT.B.4)** has a leading role in developing regional legislation for spectrum management. In addition to its responsibilities for technical harmonisation and the promotion of connectivity, it awards contracts for independent studies of policy questions, monitors the effectiveness of the Member States' spectrum authorization processes and coordinates EU relations with the ITU. Sub-unit **CNECT.B.4.001** deals with wireless broadband.

Mandates are used by the Commission to activate work by the EU's specialized technical agencies on questions or topics which need clarification or resolution to facilitate the implementation of European legislation or policy. Mandates concerning spectrum use and radio equipment are often issued by the **Radio Spectrum Committee (RSC),** which supports and advises the Commission, or the **Radio Spectrum Policy Group[58] (RSPG)**, which has a similar function on less technical topics**.** Mandates and standards requests both identify tasks to be performed and propose timetables for completing them.

The Commission may also request the **European Technical Standards Institute (ETSI)** to develop harmonized standards for radio equipment in order to facilitate regional integration and the smooth functioning of the internal market. In ETSI, the Technical Committee on EMC and Radio Spectrum Matters (ERM) is primarily responsible for developing and maintaining standards concerning use of the radio spectrum. The Technical Committee on Aeronautics (TC AERO) mainly supports European initiatives in air traffic management, especially the Single European Sky.

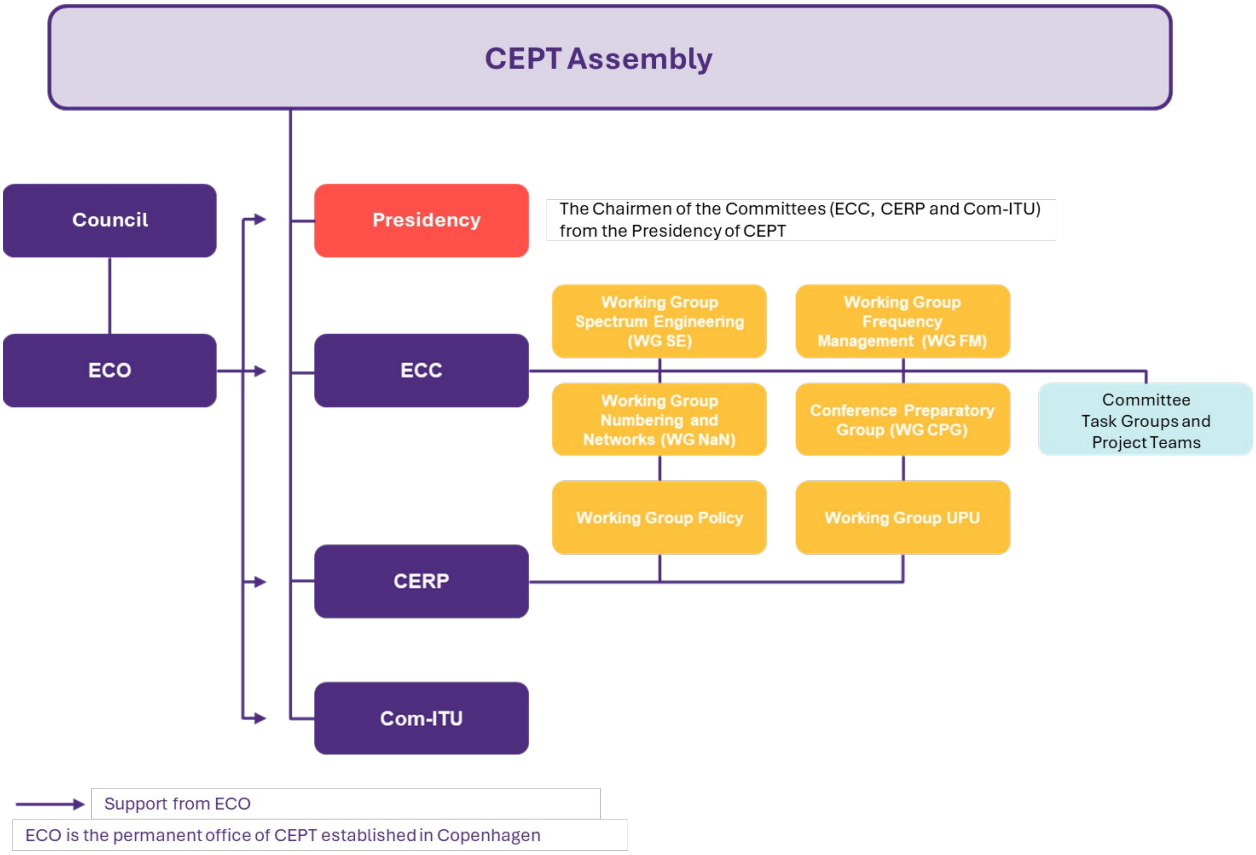
The **European Conference of Postal and Telecommunications Administrations (CEPT)**, with its many specialized working groups (WG) and project teams (PT), is Europe's chief technical cooperation platform with expertise in radio. The CEPT Electronic Communications Committee brings together 46 countries (including non-EU Members) to develop common policies and non-binding regulations. ECC members can request the CEPT to undertake compatibility studies and establish parameters and conditions under which spectrum sharing by different services can safely occur. These requests, if accepted, become Work Items, much like mandates from the EC.

Kottmann, "Legal Opinion On the European System of Harmonised Standards" (2020) - https://www.bmwk.de/Redaktion/EN/Downloads/L/legal-opinion-on-the-european-system-of-harmonised-standards.pdf, which notes, in paragraph 4 of the Executive Summary, that the European Commission can ask only ETSI, CEN and CENELEC to draft harmonized technical standards.

[57] European Commission, "Standards in Europe" - https://europa.eu/youreurope/business/product-requirements/standards/standards-in-europe/index_en.htm

[58] https://ctu.gov.cz/en/rspg

Figure 3: How CEPT is organized



Source: CEPT (2012)[59]

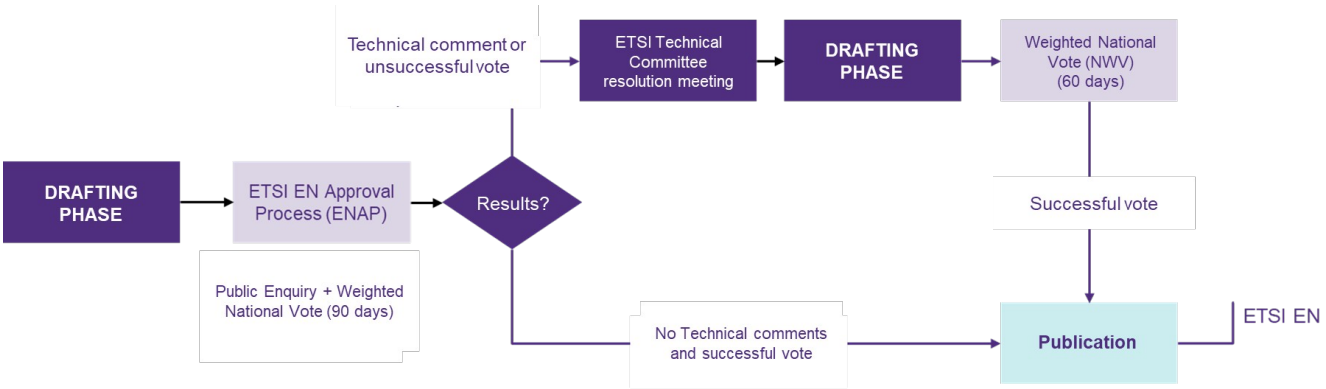
The **European Committee for Electrotechnical Standardization (CENELEC)** is an association formed by the national electrotechnical committees of 34 European countries. As mentioned above, CENELEC is one of the three standards development organizations that the European Commission can ask to develop harmonized technical standards for the region (the other two are ETSI and CEN). CENELEC and CEN have such close relations that they have a common website, they jointly developed a long-term strategy and they share the same Director General (Elena Santiago Cid). CENELEC also has close relations with the International Electrotechnical Commission (IEC). So it may not be surprising that over 72% of CENELEC's 7,691 standards are identical to the IEC's.

Any interested party can propose the drafting of a new standard, although most proposals come through a CENELEC or CEN member. "About 20% of all European standards are developed following a standardisation request from the European Commission."[60] If the proposal is accepted by the relevant Technical Body, standardization work on the same topic at the national level is suspended and drafting by regional experts begins. When the drafting is finished, the proposed standard is released for public comments and voting in a process called an "enquiry." The comment period lasts 90 days. If comments are received, they must be resolved, which could require some redrafting. If so, the modified draft is published for public comments in a 60-day "recirculation" process. CEN or CENELEC member organizations then vote on the standard (votes are population-weighted) and if, after 60 additional days, there is 100% approval, competing national standards are rescinded and the regional harmonized standard is published, first by ETSI, then by the national standardization organizations that participate in CEN or CENELEC. Neither CENELEC nor CEN distribute or sell European Standards. Instead, they are sold or distributed by the national technical committees that are CEN or CENELEC members.

[59] http://www.cept.org/cept/cept-structure

[60] "Standards in Europe" - https://europa.eu/youreurope/business/product-requirements/standards/standards-in-europe/index_en.htm

Figure 4: The process of developing a harmonized European Standard (EN)



Source: Hiertz and Max (2023)[61]

Founded in 1961, the **European Committee for Standardization (CEN)** brings together the national standardization bodies of 34 European countries. It has 1,533 Working Groups and 319 Technical Committees which have collectively produced 16,672 European standards. The most prolific publisher of standards is CEN's aerospace committee, ASD-STAN (https://asd-stan.org/en). The ASD-STAN D07/WG02 Working Group is currently developing harmonized European standards for embedded equipment in WAIC systems. "This involves defining minimum performance and RF emissions requirements for integrating such equipment inside or near an aircraft."[62]

Finally, mention must be made of a regional agreement on the coordination of radio frequencies to prevent mutual cross-border interference among stations in the Fixed and Land Mobile Services: the **"Harmonised Calculation Method" (HCM) Agreement.**[63] The most recent version of the Agreement was signed in 2022 by Austria, Belgium, Croatia, the Czech Republic, France, Germany, Hungary, Italy, Liechtenstein, Lithuania, Luxembourg, the Netherlands, Poland, Romania, the Slovak Republic, Slovenia and Switzerland.

The HCM Agreement covers 19 frequency bands in the Land Mobile Service (including 3400 – 3800 MHz) and 29 frequency bands in the Fixed Service (including 3600 – 4200 MHz).[64] It also proposes a pre-coordination procedure for introducing planned land mobile networks.

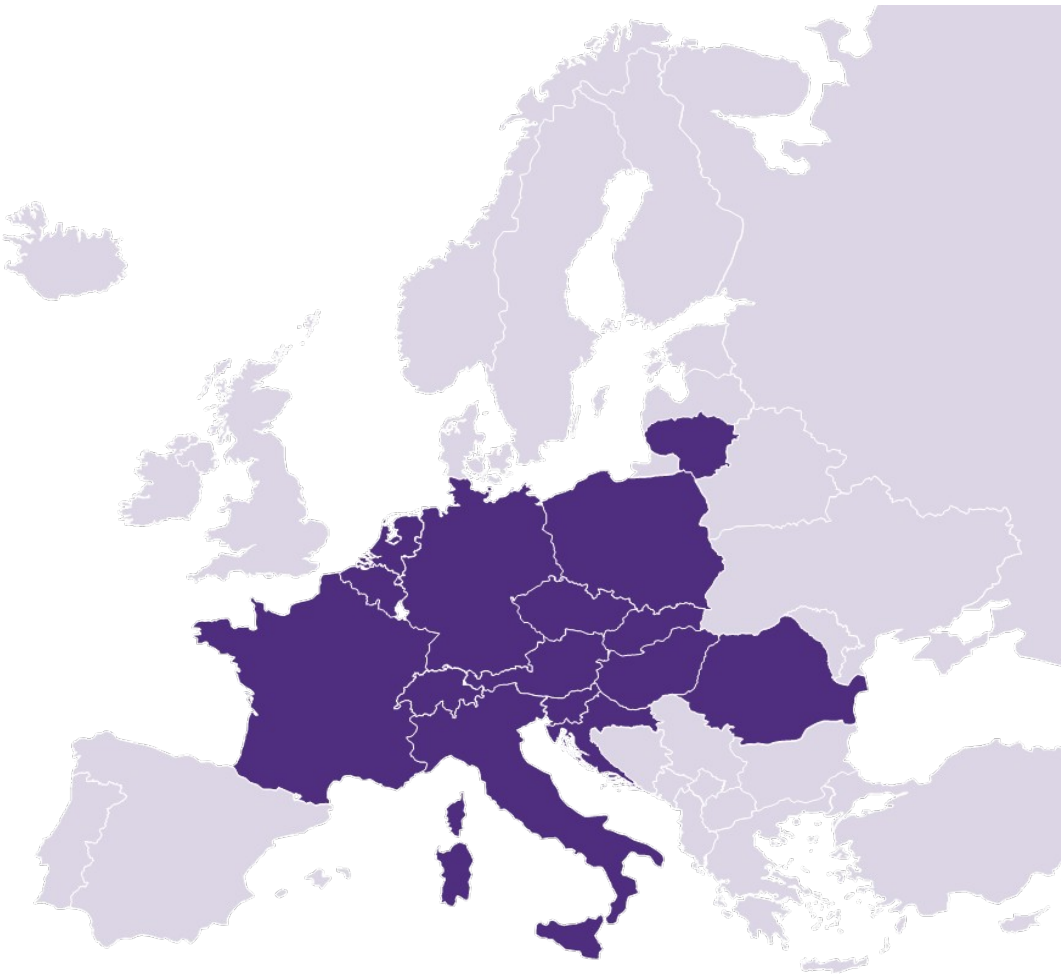
[61] Guido Hiertz a Sebastian Max, "European spectrum regulation and the harmonised market of the European Union - An overview," IEEE 802.18-23/54r2 - https://mentor.ieee.org/802.18/dcn/23/18-23-0054-02-0000-european-spectrum-regulation-and-the-harmonised-market-of-the-european-union-an-overview.pdf

[62] ASD-STAN, *Work Programme for 2024 and Beyond* - https://cms.stan-shop.org/wp-content/uploads/2024/02/WORK-PROGRAMME-2024.pdf

[63] http://www.hcm-agreement.eu/http/englisch/verwaltung/index_europakarte.htm

[64] Note that in the 3800 - 4200 MHz band, the Agreement covers the Fixed Service but not the Land Mobile Service. See *Harmonized Calculation Method – Fixed Service* - http://www.hcm-agreement.eu/programs/fixed_service/Old%20program%20versions/Documentation/HCM-FS_rev10.pdf. Software and documentation for the Land Mobile Service in other bands can be found in http://www.hcm-agreement.eu/programs/mobile_service/dir.php

Figure 5: Map showing the signatories to the HCM Agreement in purple



Source: HCM Agreement Management (Bundesnetzagentur)[65]

A significant provision of the Agreement is:

- Article 4.1: “In the case of the Land Mobile Service a transmitting frequency shall be co-ordinated if the transmitter produces a field strength, at the border of the country of the Administration affected, which, at a height of 10 m above ground level, exceeds the maximum permissible interference field strength as defined in Annex 1. A receiving frequency shall be co-ordinated if the receiver requires protection. It is strongly recommended to co-ordinate radio-relay links in the Fixed Service if the shortest distance from the border of at least one station is less or equal to the one defined in Annex 11. All stations which may cause harmful interference to stations in other countries or need protection shall be co-ordinated regardless of the distance.“

[65] https://hcm.bundesnetzagentur.de/http/englisch/verwaltung/index_europakarte.htm

4.2.1 Current Use of 3400-4200 MHz in Europe[66]

4.2.1.1 Fixed-Satellite Service (FSS)

Launched in 1963, Syncom 2 was the first geosynchronous communications satellite. By matching its orbital period to the Earth's speed of rotation, the satellite appeared to hover in the sky, making it like one end of a fixed point-to-point link relative to locations on the ground.

Unfortunately, the frequency range that was optimal for relay satellites—1 to 10 GHz—was already extensively used by terrestrial fixed microwave networks. These competing demands for the same region of spectrum led to an Extraordinary Administrative Radio Conference convened by the ITU in 1963:

> "With the technical feasibility of sharing between satellite and terrestrial systems in the foreground, and the economic advantages of satellites in the background, a sharing system was approved. Specifically, it has been determined that microwave radio relay services, with their narrow beam parallel to the earth's surface, and satellite services, with their transmission paths pointing away from the earth, can avoid harmful interference by coordinating the location and defined/determined parameters of their systems. This case was the first where two different radiocommunication services were authorised to use common operating frequencies simultaneously in a common area, which sets an important precedent."[67]

The first satellites to carry video had been intercontinental relays between terrestrial networks. Their transmissions were not intended for direct reception by the public. But in 1967, the Soviet Union introduced a domestic direct broadcasting satellite network (Orbita, which also relayed long-distance phonecalls and carried sensors to monitor the earthly environment). Orbita's TV downlinks used frequencies between 3.4 and 4.1 GHz.[68] American hobbyists soon found it possible to use an outdoor dish antenna to tune in various satellites' signals which were intended for re-broadcast by cable TV networks. Kits with hard-to-find components quickly gave way to pre-assembled mass-market products which stimulated public interest and demand for the legalization of direct public access to TV broadcasts via satellite.

For decades, C-band was the preferred option for both TV program distribution and telecommunications. But no more. According to Robert Matheson, the number of licensed downlinks peaked in 1988.[69] A more recent study by EuroConsult found that:

> "Demand for extended C-band capacity at 3400-3700 MHz… is on a declining trend which seems likely to continue… Video distribution seems otherwise limited to a few national markets in Africa and to Russia and is essentially absent from the Middle East… Even in Africa and Russia, 90% of channels use only the top 100 MHz of the 3400-3700 MHz band… We find little or no evidence that extended C-band is used, on a significant scale or at all, in the CEPT countries except from a small number of well-identified and protected teleports… The relatively low use rate of a majority of those satellites [in ITU Region 1], combined with the limited prospects for usage, results in a limited rationale for their replacement or new programs. Probability of investment in a new planned C-band satellite seems low...
>
> "As far as operators' plans are known, about 70% of the 54 satellites deploying extended/planned C-band DL and visible from R1 are expected to no longer be in operation by 2030. It seems likely that many will not be replaced… Two key inhibitors to the deployment of new networks using the extended C-band include:
>
> - "The preference given to solutions in higher frequency bands (Ku and Ka-band primarily) and enabling higher data rates,

[66] ERC Recommendation 12-08 is accompanied by a spreadsheet that gives an overview of EU Member States use and restrictions on use of 3600-4200 MHz - https://efis.cept.org/recommendationMatrixViewer.jsp?sectionRowId=3. It is outside the scope of this study, but the 2700-3400 MHz band is allocated to the radiodetermination services; 2900–3400 MHz band is allocated to the Radiolocation Service for "non-civil" (i.e. military) radar. The 3100–3300 MHz band is used by the Earth Exploration-Satellite and Space Research Services to measure physical characteristics of the Earth's surface, oceans and the atmosphere using radars and active sensors.

[67] Vernon T. Williams & Martin K. Collins, *The Radio Spectrum: International Allocation and Regulation*, US Naval Postgraduate School, master's thesis (1979) - https://upload.wikimedia.org/wikipedia/commons/4/41/The_radio_spectrum_international_allocation_and_regulation_%28IA_radiospectrumint00will%29.pdf

[68] "Molniya 1/ 1," NSSDCA/COSPAR ID: 1965-030A, NASA Space Science Data Coordinated Archive - https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1965-030A

[69] Robert J. Matheson, *Spectrum Usage for the Fixed Services,* NTIA Report 00-378 (2000) - https://its.ntia.gov/publications/download/TR-00-378.pdf

- The preference not to share with terrestrial networks, and the limited long-term visibility… on solutions based on extended C-band spectrum."[70]

CEPT Report 088, which was adopted at the ECC Plenary in November 2024, notes that:

> "FSS earth stations in CEPT countries have mainly used the 3600-3800 MHz and 3800-4200 MHz bands, rather than the lower 3400-3600 MHz band… CEPT recommended administrations to avoid authorizing new FSS sites in the 3400-3800 MHz band in areas intended for 5G, and instead consider using higher bands above 3800 MHz for future FSS usage.[71] As a result, a limited number of FSS earth stations have been maintained below 3800 MHz band, while many stations have migrated to the 3800-4200 MHz frequency band…

"CEPT is also studying the possibility of exempting small C-band IoT terminals in other frequency bands from individual licensing, which could lead to the need for more gateway earth stations in the 3.8-4.2 GHz band… Existing FSS earth stations in the 3800-4200 MHz band within Europe are limited in number and well-identified in location. Future new earth station sites can also be expected to be located in well-defined locations… As the 3800-4200 MHz is the only remaining part of the C-band for downlink communication, CEPT has assessed and proposed conditions to preserve this band for the long-term development of FSS…"[72]

EuroConsult found that 37% of the 3400-3700 MHz "downlink marketable capacity in service" was used for telecommunications, 17% was used for television, and 46% was unused. This was based on 10 days of monitoring 19 satellites which were more than 7 degrees above the horizon as viewed from a teleport near Munich, Germany, in January 2022.

A more striking statistic is that the actually used C-band satellite capacity has fallen to about 2% of the total commercial satellite capacity serving ITU Region 1.

Business researchers are fairly consistent in their assessments of the FSS market now and in the near future, although their assessments mainly reflect the growing dominance of services based on Ku and Ka band frequencies (12–18 GHz and 27–40 GHz, respectively) and the boom in broadband access via low-earth orbit (LEO) constellations. We have not seen any study which estimates the monetary value of C-band satellite services in the EU.

- IMARC Group claims that "The global fixed satellite services (FSS) market size reached USD 25.0 Billion in 2023. The market is expected to reach USD 36.6 Billion by 2032, exhibiting a growth rate (CAGR) of 4.19% during 2024-2032..."[73]
- 360iResarch claims that "The Fixed Satellite Services Market size was estimated at USD 21.65 billion in 2023 and expected to reach USD 23.11 billion in 2024, at a CAGR 6.83% to reach USD 34.41 billion by 2030…"[74]
- The Business Research Company claims that the FSS market "will grow from $21.59 billion in 2023 to $22.96 billion in 2024… to $28.47 billion in 2028 at a compound growth rate (CAGR) of 5.5%. The growth in the forecast period can be attributed to increasing demand for high-throughput satellites (hts), expansion of satellite broadband services, rising demand for mobility solutions, growth in remote sensing applications, development of small satellite constellations…"[75] However, this growth seems more likely to lure subscribers away from C-band services rather than to attract them.

