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Policy and Regulation Initiative for Digital Africa

Spectrum sharing and compatibility studies to boost IMT deployment

Policy and Regulation Initiative for Digital Africa: Spectrum sharing and compatibility studies to boost IMT deployment

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Introduction

The Policy and Regulation Initiative for Digital Africa (PRIDA) is a joint initiative between the African Union, the European Union and the International Telecommunication Union (ITU). It aims to foster universally accessible and affordable broadband across the continent to unlock future benefits of Internet-based services. Its specific objective is to create a more harmonized and enabling legal and regulatory framework for the use of ICT for social and economic development, with an emphasis on boosting the spectrum market across Africa.

The activities of PRIDA are based on three pillars or tracks:

1) efficient and harmonized spectrum utilization (track 1);
2) harmonization of measurable telecommunication/ICT policy, legal and regulatory frameworks (track 2);
3) African decision-makers' active participation in the global debate on Internet governance (track 3).

ITU is implementing track 1 of PRIDA while the African Union Commission (AUC) is implementing tracks 2 and 3. This report includes the results of the work carried out under PRIDA track 1 on spectrum harmonization, with a focus on improving spectrum allocation based on international best practices.

Study background and objective

PRIDA track 1 aims to harmonize spectrum utilization in Africa, in particular spectrum allocated for wireless broadband access. Several spectrum bands were identified as suitable bands for wireless broadband deployment in Africa: 700 MHz, 800 MHz, 1.4 GHz, 2.3 GHz, 2.6 GHz, 3.5 GHz, 26 GHz and the upper frequency range 37-71 GHz.

For the deployment of new wireless broadband services in the above-mentioned spectrum bands, spectrum sharing and compatibility with the incumbent services in these bands should be considered, so as to ensure unimpeded use of both the new wireless broadband and incumbent services.

This report covers the study carried out on sharing and compatibility between wireless broadband and the incumbent services. It provides a comprehensive set of guidelines to facilitate the deployment of wireless broadband in Africa.

Study scope

Given the wide range of wireless broadband services, those considered in this study have been defined as all those mobile services that:

1) use the terrestrial component of IMT systems, encompassing IMT-2000, IMT-Advanced and IMT-2020,[1] also commonly referred to as 3G, 4G and 5G, respectively;

[1] The key features of IMT-2000, IMT-Advanced and IMT-2020 systems are contained in Recommendations ITU-R M.1645, ITU-R M.1822 and ITU-R M.2083. In addition, the radio interfaces of IMT-2000 and IMT-Advanced are detailed in ITU-R M.1457 and ITU-R M.2012, respectively.

2) have a recommended frequency arrangement in the spectrum bands identified for IMT in the Radio Regulations (RR).[2]

As ITU defines the key features and frequency arrangements of IMT systems in its Recommendations, it is important to refer to the standardization work of 3GPP and IEEE[3] for equipment operating in these bands. These standardization bodies define the technical specifications of the various wireless broadband technologies falling under the IMT systems,[4] such as Universal Mobile Telecommunications System (UMTS), high-speed packet access (HSPA), Long-Term Evolution (LTE), LTE-Advanced, 5G-NR (new radio)[5] and worldwide interoperability for microwave access (WiMAX).[6]

It is assumed that administrations (or national regulatory authorities) assign and manage spectrum in conformity with the ITU Radio Regulations (ITU-RR). Hence, administrations should consider the International Table of Frequency Allocations (ITFA), i.e. Article 5 of the ITU-RR. This table shows the spectrum allocations for the different services, such as mobile,[7] fixed, broadcasting, fixed-satellite, earth exploration-satellite, radiolocation and other services. Consequently, this report considers the sharing and (in) compatibility between the various services as indicated in the ITFA for Region 1 (as all African countries are part of ITU Region 1).

The ITFA indicates spectrum allocations for primary and secondary services. Stations of a secondary service shall not cause harmful interference to stations of primary services and cannot claim protection from harmful interference from stations of a primary service (ITU-RR, 5.29/5.30). In this report only sharing and (in) compatibilities between IMT systems and systems of other primary services in the same or adjacent band are considered.