Satellite dish owners regularly scan transponders whose signals are accessible and report what they find to a variety of websites. We visited two of those websites and found that migration out of the 3400-3700 MHz band has accelerated in the 2 years since EuroConsult's report was published:

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[70] Pacôme Révillon, Stéphane Chenard, et al., "The Use of Extended C Band, Planned C Band and the 7025-7075 MHz Band for Satellite Services: Key Findings," EuroConsult (2022) - https://www.euroconsult-ec.com/connectivity-expertise/download-extended-c-band-presentation

[71] In fact, ČTÚ's spectrum utilization plan for 2700-4200 MHz says, in Article 8, "Due to the implementation of the Commission's [band harmonization] Decision, no new individual authorizations are granted for new earth stations of the satellite fixed service in the 3400-3800 MHz band" - https://ctu.gov.cz/sites/default/files/obsah/ctu/sdeleni-o-vydani-opatreni-obecne-povahy-casti-planu-vyuziti-radioveho-spektra-c.pv-p/7/02.2022-3-pro-kmitoctove-pasmo-2700-4200-mhz/obrazky/pvrs7p.pdf

[72] *CEPT Report 088: 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* (2024) - https://docdb.cept.org/document/28629

[73] IMARC Group, *Fixed Satellite Services (FSS) Market Report… 2024-2032* - https://www.imarcgroup.com/fixed-satellite-services-market

[74] 360iResearch, *Fixed Satellite Services Market by Service Type (Consumer Broadband, Enterprise & Government, Media & Broadcast), Vertical (Oil & Gas), Maritime - Global Forecast 2025-2030* - https://www.360iresearch.com/library/intelligence/fixed-satellite-services

[75] The Business Research Company, *Fixed Satellite Services Global Market Report 2024* - https://www.thebusinessresearchcompany.com/report/fixed-satellite-services-global-market-report

Table 5: Frequency ranges used by C-band satellites parked above Central Europe

Orbital position	Satellite name	Frequency range for downlink (MHz)	Transponder content, areas served
2.9° E	Rascom QAF	3970-4147	Africa, Spain & France
3.0° E	Eutelsat 3B	3672-4170	Africa, raw feeds
5.0° E	SES 5	3922-4111	BBC, VOA & African TV
10.0° E	Eutelsat 10B	3836-4039	Only African stations
17.0° E	Amos 17	3846-4119	Africa, without direct-to-home service
20.0° E	Arabsat 5C	3747-4194	Radio/TV in Africa & Middle East
26.0° E	Badr 8	4080-4099	Africa

Sources: Lyngsat.com and Satbeams.com (October 2024)

But lest one conclude that protecting the remaining C-band FSS links is pointless, one must recognize that the active frequencies reported by dish owners are based on TV signals, which are only part of the satellites' payload. EuroControl acknowledges that:

> "The usage of the extended and planned C-band for telecommunication applications is more difficult to quantify than television… It appears to come to a few hundred user terminals in Africa, and to a smaller number of teleport facilities in Europe. Those installations appear to correspond exclusively or almost exclusively to legacy networks, as we have not identified any significant deployment of a new network in recent years. The available use cases, however, confirm that, for the telecom applications which rely on it, C-band is usually the only possible choice, primarily because of their need for high reliability… These are of critical importance to their operation but rely on a small number of facilities at discrete locations, and this use appears likely to reduce as these satellites are retired and their successors move on to other frequencies for gateway links. However this process may be slow, as some of the satellites concerned can be long-lived… C-band spectrum, is valued because its physical properties allow more reliable communications and broader coverage than generally possible at higher frequencies."[76]

As noted earlier, these frequencies are desirable for both space and terrestrial services. Fortunately, sharing is possible and CEPT has created a technical toolkit for Administrations to manage coexistence with satellite earth stations in this band: *ECC Report 254*.[77]

This may have limited relevance to the Czech Republic, but the ITU points out that:

> "The use of the band 3 400-4 200 MHz by FSS includes governmental uses and international commitments within the WMO.[78] WMO usages of the band, which are essential for civil aviation and weather, water, climate and environmental alerts, are currently using only a few channels in the 3 600-3 800 MHz band.[79] The 3 400-4 200 MHz band is also utilized for tracking, telemetry and command (TT&C) purposes, under the FSS allocation, by a majority of FSS satellites operating in this band… It is up to each administration to decide which stations within its own territory it wishes to protect in accordance with the RR… The Radio Regulations do not provide any criteria or procedures for all kinds of required coordination under RR Article 9, such as between GSO FSS networks and between FSS and terrestrial network, for how this bilateral coordination is to take place."[80]

[76] Révillon, Chenard (EuroControl), op. cit.

[77] *ECC Report 254: Operational guidelines for spectrum sharing to support the implementation of the current ECC framework in the 3600-3800 MHz range* (2016) - https://docdb.cept.org/document/958; *Recommendation ITU-R F.1403-0: Power flux-density criteria in ITU-R Recommendations for protection of systems in the fixed service in frequency bands shared with space stations of various space services* (1999) - https://www.itu.int/rec/R-REC-F.1403/recommendation.asp?lang=en&parent=R-REC-F.1403-0-199905-I

[78] World Meteorological Organization.

[79] This seems to be a reference to GEONETcast's Disaster Channel. Sponsored by EUMETSAT, it provides video alerts, information updates and meteorological data about major storms and environmental emergencies through affiliated broadcast channels available on Ku- and C-band satellites. EUMETSAT Europe claims to have over 3,000 registered users. See https://old.earthobservations.org/geonetcast.php

[80] REPORT ITU-R M.2109

4.2.1.2 Fixed Service

The Fixed Service is the oldest radio service, having evolved from wireless telegraphy. The first FS allocation was made at the 1912 International Radio Conference which endorsed an American proposal for frequencies below 200 kHz to be reserved for long distance point-to-point communication.[81]

The 1959 World Radiocommunication Administrative Conference agreed on a substantial increase in FS allocations in the microwave region to support the expansion of telephone and television networks. Growing demand for fixed wireless connectivity was coming from national telephone networks (for intercity voice links) and television broadcasters (for the distribution of live/real-time and pre-recorded audiovisual programs). However, in the past two decades, demand for new fixed links has come primarily from cellular mobile networks, which use point-to-point microwave to connect base stations to switching centers and other infrastructure elements (backhaul). In France, for example, about 80% of the link capacity in the Fixed Service is now occupied by mobile operators.[82] Private networks connecting the branch offices of data-intensive businesses have also increased. Although fibre-optic networks have proliferated, fibre-optic and microwave links are often used complementarily. In these cases, microwave serves as a backup technology for optical fibre, especially in applications requiring high reliability, such as control of electrical networks or train systems.[83]

Recent growth in the deployment of fixed microwave has mainly been within cities, rather than between cities. This fact is also related to the gradual increase of the frequency band boundaries. In the past, bands up to 6/7 GHz were typical for this type of connection, which then gradually expanded to the 11/13 GHz bands, eventually reaching the e-band (60-90 GHz). So the average link length has shortened, making it practical to utilize higher frequencies despite their more limited propagation range. (A key benefit of higher frequency bands is that wider channels are available there, especially above 15 GHz, providing more capacity per link.) According to *ECC Report 173*, "the number of active P-P links declared by respondent administrations increased [from] about 160,000 links reported in 1997 to about 740,000 declared in 2021."[84] The vast majority of those links are bi-directional, with only 1-2% being uni-directional.

It is important to note, however, that the 3600-4200 MHz range has not participated in the rapid growth of new point-to-point links. According to *ECC Report 173*, "The band 3.6-4.2 GHz had a continuous negative trend since 1997 and has now probably reached its minimum possible number of links. The links that are still in operation are mainly long-haul links for telecommunication and broadcasting network infrastructure…" 4 GHz now has the longest hops of any fixed microwave band.

In the Czech Republic, according to ČTÚ, "the operation of fixed point-to-point connections in [the 3600-3800 MHz] band ended in 2011."[85] And yet the Fixed Service retains its co-primary status with the Mobile Service—presumably to enable deployments of MFCN.[86]

ČTÚ's online database of individual authorizations shows 47 currently active licenses for Fixed Service frequencies between 3800 and 4200 MHz. Most of these are believed to belong to České Radiokomunikace. Each FS channel is 29 MHz wide, grouped into six FDD pairs. The band is harmonized according to Recommendation ITU-R F.382-7:[87]

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[81] Williams & Collins, op. cit.

[82] *ECC Report 173: Fixed Service in Europe - Current use and future trends post 2022* (2023) - https://docdb.cept.org/document/281

[83] ETSI EN 302 217-3 V2.2.1 (2014-04): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 3: Equipment operating in frequency bands where both frequency coordinated or uncoordinated deployment might be applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive" - https://www.etsi.org/deliver/etsi_en/302200_302299/30221703/02.02.01_60/en_30221703v020201p.pdf

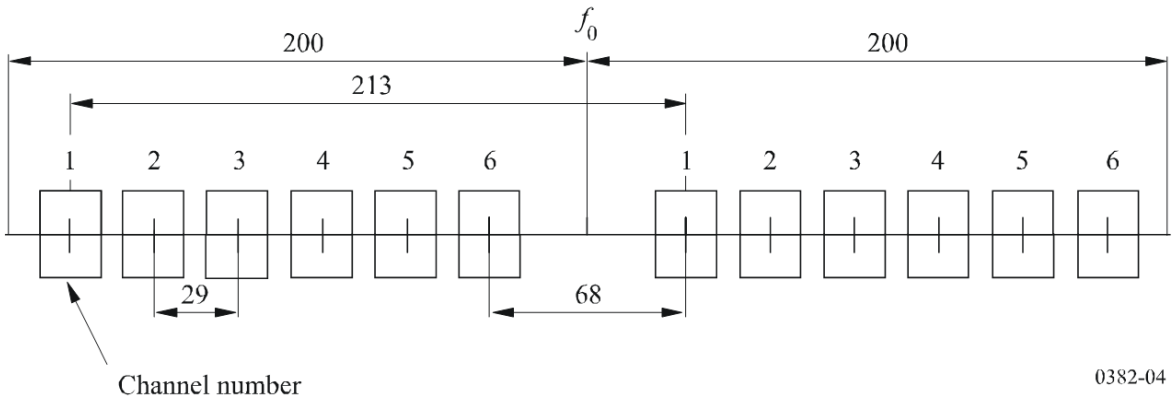
[84] *ECC Report 173*. These numbers representing the deployment trend do not include links deployed under block authorizations as they usually do not require the reporting of new sites to the national regulator. Therefore, the figure cited for 2021, as large as it is, is almost certainly an under-estimate.

[85] ČTÚ, "Invitation to Tender for the award of rights to use radio frequencies to provide an electronic communications network in the 3600–3800 MHz band," ČTÚ-1/2017-613 (March 2017) - https://ctu.gov.cz/sites/default/files/obsah/ctu/oznameni-ceskeho-telekomunikacniho-uradu-o-vyhlaseni-vyberoveho-rizeni-za-ucelem-udeleni-prav-k/obrazky/20170327-vyhlasenivyberovehorizeni-en.pdf

[86] These operate under the harmonised frequency arrangements and least restrictive technical conditions stipulated in ECC/DEC/(11)06

[87] Recommendation ITU-R F.382-7: "Radio-frequency channel arrangements for fixed wireless systems operating in the 2 and 4 GHz bands" (1997) - https://www.itu.int/rec/R-REC-F.382/recommendation.asp?lang=en&parent=R-REC-F.382-7-199709-S. Note that this Recommendation has been superceded by F.382-8 (2006).

Figure 6: Channel arrangement for digital radio-relay systems in the Czech 4 GHz FS band



Source: Recommendation ITU-R F.382-7

Six of CTU's fixed service licenses expire in 2025, twenty-five in 2026, nine in 2027, three in 2028, and four in 2029. None of the licenses extend to 2030 or beyond, as all individual licenses are valid for a maximum of 5 years (2024+5 = 2029), assuming the license is not extended by the IO holder.

A byproduct of the break-up of national telephone monopolies in the 1990s was the stimulation of competition in the Fixed Service —which resulted in pressure to search for new applications and markets for fixed network services–e.g. for contracts to supply backhaul connectivity to support the expansion of mobile telephony and public Internet access. The spirit of liberalization which ended telco monopolies also led to the introduction of technology-neutral licenses in many radio services, including FS. That in turn allowed the emergence of new link configurations, like point-to-multi-point (P-MP), and more recently, non-line-of-sight (NLOS) links in urban areas, for which lower frequency bands like 4 GHz are particularly well-suited. The evolution of technology neutrality into service neutrality opened the door to new applications like mobile/fixed converged networks (MFCN), Fixed Wireless Access (FWA) and nonpublic cellular.

In 1998, 3400-3600 MHz was identified by CEPT as a preferred frequency band for Fixed Wireless Access.[88] FWA, however, fizzled:

> " Although FWA is in principle well suited for serving any customers, ranging from residential to small businesses (SOHO/SME) and large corporations, the analysis of current market situation shows that 'pure' FWA operators have today less and less hope to make profitable business plans by serving residential customers… prices were driven down by competition and by the advent of efficient BWA in lower bands, [so] it became extremely hard for FWA to compete in [the] residential market because of still high CPE pricing.
>
> "Therefore, FWA networks in these higher bands are confined in niche deployments and no real expansion is expected… Other bands used for FWA in a few European countries are mostly those below 3 GHz (around 1.5 GHz and 2-2.7 GHz)…
>
> "With increased regulatory liberalisation and particularly in some lower frequency bands (currently 3400-3600 MHz and 3600-3800 MHz), FWA designations have been replaced with BWA designations and in many CEPT countries the original FWA spectrum authorisations have themselves been liberalised to reflect this new flexibility without any change of authorisation ownership.[89] This new BWA designation introduces regulatory flexibility to support fixed, nomadic and mobile services and in many cases the access technology is derived both from fixed and/or mobile standardisation origins for building up Mobile/Fixed Communication Networks (MFCN)… The 3400-3600 MHz and 3600-3800 MHz ranges are

[88] See CEPT/ERC/Recommendation 14-03 E (Turku 1996, Podebrady 1997): "Harmonised Radio Frequency Channel Arrangements and Block Allocations for Low and Medium Capacity Systems in the Band 3400 MHz to 3600 MHz" - https://docdb.cept.org/download/2422; "ERC/REC 13-04 of 25 September 1998 on preferred frequency bands for fixed wireless access in the frequency range between 3 and 29.5 GHz" (1998) - https://docdb.cept.org/download/2417.

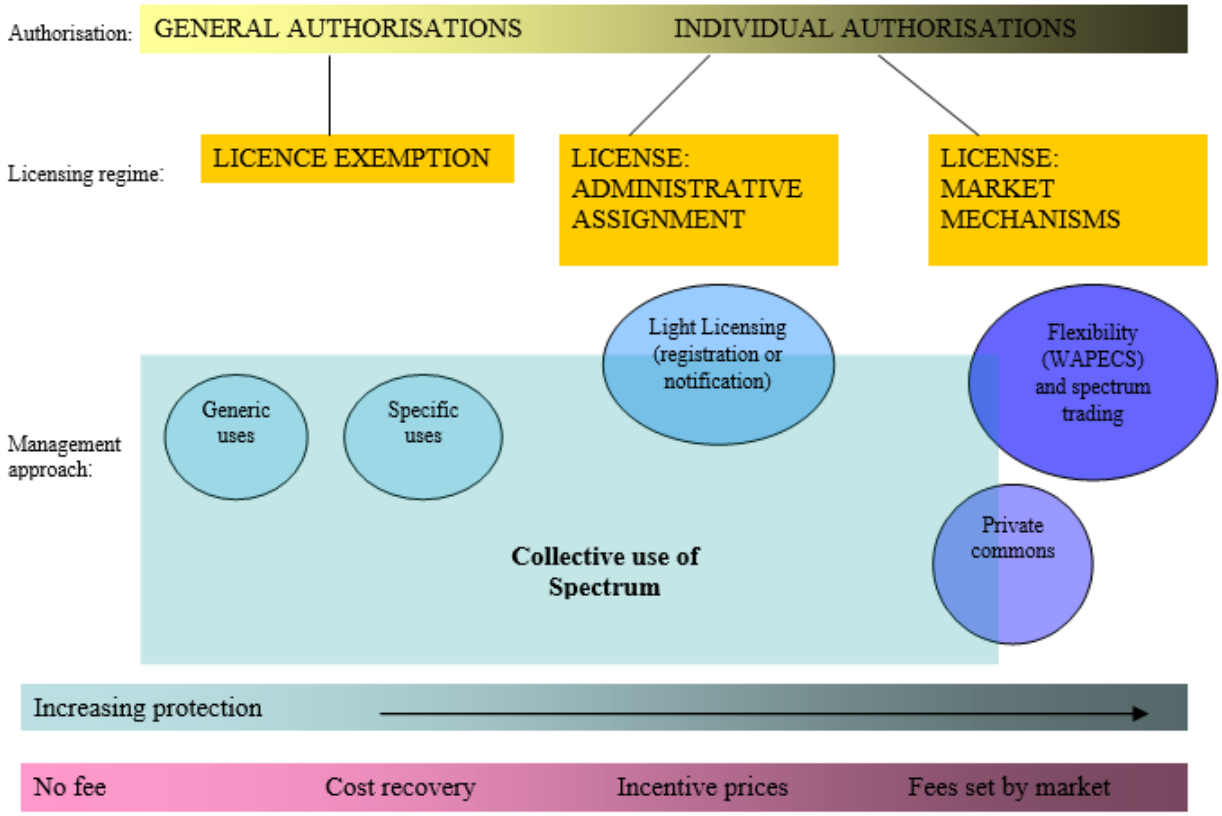
[89] Frequency block arrangements for FWA systems in the 3400-3800 MHz band were proposed in Recommendation ITU-R F.1488. The key difference between FWA and BWA is that BWA is not limited to fixed installations. BWA includes fixed, nomadic and mobile networks.

> the most popular for BWA and underpinned by harmonisation measures in… EC Decision 2008/411/EC[90]…and 2014/276/EU[91]…[ECC Decision (11)06[92] harmonized] the band arrangements for MFCN usage (including IMT)… This complements the BWA framework with specific harmonised frequency channel arrangements."[93]

The development of variants like P-MP, BWA and FWA in the Fixed Service bands has led some national regulatory agencies to re-examine what is the most appropriate authorization regime:

> "…individual licensing (frequency assignment of each individual link…) continues to be the predominant method in making assignments in the majority of the bands for which information has been provided. This is followed by block assignment, which, while it does not dominate as a method, tends to be applied across most bands. Block assignment is on par with link-by-link assignment in the 3.4-4.2 GHz range… The reason for this is presumed to be related to the initial P-P links deployment, later on partially switched to possible P-MP applications."[94]

Figure 7: License regimes in spectrum management and the Authorization Directive



Source: ECC Report 137[95] (2010)

[90] "Commission Decision of 21 May 2008 on the harmonisation of the 3400-3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community" (2008/411/EC) - https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008D0411 ECC Decision (07)02 was also listed in this sentence from *ECC Report 173*, but that Decision was withdrawn in 2018.

[91] "Commission Implementing Decision of 2 May 2014 on amending Decision 2008/411/EC on the harmonisation of the 3400-3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community" (2014/276/EU) - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2014.139.01.0018.01.ENG

[92] ECC Decision (11)06: "Harmonised frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the band 3400-3800 MHz" (2011, 2018) - https://docdb.cept.org/download/1531

[93] *ECC Report 173*.

[94] Ibid.

4.2.1.3 Mobile, IMT and Mobile/Fixed Converged Services

There was an early hint at WRC-03 that changes might be coming when Agenda Item 1.4 was agreed for WRC-07 to consider frequency-related matters for future iterations of IMT. WRC-03 invited ITU-R to report, in time for WRC-07, the results of studies on spectrum requirements and potential frequency ranges suitable for future IMT networks.[96] That led to the publication in 2006 of Report ITU-R M.2079, which identified many candidate bands. As CITEL told its member states, "After four weeks and many late hours of debate on all the candidate bands, the WRC-07 concluded that it was not feasible to identify any part of the C-band on a global basis for IMT systems."[97] Nevertheless, dozens of administrations endorsed the addition of Footnote 5.430A to the International Table of Frequency Allocations, identifying 3400-3600 MHz for IMT. The Czech Republic was among them, along with 22 other EU Members. Dozens more countries added footnotes identifying IMT in either the 3400-3500 MHz or 3500-3600 MHz bands.

Fast forward to November 2016: RSPG's *Strategic roadmap towards 5G for Europe* "considers the 3400-3800 MHz band to be the primary band suitable for the introduction of 5G-based services in Europe… noting that this band is already harmonised for mobile networks..." [98] However, it was not clear that 5G would satisfy the harmonized conditions. There were reasons for doubt. LS telecom's review of C-band compatibility studies, for example, found that:

> "Introducing [IMT/5G] into the band is far more complex than for previous fixed services if satellite reception is to be protected as:
>
> - "mobile base station transmissions are much higher powered;
> - "mobile base stations transmit in all directions and not just on a point-to-point basis;
> - "user devices can be anywhere, making controlling their proximity to satellite receivers nigh on impossible."[99]

So following publication of RSPG's roadmap, the Radio Spectrum Committee issued a mandate to CEPT to review (in cooperation with ETSI) the harmonized technical conditions governing the use of 3400-3800 MHz to assess their suitability for 5G networks, and amend those conditions, if necessary.[100] The findings were published in *ECC Report 281*[101] which noted several problems:

- There is a need to reorganise and defragment the band. The ECC is now developing guidelines/best practices for administrations suggesting ways to facilitate availability of largest possible contiguous portions of spectrum."[102]
- The existing block edge mask (BEM) adequately protects stations operating below 3400 MHz and above 3800 MHz from out-of-band emissions of MFCN/IMT base stations which are *not* using active antenna systems, but a different BEM is needed to protect stations from MFCN/IMT base stations using AAS.
- New out-of-block power limits were needed to prevent interference between synchronized MFCN base stations.

Even before the RSPG roadmap was issued (and before the changes recommended by the ECC were defined), ČTÚ began preparing to auction 15-year nationwide MFCN licenses for the 3600-3800 MHz band. "This frequency band is not currently in use," ČTÚ noted. "The operation of fixed point-to-point connections in this band ended in 2011, meaning before the planned award of assignments pursuant to this Tender. None of the frequency assignments in this band have as yet been issued."[103] So five 40 MHz

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[95] *ECC Report 137: Introducing Greater Flexibility in the Current Regulatory Structure with a View to Taking Forward Convergence and Harmonisation in the ECC* (January 2010) - https://docdb.cept.org/download/547

[96] See Resolution 228 (rev. WRC-03).

[97] "WRC-07 Decisions and Next Steps for Protecting the Satellite C-band," *CITEL Electronic Bulletin*, No. 43 (January 2008) - https://www.oas.org/en/citel/infocitel/2008/enero/bandaC_i.asp

[98] RSPG, "Strategic Roadmap Towards 5G in Europe: Opinion on spectrum related aspects for next-generation wireless systems (5G)" (RSPG16-032) - https://radio-spectrum-policy-group.ec.europa.eu/document/download/2d1c7750-4810-418e-8aa3-d58403b1a516_en?filename=RPSG16-032-Opinion_5G.pdf

[99] R. Womersley, *A review of 5G/Satellite compatibility studies in C-band,* LS telecom (2021) - https://www.lstelcom.com/fileadmin/content/lst/marketing/brochures/C-band_compatibility_report.pdf

[100] Radio Spectrum Committee, "Mandate to CEPT to develop harmonised technical conditions for spectrum use in support of the introduction of next-generation (5G) terrestrial wireless systems in the Union: Opinion of the RSC," RSCOM16-40rev3 (7 December 2016) - https://circabc.europa.eu/sd/a/448dc765-51de-4fc8-b6e0-56ed6a1d0bca/RSCOM16-40rev3%205G%20draft_mandate_C. The 3400-3800 MHz band was harmonized for MFCN by ECC Decision (11)06 in the CEPT member states and in the EU by Commission Decision 2008/411/EC as amended.

[101] *ECC Report 281: Analysis of the suitability of the regulatory technical conditions for 5G MFCN operation in the 3400-3800 MHz band* (6 July 2018) - https://docdb.cept.org/download/3419

[102] Ibid..

[103] Ibid.

blocks were offered at a starting price of CZK 29 million per block. In the end, ČTÚ reaped CZK 1015 million (CZK 203 million per block).

In-block EIRP limit values for the base stations using 3600-3800 MHz were set at "68 dBm/(5 MHz), with the exception of the lowest 5 MHz of each frequency segment… where the output level is limited to +4 dBm/(5 MHz)."[104] If the same licenseholder controls adjacent frequency blocks, the 5 MHz output level reduction to limit out-of-block interference does not apply between the blocks with a common licensee.

In November 2020 ČTÚ auctioned 12-year licenses in the 3400-3600 MHz band for the deployment of 5G networks. Two 20 MHz blocks (3400-3420 MHz[105] and 3420-3440 MHz) came with the expectation that the frequencies would be sublet to enable the creation of non-public networks supporting Industry 4.0.[106] The starting price for those two blocks was CZK 110 million per block, while the other eight 20 MHz blocks had a reserve price of CZK 140 million per block.[107] In the end CTU reaped CZK 1606 million from the auction.