Spectrum sharing and compatibility between services may not be confined only to within a single administration's territory, but it may also be necessary to consider sharing and compatibility between services deployed in different countries. For example, a deployment of digital terrestrial television broadcasting (e.g. Digital Video Broadcasting – Second Generation Terrestrial DVB-T2 or ISDB-T Integrated Services Digital Broadcasting – Terrestrial) in country A may be incompatible with an IMT deployment in country B in certain geographical areas. With appropriate cross-border spectrum coordination between countries A and B, any identified incompatibilities can be mitigated. Where relevant cross-border incompatibilities and coordination are addressed

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2 Recommendation ITU-R M.1036-6 provides these frequency arrangements for the spectrum bands as listed in the "Introduction" to this report, except for the mm-Wave bands 26 GHz, 40 GHz and 66 GHz. The Final Acts of WRC-19 include new provisions for the identification of new mm-Wave spectrum above 24 GHz. Also, the Final Acts of WRC-19, in combination with the ITU-RR 2016, update the International Table of Frequency Allocations (Article 5).

3 The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard-development organizations: Association of Radio Industries and Businesses (ARIB); Alliance for Telecommunications Industry Solutions (ATIS); China Communications Standards Association (CCSA); European Telecommunications Standards Institute (ETSI); Telecommunications Standards Development Society, India (TSDSI); Telecommunications Technology Association (TTA); and Telecommunication Technology Committee (TTC). The Institute of Electrical and Electronics Engineers (IEEE) is a professional standard-setting association based in the United States of America.

4 See footnote 1.

5 The radio aspects of UMTS/HSPA, LTE/LTE-Advanced and 5G-NR are defined by 3GPP in series 25, 36 and 38, respectively. The WiMAX specifications are defined by IEEE in the 802.16 set of standards.

6 It is noted that Wi-Fi technology (i.e. WAS/RLAN) is not part of IMT.

7 It is noted that IMT is a system identification under the mobile service allocation.

in this report, cross-border coordination is often focused on avoiding co-channel interference between services.[8]

In addition to the ITU IMT Recommendations mentioned above, ITU has a wide range of reports, recommendations, guidelines and handbooks on spectrum sharing and compatibility and frequency coordination between the various services. In this report, extensive use is made of these ITU documents. However, reports have also been used from regional telecommunication organizations such as the European Conference of Postal and Telecommunications Administrations (CEPT), the African Telecommunications Union (ATU), and the Asia-Pacific Telecommunity (APT), as well as from industry initiatives (such as GSMA, 3GPP and IEEE) and national regulatory authorities.

Report structure

This report is structured as follows:

1) Sections 1 to 8 address the sharing and compatibility between IMT and other services in the following bands:
    a. 700 MHz, 800 MHz, 1.4 GHz, 2.3 GHz, 2.6 GHz, 3.5 GHz, 26 GHz band and the upper frequency range 37-71 GHz. Each section is concluded with a number of guidelines specific to the spectrum band covered in the section.
    b. It is noted that, because of the similar deployment status and available studies for the frequency range 37-71 GHz, the analysis of the conditions for the IMT introduction is conducted for the whole frequency range.
2) Section 9 addresses the transition from broadcasting analogue television to digital terrestrial television as a special spectrum-refarming process. This section concludes with specific guidelines for this transition process.
3) Section 10 addresses the technical conditions necessary for introducing IMT in the incumbent mobile bands before concluding with specific guidelines for introducing IMT in those bands.
4) Section 11 addresses the funding of refarming efforts (as described in Sections 1 to 8), necessary for clearing spectrum for the introduction of IMT, before offering specific guidelines on the said funding.
5) Section 12 provides an overview of general guidelines, applicable to all spectrum bands and aiding administrations in preparing for the introduction of IMT.

The following appendices are included in this report:

1) Glossary of abbreviations.
2) Appendix A: Cross-border frequency coordination.
3) Appendix B: ITU Recommendations and Reports.