The successful auction bidders "committed to refarming the 3400-3800 MHz frequency band with the aim of unifying allocations and the creation of continuous frequency sections for individual operators. The commitment was fulfilled in July 2021 by making changes to the assigned radio frequency ranges… The radio spectrum utilization plan issued in February 2022 determined the parameters of uniform mutual synchronization of TDD time frames, taking into account both the already operating 4G-LTE networks and the newly built 5G networks, for the purpose of optimizing the use of radio frequencies."[108]

TDD networks operating in the same area and using the same span of frequencies need to be synchronised. Otherwise, network performance suffers, transmission speeds are reduced and interference between stations (end-user terminals as well as base stations) becomes likely. GSMA recommends uniform synchronization at the national or even international level, as well as a nationally consistent frame structure.[109] When synchronization is not possible—for example, when co-existing networks use different technologies or when a local/industrial cellular network needs special parameters to support some essential application—limits on power output, guard bands or greater separate distances may be necessary. So synchronization is an important consideration in band sharing between IMT and other radio services as well as between national and local/industrial MFCN networks.

In January 2018, RSPG issued a second "roadmap" opinion on 5G, which put these issues in a broader context:

- Beam-forming (a key feature of 5G) may change the calculation of minimum separation distances required between stations in services and networks that share frequencies:
    - "The antenna beam forming technologies being developed for 5G will be used to improve link quality and throughput to individual end users. It should be investigated where it is feasible for antenna beamforming technologies to also be used in a way that explicitly minimises radiation in specific directions, i.e. towards receiving stations of other services. If this is feasible then, when coupled with other technical approaches (e.g. database / geolocation technologies), it could potentially be effective in mitigating interference to other services. This may offer the possibility to deploy 5G stations closer to the existing stations to be protected than would otherwise be the case. However, such features would have to be implemented in the antenna beamforming and massive MIMO algorithms in a way that allows operators to define the radiation limitation in any given direction.

[104] "Invitation to Tender for the award of rights to use radio frequencies to provide an electronic communications network in the 3600–3800 MHz band" (27.03.2017) - http://www.ctu.cz/sites/default/files/obsah/ctu/oznameni-ceskeho-telekomunikacniho-uradu-o-vyhlaseni-vyberoveho-rizeni-za-ucelem-udeleni-prav-k/obrazky/20170327-vyhlasenivyberovehorizeni-en.pdf

[105] The Amateur Service has a secondary allocation at 3400–3410 MHz which is governed by the conditions in Note CZ7 of the National Frequency Table and Annex No. 1 of Decree No. 156/2005 Coll., (on the technical and operational conditions of the amateur radio communication service). Amateur stations in this band may not disrupt the operation of existing or future electronic communications networks nor are they entitled to protection from those networks.

[106] ČTÚ, "Český telekomunikační úřad vydražil kmitočty v pásmech 700 MHz a 3400–3600 MHz," press release (13. 11. 2020 - https://ctu.gov.cz/tiskova-zprava-cesky-telekomunikacni-urad-vydrazil-kmitocty-v-pasmech-700-mhz-3400-3600-mhz

[107] ČTÚ, "Appendix 3 of „Vyhlášení výběrového řízení za účelem udělení práv k využívání rádiových kmitočtů pro zajištění sítí elektronických komunikací v kmitočtových pásmech 700 MHz a 3400–3600 MHz"; published 21. September 2020 under nr. ČTÚ-38 426/2020-613/IV.vyř. - https://ctu.gov.cz/sites/default/files/obsah/ctu/oznameni-ceskeho-telekomunikacniho-uradu-o-vyhlaseni-vyberoveho-rizeni-za-ucelem-udeleni-prav-k/obrazky/20200921-priloha3czoprava.pdf

[108] ČTÚ, "Strategie správy rádiového spektra - Druhá Situační zpráva o stavu plnění opatření" [Radio Spectrum Management Strategy - Second Situation report on the status of implementation measures], June 2022 - https://ctu.gov.cz/sites/default/files/obsah/stranky/49264/soubory/druha_situacni_zprava_ve_zneni_projednanem_radou_ctu_v_srpnu_2022.pdf

[109] GSMA, *5G TDD Synchronisation: Guidelines and Recommendations for the Coexistence of TDD Networks in the 3.5 GHz Range* (April 2020) - https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2020/04/3.5-GHz-5G-TDD-Synchronisation.pdf

- "It is important for standards bodies such as 3GPP and ETSI and for research programmes such as the 5G-PPP to investigate these features. Where feasible, manufacturers should include them in the development of 5G equipment to facilitate increased sharing.
- "Member States should take into account these potential technology developments when analysing spectrum sharing opportunities between 5G and existing users."

- 5G is designed to be more customizable than previous generations of cellular technology, in order to serve more diverse client classes, e.g. industrial enterprises, PPDR, the Internet of Things, etc. Therefore:
  - "Authorisation should take into account that different classes of applications have different requirements… Member States will require flexibility in the mix of authorisation approaches to use. Alternative authorisation approaches may include general authorisation regimes (licence exemption), licensed shared use between different users, geographical sharing (including sub-national, regional and site-specific licensing, including at the local level directly to businesses), or more dynamic approaches to spectrum sharing in time and space, possibly using geolocation databases… To enable optimal use of spectrum, industry should develop suitable protocols to ensure coexistence between various 5G applications in general authorisation bands and at the boundaries of geographic licences."[110]

A third RSPG opinion was issued in 2019. It offered a logical framework for thinking about the differing needs of verticals for network services, in order to clarify what types of frequency allocation and authorization might be appropriate. It does not cover every possible case, but their analysis speaks directly to one of the priority questions this report is supposed to answer:

- "Connectivity for vertical industries could be provided by mobile operator's solutions, third party providers [or] directly by verticals themselves in EU harmonised [electronic communication services] bands or in dedicated spectrum for verticals.
- "The RSPG recommends that Member States consider other spectrum solutions including dedicated or shared spectrum for the business/sectoral needs ('verticals needs') that may not be met by mobile operators.
- "The RSPG notes that, in addition to the above, in order to respond to some targeted EU public policy objectives requiring, for example pan European services for specific verticals, there may be need for technology neutral dedicated EU harmonised spectrum. RSPG recommends assessing these needs on a case by case basis...".

Table 6: Supplying verticals' needs for network services

<table>
<tr><th rowspan="2">Connectivity provided in…</th><th colspan="3">Connectivity provided by…</th></tr>
<tr><th>Mobile network operator (MNO)</th><th>Third party solution provider</th><th>The industry vertical (user)</th></tr>
<tr><td rowspan="2">Regionally harmonized MFCN spectrum</td><td rowspan="2">Verticals that are infrastructure-dependent, needing wide-area coverage, could be satisfied with a network slice / virtual private network</td><td rowspan="3">Can respond to and consolidate demand from many niche users with bespoke solutions in either shared or dedicated spectrum</td><td>Application needs are permanently evolving</td></tr>
<tr><td>Niche users mainly requiring local site coverage</td></tr>
<tr><td rowspan="2">Dedicated spectrum for verticals</td><td rowspan="2">Service provision in sub-leased spectrum</td><td>Wants full control of network for data security, cost, flexibility to change technologies or other reasons</td></tr>
<tr><td colspan="2">Needs not met by MNOs</td></tr>
</table>

Source: Based on RSPG (2019), processed by GTA

[110] "Strategic Spectrum Roadmap Towards 5G For Europe: RSPG Second Opinion on 5G networks," RSPG18-005 FINAL (30 January 2018) - https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/rspg18-005final-2nd_opinion_on_5g.pdf

- Verticals needing dedicated spectrum: “This includes two types of verticals. The first type is largely networked infrastructure-dependent. Such verticals are able to generate aggregated demands/needs to spectrum managers (mainly regarding wide area coverage). The other covers more fragmented and niche users mainly requiring local coverage and typically using a private network, as local areas for ‘on-site’ industry. These types of users may have requirements for dedicated spectrum due to reasons of cost, security, or their want to have full control over the network. In both cases, EU harmonised technical conditions suitable for mobile networks and providing economies of scale are also suitable for these types of usages.”
- MNO provided solutions for verticals: “5G network slices provide opportunities for virtual private networks, potentially offering different levels of service to different customer/business segments based on key performance indicators (KPIs) such as bit rate, latency, availability, and reliability… [That] may reduce the need for exclusive assignment of spectrum for some applications, particularly those that require wide area coverage (e.g. nationally for many IoT applications, critical PPDR infrastructure, FRMCS, etc.)
- “Access to dedicated spectrum may be based on specific authorisation regime for verticals or through trading or leasing of operators’ spectrum. The verticals’ needs for dedicated spectrum vary from country to country and depend on what services/slicing mobile operators may offer.”
- “This could also include hybrid solutions, for example, a vertical using their own private network, as well as using a mobile operator’s network.”[111]

Release 16 of the IMT standards suite was published by 3GPP in June 2020, introducing what was marketed as 5G. 5G was distinguished from previous releases in focussing strongly on the needs of industrial automation, niche applications and machine-to-machine communication (the Internet of Things). Enhancements were made to support factory production, time-sensitive communication, “vehicle-to-everything” and non-public networks (NPNs). Release 17 was “frozen” (no more changes) in early 2022. It added more features for 5G verticals, including a new IoT standard called NR-light. Release 18, frozen in the middle of 2024, added even more specifications aimed at verticals.

In 2021, the RSPG published a brief Opinion recommending “that [Member States] investigate the possible use of the band 3.8-4.2 GHz for local vertical applications (i.e. low/medium power) while protecting receiving satellite earth stations and other existing applications and services.”[112] In fact, many EU Members had already reached the same conclusion. But the RSPG Opinion prompted more countries to act. However, as this was a “bottom-up” movement, there was little coordination in the conditions set for these local vertical networks. It was a “let a thousand flowers bloom” experiment, to see what worked and what did not. However well-intentioned that approach may have been, the result was paralysis in the development of equipment for 5G verticals because of inconsistencies in the frequencies allocated and uncertainty about responsibilities for site planning.

[111] “Strategic Spectrum Roadmap Towards 5G For Europe: RSPG Opinion on 5G implementation challenges (RSPG 3rd opinion on 5G)” RSPG19-007 FINAL (30 January 2019) - https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-01/RSPG19-007final-3rd_opinion_on_5G.pdf

[112] “RSPG Opinion on Additional Spectrum Needs and Guidance on the Fast Rollout of Future Wireless Broadband Networks,” RSPG21-024 FINAL (16 June 2021) - https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-01/RSPG21-024final_RSPG_Opinion_Additional_Spectrum_Needs.pdf

*Figure 8: C-band IMT allocation in selected countries **

Based on source, not representing current practices in every country, e.g. in Czechia 3,4 - 3,8 GHz is already allocated.

Source: GSA (2024)[113]

The following table shows that rules for accessing and using the radio spectrum for the deployment of industrial and non-public IMT networks have differed across the region, as have the allocations of frequencies. This diversity allowed many approaches to be tested simultaneously, but the time has come to identify and converge on the approaches that work best, making them into a harmonized regional standard. Because of the many different starting points, each administration must follow a different path toward a common position.

Table 7: European spectrum for industry verticals

AUSTRIA Frequency band: 3400-3800 MHz Band width: 390 MHz An auction of regional licenses for 5G in the 3400-3800 MHz band was held in March 2019. Some spectrum remained unassigned, varying from 10 MHz each in two regions to 40-60 MHz in the other regions. A consultation was held in 2021 to ask the public if these left-over channels should be awarded to industry verticals, or to public cellular operators (celcos) to expand their networks. The celcos won.
BELGIUM Frequency band: 3800-3840 MHz, 3880-3960 MHz Band width: 120 MHz This information comes from "Decision of 19 December 2023 concerning local private networks in the 3800-4200 MHz band and the assignment of E.212 mobile network codes" (original in French and Flemish)[114]: BIPT offers TDD mode licenses of 20 or 40 MHz bandwidth for non-public IMT networks, with a maximum duration of 10 years. There is a cap of 40 MHz for each licensee and licenses cannot be traded. Annual spectrum usage fees are €400/MHz/km² (amounts adjusted for inflation in subsequent years). "The authorization holder may deploy as many stations as it wishes within the service area of its authorization…. In order to avoid interference to public mobile networks, private LANs in the 3800-3860 MHz sub-band must use the DDDSU frame structure. [Because this frame structure may not be appropriate in all situations,] BIPT therefore does not intend, at this stage, to impose the DDDSU frame… above 3860 MHz. "For non-synchronized outdoor networks, this Decision sets an EIRP limit of 18 dBm/5 MHz with antenna height limited to 10 m. This limit is identical to that applied in the United Kingdom and Norway… For synchronized outdoor networks, this Decision sets an EIRP limit of 30 dBm/5 MHz with an antenna height limited to 10 m, *i.e.* 12 dB more than for non-synchronized networks. BIPT calculations show that even with this 12 dB difference, the risk of interference is not higher than for non-synchronized networks. "For indoor networks, BIPT compatibility calculations take into account an attenuation of 12 dB due to building penetration... This attenuation of 12 dB makes it possible to increase the EIRP by 6 dB while reducing the distance between two networks thanks to a 6 dB margin for propagation losses. For non-synchronized indoor networks, this Decision sets an EIRP limit of 24 dBm/5 MHz. For synchronised indoor networks, BIPT considers that a limit of 30 dBm/5 MHz is sufficient to ensure coverage. This Decision sets a [total radiated power] limit of 28 dBm for terminals. This limit is identical to that applied for terminals in the 3400-3800 MHz band... "**Emission mask:** The EIRP limits outside the assigned block for base stations are stipulated in Table 1. Unless otherwise specified, the measurement bandwidth is 5 MHz. These limits are aligned with the harmonised conditions of the CEPT Report

[113] Global mobile Suppliers Association, *GSA Snapshot: Spectrum Positions Used for Mobile Services* (June 2024) - https://gsacom.com/download.php?id=17360

[114] https://www.bipt.be/operators/publication/decision-of-19-december-2023-concerning-local-private-networks-in-the-3800-4200-mhz-band-and-the-assignment-of-e.212-mobile-network-codes

088 [on least restrictive technical requirements for WBB LMP at 3800-4200 MHz]:

Frequency band	EIRP limit for base stations
0 to 5 MHz below and 0 to 5 MHz above the assigned block	maximum carrier power minus 40 dB per antenna
3800-4200 MHz except the assigned block and frequencies 0 to 5 MHz below and 0 to 5 MHz above the assigned block's maximum carrier power	minus 43 dB per antenna
Below 3800 MHz	For networks using DDDSU frame structure: maximum carrier power minus 43 dB per antenna For other networks: -43 dBm/MHz per antenna

"Protection of other services: RTBF [Radio-Television Belgium] uses radio links in the 3800-4200 MHz band. For the protection of RTBF radio links, BIPT uses the same compatibility criteria as those provided for international coordination in the HCM agreement (Berlin, 8 September 2022), namely a maximum permissible degradation of the threshold of 1 dB (which corresponds to an I/N value of -5.9 dB). Earth stations: There are two sites where earth stations using the 3800-4200 MHz band for reception are deployed in Belgium: a site in Redu (the European Space Agency Centre) and a site in Gosselies. For the protection of earth stations, BIPT uses as a protection criterion a limit of the power received by an isotropic antenna, for a probability of 20%, at 15 m above ground level, of -184 dB(W/4kHz)...[115] [BIPT calculates that there is no interference risk to radio altimeters using the EIRP limits for base stations cited above.]

"International coordination: There is no agreement on border coordination for the 3800-4200 MHz band. If the calculations show that the potential field created at the border exceeds the limit of 41 dBµV/m/5 MHz at a height of 10 m above ground level at the border with a neighbouring country, BIPT will initiate coordination with this neighbouring country, or impose constraints in the authorization so that the limit of 41 dBµV/m/5 MHz is respected.

Compatibility between private local area networks: ...BIPT uses the technical conditions adopted in the United Kingdom and Norway for the 3800-4200 MHz band where relevant. In the United Kingdom and Norway, the networks are not synchronized. BIPT therefore uses the technical conditions adopted in the United Kingdom and Norway only for non-synchronized networks. CEPT Recommendation (15)01 proposes threshold values at the border between neighbouring countries for the 3400-3800 MHz band, for both synchronized and non-synchronized networks. For non-synchronized networks, where interference between base stations is preponderant, this recommendation is less relevant since it is based on public mobile networks with antenna heights much greater than the 10 m authorized for private local networks in the 3800-4200 MHz band. For synchronized networks (interference into terminals of network B by base stations of network A), the threshold level is 61 dBµV/m/5 MHz at 3 m above ground level.[116] For unsynchronized networks (interference into base stations of network B by base stations of network A), BIPT takes into account a noise factor of 13 dB and an I/N value of -4 dB for its compatibility calculations. The threshold level is therefore 55 dBµV/m/5 MHz at 10 m above ground level.

"This Decision may be revised as soon as a European Commission implementing decision setting the harmonised technical conditions for the 3800-4200 MHz band is adopted."

CZECH REPUBLIC Frequency band: 3400-3440 MHz Band width: 40 MHz

Two bidders (CentroNet and O_2) acquired 20 MHz blocks at 3400-3440 MHz in a November 2020 auction. These blocks had the

[115] See *ECC Report 100: Compatibility studies in the band 3400- 3800 MHz between broadband wireless access (BWA) systems and other services* (February 2007) - https://docdb.cept.org/document/208

[116] Value proposed in CEPT Recommendation (15)01 for synchronized networks using non-preferential PCI (physical-layer cell-identity) for the 3400-3800 MHz band.

condition attached that the spectrum must be leased to industry verticals on request. In 2023 CentroNet sold its license with the obligation to T-Mobile.

DENMARK Frequency band: 3740-3800 MHz Band width: 60 MHz

TT-Network (a joint venture of Telenor and Telia in Denmark) bought a license for 3660-3800 MHz at the April 2021 auction which included the obligation (until 2025) to sublet its frequencies to businesses and public institutions on a "first come, first served" basis for the creation of local non-public networks serving only the subletter's internal needs where they have tenancy. Sublets come with strict technical rules designed to prevent interference to radars and public cellular networks operating in neighbouring frequencies. The private networks must satisfy the same technical requirements as the principal license-holder to ensure that the private networks can coexist with the public mobile network. "The Lessee shall ensure that the accumulated power flux density (PFD) from the Lessee's Private Network at a distance of 500 metres outside the borderline of the Private Network… shall not exceed -5 dBm/m^2/(5 MHz) at a height of 1.5 metres."

The standard lease contract is online at https://ens.dk/sites/ens.dk/files/Tele/annex_m_-_standard_contract_for_leasing_spectrum.pdf

The annual rent is limited to "a geographically proportional share [of Denmark's land area] considering the amount of frequencies included in the Contract," the amount paid for the license at auction, and the annual frequency use fee that the license holder pays to the regulator.

FINLAND Frequency band: 2300-2320 MHz, 3410-3800 MHz Band width: 410 MHz

Since 2020, local licenses are available for 2300-2320 MHz and 24.25-25.1 GHz enabling factories, ports, airports, shopping centres, power plants, mines, educational institutions, etc. to develop IMT or FWA networks for their own needs. The 3410-3800 MHz band was allocated in October 2018 to MNOs with an obligation to use it or lease it.

FRANCE Frequency band: 2575-2615 MHz, 3490-3800 MHz, 3800-4200 MHz Band width: 340 MHz

In 2019, ARCEP decided to make local cellular licenses available to private industries in the 2575-2615 MHz band. Starting in 2022, ARCEP allowed 3800-4000 MHz to be used for industrial/vertical trials as well. Allocated in 2020 to four MNOs, licensees in the 3.6 GHz band must grant reasonable requests from economic actors (enterprises, local authorities) for tailored network solutions with agreed coverage and performance levels or, if the operator prefers, grant them local access to its frequencies, via "secondary" licences for a maximum of 3 years). This obligation began in 2024 and will be complemented by a roll-out obligation in rural and industrial areas at the end of 2024.

GERMANY Frequency band: 3700-3800 MHz Band width: 100 MHz

The following information comes from Bundesnetzagentur, "Administrative rules for spectrum assignments for local spectrum usages in the 3700-3800 MHz band" (15 May 2023)[117]:

Germany found that many manufacturers wanted to deploy private networks which were more powerful and secure than WiFi—but they also heard complaints that MNOs could not supply them with such networks. So BNetzA reserved up to 100 MHz (in 10 MHz blocks) in the 3700-3800 MHz band for local assignments of frequencies directly to enterprises on a technology-neutral, first come, first served basis. The licenses can be for up to 10 years, but may not extend past the end of 2040. Spectrum use

[117] https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/FrequencyAssignment/LocalBroadband3,7GHz.pdf

fees are calculated annually using this formula:

$$\text{Fee (EUR)} = 1000 + B \cdot t \cdot 5 \cdot (6 \cdot a_1 + a_2)$$

Where: 1000 is the base amount in EUR

B is bandwidth in MHz (from 10 MHz to 100 MHz)

t is the assignment period in years

a is the surface area in square kilometres (km^2)

a_1 is settlement and transport land

a_2 is other types of land

The window for applications opened in November 2019. So far every company that has applied has gotten a license. There is a "use it or lose it" policy – the network must be deployed within a year of the license being issued or it will be cancelled. Applicants are required to sign a document confirming their specialist knowledge, financial capacity and reliability.

BNetzA does not define a maximum permissible field strength at the edge of the licensed area, but network owners must agree to negotiate with neighbouring network owners to resolve interference complaints. Any written agreement about interference must be filed with BNetzA. If agreement proves elusive, BNetzA can impose a field strength limit of 32 dBµV/m/5 MHz at a height of 3m at and beyond the border of the assignment area (as provided in ECC Recommendation (15)01). No in-block EIRP limits have been defined for base stations.

GREECE Frequency band: 3400-3410, 3410-3800 MHz Band width: 400 MHz

RSPG: "In Greece, most verticals implement their own private networks based on MNOs' resources. Stand-alone private networks are managed by mobile operators."

LUXEMBOURG Frequency band: 3700-3800 MHz Band width: 100 MHz

Assignment rules were released in March 2020 for local applications to use 3700-3800 MHz.

NETHERLANDS Frequency band: 3400-3450, 3750-3800 MHz Band width: 100 MHz

A press release from the Dutch Ministry of Economic Affairs in November 2023 announced that permits for local, private 5G networks will be available from 1st December 2023. Companies were already able to use 1780-1785 MHz and 1875-1880 MHz without a license under the terms set forth in "Regeling gebruik van frequentieruimte zonder vergunning en zonder meldingsplicht 2015" [Control of the use of frequency space without a permit and without a notification obligation 2015].[118] But the 100 MHz made available in the C-band support much higher speeds. The Dutch government refers to those channels as being for "parcel-bound" networks, because they are intended to be used only on plots of land which your company or organization owns or has rights to use. The bandwidth that can be applied for is limited only by what is available in the area you want to cover. The default duration of the permit is until 31 December 2040 and renewal will not be possible. "You are obliged to cooperate with the other permit holders of a parcel-related network in your area" and interference may not be caused to other spectrum users. However, all parcel-related networks have equal rights—the order in which they were activated does not establish priority—with the important exception that parcel-related networks with permits issued before 2018 do have priority over later arrivals, until 1 September 2026, when their permits expire. The Ministry's online database of networks shows that there are currently 27 parcel-related networks in the Netherlands. Fixed antenna installations with a transmission power greater

[118] https://wetten.overheid.nl/BWBR0036378/2021-12-15

than 10 dbW must register in the national Antenna Register as well.[119] However, there seems to be a dirth of technical information about these networks – no indication what the power limit is, BEM, whether synchronization is necessary, etc. The application form indicates that bandwidths are available in multiples of 10 MHz and TDD is mandatory, but in their drive to keep things simple, they have made it difficult to describe a practical deployment.

NORWAY Frequency band: 3800-4200 MHz Band width: 100 MHz

Information in this box comes from NKOM's "Regulation of local networks in 3.8-4.2 GHz," Version 02 (January 2023)[120].