[8] However, adjacent channel interference may also be addressed (for example in the situation of case-based frequency coordination), particularly for very sensitive receivers of some services, like Earth-exploration satellite services. For terrestrial services, adjacent channel interference is often limited to relatively small areas in the service or coverage areas of the service under consideration.

1 IMT sharing and compatibility with other services in the 700 MHz band

This section addresses the sharing and compatibility of IMT services in the 700 MHz band (i.e. allocated according to frequency arrangements as detailed by ITU-R and as identified in the ITU-RR) with other primary services in the same or adjacent bands.

1.1 IMT frequency arrangements in the 700 MHz band

Table 1 shows the IMT frequency arrangements in the 700 MHz band as included in Recommendation ITU-R M.1036-6. It is noted that administrations may implement a part of each frequency arrangement. The recommended frequency arrangement by the African Union Commission (AUC) is highlighted in grey.[9]

Table 1: IMT frequency arrangements in the 700 MHz band

Frequency arrangement	Paired arrangements (Frequency division duplex – FDD)				Unpaired arrangements (time division duplex) (MHz)
	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
A4	698-716	12	728-746	30	None
	776-793	13	746-763	30	None
					716-728
A5	703-748	10	758-803	55	None
A6					698-806
A7[10]	703-733	25	758-788	55	None
A8[11]	698-703	50	753-758	55	None
A9[12]	733-736	52	788-791	55	None
A10[13]	External		738-758		None
A11 (harmo-nized with A7 and A10)	703-733	25	758-788	55	None
	External		738-758		

9 AUC recommendation of 26 December 2016, "Guidelines on the Harmonized use of the Digital Dividend in Africa: Policy, Technical and Regulatory Procedures".
10 A7 arrangement aligns with the lower duplexer of A5.
11 A8 arrangement can be implemented alone or in combination with parts of A7.
12 A9 arrangement aligns with part of the upper duplexer of A5.
13 For A10 and A11, zero to four frequency blocks of 5 MHz in 738-758 MHz could be used to complement the downlink capacity of a frequency arrangement in this or other bands (i.e. supplemental downlinks).

From Table 1 the following can be observed and concluded:

1) Eight IMT frequency arrangements are identified in the 700 MHz band.
2) These eight frequency arrangements range from 698 MHz to 803 MHz.
3) Frequency arrangement A5 corresponds with the Asia-Pacific Telecommunity (APT) 700 MHz band plan for IMT.
4) Frequency arrangement A5 (including 3GPP band 28 and 17) is the most commonly applied frequency arrangement in the 700 MHz band around the world.[14]
5) Frequency arrangement A7, the lower duplexer of A5, is also aligned with the lower duplexer of the APT 700 MHz band plan. Hence, resulting in harmonization across Region 1 and the APT region.
6) Furthermore, the AUC proposes frequency arrangements A8, A9 and A10 as additional options for:

    a. A8 and A9, as options for the allocation of broadband to public protection disaster relief (PPDR)[15] or as additional capacity for non-PPDR services;
    b. A10, as an option for an additional downlink to the A7 arrangement for non-PPDR services.

1.2 Other services allocated in the 700 MHz band and adjacent bands

The frequency range of 698 MHz to 806 MHz (i.e. the range of the lowest to the highest frequency in Table 1) corresponds with the following (adjacent) parts of the ITFA for Region 1, as depicted in Table 2. Table 2 also includes the footnotes listed in the ITFA. Footnotes not relevant for the African countries or not relevant for the introduction of IMT are in brackets. Footnotes referring to IMT identifications are in blue.

Table 2: ITFA corresponding with the identified IMT frequency arrangements for the 700 MHz band (Region 1)

470-694 MHz		
Services:	Footnote number:	Footnote:
Broadcasting	(5.149)	Administrations are urged to take all practicable steps to protect the radio astronomy service. However, this request applies for the band 608-614 MHz in (Regions 1 and 3) which is 84 MHz apart from the lowest IMT frequency (698 MHz) in Table 1.
	(5.291A)	Additional allocation (to broadcasting) in the band 470-494 MHz to the radiolocation service on a secondary basis for eight countries in Europe.