Since 2022, NKOM has been accepting applications from companies for 20, 40, 60 or 80 MHz of bandwidth in the 3800-4200 MHz range to support low- and medium-power local area networks serving geographically delimited areas as supplements to national cellular coverage. Low-power licenses are granted as "site licenses" (one license for as many low-power stations as desired, so long as they fit within a circle 50 m in radius), while medium-power licenses are granted as "transmitter licenses" (one license per base station). Low-power means a maximum permissible power spectral density of 18 dBm/5 MHz EIRP for the base stations. The maximum permitted antenna height for an outdoor low-power transmitter is 10 m. This table shows the maximum permitted EIRP across the entire low-power bandwidth:

Band Width	EIRP	EIRP
20 MHz	24 dBm	0.25 W
40 MHz	27 dBm	0.50 W
60 MHz	29 dBm	0.76 W
80 MHz	30 dBm	1.01 W

Medium-power means a maximum permitted power spectral density of 36 dBm/5 MHz EIRP for the base stations. This table shows the maximum allowed EIRP across the entire medium-power bandwidth:

Band Width	EIRP	EIRP
20 MHz	42 dBm	16 W
40 MHz	45 dBm	32 W
60 MHz	47 dBm	48 W
80 MHz	48 dBm	64 W

Operators must state the antenna gain for medium-power base stations on their application for a permit (the maximum allowed is 16 dBi). Medium-power base stations and their connected devices are not allowed within 10 km of an urban settlement with more than 10,000 inhabitants. For mobile and nomadic terminals that connect to base stations, the TRP limit is 28 dBm (0.631 W); for terminals at a fixed location the limit is 28 dBm EIRP. All devices in a network must be registered with NKOM. Bandwidth requests over 50 MHz must be justified in the application. Only "stand-alone" networks are allowed – no connection to or shared resources with public cellular networks. And only equipment that can tune the full frequency range of 3800-4200 MHz can be used, because NKOM can order the re-tuning of transmitters to solve interference problems. Applicants are responsible for planning their own networks.

NKOM uses the following spectrum masks for compatibility calculations (transmission in the first table, reception in the following two):

[119] https://antenneregister.nl/Html5Viewer/Index.html

[120] https://nkom.no/aktuelt/nkom-has-opened-3-8-4-2-ghz-for-local-area-5g-networks

Low- and medium-power transmission mask – all bandwidths

Offset center frequency (MHz)	Gain (dB)
–2,5 x BW	–53
–BW/2-10	–53
–BW/2-5	–53
–BW/2-5	–45
–BW/2	–45
–BW/2	0
0	0
BW/2	0
BW/2	–45
BW/2+5	–45
BW/2+5	–53
BW/2+10	–53
2,5 x BW	–53

Low- and medium-power reception mask – 20 MHz bandwidth

Offset center frequency (MHz)	Low-power gain (dB)	Medium-power gain (dB)
–2,5 x BW	–54,1	–57,1
–BW/2-5	–54,1	–57,1
–BW/2-5	–45,1	–48,1
–BW/2	–45,1	–48,1
–BW/2	0	0
0	0	0
BW/2	0	0
BW/2	–45,1	–48,1
BW/2+5	–45,1	–48,1
BW/2+5	–54,1	–57,1
2,5 x BW	–54,1	–57,1

Low- and medium-power reception mask – bandwidths exceeding 20 MHz

Offset center frequency (MHz)	Low-power gain (dB)	Medium-power gain (dB)
–2.5 x BW	–48.1	–51.1
–BW/2-5	–48.1	–51.1
–BW/2-5	–39.1	–42.1
–BW/2	–39.1	–42.1
–BW/2	0	0
0	0	0
BW/2	0	0
BW/2	–39.1	–42.1
BW/2+5	–39.1	–42.1
BW/2+5	–48.1	–51.1
2.5 x BW	–48.1	–51.1

NKOM performs coexistence calculations between the local networks and satellite earth stations, and may also restrict the location of base stations near airports and helicopter landing pads. Because synchronization with public cellular is not required, there is a guard band at 3800-3840 MHz. (Unsynchronized medium-power outdoor base stations are limited to 3840-4000 MHz; synchronized base stations can use frequencies in the guard band.) Assessments will also be made regarding coexistence with aeronautical altimeters above 4200 MHz and public mobile networks below 3800 MHz, to ensure they are protected. License duration is up to 10 years. The annual fee depends on bandwidth and power level. For low-power applications, the annual fees are calculated per license area. For medium-power applications, the fee is calculated per base station.

This initiative began when nationwide licenses were awarded for the whole 3400-4200 MHz band instead of being partly reserved for local verticals and industries. The rules cited here are based on Ofcom UK's "Shared Access License" regime. The technology used is 5G, but FWA operators have challenged this, desiring to use IEEE 802 equipment. A synchronization requirement would make it very difficult to use IEEE equipment. Other problems reported include acquiring the right equipment, the cost of implementation, and uncertainty about spectrum availability in the future.

POLAND Frequency band: 3900-4200 MHz Band width: 300 MHz

The information in this box comes mainly from "Sieci prywatne w paśmie 3,8-4,2 GHz już od wakacji" [Private networks in the 3.8-4.2 GHz band starting from the summer], 6 April 2023.[121]

The frequency range 3800-3900 MHz is reserved for local government units, to fulfil their own requirements (they cannot use that band to provide communication services to others). Available since 2023, one entity may apply for a permit to use part of 3900-4200 MHz in up to 20 "communes." That frequency range will also be used by other services, so consideration, cooperation and politeness are necessary. Bandwidths for private networks come in multiples of 10 MHz, up to a maximum of 100 MHz. Permits will be issued for either low- or medium-power networks. To prevent interference to altimeters operating in the band above 4200 MHz, medium-power transmitters cannot be used outdoors in the 4000-4200 MHz range. If the entity uses the network exclusively for its own needs, then its permit will cost a one-off sum of PLN 82 (€19). If it provides a public telecommunication service, the fee will be PLN 1939 (€447). In addition, there are monthly fees for spectrum use, which vary according to location and bandwidth, as summed up in the table below:

Annual Frequency Fees

Bandwidth	Rural Commune	Urban-rural Commune	Municipal Commune	City with county rights
10 MHz	100 PLN	250 PLN	1250 PLN	2500 PLN
20 MHz	200 PLN	500 PLN	2500 PLN	5000 PLN
30 MHz	300 PLN	750 PLN	3750 PLN	7500 PLN
40 MHz	400 PLN	1000 PLN	5000 PLN	10,000 PLN
50 MHz	500 PLN	1250 PLN	6250 PLN	12,500 PLN
60 MHz	600 PLN	1500 PLN	7500 PLN	15,000 PLN
70 MHz	700 PLN	1750 PLN	8750 PLN	17,500 PLN
80 MHz	800 PLN	2000 PLN	10,000 PLN	20,000 PLN
90 MHz	900 PLN	2250 PLN	11,250 PLN	22,500 PLN
100 MHz	1000 PLN	2500 PLN	12,500 PLN	25,000 PLN

[121] https://uke.gov.pl/blog/sieci-prywatne-w-pasmie-3-8-4-2-ghz-juz-od-wakacji,77.html

The maximum permitted EIRP as a function of bandwidth is almost the same as Norway's:

Bandwidh	Maximum low-power EIRP	Maximum medium-power EIRP
10 MHz	21 dBm	39 dBm
20 MHz	24 dBm	42 dBm
30 MHz	26 dBm	44 dBm
40 MHz	27 dBm	45 dBm
50 MHz	28 dBm	46 dBm
60 MHz	29 dBm	47 dBm
70 MHz	29 dBm	48 dBm
80 MHz	30 dBm	49 dBm
90 MHz	31 dBm	49 dBm
100 MHz	31 dBm	49 dBm

SLOVAKIA Frequency band: 3600-3800 MHz Band width: 200 MHz

Regional licences for Broadband Wireless Access using LTE/4G were auctioned in October 2017 in 40 MHz blocks at 3600-3800 MHz. The licenses, valid only to the end of 2024, were acquired by 16 bidders.[122] In May 2018, RU launched a call for tenders for regional licences in the 10 GHz band for the provision of public fixed wireless access communications. A pilot project in non-public 5G—the only one in the country, so far as we can tell— at the Technical University of Košice, has been a test bed for equipment since 2023.

SLOVENIA Frequency band: 3400-3420 Band width: 20 MHz

PolicyTracker reported last March that "The Slovenian spectrum regulator (AKOS) recently assigned specific 5G regional spectrum licenses (3400-3420 MHz, 2300-2320 MHz, and 2390-2400 MHz) to several local municipalities, industrial enterprises, as well as mobile network operators. With this approach, AKOS is trying to additionally strengthen industry-based and local network 5G use cases."[123]

SWEDEN Frequency band: 3720-3800 MHz Band width: 80 MHz

Starting in November 2021, Sweden's regulator began accepting applications for local and regional 5G licenses in the 3760-3800 MHz, and 24.25-25.1 GHz bands. "What we tried to do was to make the licenses small enough and attractive enough to be in abundance, so you can actually do first-come, first-serve on that level… very simple rules [and] very low fees [but we] had not a very large pick-up of this," according to a PTS spokesperson.[124] Sweden also permits the subletting of spectrum locally in block-licensed bands, when an MNO has excess spectrum in the area and agrees to such an arrangement. A small number of larger leasing agreements have been approved by PTS. Smaller leasing agreements (fewer than 10 base stations) don't need regulatory approval. A third possibility is local sharing of frequencies within the block licence. Block licences in Sweden are not exclusive assignments. All block licences include licence conditions that allow the regulator to introduce sharers in their licensed frequency ranges as long as it doesn't interfere with the primary licence holder's service provision. But a PTS spokesperson told *RCR Wireless News* that even though this possibility has existed for many years, the regulator has not received a single application for sharing in block licensed bands. Instead, verticals have implemented their own private networks in the 3.6 GHz

[122] 5G Observatory https://5gobservatory.eu/national-5g-spectrum-assignment/

[123] "Slovenia Regional 5G Spectrum Licenses," *Spectrum Tracker*, 25 March 2024 - https://www.spectrum-tracker.com/news/26

[124] Kelly Hill, "Private network spectrum strategy, Part 2: Sweden's PTS," *RCR Wireless News*, 22 November 2022 - https://www.rcrwireless.com/20221122/spectrum/private-network-spectrum-strategy-part-2-swedens-pts

band.

SWITZERLAND Frequency band: 3400-3500 MHz Band width: 100 MHz

This information comes mainly from “Swiss Government implements spectrum plan for private 5G networks,” *Mobile Europe,* 12 September 2023 - https://www.mobileeurope.co.uk/swiss-government-implements-spectrum-plan-for-private-5g-networks/

Starting on 1 January 2024, BAKOM will offer radio licenses in the 3400-3500 MHz range for private 5G networks, with 10 MHz as the minimum bandwidth. As the cost of the licenses is CHF 48/MHz/year, the minimum cost will be CHF 480 per campus. “Unlike other jurisdictions, the Swiss Government has not opted for a cost/square km, meaning that, as it stands, a small enterprise would cost the same as a large manufacturing facility or airport.”

To reduce the risk of interference, the maximum permitted power will be 6 W and the maximum allowed field strength at the boundary of the campus will be specified for each concession. The technical and regulatory framework for these networks is apparently still being developed (there is no further information on BAKOM’s website, other than the application for a permit, which is even simpler than the Netherlands’). The duration of the permit also seems to be undecided, nor is the applicant asked to specify it on the application form.

UNITED KINGDOM Frequency band: 1781,7-1785 / 1876,7-1880 MHz; 2390-2400 MHz; 3800-4200 MHz Band width: 406,6 MHz

Information in this box comes mainly from Ofcom, “Enabling wireless innovation through local licensing: Shared access to spectrum supporting mobile technology,” https://www.ofcom.org.uk/data/ assets/pdf_file/0033/157884/enabling-wireless-innovation-through-local-licensing.pdf and “Ofcom Enhance Spectrum Sharing for UK Mobile and Wireless Broadband” by Mark Jackson, *ISP Review*, 2 December 2024 - https://www.ispreview.co.uk/index.php/2024/12/ofcom-enhance-spectrum-sharing-for-uk-mobile-and-wireless-broadband.html

At the end of 2019, "shared access licences" were made available for the 1800 MHz, 2300 MHz and lower 26 GHz bands, followed by the 800 MHz, 900 MHz, 1400 MHz, 1900 MHz, 2100 MHz, 2600 MHz and 3400 MHz bands. The UK has been one of the most successful countries in developing local non-public mobile networks. According to data published in December 2024, there are now 394 active shared access licences in the 1800 MHz band, 29 in the 2300 MHz band and 564 in the 3800-4200 MHz band. Ofcom "continues to issue 20-70 new shared licences per month...".

Ofcom permits non-MNOs to use spectrum licensed by an MNO that is not in use or expected to be used in the area within three years, provided that the new user must not cause interference. Two types of shared licences are offered: a low power licence which allows users to place any number of base stations within a circular area of 50 metres radius (a 'per area' licence; applicants must provide coordinates of the centre of the circle so that Ofcom can determine whether there is any conflict with the existing licence holder), or a medium power licence for a single base station (a 'per base station' licence). Until recently, medium power licences were mainly available in rural areas because deployment in urban areas would block large numbers of low power users. A medium power licence is considered suitable for FWA or for industrial or business use spread over a large area (e.g. ports, agriculture or forestry). Ofcom now provides maps showing where such spectrum is available. Airborne use is not permitted. They add: "In the future, we would like to move to a Dynamic Spectrum Access (DSA) approach where appropriate, where users' devices would communicate directly with a central database to access spectrum."

Maximum power density for the 2 types of local shared spectrum cellular licenses in the UK (3805-4195 MHz)

Equipment	Low Power	Medium Power
Base station	27 dBm / carrier EIRP per cell for carriers ≤ 20 MHz; or 21dBm / 5 MHz EIRP per cell for carriers > 20 MHz Outdoor antenna height ≤ 10m	42 dBm / carrier EIRP per cell for carriers ≤ 20 MHz; or 36 dBm / 5 MHz EIRP per cell for carriers > 20 MHz
Fixed terminal station	28 dBm EIRP (includes a 2 dB tolerance)	28 dBm TRP and 35 dBm / 5 MHz EIRP (includes a 2 dB tolerance)
Mobile or nomadic terminal station	28 dBm TRP (includes a 2 dB tolerance)	28 dBm TRP (includes a 2 dB tolerance)
The maximum mean power relates to the EIRP irrespective of the number of transmit antennas.		

At the end of 2024, Ofcom decided:

- eliminate the “terminal registration requirement” for all low-power deployments;
- to streamline the process of applying for a medium-power license;
- to reduce the cost of a medium-power license in urban areas to £160 per 10 MHz per year;
- to put a 100 MHz “cap” on spectrum holdings by any non-MNO operating in the area.

Sources: 5G Observatory, Mobile Europe, PolicyTracker, RCR Wireless News, RSPG,[125] OpenSignal, Ericsson (2024),[126] webpages of regulators and GTA

The above table makes it clear that there is great diversity now in the regulations, procedures, fees and allocated frequencies among European countries that authorize local non-public cellular networks. Presumably the newly adopted harmonized technical conditions in ECC Decision (12)01 will change that.

How did we get to that decision? In December 2021, the EC’s Radio Spectrum Committee issued this mandate:

> *"*PT1_47: *Mandate to CEPT on Technical Conditions Regarding the Shared Use of the 3.8-4.2 GHz Frequency Band for Terrestrial Wireless Broadband Systems Providing Local-Area Network Connectivity in the Union"*[127]
>
> [Task 1] “Study and assess 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. In this regard, consider sharing solutions, including innovative features, which ensure:
>
> > "a. protection and the future evolution and development of incumbent users sharing this band, in particular receiving satellite earth stations and terrestrial fixed links,
> >
> > “b. co-existence of terrestrial wireless broadband systems providing local-area network connectivity and uses operating in adjacent bands such as terrestrial systems providing wireless broadband electronic communications

[125] RSPG, “Opinion: 5G developments and possible implications for 6G spectrum needs and guidance on the rollout of future wireless broadband networks,” RSPG23-040 FINAL (25 October 2023) - https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-10/RSPG23-040final-RSPG_Opinion_on_5G_developments_and_6G_spectrum_needs.pdf

[126] Finn Pedersen, Rowan Högman, et al., “5G spectrum for local industrial networks,” Ericsson - https://www.ericsson.com/en/reports-and-papers/white-papers/5g-spectrum-for-local-industrial-networks

[127] https://ec.europa.eu/newsroom/dae/redirection/document/82230

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.

[Task 2] "Subject to the sharing solutions and the results of Task 1, as appropriate, develop a harmonised frequency arrangement as well as 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. These harmonised technical conditions shall avoid interference, protect relevant incumbent uses within the band and in adjacent bands, and facilitate cross-border coordination.

"Based on the results of sharing studies within the 3.8-4.2 GHz frequency band and co-existence studies with uses in adjacent bands, the CEPT may include, where necessary, guidance on appropriate receiver characteristics for radio equipment as part of the harmonised technical conditions or/and recommend to ETSI to consider the results of those studies when developing relevant harmonised standards." [128]

CEPT assigned these tasks to PT1 and a new work group—FM60[129]—created specifically to study shared uses of 3800-4200 MHz. The Commission indicated particular interest in having this Work Item deliver harmonized conditions for co-existence which are both technology neutral and "suitable for 5G, however, the actual terms of reference of the studies assumed technologically neutral conditions."[130] The Commission's mandate also invited suggestions for "innovative sharing conditions" such as Licensed Shared Access, which can facilitate the introduction of new services in a band before incumbent license-holders have moved out.[131]

CEPT began work on these tasks in March 2022. Agreement was reached at a meeting of PT1 in January 2024 to amend Work Item PT1_40 so as to merge the findings on altimeter susceptibility into the report on PT1_47 Task 1b, which was then still just a draft titled *ECC Report 362: on Compatibility between 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.* That report was discussed and approved at the ECC plenary in November 2024. It is discussed in the altimeters chapter of this study. The report resulting from PT1_47 Task 2 of the *CEPT Report 088* document is titled*: On shared use of 3800-4200 MHz by terrestrial wireless broadband systems providing local-area network connectivity (WBB LMP)*[132]— was also approved at the November 2024 CEPT/ECC plenary.

The report on PT1_47 Task 1a was finished more quickly. It was approved by the ECC after a public consultation and published in June 2024 as *ECC Report 358: "In-band and adjacent bands sharing studies to assess the feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area (i.e. low/medium power) network connectivity."*[133]

In May 2024, *ERC Recommendation 12-08: "Harmonised radio frequency channel arrangements and block allocations for low, medium and high-capacity systems in the band 3600 MHz to 4200 MHz"* was amended with new guidance about national implementations of channel arrangements for the Fixed Service.[134] Findings from that document are excerpted below.

And of paramount importance, ***ECC Decision (24)01: "Harmonised technical conditions for the shared use of the 3.8-4.2 GHz frequency band by low/medium power terrestrial wireless broadband systems (WBB LMP) providing local-area network connectivity"***[135] was adopted at the November 2024 ECC plenary after a public consultation which ended in August 2024.

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[128] "EC Mandate 3.8-4.2 GHz" (16 December 2021) - https://cept.org/files/6813/Mandate%203_8-4_2GHz.pdf The contact person for this Work Item is Doriana Guiducci (doriana.guiducci@eco.cept.org).

[129] FM identifies the group as belonging to the Frequency Management cluster. Their online archive for documents is at https://www.cept.org/ecc/groups/ecc/wg-fm/fm-60/client/introduction

[130] This apparently self-contradicting instruction means that the recommended technical conditions should not require use of equipment based on a particular technology standard. Rather, it should permit the use of any equipment that conforms to generic requirements like block edge masks (BEM), selectivity, etc., but these requirements should be formulated to permit the use of 5G technology.

[131] Licensed Shared Access, according to the RSPG, is a "regulatory approach aiming to facilitate the introduction of radiocommunication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users… the additional users are authorised to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorized users, including incumbents, to provide a certain Quality of Service (QoS)." "RSPG Opinion on Licensed Shared Access," RSPG13-538 - https://circabc.europa.eu/sd/d/3958ecef-c25e-4e4f-8e3b-469d1db6bc07/RSPG13-538_RSPG-Opinion-on-LSA%20.pdf

[132] https://cept.org/files/9522/Draft-CEPT-Report-088.docx

[133] https://docdb.cept.org/document/28615

[134] https://docdb.cept.org/document/821

The rest of this section consists mainly of excerpts from the above-mentioned documents. Some key highlights:

ECC Report 358: "In-band and adjacent bands sharing studies to assess the feasibility of the shared use of the 3.8-4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area (i.e. low/medium power) network connectivity)".

- This Report contains studies of various coexistence conditions, including geographical separation and frequency separation, as well as a range of WBB LMP parameters for analysis (e.i.r.p., antenna height, antenna gain, emission and reception masks, etc.). Both AAS and non-AAS scenarios are considered.
- Two WBB LMP network technologies are analysed, one based on 3GPP specifications and the other based on DECT-2020 NR specifications. 3GPP technologies are likely to be more widely deployed than DECT-2020 NR but "technology neutrality" means that the DECT alternative cannot be excluded or ignored.
- The importance of real terrain data in assessing coexistence with Fixed Service stations was highlighted by one study. Terrain has very significant impacts on the propagation of radio signals in the 3.8-4.2 GHz band. It can alter the minimum separation distances and the size of exclusion areas required between WBB LMP and FS. Given the importance of terrain, the Report concludes that it is not possible to define a single set of generic technical conditions which guarantee the protection of FS and FSS stations from interference by WBB LMP stations in all scenarios. Instead, a case-by-case analysis is needed, in combination with appropriate mitigation techniques, to ensure satisfactory coexistence.
- Due to the large separation distances that may be necessary, the protection of FS cannot always be managed at national level but may require cross border coordination on a case-by-case basis, as well as bilateral or even multilateral agreements between neighbouring countries.
- Analysis of in-band and adjacent band operation demonstrates the feasibility of unsynchronised WBB LMP operation in the frequency band 3.8-4.2 GHz, although a coordination process may be needed in some cases. For example, coordination may be needed for unsynchronised WBB LMP operation in the lower part of the 3.8-4.2 GHz band. Examples of coordination may include geographical/frequency separation, defining a maximum allowed power level (pfd) at the edge of the WBB LMP licensed area, synchronised operation, semi-synchronised operation which only allows DL to UL modifications to the WBB LMP network compared to the MFCN frame structure, and/or defining the maximum unwanted emissions below 3.8 GHz depending on the location of WBB LMP in relation to MFCN.
- ECC Report 358 also does not provide any conclusions about the protection of radio altimeters using the 4200-4400 MHz band. That topic was re-assigned to the group drafting ECC Report 362.

CEPT Report 088: "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"

Because *ECC Decision (24)01* embraces and activates the technical conditions proposed in *CEPT Report 088*, quantitative details concerning the conditions are given in our synopsis of *Decision (24)01*. In this section explanations and observations from *Report 088* are cited to provide context.