[14] Source: Halberd Bastion, mobile networks deployment database. See https://halberdbastion.com/intelligence/mobile-networks/.

[15] This is according to the harmonized frequency arrangement for broadband PPDR by ATU in ITU-R Recommendation M.2015-2 (01/2018). It is noted that in this Recommendation, a third option for PPDR (in Section 1-1.4) is also included by ATU. However, with a selection of A7 to non-PPDR services this PPDR option is not possible.

Table 2: ITFA corresponding with the identified IMT frequency arrangements for the 700 MHz band (Region 1) (continued)

	(5.294)	Additional allocation (to broadcasting) in the band 470-582 MHz to the fixed service on a secondary basis for the following African countries: Cameroon, Côte d'Ivoire, Egypt, Ethiopia and Chad. However, the additional allocation is far apart from the lowest IMT frequency (see Table 1) and is an allocation on secondary basis which is outside the scope of this report (see Introduction).
	(5.296)	Additional allocation (to broadcasting) in the band 470-694 MHz to the land mobile service on a secondary basis, intended for applications ancillary to broadcasting and programme-making (SAB/SAP) in most European and African countries. This concerns an additional allocation on secondary basis which is outside the scope of this report (see Introduction).
	(5.300)	Additional allocation (to broadcasting) in the band 582-790 MHz to the fixed and mobile (except aeronautical mobile) services on a secondary basis in the following African countries; Cameroon, Egypt, Libya and Sudan.
	(5.304)	Additional allocation (to broadcasting) in the band 606-614 MHz to the radio astronomy service on a primary basis in the African Broadcasting Area.[16] However, the upper side of this radio astronomy band (i.e. 614 MHz) sits 84 MHz apart from the lowest IMT frequency (698 MHz) in Table 1.
	(5.306)	Additional allocation (to broadcasting) in the band 606-614 MHz to the radio astronomy service on a secondary basis, except in the African Broadcasting Area and Region 3.
	(5.312)	Additional allocation (to broadcasting) in several bands to the aeronautical radionavigation service on a primary basis in a number of European countries.

[16] Including all 54 African countries and a number of neighbouring countries in the Middle East. For the exact definition, see Articles 5.10-5.13 in the ITU-RR.

Table 2: ITFA corresponding with the identified IMT frequency arrangements for the 700 MHz band (Region 1) (continued)

694-790 MHz		
Services:	Footnote number:	Footnote:
Mobile except aeronautical mobile; broadcasting	5.312A	Resolution 760: Given various considerations, recognitions and notes, WRC-19[17] resolves that administrations resolving interference between broadcasting and other services should: a. Apply the procedures of GE-06[18] (where applicable) and consider ITU sharing studies; b. Resolve adjacent interference within a country as a national matter. Resolve adjacent channel interference between countries by using mutually agreed criteria (see ITU-R BT.1368, ITU-R BT.1895, ITU-R BT.2033 and ITU-R M.2090); c. WRC-19 also invites ITU-R to pursue further compatibility studies and invites administrations to contribute. Resolution 224: Given a number of considerations, recognitions and emphases, WRC-19 resolves that administrations should: a. Consider the relevant ITU-R Sector studies when implementing IMT; b. Protect existing and future broadcasting stations both analogue and digital, except analogue in the GE-06 planning area (in the band 470-806/862 MHz), as well as other primary terrestrial services; c. Coordinate, as required, with all neighbouring administrations prior to implementation; d. Implement IMT stations in line with the procedures contained in the GE-06 Agreement.[19]
	5.317A	The frequency bands 694-790 MHz and 790-960 MHz in Region 1, which are allocated to the mobile service on a primary basis, are identified for IMT.
	(5.300)	See above
	(5.312)	See above

17 The World Radiocommunications Conference 2019 (WRC-19) was held in Egypt from 28 October to 22 November, attended by 3 400 delegates representing 165 countries.

18 https://www.itu.int/en/ITU-R/terrestrial/fmd/Pages/GE-06-list.aspx.