- According to a news item on the CEPT website, a meeting of FM60 (16-19 September 2024) "considered the results of the public consultation of the draft *CEPT Report 88*. FM60 resolved the vast majority of comments, however WG FM will need to discuss outstanding unresolved issues, before endorsing publication by the ECC. In particular relating to whether to allow local exceptions outside the harmonised technical conditions to be considered by national administrations in specific circumstances, or whether restrictions need be made regarding medium power base station operated very near airport runways."
- "The proposed harmonised technical conditions in this Report are based on the results of the technical studies in *ECC Report 358* and in *ECC Report 362*… The proposed harmonised technical conditions for WBB LMP have been developed assuming an authorisation regime where the location of WBB LMP networks or base stations is known. An authorisation regime where the location is not known is out of scope for the harmonisation proposed in this Report as this situation may create a risk of interference for existing and new WBB ECS base stations below 3.8 GHz, fixed links and FSS earth stations as well as between WBB LMP networks."
- **Synchronisation of WBB LMP:** "Two WBB LMP network technologies have been considered, one based on 3GPP technical specifications and the other based on DECT-2020 NR technical specifications. Networks using these two technologies cannot synchronise with each other due to different operational principles. Synchronised operation of WBB LMP networks with MFCN below 3800 MHz is only possible for WBB LMP based on 3GPP technical specifications. The study results of these two technologies are presented separately."
- "For studies based on 3GPP technology, the technical characteristics were based on current ETSI technical specifications… For the purpose of studies, the following base station power levels for 3GPP WBB LMP were defined:
  - low power with up to 31 dBm/100 MHz e.i.r.p.;

[135] https://cept.org/files/9522/Draft-ECC-Decision-24-01.docx

- medium power with up to 51 dBm/100 MHz e.i.r.p.

" These power levels were also adopted to be a part of the harmonised technical conditions in CEPT."

- "DECT-2020 NR parameters were taken from ETSI TS 103 636-2 v1.4[136]...For studies relating to DECT-2020 NR, the maximum e.i.r.p. of 23 dBm was assumed in a channel bandwidth of 6.912 MHz.… The DECT-2020 NR specifications only define a single set of parameters for all devices, i.e. there is no distinction between 'base station' equipment or 'terminal' equipment. Devices within a DECT-2020 NR network may be considered a radio device fixed terminal (RDFT) or radio device portable terminal (RDPT)… It is noted that for DECT-2020 NR, the technical specification mandates that all radio devices within the network shall employ TPC, including the fixed radio device…"
- **Co-existence between WBB LMP and FSS:** "it is not possible to define generic technical conditions that guarantee the protection of FSS. To ensure the protection of current and future deployment of FSS, careful planning and case-by-case analysis is needed, also in considering appropriate mitigation techniques. In addition, due to the large separation distances that may be necessary, the protection of FSS within the frequency band as well as below 3.8 GHz cannot always be managed at national level only, but may also require cross-border coordination on a case-by-case basis as well as bilateral or even multilateral agreements between neighbouring countries. CEPT intends to develop guidelines in order to help administrations to address coordination and planning both at national level and with the neighbouring countries…"
- "Studies using real terrain data show [FSS] separation distances in the range of 5.3-17.2 km for WBB low power and 17.5 - 70 km for WBB medium power stations. Results for DECT-2020 NR are consistent with the low power separation distances noted above when a transmitter power of 23 dBm is considered… When the result is evaluated against the short-term protection criterion,[137] the protection distance was found to be up to 277 km (medium power, flat terrain, and no clutter loss assumed)…"
- **Coexistence between WBB LMP and FS:** "For medium power WBB LMP base stations, studies assuming flat terrain indicate that required separation distances in the direction of the FS main lobe could range up to 113 km. In flat terrain if the WBB MP BS site is in the side lobe of the receiving FS antenna, the required separation distance will be shorter (up to 69 km). Case studies performed show the importance to consider real terrain data, because real terrain can either hinder or favour propagation significantly… For DECT-2020 NR, studies indicate a required separation distance of 37 km when sited in the FS main lobe with clutter applied at one end of the propagation path. In conclusion, it is not possible to define generic technical conditions that guarantee the protection of FS…"
- **Coexistence with MFCN / WBB ECS below 3.8 GHz:** "The 3.4-3.8 GHz band has been harmonised for WBB ECS in CEPT under *ECC Decision (11)06*[138] and in the EU under *Decision 2008/411/EC* as amended[139] and is recognised to be the 5G primary band in Europe. It is crucial that the WBB ECS service is adequately protected… The studies are mainly based on the assumption of no synchronisation between WBB LMP networks in the frequency band 3.8-4.2 GHz and WBB ECS below 3.8 GHz. Adjacent channel coexistence between 3GPP-based synchronised WBB LMP networks and WBB ECS is considered as being covered by ETSI technical specifications and thus is not studied in this Report. CEPT plans to develop recommendations for administrations to provide guidance on the protection approach for the coexistence with WBB ECS below 3.8 GHz. There may be also a need to develop relevant cross-border recommendations."
- **Coexistence with radio altimeters above 4200 MHz:** "The overall conclusion is that… coexistence between WBB LMP in the 3.8-4.2 GHz band and radio altimeters operating above 4.2 GHz is feasible. Only in some rare cases near an airfield, where a medium power base station operating very close to the runway, coordination may be needed in order to ensure the protection of the radio altimeters."
- **Harmonised technical conditions:** "It has not been possible to define generic technical conditions that alone guarantee the protection of all incumbent services. Careful planning and case-by-case analysis is needed, in combination of considering appropriate mitigation techniques. In order to facilitate and maximise the opportunities for the deployment of WBB LMP and to manage remaining coordination cases that may not be addressed by the harmonised technical conditions, administrations may want to complement certain aspects of their use of the frequency band 3.8-4.2 GHz at the national and/or the local level circumstances, for example on synchronisation, pfd limits, separation distance and/or

[136] A newer version of this standard has been published: ETSI TS 103 636-2 V1.5.1 (2024-03): "DECT-2020 New Radio (NR); "Part 2: Radio reception and transmission requirements; Release 1" - https://www.etsi.org/deliver/etsi_ts/103600_103699/10363602/01.05.01_60/ts_10363602v010501p.pdf. Note that according to ETSI, an even newer standard for DECT-2020 is planned (i.e. Release 2) "with improved functionality to better support new application scenarios."

[137] Defined in Recommendation ITU-R SF.1006, the "short-term interference criterion" is I/N = −1.3 dB which may be exceeded up to 0.001667% of the time (≈ 8.76 min/year). Based on Recommendation ITU-R S.1432, the "long-term interference criterion" is I/N = −10 dB (DT/T = 10%) corresponding to the aggregate interference from a co-primary allocation for 20% of any month.

[138] ECC Decision (11)06: "Harmonised frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the band 3400-3800 MHz" (amended 2018) - https://docdb.cept.org/download/1531

[139] "Commission Decision of 21 May 2008 on the harmonisation of the 3400 - 3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community," 2008/411/EC - https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008D0411

frequency separation requirements. CEPT intends to develop relevant recommendations in order to support administrations as appropriate."

- **National administrations' exceptions to harmonized technical conditions:** "With respect to in-band [base station] power, e.i.r.p. limits are defined for low power and medium power WBB LMP BS as part of the harmonised technical conditions. This does not preclude local exceptions outside the harmonised technical conditions to be considered by national administrations in specific circumstances...".

- It is necessary to define the necessary range of input parameters for the analysis. FS input parameters are given, given their nature only TD analysis can be applied. Other data that would lead to more efficient coordination are not available to the CTU. Alternatively, recalculation from the given modulations can be used to determine the C/I+N spacing, but this data is not fully validated at the CTU input. Moreover, the number of requests for new connections is minimal.
- It is necessary to determine the range of data required for future WBB networks in order to make a relevant calculation and indicate whether the risk of interference is acceptable or not.

- A separate issue is the regulatory measure that will be applicable in the event of a change to an existing FS link or the location of a new.

- **GALILEO: "**There is a globally well-distributed network of VLBI Global Observing System (VGOS) stations, which are highly sensitive passive receivers and are expected eventually to number ~40. Some VGOS observatories are installed around Europe [including at Wettzell in Germany, about 20 km from the Czech border[140]]. These are part of the European Critical Infrastructure Project Galileo which has to be supported from all European countries. The start frequencies of these VGOS stations… is 3960.4 MHz (Block A) (see Report ITU-R RA.2507,[141] page 25). It is recognised that for the moment these observations, which are operating in the spectrum bands of the 2-14 GHz range, have no radio astronomy allocation in 3.8-4.2 GHz and therefore cannot claim interference protection on international or European level. Nevertheless, administrations are urged to take all practicable steps to protect these observatory operations from harmful interference."

[140] There are two 13m dishes at Wettzell, located at 49º 08' 38.1" N x 12º 52' 39.4" E and 49º 08' 36.4" N x 12º 52' 41.6" E.

[141] Report ITU-R RA.2507-0: "Technical and operational characteristics of the existing and planned Geodetic Very Long Baseline Interferometry" (2022) - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-RA.2507-2022-PDF-E.pdf

Figure 9: Wettzell twin telescope

Source: ITU-R Report R.A. 2507-08

Figure 10: Location of the Wettzell twin telescopes in Germany

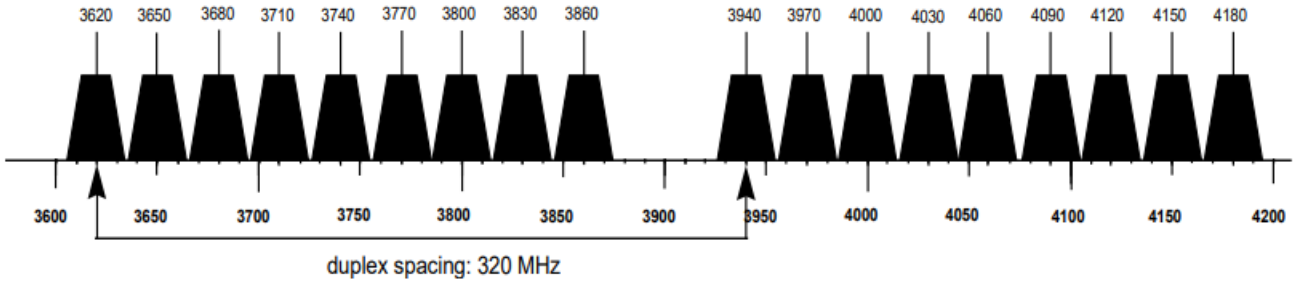
Source: Google Maps

ERC Recommendation 12-08 (amended 10 May 2024): "Harmonised radio frequency channel arrangements and block allocations for low, medium and high-capacity systems in the band 3600 MHz to 4200 MHz"

This Recommendation is intended to harmonize the channel arrangements and block allocations for point-to-point and point-to-multipoint systems sharing the 3600-4200 MHz band:

> noting… that current use of the band 3600-4200 MHz in most European countries is according to Recommendation ITU-R F.635[142] and/or Recommendation F.382[143]; [and] that ITU-R Recommendation F.635 only sets a basic raster of 10 MHz without defining a specific channel spacing or a duplex spacing...
>
> recommends:
>
> 1. that CEPT administrations having the band 3600-4200 MHz available for the fixed service should adopt channel arrangements in accordance with either:
>
> 1) Annex A – which is based on ITU-R Recommendation F.635 for the frequency range 3600-4200 MHz with channel spacings of 30 or 15 MHz and a duplex spacing of 320 MHz;
>
> or
>
> 2) Annex B – which is based on ITU-R Recommendation F.382 for the frequency range 3800-4200 MHz.

Figure 11: Channel arrangement presented in Annex A

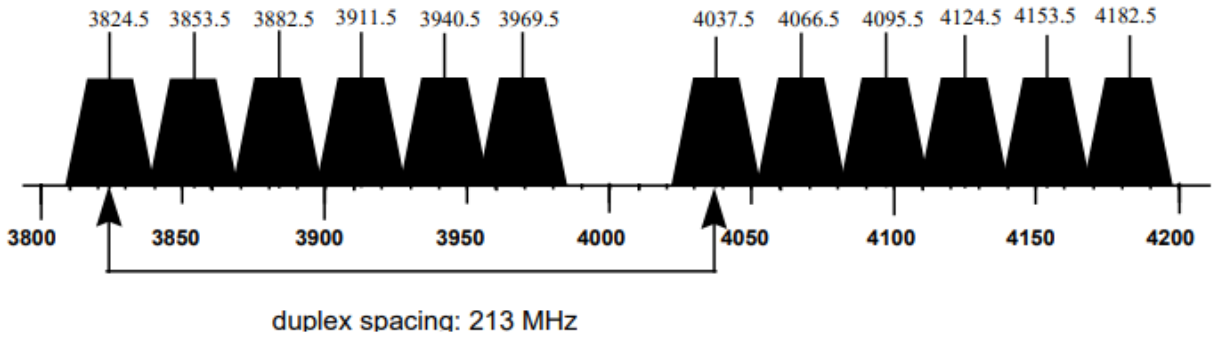


Source: Recommendation ERC 12-08

[142] Recommendation ITU-R F.635-7 (02/2013): "Radio-frequency channel arrangements based on a homogeneous pattern for fixed wireless systems operating in the 4 GHz (3 400-4 200 MHz) band" - https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.635-7-201302-I!!PDF-E.pdf

[143] Recommendation ITU-R F.382-8 (04/2006): "Radio-frequency channel arrangements for fixed wireless systems operating in the 2 and 4 GHz bands" - https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.382-8-200604-I!!MSW-E.doc. "The channel spacing recommended in the main text is 29 MHz with possible use of the interleaved 14 MHz spacing channels. Another channel arrangement with 28 MHz channel spacing in the range 3 700-4 200 MHz is provided in the Annex. Other arrangements used in some countries are also described in the Notes."

Figure 12: Channel arrangement presented in Annex B



Source: Recommendation ERC 12-08

4) (ECC Decision (24)01: "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."

This Decision proposes harmonized technical conditions for the shared use of 3.8-4.2 GHz by existing services with the addition of terrestrial wireless broadband systems providing local-area connectivity (WBB LMP). The Decision directs CEPT member states to "designate the frequency band 3.8-4.2 GHz, or parts of this band, on a non-exclusive basis for the use of terrestrial wireless broadband systems providing local-area i.e. low/medium power (WBB LMP) network connectivity… These systems should support innovation and digital transformation of vertical industries, as well as wireless local-area connectivity serving both private (e.g. enterprise) and public (e.g. community-type) networks." The Decision aims to define the least restrictive technical conditions harmonized on a Europe-wide basis for WBB LMP systems to use all or part of this frequency range —even though ECC Report 358 concluded that is not possible to define generic conditions that would guarantee the protection of Fixed Service and Fixed Satellite Service stations against interference from WBB LMP in all situations. Thus, regulators may still need to act in specific situations where harmless co-existence cannot be guaranteed.

Therefore, in addition to Decision (24)01:

> "CEPT will develop guidelines to ensure, on a case-by-case basis, the protection and future evolution of FSS receiving earth stations and of terrestrial fixed links sharing the 3.8-4.2 GHz band with WBB LMP, for managing coexistence between WBB LMP networks and between WBB LMP and MFCN below 3.8 GHz… e.i.r.p. limits are defined for low power and medium power WBB LMP [base stations] as part of the harmonised technical conditions. This does not preclude local exceptions to be considered by national administrations in specific circumstances under the following conditions:
>
> - it shall be on a case-by-case basis in exceptional cases;
> - "it shall remain a local area coverage (no nationwide network);
> - "protection of incumbent services is ensured within the band where appropriate, taking into account their long-term development, as well as in adjacent bands;
> - "coordination is completed if required.

The Decision indicates that CEPT will produce up to five Recommendations to help regulators implement "national measures" for resolving coexistence problems between:

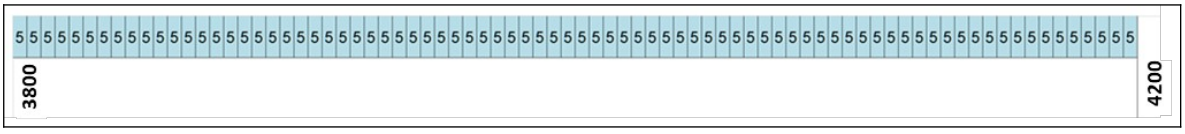
- WBB LMP and FSS earth stations;
- WBB LMP and FS links;
- WBB LMP and MFCN in the adjacent 3.4-3.8 GHz band;
- WBB LMP and radio altimeters and wireless avionics intra-communication systems in the adjacent 4.2-4.4 GHz band; and
- WBB LMP networks interfering with each other.

Work on these Recommendations has been assigned to the FM60 group.[144] According to FM60's web page, the target delivery date for WGFM/ECC approval is 1 October 2025.

ANNEX 1 of the Decision contains the regionally harmonized technical conditions for WBB LMP systems to be compatible with other systems in the 3.8-4.2 GHz band:

- **WBB LMP channelization plan**: "The frequency arrangement is a TDD arrangement, based on a block size of 5 MHz starting at the lower edge of the band at 3800 MHz. Multiple adjacent blocks of 5 MHz can be combined to obtain wider channels."

Figure 13: 3800-4200 MHz frequency arrangement



- **AAS and Non-AAS base stations defined:** "Non-AAS (non-active antenna systems) refers to WBB LMP base station transmitters which use a passive antenna with a fixed antenna pattern… non-AAS cannot respond to short term changes in the radio environment. AAS refers to a WBB LMP base station and antenna system where the amplitude and/or phase between antenna elements is continually adjusted resulting in an antenna pattern that varies in response to short term changes in the radio environment. This is intended to exclude long term beam shaping such as fixed electrical down tilt."
- **WBB LMP base station in-block power limits:** "To protect MFCN operating below 3.8 GHz, coordination may be required at national level. Examples of coordination may include geographical/frequency separation, defining a maximum allowed power level (pfd) at the border of the WBB LMP licensed area, synchronised operation, specific sub-case of semi-synchronised operation, which only allows DL to UL modifications to the WBB LMP network compared to the frame structure of the MFCN network and/or defining the maximum unwanted emissions below 3.8 GHz depending on location of WBB LMP in relation to MFCN."

Table 8: Maximum in-block e.i.r.p. per cell for 3GPP WBB LMP base stations operating in 3.8-4.2 GHz

Category	e.i.r.p. per cell (Note1 and Note 2)
Low power BS	≤ 24 dBm/channel for BW ≤ 20 MHz Otherwise ≤ 18 dBm/5 MHz
Medium power BS	≤ 44 dBm/channel for BW ≤ 20 MHz Otherwise ≤ 38 dBm/5 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...	

- **WBB LMP terminal station in-block requirements:**
  - "Maximum terminal station power: 28 dBm t.r.p. (including a 2 dB tolerance);
  - "For fixed terminals an in-block e.i.r.p. limit may be defined at national level, provided that protection of in-band and adjacent band incumbent services and cross-border obligations are fulfilled;
  - "Transmission power control is mandatory and shall be activated."
- **Unwanted emissions above 4200 MHz from WBB LMP base station:** The following maximum unwanted emission levels above 4.2 GHz are defined. These levels are believed to protect the operation of radio altimeters above 4.2 GHz.

[144] CEPT, "Work Item FM60_02 details" - https://eccwp.cept.org/WI_Detail.aspx?wiid=835

Table 9: WBB LMP base station unwanted emissions above 4200 MHz

Frequency range	Non-AAS LP BS e.i.r.p. limit dBm/5 MHz per cell (Note 1)	Non-AAS MP BS e.i.r.p. limit dBm/5 MHz per cell (Note 1)	AAS MP BS t.r.p. limit dBm/5 MHz per cell (Note 1)
4200-4205 MHz	3	11	1
4205-4210 MHz	-5	8	-3
4210-4240 MHz	-11	8	-3
Note 1: In a multi-sector site, the value per 'cell' corresponds to the value for one of the sectors.			

- "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 of coordination may 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, or AAS medium power base stations in compliance with emission levels meeting the spurious emission limit between 4200 and 4240 MHz."

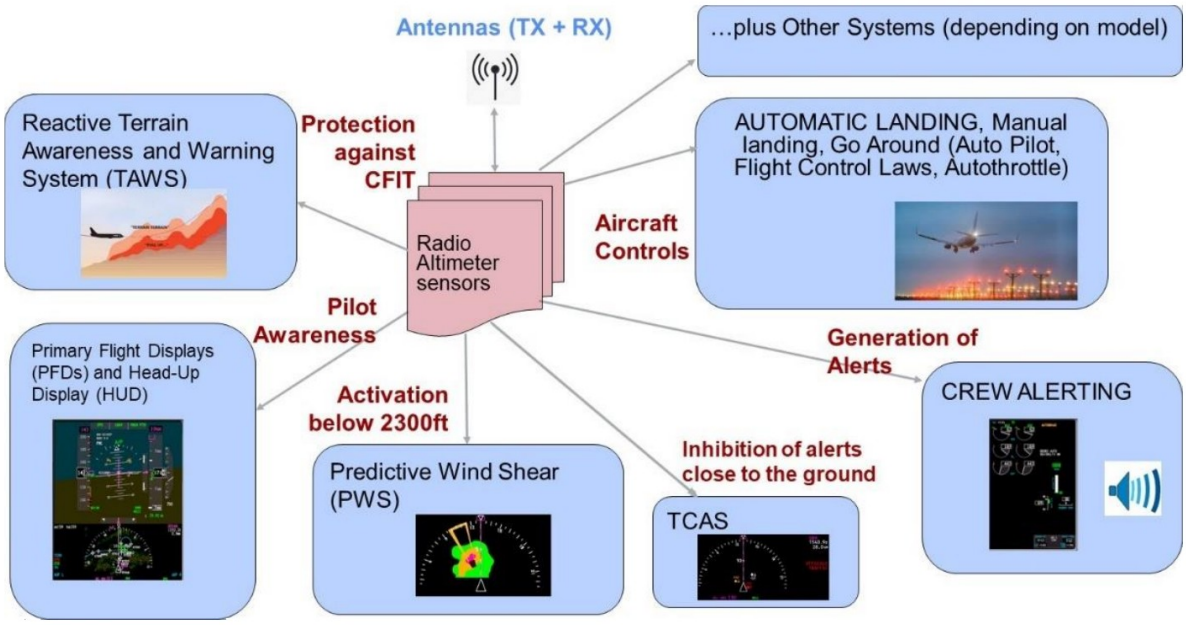
4.2.2 Current Use of 4200-4400 MHz

4.2.2.1 Aeronautical Radionavigation Service: Altimeters

Altimeters are a type of radar that accurately measures an aircraft's altitude by sending probe signals toward the ground and measuring the delays and frequency shifts of the return signal, either from the ground itself or from ground-level transponders.[145] Altimeters provide essential input to many aircraft systems:

[145] Recommendation ITU-R M.2059 (2014): "Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4 200-4 400 MHz" - https://www.itu.int/rec/R-REC-M.2059-0-201402-I/en

Figure 14: Scheme of data for aircraft systems provided by altimeters



Source: ICAO[146]

4.3 The Global Legal and Regulatory Framework

4.3.1 International Telecommunication Union (ITU)

Resolution 424,[147] adopted at WRC-15, modified the International Radio Regulations to permit Wireless Avionics Intra-Communications (WAIC) in the 4200-4400 MHz band, which had been allocated exclusively to the Aeronautical Radionavigation Service for the use of altimeters, provided that WAICs neither "cause harmful interference to, nor claim protection from" altimeters.

It is also worth noting that the *Conference Preparatory Meeting (CPM) Report* for WRC-23 included this information as background:

> "In preparation for WRC-15, ITU-R carried out sharing and compatibility studies between aeronautical mobile/ground mobile applications and potential IMT systems in the frequency band 4 400-4 990 MHz that resulted in PDN Report ITU-R M.[AERO-IMT.SHARING.C-BAND]… WRC-15 adopted RR No. 5.441B and identified the frequency band 4 800-4 990 MHz, or portions thereof, for use by administrations wishing to implement IMT and established, among other things, the pfd limit for use of IMT in that frequency band as an additional measure to provide protection to AMS outside the territorial water of coastal States… The pfd criterion as in RR No. 5.441B was not resulting from ITU-R studies in preparation of WRC-15 but from discussions at WRC-15 since for co-channel scenario the above-mentioned technical studies concluded that sharing between aeronautical mobile applications and IMT systems in 4 400-4 990 MHz is not practical. The pfd value of −155 dB(W/(m^2 · 1 MHz) was derived based on simplified assumptions during WRC-15. This pfd value was based on IMT indoor small cells deployment and one specific AMS system. WRC-19 attempted to review that criterion without any definitive outcome…"[148]

[146] Op. cit.