19 Administrations which deploy stations in the mobile service for which coordination was not required, or without having obtained the prior consent of those administrations that may be affected, shall not cause unacceptable interference to, nor claim protection from, stations of the broadcasting service of administrations operating in conformity with the GE-06 Agreement. Those administrations shall also not object to nor prevent the entry into the GE-06 plan or recording in the MIFR of additional future broadcasting allotments or assignments.

Table 2: ITFA corresponding with the identified IMT frequency arrangements for the 700 MHz band (Region 1) (continued)

790-862 MHz		
Services:	Footnotes number:	
Fixed mobile except aeronautical mobile; broadcasting	5.316B	For countries party to the GE-06 Agreement, the use of stations of the mobile service is also subject to the successful application of the procedures of that Agreement (see Resolution 224 above).
	5.317A	See above
	(5.312)	See above
	(5.319)	Additional allocation in the bands 806-840 MHz and 856-890 MHz to the mobile-satellite (except aeronautical mobile-satellite) service in Belarus, the Russian Federation and Ukraine.

From Table 2 the following can be observed and concluded:

1) The non-IMT spectrum allocations in the range of 698 MHz to 803 MHz and in the adjacent bands include the following primary services:
    a. mobile except aeronautical mobile;
    b. broadcasting;
    c. fixed.
2) Only a limited number of footnotes are relevant for the African countries and the introduction of IMT:
    a. In the band 694-790 MHz (700 MHz band):
        i. 5.312A: Respecting the GE-06 Agreement and protecting the incumbent broadcasting services;
        ii. 5.317A: IMT identification.
    b. In the adjacent band 790-862 MHz:
        i. 5.316B: Implementation of IMT stations should comply with GE-06;
        ii. 5.317A: IMT identification.

Table 3 provides an overview of the applications and technology standards commonly applied[20] in Region 1 for the non-IMT applications as included in Table 2.

[20] This does not exclude the possibility that country-specific applications exist in the band, such as land and maritime military systems, alarms, remote controllers and radio-frequency identification (RFID).

Table 3: Common applications and technology standards per ITU-RR service for Region 1

Radio service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Mobile except aeronautical mobile 694-790 MHz 790-862 MHz	Services ancillary to broadcasting and services ancillary to programme-making (SAB/SAP).	Programme-making and special events (PMSE).[21]	Wireless microphones, wireless cameras and microwave links (for outdoor newsgathering), assistive listening services (ALD).	Various, for professional licensed and unlicensed (lower power) equipment.	European Telecommunications Standards Institute (ETSI)
	Public protection and disaster relief (PPDR).	Public protection and disaster relief (PPDR).[22]	Two-way mission critical narrow and broadband communication systems with specific requirements. The legacy narrowband systems are also referred to as PMR (professional mobile radio) and PAMR (public access mobile radio).	APCO (Association of Public-Safety	The Association of Public-Safety
				DMR (digital mobile radio)	ETSI
				TETRA (terrestrial trunked radio)	ETSI
				(Broadband) LTE/LTE-A[23]	3GPP, ITU
Broadcasting 470-694 MHz 694-790 MHz 790-862 MHz	Digital terrestrial television broadcasting (DTTB)	Digital terrestrial television	Digital terrestrial television	DVB-T/ DVB-T2	ITU, DVB consortium

21 According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), radio microphones and ALD are designated in 470-789 MHz (on a tuning range basis) and band 823-832 MHz, respectively.

22 According to ITU-R Rec. M.2015-2, the ATU recommends for broadband PPDR, frequency arrangements A8 and A9. See also footnote 16. According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), Broadband PPDR can be designated in the bands 698-703/753-758 MHz, 703-733/758-788 MHz and 733-736/788-791 MHz.

23 See ITU Recommendation ITU-R M.2015-2 (01/2018), frequency arrangements for public protection and disaster-relief radiocommunication systems in accordance with Resolution 646 (Rev.WRC-15).