[147] Resolution 424 (WRC-15): "Use of Wireless Avionics Intra-Communications in the frequency band 4 200-4 400 MHz" - https://www.itu.int/dms_pub/itu-r/oth/0C/0A/R0C0A00000F00106PDFE.pdf. The change in allocation was implemented with footnote 5.436.

- RESOLUTION 256 (WRC 23): “Sharing and compatibility studies and development of technical conditions for the use of International Mobile Telecommunications (IMT) in the frequency bands 4 400-4 800 MHz, 7 125-8 400 MHz (or parts thereof), and 14.8-15.35 GHz for the terrestrial component of IMT.” This Resolution invites “the ITU Radiocommunication Sector to complete in time for the 2027 world radiocommunication conference… sharing and compatibility studies, with a view to ensuring the protection of services to which the frequency band is allocated on a primary basis… without imposing additional regulatory or technical constraints on those services, and also on services in adjacent bands, for the frequency bands: 4 400-4 800 MHz [et al. and] invites the 2027 world radiocommunication conference to consider, based on results of studies, the identification of frequency band(s): 4 400-4 800 MHz, or parts thereof, in Region 1 and Region 3… for the terrestrial component of IMT.”[149]

Identification of these additional bands for IMT was subsequently accepted as WRC-27 *Agenda Item 1.7*.

- RESOLUTION 424 (REV.WRC-23): “Use of Wireless Avionics Intra-Communications in the frequency band 4 200-4 400 MHz… The World Radiocommunication Conference (Dubai, 2023)… invites the International Civil Aviation Organization to take into account the most recent version of Recommendation ITU-R M.2085[150] in the course of development of SARPs [Standards and Recommended Practices] for WAIC systems.”[151]
- RESOLUTION 674 (WRC-23): “Studies on possible allocations to the Earth exploration-satellite service (passive)[152] in the bands 4 200-4 400 MHz and 8 400-8 500 MHz.” ITU Study Groups “should complete in time for the 2027 World Radiocommunication Conference sharing and compatibility studies to determine the possibility of… considering a new primary allocation in all Regions to the EESS (passive) in the frequency bands 4 200-4 400 MHz and 8 400-8 500 MHz, without protection from existing services in these frequency bands and in adjacent bands.”[153]
- RESOLUTION 813 (WRC 23): “Agenda for the 2027 World Radiocommunication Conference.” A few already-proposed items are relevant to the 4 GHz band:

  > "1.7 to consider studies on sharing and compatibility and develop technical conditions for the use of International Mobile Telecommunications (IMT) in the frequency bands 4 400-4 800 MHz and 7 125-8 400 MHz (or parts thereof), and 14.8-15.35 GHz taking into account existing primary services operating in these, and adjacent, frequency bands…”
  >
  > “1.19 to consider possible primary allocations in all Regions to the Earth exploration-satellite service (passive) in the frequency bands 4 200-4 400 MHz and 8 400-8 500 MHz..."

- **RR Footnote 5.436:** “Use of the frequency band 4 200-4 400 MHz by stations in the aeronautical mobile (R) service is reserved exclusively for wireless avionics intra-communication systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution 424. (Rev.WRC 23)”
- **RR Footnote 5.437**: “Passive sensing in the Earth exploration-satellite and space research services may be authorized in the frequency band 4 200-4 400 MHz on a secondary basis. (WRC 15)”
- **RR Footnote 5.438: “**Use of the frequency band 4 200-4 400 MHz by the aeronautical radionavigation service is reserved exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground. (WRC-15)” [154]

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[148] ITU, *Report of the CPM on technical, operational and regulatory/procedural matters to be considered by the World Radiocommunication Conference 2023*, p.14 - https://www.itu.int/pub/R-ACT-CPM-2023

[149] ITU, *World Radiocommunication Conference 2023 (WRC-23): Final Acts* (2024) - https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.16-2024-PDF-E.pdf

[150] Recommendation ITU-R M.2085-0 (2015): “Technical conditions for the use of wireless avionics intra-communication systems operating in the aeronautical mobile (R) service in the frequency band 4 200-4 400 MHz” - https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2085-0-201509-I!!PDF-E.pdf

[151] ITU, *World Radiocommunication Conference 2023 (WRC-23): Final Acts* (2024) - https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.16-2024-PDF-E.pdf

[152] ITU, *Handbook: Earth Exploration-Satellite Service* (2011) - https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-56-2011-PDF-E.pdf; also ITU-R, “Recommendation RS.1624-0: “Sharing between the Earth exploration satellite (passive) and airborne altimeters in the aeronautical radionavigation service in the band 4 200-4 400 MHz” (2003) - https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.1624-0-200305-I!!PDF-E.pdf

[153] For passive EESS in the 4200-4400 MHz band, the currently permitted maximum interference level is -166 dBW in a reference bandwidth of 200 MHz, to be exceeded no more than 0.1% of the time from all locations within a sensor service area of 10 million km^2 on the Earth’s surface. ITU-R, “Recommendation RS.2017: Performance and interference criteria for satellite passive remote sensing” (2012) - https://www.itu.int/rec/R-REC-RS.2017-0-201208-I/en

[154] *ITU Radio Regulations*, Chapter 2, Section IV: “Table of Frequency Allocations,” pages RR5-100 – RR5-102.

4.3.2 Civil Aviation Organizations

4.3.2.1 International Civil Aviation Organization (ICAO)

Like telecommunications, civil aviation has developed into a global industry with a multi-layer legal and regulatory framework encompassing commercial and governmental bodies at the national, regional and global levels. Like the ITU, the International Civil Aviation Organization (ICAO) is a United Nations specialized agency which acts as a consensus-seeking policy forum, standards setter and information clearinghouse for Member States and stakeholders on matters within their sphere of competence. ICAO's International Standards and Recommended Practices (SARPs) are comparable in status to the International Radio Regulations.

Since its founding in 1944, the ICAO has worked closely with the ITU on the development of standards and practices for the use of radio in civil aviation, because reliable access to the radio spectrum has long been recognized as essential for flight safety. The importance of radio in aviation is likewise recognized in the ITU Constitution, which states in Article 40:

> "international telecommunication services must give absolute priority to all telecommunications concerning safety of life at sea, on land, in the air or in outer space…"[155]

Similarly, the International Radio Regulations state in Article 4.10:

> "ITU Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies."[156]

The extent of ICAO's involvement in the setting of global standards and regulations for radio equipment and use in aviation is indicated by the size of Annex 10 to the Convention on International Civil Aviation (the ICAO treaty). Titled *Aeronautical Telecommunications*, Annex 10 now comprises six volumes. ICAO also provides input to ITU discussions on matters related to radio frequency equipment and use by civil aviation, and coordinates frequency assignments in bands exclusively allocated to Aeronautical Services. Note, however, that ICAO's COM lists have no legal status within the ITU. Nevertheless, there is a clear division of responsibilities between ICAO and the ITU, as well as coordination to minimize inconsistencies and conflicts in decision-making and regulatory actions.

The ICAO Aeronautical Communications Panel has a variety of specialized working groups. WG-F is responsible for spectrum management.[157] It drafts the ICAO's contributions to WRCs and coordinates ICAO input to meetings of the ITU Study Groups and regional telecommunication organizations. WG-T is responsible for technology. Among other activities, it represents the ICAO in a joint public-private undertaking called Single European Sky ATM[158] Research (SESAR, https:// https://www.sesarju.eu/), as a partner to the European Commission and EUROCONTROL. Together they plan to integrate Europe's airports, air/ground data links and air traffic control system.

Before considering the ICAO's role in the use of 4200-4400 MHz, two more international aviation organizations should be introduced.

4.3.2.2 Radio Technical Commission for Aeronautics (RTCA)

The RTCA is a US-based organization that develops technical performance standards for the global aviation industry as well as guidance for government regulatory authorities to use.[159] Founded as an association in 1935, it was re-incorporated in 1991 as a private not-for-profit corporation. It describes itself now as "a public-private partnership venue for developing consensus among diverse, competing interests"— not unlike 3GPP. Dozens of Special Committees (SC) develop and issue RTCA standards which can be used as the basis for regulations or in assessing compliance with regulations. The following RTCA standards are especially relevant to this study:

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[155] Article 40: "Priority of Telecommunications Concerning Safety of Life," ITU Constitution in *Collection of the basic texts of the International Telecommunication Union adopted by the Plenipotentiary Conference*, 2011 edition - https://www.itu.int/dms_pub/itu-s/opb/conf/S-CONF-PLEN-2011-PDF-E.pdf

[156] ITU, *Radio Regulations, edition of 2024* - https://www.itu.int/hub/publication/r-reg-rr-2024/

[157] ICAO Frequency Spectrum Management Panel (FSMP) - https://www.icao.int/safety/fsmp/Pages/default.aspx).

[158] ATM = Air Traffic Management.

[159] https://my.rtca.org/

- DO-155: “Minimum Performance Standards - Airborne Low Range Radar Altimeters (issued 1 November 1974 but still in force): “standards and test procedures for those characteristics of an Airborne Low-Range Radar Altimeter that are essential for its operation in applications to provide measured height above terrain for obstruction clearance and landing. Coordinated with EUROCAE.” (Note: After 50 years, an updated version—DO-155A—is planned for release by the end of 2024.“
- DO-378A: “MASPS for Coexistence of Wireless Avionics Intra-Communication Systems within 4200-4400 MHz” (issued 23 June 2022): “EUROCAE and RTCA have defined this Minimum Aviation System Performance Standard (MASPS) that applies to Wireless Avionics Intra-Communications (WAIC) systems utilizing the frequency band 4 200 4 400 MHz as allocated by the World Radiocommunication Conference (WRC) in 2015. Key criteria for allocation of the band by the WRC were (i) coexistence between WAIC systems and (ii) coexistence between WAIC systems and Radio Altimeters (RA), both on board neighbouring aircraft. This MASPS defines two Performance Requirements (PR) that ensure WAIC systems meet the above coexistence criteria. The first PR specifies the power spectral flux density allowed to be emitted by WAIC systems on board an aircraft. The second PR specifies tolerance of WAIC systems to Radio Frequency (RF) emissions from RA and WAIC systems from neighbouring aircraft. Both PRs were developed consistent with ITU-R documentation and validated by significant work by the Aerospace Vehicle Systems Institute (AVSI), EUROCAE and RTCA organizations to understand and characterize the worst-case conditions that may be experienced during the normal course of operation of the worldwide aircraft fleet. Revision A is harmonized with the intended content of the ICAO SARPs for WAIC systems.”
- RR-001: “Survey of Radio Frequency (RF) Performance Standards for Aeronautical RF Systems” (issued 28 November 2023): “This report summarizes the results of the 2022/2023 survey conducted jointly by RTCA Special Committee-242 and EUROCAE Working Group-124 (SC-242/WG-124) on the applicable RTCA and EUROCAE published standards for Radio Frequency (RF) performance that could be used for spectrum compatibility analysis with external systems…“

4.3.2.3 Aerospace Vehicle Systems Institute (AVSI)

"AVSI is a cooperative research environment comprised of major aerospace companies and government organizations working along with academia to solve problems common to its members. AVSI provides a predefined framework for cooperative research allowing members to save money through cost sharing and to solve problems outside the scope of a single organization.”[160] Two of their projects are of particular relevance:

- AFE 76s1 – Wireless Avionics: “The Wireless Avionics Intra-Communication (WAIC) project addresses common issues associated with wireless avionics and works to assure needed WRC spectrum allocation. The project provided ITU-R with working papers forming the basis for a WRC-15 agenda item to secure a specific spectrum allocation satisfying the needs of WAIC systems… The WAIC project has its own website at waic.avsi.aero.”
- AFE 76s2 – Out-of-band Interference with Radio Altimeters: “Members of the aerospace industry have suggested that it is imperative to obtain data that characterizes the potential effects of IMT operation on radio altimeters (RAs) operating in the adjacent frequency band (4200-4400 MHz). The potential loss of accuracy of RAs due to IMT interference is a safety issue, especially near airports where airplanes are in the landing phase of flight. Empirical data that quantifies the scope of the issue must be provided to the appropriate rule making bodies to ensure they can preserve continued safe operation of aircraft.” [161]

According to AFE 76s2, “Most altimeters used in commercial transport aircraft are frequency-modulated continuous wave (FMCW) with a typical chirp bandwidth of ~100-180 MHz centered at 4300 MHz.”[162] Large passenger jets often have up to 3 altimeters with different center frequencies and sweep times, mounted on the underside of their fuselage, for fail-safe reliability, mutual backup, and so measurements can be compared and averaged.

[160] https://avsi.aero/

[161] https://avsi.aero/projects/current-projects/rf-interference-with-radar-altimeters/

[162] “AVSI Publishes Report Cataloging Out-of-Band Interference to Radar Altimeters” (6 December 2021) - https://avsi.aero/afe76s2-report/. AVSI’s statement that “Most altimeters used in commercial transport aircraft are frequency-modulated continuous wave” is contradicted by a survey conducted in 2022 at three airports in the US state of Washington and reported to the FAA: “Our 25 days of field testing at 3 airports in WA indicates that 66% of radio altimeters are PULSE technology…” FAA-2022-1647-0046_attachment_1 - https://downloads.regulations.gov/FAA-2022-1647-0046/attachment_1.pdf

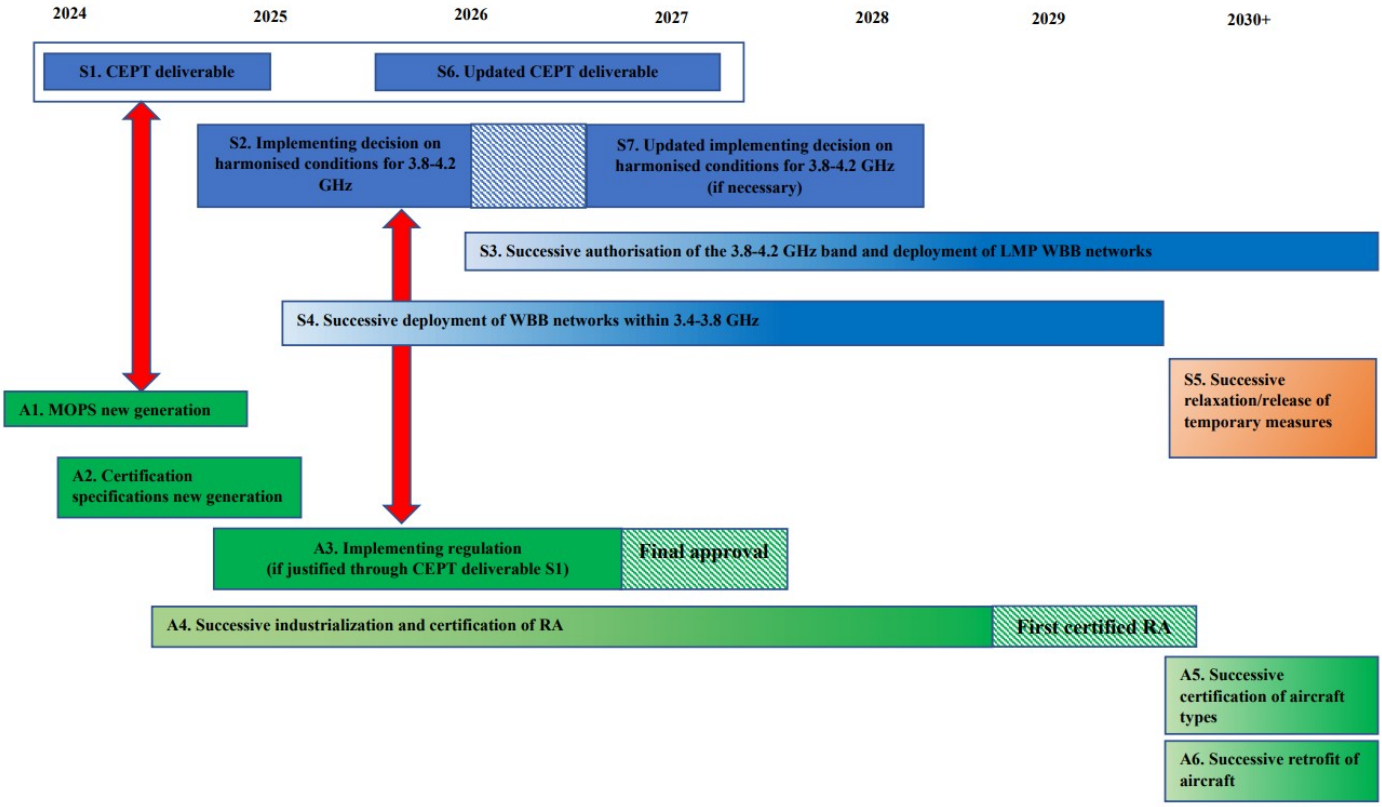
Figure 15: Aircraft with two altimeters

Source: Moniem-Tech[163]

[163] Moniem-Tech, “Summary of the 5G Interfering with Aviation Safety in the US,” (2022) - https://moniem-tech.com/2022/01/20/summary-of-the-5g-interfering-with-aviation-safety-in-the-us/

4.4 Regional and Legal Regulatory Framework

Figure 16: 'EU Roadmap' schedule: IMT/altimeters co-existence (Gantt chart)



Source: European Commission (2024)[164]

In January 2021, recognizing that some individual EU Members had begun imposing altimeter protection measures near airports in response to the Commission-encouraged introduction of 5G networks in the "pioneer" band at 3400-3800 GHz—national measures which were not necessarily consistent with one another—eight ECC members[165] submitted a draft Work Item to ECC PT1, the project team that deals with matters related to the IMT technologies including 5G. When approved by the ECC, this Work Item became known as **PT1_40: "Radio Altimeters."** Its purpose was to assess the susceptibility to interference of already-deployed Radio Altimeters and analyse the aviation industry's corrective actions:

> Scope: Assessment of susceptibility of deployed RA receivers operating in 4200-4400 MHz, while taking into account any civil aviation initiatives on improving RA receivers, in order to study the following compatibility scenarios:
>
> 1) Unwanted emissions from MFCN operating in 3400-3800 MHz and WBB LMP operating in 3800-4200 MHz into 4200-4400 MHz radio altimeters band
>
> 2) Impact of blocking of radio altimeters from 3400-3800 MHz MFCN in-band emissions and from 3800-4200 MHz WBB LMP in-band emissions

[164] Commission Services Working Document: "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" (18 April 2024) - https://circabc.europa.eu/sd/a/9e35cb97-0cac-422a-959e-b1b920a26dfc/EU%20Roadmap_WBB-RA_Coexistence_v1.pdf

[165] Belgium, France, Germany, Greece, Latvia, Netherlands, Portugal and Sweden.

Start date	05-03-2021
Target date	08-11-2024
Public Consultation	28-06-2024
Deliverable:	ECC Report

Comments: It is recognised that realistic scenarios and parameters for RA and MFCN AAS parameters are needed before compatibility studies can be commenced.

Based on the results of the study, consider the need for possible future steps, e.g. improvement of RA susceptibility to interference, in particular regarding blocking characteristics.

It is to be noted that radio altimeters are used globally and once installed they are used over many years. Therefore, development of future MOPS (Minimum Operational Performance Standards) for RA should be forward-looking as well as considering the various 5G MFCN deployments already existing in frequency bands both below 4.2 GHz as well as above 4.4 GHz, in both Europe and globally.[166]

Two additional, lesser known regional organizations need to be mentioned because of their specific interests in the 4 GHz band. Created in 1963, the **European Organisation for Civil Aviation Equipment (EUROCAE)** is a nonprofit aviation standards development platform similar to RTCA and AVSI.[167] Its 450 members include service providers, regulators, research institutes, aviation experts and international organizations. Its standards are designed to "support international harmonization and global interoperability and significantly contribute to the safety, efficiency and environmental sustainability of the global aviation system."[168] Like other organizations of this type, EUROCAE has a large number of specialized working groups, including:

- WG-119 – Radar altimeters. "To ensure compatibility of current and future Radar Altimeters (RA) with the Radio Frequency environment allocated for 5G Telecommunications, WG-119 has been launched jointly with RTCA SC-239 to develop Radar Altimeter MOPS ED-30A/DO-155A. A new ED-310 Standard Guidance Document on Radar Altimeter RF Interference Rejection and Tolerance has been in open consultation since Q4-2022, to provide specifications to RA suppliers and avoid continual RA upgrades in an undefined environment. The revision of the ED-30A/DO-155A MOPS, intended to address new generation of Radio Altimeter receiver is scheduled for the end of 2024… The current ED-30 and DO-155 are not technically identical; one of the aims of this revision is to align these documents and to develop technically identical documents (ED-30A/DO-155A)…"[169]
- WG-124/SC-242 – Spectrum Compatibility, a joint committee with RTCA SC-242, "intended to support other WGs developing standards with spectrum aspects... The guidance material, planned to be published in 2025, should also provide information to a broader audience including non-aeronautical sectors on the RF performance necessary to meet existing aviation performance standards (e.g. availability, reliability, continuity, latency etc) for safety-of-life functions. The Guidance material will rely on the development of two EUROCAE Reports (ER), the first one being "Survey of Radio Frequency (RF) Performance of Standards for Aeronautical RF Systems".[170] This ER is intended to be the reference for non-aerospace spectrum stakeholders, to support effective and successful discussions with the aerospace industry, and to inform Civil Aviation Authorities and ICAO, while the second ER, "Report for Aeronautical Radio Frequency Systems, their Regulatory Framework, and Operational Considerations," will be a reference for a broader audience including aviation systems developers, as well as for non-aerospace spectrum stakeholders. As such, it will support effective and successful discussions with the aerospace industry and regulators in future ITU Study Cycles. The deliverables are envisaged to be referenced by EASA, other CAAs, ICAO, and national/international spectrum regulators..."[171]

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[166] "Draft new WI – radio altimeters," ECC PT1(21)086_Annex VIII-12 - https://api.cept.org/documents/ecc-pt1/62871/ecc-pt1-21-086_annex-viii-12_draft-new-wi-radio-altimeters

[167] As this chapter indicates, there are many European entities working in parallel to develop standards for avionics. To reduce duplication and conflicts in their work, ASD-STAN and EUROCAE signed a Memorandum of Cooperation in July 2024. See "EUROCAE and ASD-STAN Forge Cooperation to Enhance European Aerospace Standards," 4 July 2024 - https://www.eurocae.net/news/posts/2024/july/eurocae-and-asd-stan-forge-cooperation-to-enhance-european-aerospace-standards/

[168] https://www.eurocae.net/

[169] EUROCAE, *Technical Work Programme*, Edition 2024 - https://eurocae.net/media/2209/twp-2024.pdf

[170] Issued in November 2023, it costs 115 euros for non-EUROCAE/non-RTCA members - https://eshop.eurocae.net/eurocae-documents-and-reports/er-028/

[171] EUROCAE, *Technical Work Programme*, Edition 2024 - https://eurocae.net/media/2209/twp-2024.pdf

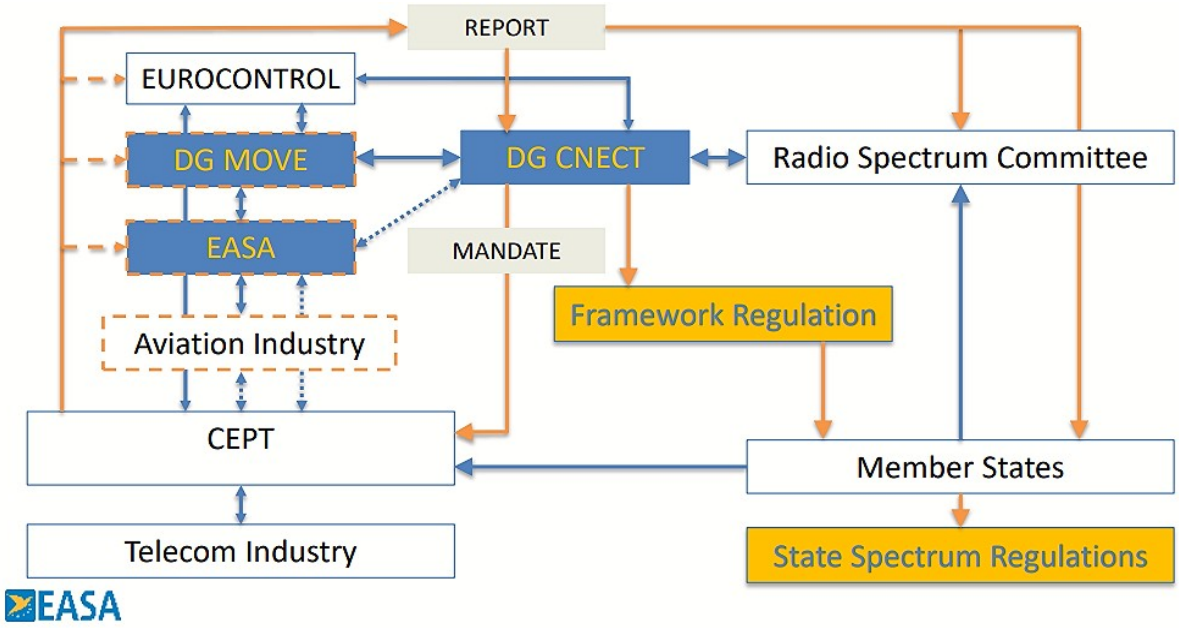
4.4.1 European Aviation Safety Agency (EASA)

This agency, established in 2002, certifies aircraft, parts and equipment for safe operation, formulates rules for "air worthiness," licenses crews, airports and air traffic management services.[172] Its responsibilities are growing as integration of the European air traffic system progresses and it absorbs responsibilities that had been vested in national airspace regulators.

EASA's certifications of equipment, personnel, services and airworthiness are based on tests of compliance with European Technical Standard Orders (ETSOs). ECC Report 362 notes that "Radio altimeters used by EASA certified aeroplanes must comply with European technical standard order ETSO-C87A[173] which defines certification testing procedures and the required minimum performance of the equipment." Similarly, in May 2024, EASA updated its Certification Memorandum on "Guidance to Certify an Aircraft as PED Tolerant"[174] by adding references to industry standards for 5G and WiFi 6e which emerged after publication of the Memorandum's 2017 edition, as well as a reference to "intentional emissions in the vicinity of frequency bands of aircraft radio receivers, like the case of Radio Altimeters… Previous versions of EUROCAE ED-130, RTCA DO-307 and RTCA DO-294C do not include guidance to evaluate the effects of emissions from 5G PED on the Radio Altimeter."

Elsewhere, EASA indicates that "Whenever possible, the ETSOs are… equivalent to the corresponding FAA TSO standards..."[175] That highlights the importance of technical standards set by the US Federal Aviation Administration. FAA's response to 5G interference into altimeters may be an exception, however, as EASA does not see the US as a model for Europe in this specific instance: "*At this stage, no risk of unsafe interference has been identified in Europe. EASA acknowledges the FAA's assessment of the increased risk specific to the USA due to the implementation of potentially higher 5G ground stations power emissions,"*[176] *as well as a much smaller frequency gap between the aeronautical and MFCN allocations. But* ECC Report 362 *cautions us not to believe those differences are permanent*.

Figure 17: Landscape for aviation radio policy-making in Europe



Source: EASA[177]

[172] Although EASA could be seen as a regional affiliate of ICAO, ICAO has its own Europe / North Atlantic regional office in Paris, France (e-mail: icaoeurnat@icao.int, tel: +33 1 46 41 85 85, web: http://www.icao.int/EURNAT/

[173] https://www.easa.europa.eu/download/etso/ETSO-C87a_CS-ETSO_8.pdf

[174] EASA, "FINAL UPDATE to Certification Memorandum ref. CM-ES-003 Issue 02 on 'Guidance to certify an aircraft as PED Tolerant' (2017)," (2024) - https://www.easa.europa.eu/en/downloads/139882/en

[175] EASA, "Explanatory Note to Decision 2013/012/R" - https://www.easa.europa.eu/en/downloads/1991/en

[176] EASA, "Safety Information Bulletin," SIB 2021-16 (17 December 2021) - https://ad.easa.europa.eu/blob/EASA_SIB_2021_16.pdf/SIB_2021-16_1

Noting that Agenda Item 1.1 at WRC-15 was "to consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT)," ICAO prepared preliminary studies for consideration by the Conference[178] and started developing new SARPs for altimeters and WAIC.

In 2018, the US Federal Communications Commission (FCC) announced that it was considering making some or all of the 3700-4200 MHz Fixed Service and Fixed-Satellite Service band available to 5G networks.[179] That inspired other countries to consider similar actions, and sparked fear in the aviation industry that the result might be widespread interference seeping into the altimeter/WAIC band.

During preparations for the US's first C-band auction of 5G licenses in 2021, AVSI conducted tests in a laboratory setting that subjected currently available altimeters to signals simulating 5G base station transmissions. Results of the tests were summarized in *AFE 76s2 Report: Effect of Out-of-Band Interference Signals on Radio Altimeters* (4 February 2020). The main finding was:

> "Protection criteria for RAs embodied in Rec. [ITU-R] M.2059-0 provide the only existing guidance for changes in the RF environment within and adjacent to the 4200 – 4400 MHz frequency band. The data presented herein largely corroborate these criteria for the 3700-4200 MHz band and can be used to develop future rules and operational characteristics for new allocations in this frequency band."[180]

Bolstered by the AVSI report, ICAO sent a liaison statement to CEPT ECC in June 2020 noting the lack of specific limits on unwanted emissions from IMT base stations into the frequency band 4200-4400 MHz:

> European Commission *Implementing Decision (EU) 2019/235 of 24 January 2019 on amending Decision 2008/411/EC as regards an update of relevant technical conditions applicable to the 3 400 - 3 800 MHz frequency band*[181] defines the baseline power limits below 3400 MHz and above 3800 MHz. In the absence of other information, this Decision suggests that within the frequency band 4200-4400 MHz the EIRP limit per antenna is defined as -2dBm/5MHz (-9dBm/MHz) for non-active antennas systems (non-AAS) and the total radiated power (TRP) limit per cell is defined as -14dBm/5MHz (-21dBm/MHz) for active antenna systems (AAS). When using AAS with an assumed maximum antenna gain of 26 dBi, the EIRP limit would reach +5 dBm/MHz… Preliminary studies using the operational and technical characteristics contained in ITU-R Recommendation M.2059 show that with the out-of-band emission limits above being applied:
>
> - For an AAS, a separation distance of more than 27 km is required (applying a 6dB safety margin, for informational purposes: more than 13 km without any safety margin being applied); and
> - For a non-AAS, more than 5.5 km (applying a 6dB safety margin, for informational purposes; more than 2.7 km without any safety margin being applied).[182]

Soon thereafter, RTCA SC-239 formed a task force to assess the potential impact on radio altimeters of out-of-band emissions from 5G networks. The US Federal Aviation Administration (FAA) commissioned the task force to produce an "Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations."[183] Looking at worst-case scenarios, the report asserted that there would be:

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[177] "5G Update" (4th January 2024) - https://www.iata.org/contentassets/047eae4355824577a2060ac745110215/easa-5g_updated_4_jan_2024.pdf

[178] ICAO, "Preliminary Study into Radio Altimeter Adjacent Band Compatibility," ACP-WG-F30/WP-14 (2014) - https://www.icao.int/safety/acp/ACPWGF/ACP-WG-F-30/ACP-WGF30-WP14%20Radio%20Altimeter%20Adjacent%20Bands%20Compatibility%20Study%20with%20IMT-FINAL%20Rev1.docx; and ICAO, "Potential Level of Interference from IMT Systems on Adjacent Band Radio Altimeters," ACP-WGF30/WP-17 (2014) - https://www.icao.int/safety/acp/ACPWGF/ACP-WG-F-30/ACP-WGF30-WP17_radio%20altimeter%20analysis.doc

[179] US FCC, "Order and Notice of Proposed Rulemaking – GN Docket No. 18-122" (issued 13 July 2018) - https://docs.fcc.gov/public/attachments/FCC-18-91A1.pdf

[180] RTCA Paper No. 274-20/PMC-2073 - https://www.rtca.org/wp-content/uploads/2020/10/SC-239-5G-Interference-Assessment-Report_274-20-PMC-2073_accepted_changes.pdf

[181] https://eur-lex.europa.eu/eli/dec_impl/2019/235/oj

[182] ICAO, "Liaison Statement to ECC on 5G emissions and Radio Altimeters in the frequency band 4200 – 4400 MHz," ECC(20)INFO 06 (24 June 2020) - https://cept.org/Documents/ecc/59495/ecc-20-info-06_liaison-statement-from-icao-to-ecc

[183] RTCA Paper No. 274-20/PMC-2073 (7 October 2020) - https://www.rtca.org/wp-content/uploads/2020/10/SC-239-5G-Interference-Assessment-Report_274-20-PMC-2073_accepted_changes.pdf

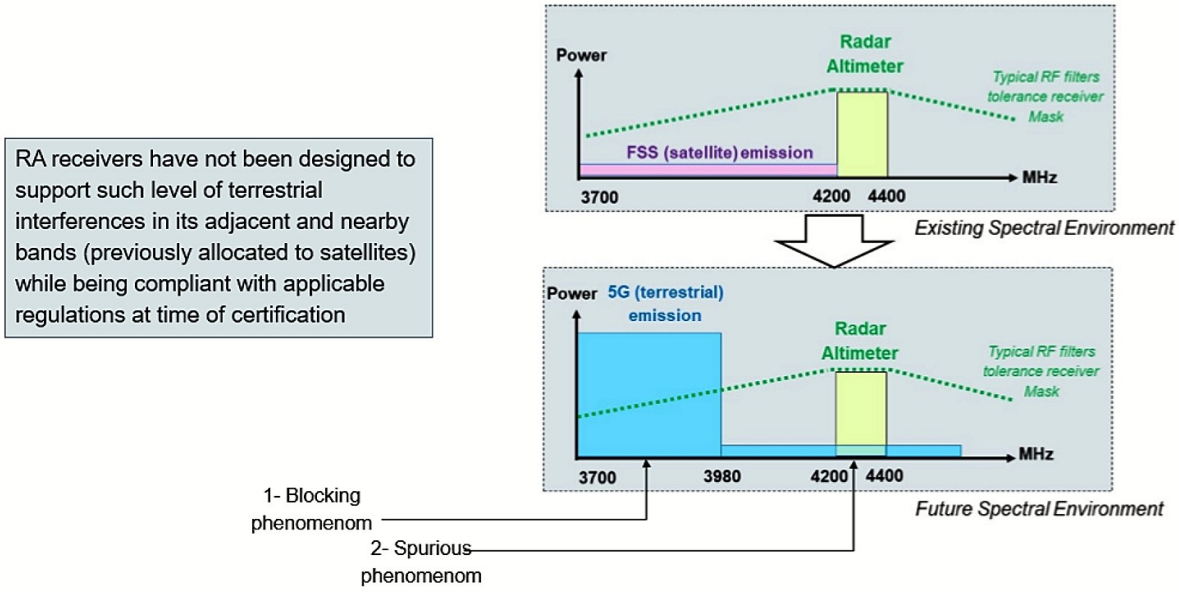
> "a major risk that 5G telecommunications systems in the 3.7–3.98 GHz band will cause harmful interference to radar altimeters on all types of civil aircraft—including commercial transport airplanes; business, regional, and general aviation airplanes; and both transport and general aviation helicopters. The results of the study performed clearly indicate that this risk is widespread and has the potential for… catastrophic failures leading to multiple fatalities, in the absence of appropriate mitigations. The extent of the RF interference is summarized by the worst-case exceedance of the safe interference limit of radar altimeters by expected 5G signals in the 3.7-3.98 GHz band: 14 dB for commercial transport airplanes…, 48 dB for business, regional, and general aviation airplanes… and 45 dB for helicopters…"

RTCA's report was severely criticized by mobile industry stakeholders and organizations like the GSMA:

> "The original RTCA study represented a set of assumptions based on highly pessimistic, overprotective and theoretical operational scenarios that together would not occur in live radio network implementations. As a result, the aviation industry wishes to claim protection from 5G networks for a handful of poorly designed and obsolete devices built on outdated standards from 1970s."[184]

Further testing of altimeters highlighted the fact that the aviation industry's performance standards (in force since 1974) lacked minimum requirements for interference rejection by altimeters—presumably because the nearby spectrum had been relatively quiet—until IMT started moving in.

Figure 18: Changed spectral environment for avionics and altimeters



Source: M. Utsunomiya (ICAO, 2023)[185]

As a result, Recommendation ITU-R M.2059-0 (2014) found a wide range of altimeter sensitivity levels, overload thresholds and interference tolerance masks in existing models. It also noted that the "radio altimeter front-end generally has modest selectivity (gradual RF-filter roll-off). Therefore, a radio altimeter is susceptible to interference both within its operational swept bandwidth as well as from outside this bandwidth." To address that problem, ITU-R M.2059 recommended the use of RF filters in altimeters, with the frequency dependent rejection characteristics shown in this table:

[184] GSMA, *5G and Aviation Altimeters Co-existence with IMT in 3.3-4.2 GHz and 4.8-4.99 GHz,* (2023) - https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2023/05/5G-and-Aviation-Altimeters.pdf

[185] Mie Utsunomiya, "Potential Safety Concerns due to Interference from 5G to Aeronautical Radio Altimeters," preparatory workshop for WRC-23, Cairo, Egypt, 28-29. August 2023 - https://www.icao.int/MID/Documents/2023/WRC-23%20and%20FSMP-SG17/FSMP-WG17-WRC23WrkShp41_Rev%20ICAO-Potential%20Safety%20Concerns%20due%20to%20Interference%20from%205G_Radio%20Altimeters.pdf

Table 10: Recommended RF selectivity for radio altimeters

Interference frequency (MHz)	RF filter attenuation (dB)
≤ 4 200	Attenuated at 24 dB per octave to a maximum of 40 dB
4 200	0
4 300	0
4 400	0
≥ 4 400	Attenuated at 24 dB per octave to a maximum of 40 dB

Source: Recommendation ITU-R M.2059-0 (2014)

That document also noted receiver desensitization can result in the reporting of false altitude measurements when an interfering in-band signal causes the interference-to-noise ratio to exceed -6dB within the altimeter's IF bandwidth. Unlike out-of-band signals, RF energy from in-band interference cannot be filtered, and because the transmit power of altimeters is limited (typically to 1-2 watts, to prevent leakage directly into the nearby altimeter receiver), the receivers must be very sensitive. That is why increasing altimeters' interference tolerance while preserving their functionality is challenging. Plus, altimeters cannot be modified without invalidating their safety certifications, so the only "quick fixes" were limited the introduction of IMT/WBB transmitters into adjacent frequency bands and/or keeping them far from airports. The FCC did both, and some other national regulatory authorities followed suit, choosing different sets of "ad hoc" restrictions.[186] Facts highlighted by ITU-R M.2059—that altimeters are designed for up to 30 years of service and differ widely in their technical performance—have made consensus on new harmonized standards for interference management elusive. And yet the need is clear, as most flights are international and a diversity of local mitigations can lead to pilot uncertainty about whether an altimeter reading is accurate or falsified by interference.

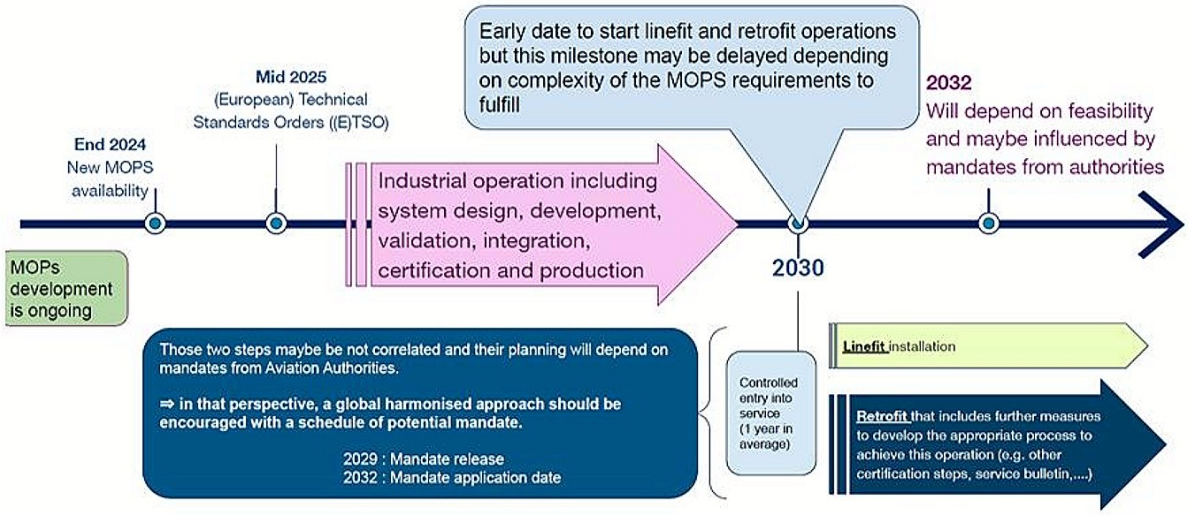
Given the scale and potential impact of the problem, many organizations are involved in solving the problem, and as a result, a globally acceptable solution is slow to emerge. ITU-R M.2059-0 recognized that the "airworthiness certification of radio altimeters is a lengthy and costly process." But ICAO's Frequency Spectrum Management Panel agreed in 2016 to add new altimeter standards to their treaty Annexes. Eight years later, this has still not happened.[187] Final approval of a new Minimum Operating and Performance Standards (MOPS) document is not expected until the end of 2024, with a new Standards and Recommended Practices (SARPs) document following in 2032, and implementation "expected in approx. 2034."[188] When the new standards are available, the studies undertaken so far—by the ITU, CEPT and national authorities—will have to be re-validated. However, no tightening of harmonisation for LMP in the 3.8-4.2 GHz band from 2024 is foreseen.

[186] The ICAO's *Circular 360* (see next footnote)

[187] However, the ICAO has published a series of interim guidance documents. For the latest version, see *Circular 360: Guidance on Safeguarding Measures to Protect Radio Altimeters from Potential Harmful Interference,* https://elibrary.icao.int/reader/471867/&returnUrl%3DaHR0cHM6Ly9lbGlicmFyeS5pY2FvLmludC9leHBsb3JlO3NlYXJjaFRleHQ9NUclMjBpbnRlcmZlcmVuY2U7c2VhcmNoU2NvcGU9MjtwaHJhc2VNYXRjaD0wO21haW5TZWFyY2g9MQ%3D%3D?productType=eBook

[188] ICAO, "Non-Final Work in Progress: ICAO Position for the International Telecommunication Union (ITU) World Radiocommunication Conference 2027 (WRC-27)" - https://www.icao.int/safety/FSMP/MeetingDocs/FSMP%20WG18/Flimsy%20-%20Copy/FSMP-WG18-Flimsy01R3_Draft%20ICAO%20Position%20for%20WRC-27.docx

Figure 19: Expected timeline for the development of new ICAO/RTCA/EUROCAE/ETSI minimum operating and performance standards for altimeters



Source: ICCAIA

Figure 6. Expected timeline necessary for ICAO SARPs and RTCA/EUROCAE compliant radio altimeters
(Image reproduced by kind permission of ICCAIA)

Source: ICAO Circular 360

The following comments are speculative, but ICAO's slow response could be due to resentment, or a way to pressure others to help accelerate the process by contributing to the costs of mitigation. As one International Air Transport Association official put it:

> "Airlines did not create this situation. They are victims of poor government planning and coordination. Industry concerns about 5G, expressed for many years in the appropriate forums, were ignored and over-ridden. Half-measure solutions have been foisted upon airlines to implement at their own expense and with little visibility into their long-term viability… these investments will bring no gains in operating efficiency. Furthermore, this is only a temporary holding action. Under current scenarios, airlines will have to retrofit most of their aircraft twice in just five years. And with the standards for the second retrofit yet to be developed we could easily be facing the same supply chain issues in 2028 that we are struggling with today. This is patently unfair and wasteful. We need a more rational approach that does not place the entire burden for addressing this unfortunate situation on aviation."[189]

This statement suggests two important questions: how many altimeters actually need to be replaced or retrofitted? And how much would that cost?

According to OliverWyman, the total global fleet of commercial aircraft in 2024 is 28,398.[190] Discussions within ICAO indicate that some 20,000 of those are equipped with altimeters that use 4200-4400 MHz.[191] The International Air Transport Association claimed in a filing with the FAA that retrofitting altimeters on the global fleet of aircraft would cost up to $637 million (about $22,431 per aircraft).[192]

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[189] Statement by Nick Careen, IATA's Senior Vice President for Operations, Safety and Security, quoted in "IATA welcomes agreement to extend 5G mitigations," Aerospace Global News (4 May 2023) - https://aerospaceglobalnews.com/news/iata-welcomes-telcos-agreement-to-extend-5g-mitigations/

[190] OliverWyman, *Global Fleet and MRO Market Forecast*, *2024-2034* - https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2024/feb/OliverWyman-Global-Fleet-and-MRO-Market-Forecast-2024-2034.pdf

[191] See for example, Laurent Azoulai (ICCAIA), "Radioaltimeter permanent functioning," FSMP-WG/19-WP/17, 19th Working Group meeting of ICAO's Frequency Spectrum Management Panel (July 2024) - https://www.icao.int/safety/FSMP/MeetingDocs/FSMP%20WG19/WP/FSMP-WG19-WP17_Radioaltimeter%20permanent%20functioning%20submitted.docx

In contrast, FAA in 2022 reported that two altimeter models deployed in about 45% of the commercial aircraft registered in the US were already sufficiently robust against 5G interference that they did not need to be either replaced or retrofitted.[193] For the remaining aircraft, *Air Worthiness Directive 2023-10-02* set a deadline of 1 February 2024 for compliance with the FAA's new rules requiring interference resistant altimeters, which are summarized below. Many airlines asked for time extensions but the FAA refused, saying:

> "The FAA re-evaluated the February 1, 2024, date based on the latest radio altimeter equipage data and determined that an extension is not justified. The only airplanes… that are forecast to be at risk of not being equipped by Februrary 1, 2024, are approximately 164 transport category airplanes that have older radio altimeters with no support from the airplane [original equipment manufacturers] or radio altimeter manufacturers. Operators of those airplanes will need to make a business decision to equip with later model radio altimeters or retire those airplanes… Airplanes without upgraded radio altimeters will be able to operate into any airport, but cannot fly the prohibited low-visibility operations… The FAA and its foreign civil aviation authority partners plan to expedite radio altimeter approvals… the FAA has used means such as approved model list [supplemental type certificates] to help with equipage…
>
> The FAA estimates that this AD affects approximately 1,000 airplanes of US registry.
>
> "As of the date of publication of this AD, there are approximately 8,000 transport and commuter category airplanes of US registry… FAA roughly estimates that almost 7,000 airplanes on the US registry have already been equipped or are being retrofitted to address radio altimeter interference tolerance, and thus will have to take no actions to comply with this AD… The FAA estimates that approximately 180 airplanes will require radio altimeter replacement and 820 airplanes will require addition of radio altimeter filters to comply with the modification requirement. As such, the FAA estimates the following costs to comply with this AD, to a total US fleet cost of compliance of up to $35,152,000.[194]

Table 11: Cost Estimate for Replacing or Upgrading U.S. Aircraft Altimeters

Action	Labour cost	Parts cost	Cost per product	Cost on US operators
AFM [air flight manual] revision until June 30, 2023	1 work-hour x $85 per hour = $85	$0	$85	$85,000 for 1,000 affected airplanes.
AFM [air flight manual] revision after June 30, 2023	1 work-hour x $85 per hour = $85	$0	$85	$85,000 for 1,000 affected airplanes.
Modification (radio altimeter replacement option)			Up to $80,000 (includes parts and labour)	Up to $14,400,000 for 180 affected airplanes.[195]
Modification (filter addition option)	24 work-hours x $85 per hour = $2,040 per filter	$8,000 per filter	$10,040 per filter	Up to $20,582,000 for 820 affected airplanes with 2 or 3 filters per airplane.

Source: FAA (op. cit.)

What makes the ICAO's slow response more puzzling is that the US Government ordered domestic aircraft to be equipped with 5G resistant altimeters quickly and that was accomplished in full earlier this year.

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[192] IATA comments on FAA Docket 2022-1647 https://www.regulations.gov/comment/FAA-2022-1647-0040 They rightly criticize the FAA's cost estimate for not including the aircraft that already complied with the new altimeter rules although they overestimate the cost estimate gap by ignoring that 45% did not need to modify their equipment.

[193] Andrew Curran, "FAA Okays Almost Half of US Passenger Jets Ahead Of 5G Rollout," *Simple Flying*, 17 January 2022 - https://simpleflying.com/faa-clears-planes-5g-rollout/

[194] FAA, *AD Final Rules – 2023-10-02*, published in the [US] Federal Register, Volume 88, Number 102 (Friday, May 26, 2023), pages 34065-34081] - https://drs.faa.gov/browse/excelExternalWindow/FR-ADFRAWD-2023-11371-0000000000.0001

[195] Note: FAA's calculation assumes only 1 altimeter replacement per aircraft. It is possible that the affected aircraft have only 1 altimeter, but most large aircraft have 2 or 3. The FAA gives no explanation for their assumption. If one quarter have 2 altimeters and one quarter have 3 altimeters, the total replacement cost would be $25,200,000, bringing the total fleet cost up to $45,952,000.

Another factor that must be mentioned is that, although interference to an altimeter during a landing could be catastrophic, that has not happened, despite the warnings of the aviation industry. In January of this year, EASA, the European Aviation Safety Agency said:

- "There have been no reports of occurrences of confirmed 5G interference of radio altimeters reported to EASA. No evidence of 5G interference found."[196]

Meanwhile, closer to home:

> "The Czech Republic has published the results of an RA test (onboard) near a new IMT BTS installed at an airport. They used two different types of planes and two types of Helicopters. The Base Station operated at 3.7 GHz. Results showed no abnormal RA function was detected."[197]

The situation in the US is very different. The main difference is that the MFCN band in Europe currently ends at 3800 MHz. In the US, it ends at 3980 MHz. The US guardband is 20 MHz while in Europe it's 400 MHz (for now). The difference is stunning:

> "On 19 January, the 5G systems were switched on. Almost immediately, complaints began rolling into NASA…
>
> "According to an *IEEE Spectrum* analysis of reports made to NASA's Aviation Safety Reporting System (ASRS), complaints of malfunctioning and failing altimeters soared after the rollout earlier this year of high-speed 5G wireless networks…
>
> In February, a civilian airliner experienced chaotic low-altitude warnings when approaching Louis Armstrong International Airport in New Orleans while flying below 1,000 feet. "These erroneous warnings would have been extremely confusing in a more difficult environment such as low visibility, icing, etc.," the pilot later wrote.
>
> "In January this year, at least three flights above Tennessee simultaneously experienced altimeter errors that made it 'impossible to maintain assigned altitude,' according to one of the pilots. One jet lost its autopilot completely, and reportedly had fire trucks waiting for it on landing…
>
> "In March, a commercial jet landing on autopilot at Los Angeles International Airport suddenly went into an aggressive descent just 100 feet above the ground. 'I took control of the aircraft and raised the nose and landed,' its pilot reported. 'It was a very alarming pushover by the autopilot. In [other] conditions, it could have caused a crash.'"[198]

Even when nothing bad actually happens, false alarms have a negative impact: "The [FAA] is concerned that repeated false warnings, which it believes 'will occur more frequently as telecommunication companies continue to deploy 5G C-Band services,' will desensitize flight crew to actual emergencies."[199]

As noted above, an important new standard (DO-155A – "Minimum Performance Standards - Airborne Low Range Radar Altimeters") is expected by the end of 2024. The ICAO has already issued *Circular 360: Guidance on Safeguarding Measures to Protect Radio Altimeters from Potential Harmful Interference*[200] (2024).

So solutions to the standards part of the conflict are in sight. But responsibility for paying the costs of replacing or retrofitting altimeters that are not 5G resistant is still an issue: the airline industry clearly wants the mobile phone industry to bear some of the costs.

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[196] EASA, "5G Update" (4 January 2024) - https://www.iata.org/contentassets/047eae4355824577a2060ac745110215/easa-5g_updated_4_jan_2024.pdf

[197] GSMA, *5G and Aviation Altimeters: Co-existence with IMT in 3.3-4.2 GHz and 4.8-4.99 GHz* (May 2023) - https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2023/05/5G-and-Aviation-Altimeters.pdf

[198] Mark Harris, "How 5G's Rollout Rattled Hundreds of Pilots," *IEEE Spectrum* (13 October 2022) - https://spectrum.ieee.org/faa-5g

[199] Brandon Vigliarolo, "FAA sets 2024 deadline for preventing 5G crash landings," The Register, 10 January 2023 - https://www.theregister.com/2023/01/10/faa_2024_altimeter_deadline/

[200] https://elibrary.icao.int/reader/471867/&returnUrl%3DaHR0cHM6Ly9lbGlicmFyeS5pY2FvLmludC9leHBsb3JlO3NlYXJjaFRleHQ9NUclMjBpbnRlcmZlcmVuY2U7c2VhcmNoU2NvcGU9MjtwaHJhc2VNYXRjaD0wO21haW5TZWFyY2g9MQ%3D%3D?productType=eBook

ECC Report 362: "Compatibility between mobile or fixed communications networks (MFCN) operating in 3400-3800 MHz and wireless broadband systems in low/medium power (WBB LMP) operating in the frequency band 3800-4200 MHz with Radio Altimeters (RA) operating in 4200-4400 MHz"[201]

This long and complex report gives the results of multiple coexistence simulations involving radio altimeters and fixed/mobile networks with diverse parameters deployed in various frequency ranges, along with a range of assumptions about the altimeters' interference tolerance, resulting in different estimates of the separation distances needed for safe operation. Because of the report's complexity and significance for flight safety it is recommended that readers rely on the full source text (ECC Report 362) rather than this brief summary.

- From the Executive Summary:

  "Two phenomena have been studied in this Report:

  - "The effect of unwanted emissions from WBB-LMP or MFCN in the adjacent bands falling in the 4200-4400 MHz band used by Radio Altimeters;
  - "The effect of blocking. Blocking is where a Radio Altimeter's receiver performance is reduced by strong radiofrequency (RF) emissions from MFCN or WBB-LMP in the adjacent frequency bands...

  "The interference tolerance threshold values of the various Radio Altimeter models differ by several magnitudes… (in the order of 30 dB)…

  "A 6 dB safety margin, as recommended by ICAO, is taken into account in the conclusion of all studies.

  "Based on the above Radio Altimeter parameters, as well as typical base station parameters and set up, this ECC Report derives the following conclusions for the modelled ILS approach scenario:

  "For MFCN (5G) operating in frequency band 3400-3800 MHz

  "All studies of unwanted emissions (See ERC Recommendation 74-01), falling into the Radio Altimeter band from 5G MFCN operating in the 3400-3800 MHz frequency band, show sufficient margins covering at least the 6 dB ICAO safety margin;…

  "Some studies of blocking using Parameter Set 2 have also extended parameters of the Radio Altimeter to heights other than 200 feet and 1000 feet. The outcome of these studies leads to some base station locations where the interference tolerance threshold at the Radio Altimeter is exceeded. A study proposes an approach in this Report in order to manage the risk of interference.

  "For Wireless Broadband Low-Medium Power (WBB LMP) operating in 3800-4200 MHz

  "For the frequency band 3.8-4.1 GHz, all studies show sufficient margins covering at least the 6 dB safety margin as recommended by International Civil Aviation Organization (ICAO).

  "For the frequency band 4.1-4.2 GHz, all studies show sufficient margins covering at least the 6 dB ICAO safety margin, except for some types of medium power beamforming base station and radio altimeter scenarios… [Using] Parameter Set 2, which applies the 200 feet interference tolerance threshold below 200 feet… unwanted emissions from these base stations do not meet the 6 dB ICAO safety margin for the modelled beamforming antenna configurations. The same study shows the 6 dB ICAO safety margin is fully covered for base station's positions greater than 1200 m from the runway threshold or 40 m laterally or with some improved out-of-band emission levels…"

- "In September 2024, the ECC requested updates from CEPT administrations on maximum Base Station transmit power in operation in in the 3400-3800 MHz frequency band. The responses from some European countries are confirming that the maximum base station e.i.r.p. from 2022 remains appropriate, so 78 to 82 dBm/100 MHz used in this Report are representative of base stations in CEPT countries…

  "In response to a question from CEPT, ETSI clarified that the 5G Base Stations (NR, LTE and MSR) operating band unwanted emission limit inside the operating band 3400-3800 MHz also extends outside the band to an offset of 40 MHz for

[201] https://docdb.cept.org/document/28630

both non-AAS and AAS BS. Outside this offset, the general spurious emission limit of -30 dBm/MHz applies, specified as TRP for AAS and conducted power to the antenna port for non-AAS. This limit is now being introduced in the EN 301 908-24 [standard] for 5G Base Stations. This EN, adopted by ETSI and proposed to the European Commission is expected to be published in *Official Journal of the European Union* (OJEU) as a Harmonised Standard (HS).

"At the time of publication of this Report the published European Harmonised Standard does not include the frequency band 3.8-4.2 GHz. It is expected that the existing Harmonised Standard will be updated or a set of new Harmonised Standards for WBB LMP in 3.8-4.2 GHz will be developed following the publication of CEPT Report 88… Nevertheless, administrations wishing to include a limit in their authorisation or to use a limit for coordination purpose may define such limits on a national basis...".

Table 12: Out-of-band radiation limits for WBB LMP (non-AAS) providing connectivity to the local area network in the 3.8-4.2 GHz band, derived from the Decision ECC (11)06

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

Source: ECC Report 362[202]

4.4.2 Aeronautical Mobile Service: Wireless Avionics Intra-Communication (WAIC)

Wireless Avionics Intra-Communications (WAIC) systems provide radiocommunication links over relatively short distances between two or more stations integrated into or installed on a single aircraft to support safe operations. WAIC systems do not provide radiocommunications between an aircraft and the ground or with other aircraft or a satellite. They are alternatives to wiring, introduced to reduce costs and aircraft weight, to provide flexibility in the location and signal routing between link end-points, or to deliver data to or from moving parts which cannot be tethered to wiring. WRC-15 adopted rules enabling WAIS to use the 4200-4400 MHz band, which had previously been allocated exclusively for radio altimeters.

The ITU relies on the ICAO to set rules ensuring that systems mounted on or within a single aircraft do not interfere with each other. The ITU's concern is with systems on one aircraft interfering with systems on another aircraft, as can occur at airports, when aircraft are parked next to one another, or when an aircraft is taking off or landing while another is taxiing nearby. That could even happen in the air, between aircraft which are vertically separated by the required minimum distance of 300 m.

ITU Resolution 424 (WRC-15) notes that WAIC and radio altimeters both use 4200-4400 MHz. Both access the full bandwidth concurrently, so interference between them is a real possibility.[203] The Resolution, as noted above, cites Recommendation ITU-R M.2085, the purpose of which is to set limits on the e.i.r.p. density generated by WAIC systems outside the aircraft, to prevent interference into the radio altimeters of nearby aircraft (the aircraft fuselage adequately shields RF emissions from WAIC systems inside). Recommendation M.2085 says the maximum e.i.r.p. should not exceed 5 dBm/MHz for "high data rate" outside WAIC applications or 6 dBm/MHz for "low data rate" outside WAIC applications. Recommendation ITU-R M.2067-0[204] defines "low data rate" WAIC applications as those having data rates less than 10 kbit/s, and "high data rate" WAIC applications as having data rates

[202] FM 60 – meeting 2023 - https://api.cept.org/documents/fm-60/77699/fm60-23-info-10_lmp-parameters-for-studies-on-3800-4200-mhz&ved=2ahUKEwjFl-bs8oaLAxWrYPEDHVGmHuYQFnoECB0QAQ&usg=AOvVaw1lGUWFUTWvvAXGk6TlOKRA

[203] According to Recommendation ITU-R M.2059-0, "radio altimeters require a bandwidth of 196 MHz" while Recommendation ITU-R M.2283-0 calculates that WAIC systems require between 145 and 185 MHz.

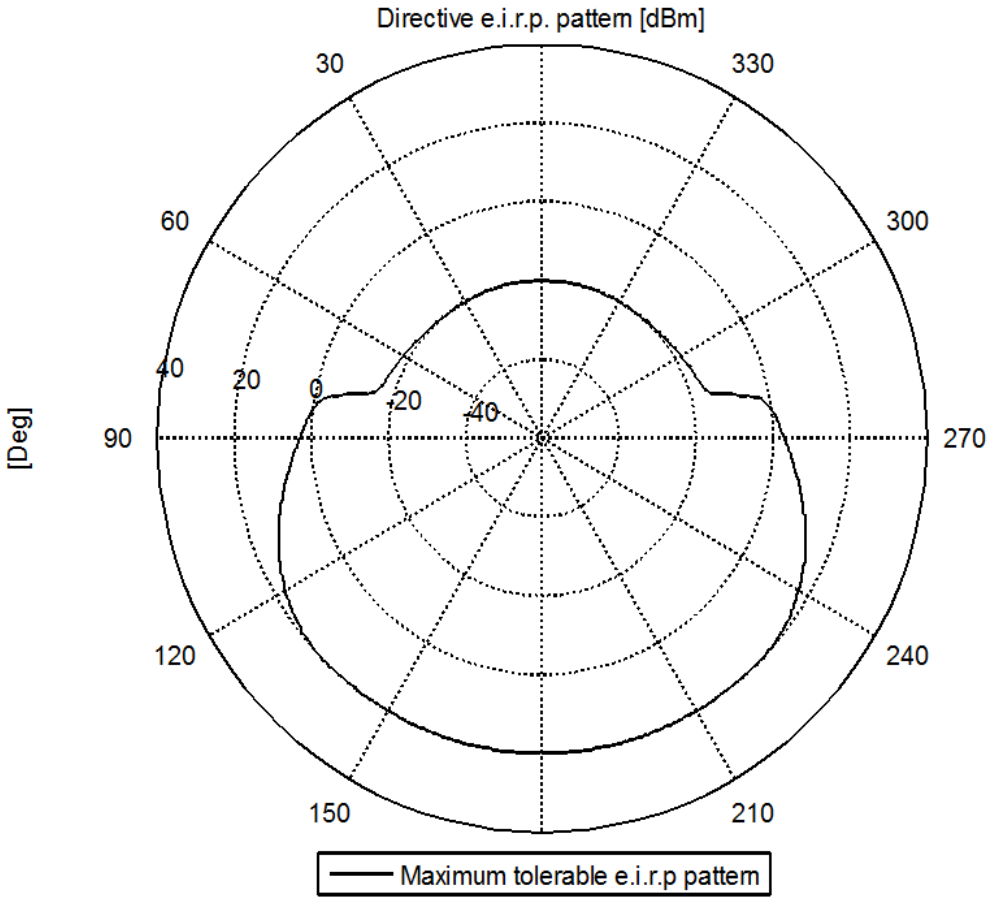
[204] Recommendation ITU-R M.2067-0 (2015): "Technical characteristics and protection criteria for Wireless Avionics IntraCommunication systems" - https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2067-0-201502-I!!PDF-E.pdf

above 10 kbit/s. The maximum transmission power of “low data rate” applications is 10 mW while the maximum transmission power of “high data rate” applications is 50 mW.

Report ITU-R M.2283-0[205] gives examples of different types of outside “high data rate” WAIC applications: voice data transfer for flight deck crew communications, external video imaging for safe taxiing and “structural health monitoring sensors employing e.g. ultrasonic technology or accelerometers.” A large passenger jet may have up to 65 outside high-rate data links, although only one can transmit at any given moment. Outside “low data rate” WAIC applications include ice detectors, landing gear position feedback for steering and deployment assurance, tire pressure sensors, tire and brake temperature sensors, engine performance sensors, etc. A large passenger jet may have up to 400 outside low data rate WAIC links, although only one can transmit at any given moment. Despite the large number of links, ICAO’s defines a “WAIC system… as the entirety of all WAIC components on board the same aircraft, so that a single aircraft contains only a single WAIC system.”[206]

A study cited in Report ITU-R M.2319-0[207] found that if omni-directional antennas are used for WAIC systems outside the aircraft, “the RF emissions… into the upward directions will exceed the protection criteria of the fixed service, the Earth exploration-satellite service (passive), and radio altimeters in the frequency band. [Therefore] an angle-dependent maximum power pattern defining the maximum tolerable RF power emissions of an aircraft expressed in e.i.r.p. is derived” and summarized in the following diagram and accompanying table:

Figure 20: Maximum angle-dependent tolerable RF power emissions caused by WAICs



[205] “Technical characteristics and spectrum requirements of Wireless Avionics Intra-Communications systems to support their safe operation” (2013) - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2283-2013-PDF-E.pdf

[206] “Proposed Modifications to Annex 10 Volume V to the Convention on International Civil Aviation,” FSMP.3.WP.03, Annex 1 - https://www.icao.int/safety/FSMP/MeetingDocs/FSMP-3/Report/FSMP.3.WP.03%20YELLOW%20COVER%20REPORT.pdf

[207] “Compatibility analysis between wireless avionics intra-communication systems and systems in the existing services in the frequency band 4 200-4 400 MHz” (2014) - https://www.itu.int/pub/R-REP-M.2319-2014

Source: Report ITU-R M.2319-0

Table 13: Angle-dependent maximum tolerable e.i.r.p. reference values

Parameter	Values										
Angle (degree)	>120	90	75	69	35	0	325	291	285	270	<240
e.i.r.p. (dBm)	20	3	-2	-15	-17	-20	-17	-15	-2	3	20

Source: Report ITU-R M.2319-0

However, in discussing that option, ICAO's WAIC SARP Correspondence Group claimed in 2020 that "an angle-dependent e.i.r.p. could severely impact the viability of the band for WAIC applications."[208]

Perhaps recognizing that directive antennas might not be the best solution, Report ITU-R M.2319 identified other ways to bring outside WAIC systems into compliance with the recommended emission limits:

- reduce the systems' transmit power
- reduce the maximum distance between the WAIC transmitter and its intended receiver
- position the transmitter on the underside of the aircraft to take advantage of the vertical shielding effect of the fuselage.

But of growing concern is interference to inside WAIC systems from onboard passengers' portable electronic devices (PEDs) especially if frequencies closer to 4200-4400 MHz are allocated to IMT and airlines expand their offers to passengers of in-flight cellular connectivity. Reports of harmful interference—mainly from cellphones, but also laptops, tablets and other PEDs—affecting sensors, displays and control circuits have been registered for decades.[209] This table summarizes current specifications for WAIS receivers with regard to interference. These parameters may be updated to deal more effectively with the continuing proliferation of PEDs, or to compensate for changes in WAIC transmitters' power limits or antenna directivity.

Table 14: Technical characteristics of existing WAIC receivers

Receiver characteristics	Low data rate systems	High data rate systems
Protection criteria (I/S)	-9 dB	-14 dB
Minimum out-of-band interference rejection	-10 dB	-10 dB
Front end overload protection level*	-30 dBm	-30 dBm

** Incident interference power must be below –30 dBm across the entire allocated frequency range to maintain sufficient linearity of operation.*

Source: Recommendation ITU-R M.2319-0 (2014)

Even though the above table comes from an ITU Recommendation, it will be ICAO's and RTCA's responsibility to review these standards in response to changes in the RF environment. In fact, ICAO's Frequency Spectrum Management Panel approved new draft SARPs in September 2022. That represents the minimum RF characteristics necessary to prevent interference between WAIC and radio altimeters. "The expected applicability date for the [proposed amendments to the ICAO treaty is November] 2025. WAIC SARPs will be included in Chapter 4 of Annex 10, Volume V, under a new section 4.5 dealing with the frequency band 4200-4400 MHz. That section will also then be appropriate for the radar altimeter SARPS once they are completed."[210]

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[208] David Redman, "Report of the WAIC SARPS Correspondence Group," presented at the 10th working group meeting of ICAO's Frequency Spectrum Management Panel (14 August 2020) - https://www.icao.int/safety/FSMP/MeetingDocs/FSMP%20WG10/WP/FSMP-WG10-WP20_WAIC%20SARPS%20CG.doc

[209] Elden Ross, *Personal Electronic Devices and their Interference with Aircraft Systems,* NASA/CR-2001-210866 (2001) - https://ntrs.nasa.gov/api/citations/20010066904/downloads/20010066904.pdf

[210] ICAO, "Connecting the World," presented at the 12th meeting of the MIDANPIRG CNS sub-group, 2-4 May 2023 - https://www.icao.int/MID/Documents/2023/MIDAMC%20and%20CNS/CNS%20SG12-PPT4.pdf

Here are excerpts from the new (but not yet formally approved) draft WAIC SARPs:

4.5.2.6.2 The power of the total aggregate emissions of all WAIC transmitters on board an aircraft shall not exceed an equivalent isotropic radiated power of -20dBm, assuming a point source located at the geometrical center of the aircraft.

4.5.2.6.3 The overall occupied bandwidth shall be maintained completely within the allocated frequency band 4 200 – 4 400 MHz including any offsets such as Doppler shift or frequency tolerances. Where the occupied bandwidth is defined as the bandwidth for which 99% of the signal energy falls within the lower and upper frequency limits…

4.5.2.6.4 The necessary bandwidth (NB) of the WAIC transmitter shall be calculated according to Appendix 1 of the Radio Regulations.

4.5.2.6.5 The boundary between the out-of-band and spurious domains shall be determined according to Annex 1 of Appendix 3 of the Radio Regulations. The required attenuation of the mean power of any unwanted emission relative to the total mean power P shall meet or exceed the following conditions:

- 50% of NB < f < 150% of NB: Linear increase (in dB) from 24dB to 35dB within a reference bandwidth of 4kHz (Note 1)
- 150% of NB < f < start of the spurious domain: 35dB within a reference bandwidth of 4kHz (Note 1)
- Spurious domain: 56+10log(P) or 40dB whichever is less stringent measured in a RBW of 1MHz (Note 2)

Note 1: Reference bandwidth of 4 kHz within the out-of-band domain in accordance with Annex 11 of Recommendation ITU-R SM.1541-6. The parameter f is the frequency separation from the center frequency of the transmit signal.

Note 2: Reference bandwidth of 1 MHz within the spurious domain in accordance with Appendix 3 paragraph 7 of the Radio Regulations and determination of attenuation for low power device radio equipment in accordance Appendix 3 paragraph 13 of the Radio Regulations.

4.5.2.7 Out-of-Band Interference Tolerance of a WAIC Receiver

Note: These requirements are for WAIC equipment and define an RF environment in which WAIC equipment must meet its performance requirements without taking into account any mitigation afforded by its installation.

4.5.2.7.1 Receivers shall tolerate interference from sources operating outside of the frequency band 4 200- 4 400 MHz whose total combined emitted power falling within the frequency band 4 200 - 4 400 MHz as measured at the receiver does not exceed a power spectral density of -120 dBm / MHz.

4.5.2.7.2 Receivers shall tolerate interference from sources operating outside of the frequency band 4 200 – 4 400 MHz whose total combined power as measured at the receiver does not exceed -20 dBm."[211]

[211] ICAO, "Proposed Amendment to the International Standards and Recommended Practices, *Aeronautical Telecommunications* Annex 10 Volume 5—Aeronautical Radio Frequency Spectrum Utilization, Convention on International Civil Aviation, ATTACHMENT A to State letter AN 7/66.1.1-23/47 - https://www.atcguild.in/iwen/IWEN2323/ICAO/047e.pdf