Table 3: Common applications and technology standards per ITU-RR service for Region 1 (continued)

Radio service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
				ISDB-T	ITU, Digital Broadcasting Experts Group (DiBEG)
	Analogue television (ATV)[24]	Analogue television	Analogue terrestrial television	PAL (G/H)	ITU, ETSI
				SECAM	ETSI
Fixed 790-862 MHz[25]	Fixed and nomadic wireless access (FWA/NWA)	Broadband wireless access	Public and private broadband wireless access systems (for at home, shopping centres, airports, schools, etc.).	IEEE 802.16 (WiMAX)	IEEE
	Point-to-Point (P-P)[26]	Point-to-Point	Backhaul radio links in IMT networks, wireless metropolitan area networks (Wi-MAN) and corporate networks.	Various, including proprietary solutions.	ETSI
	Point-to-Multipoint (P-MP)[27]	Point-to-Multipoint	As above	As above	ETSI

From Table 2 and Table 3 the following can be concluded and noted:

1) The following potential incompatibilities could occur between IMT in the 698-806 MHz (see Table 1) and:

   a. DTTB/ATV in the 470-694 MHz, 694-790 MHz and 790-862 MHz band;

[24] According to the Southern African Development Community's (SADC) harmonized Radio Frequency Spectrum Allocation Plan, ATV is to migrate to DTTB in the band 470-694 MHz.

[25] According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), dated March 2019, the band 790-862 MHz is designated to IMT (layer 3 terminology). According to ECC Decision (01)03, IMT falls under Mobile/Fixed Communication Networks (layer 2 terminology), which in turn is part of Fixed (layer 3 terminology).

[26] These types of applications (P-P and P-MP) are commonly allocated in the higher spectrum bands. For example, in the CEPT (central European) countries, P-P and P-MP are used in frequency bands above 1 GHz. See ECC Report 173, "Fixed Service in Europe - Current use and future trends post 2016", dated 27 April 2018.

[27] See footnote 25.

b. SAP/SAB and PPDR (narrowband PMR/PAMR) in the 694-790 MHz and the 790-862 MHz bands;

c. FWA/NWA, P-P and P-MP in the 790-862 MHz band.

2) The national table of frequency allocations (NTFA) may indicate whether any of the applications in Table 3 are assigned and in use in a specific African country. Consequently, such use should be considered in assessing the compatibility with IMT systems in the 700 MHz band in that country.

1.3 Sharing and compatibility between IMT and the other services in the 700 MHz band

In spectrum management terms, sharing and compatibility studies are about investigating mechanisms to facilitate the efficient use of spectrum by different services in-band or in adjacent bands, considering the expected deployment of each service as well as the applied technology standards.

Hence, with regard to Tables 1 and 3, many sharing and compatibility studies can, in theory, be carried out as the frequency arrangement for IMT (Table 1) and the other services can vary, as can the applied technology standard for IMT and the other services (Table 3).

In this report, only the key IMT sharing and compatibility studies and their results are covered. Administrations are advised to interpret these study results with caution as their local situation (including the actual frequency allocations/assignments reflected in their NTFA, the applied technologies and interference scenario) may differ from the situation covered in the studies.

1.3.1 Overview of IMT sharing and compatibility studies

When considering the sharing studies between DTTB and IMT, it is important to note that the introduction of IMT in the so-called "digital dividend" bands[28] takes place in a different order between the ITU regions. This is due to the process of harmonizing the spectrum through the subsequent ITU WRCs:

1) WRC-07 enabled the first digital dividend for IMT in the band 790-862 MHz (800 MHz band) in Region 1 and 698-790 MHz (700 MHz band) in Regions 2 and 3.
2) WRC-12 and WRC-15 enabled the second digital dividend[29] for IMT in the band 694-790 MHz (700 MHz band) in Region 1 and in the band 610/614-698 MHz (600 MHz) in a few countries in Regions 2 and 3.

This different harmonization process between the Regions explains why the first compatibility studies, field trials and service introductions of IMT in the 700 MHz band (and DTTB in the 600 MHz band) took place in Regions 2 and 3. Whilst for Region 1 the introduction of IMT started in the 800 MHz band (and DTTB in the 700 MHz band). However, the results of the compatibility

[28] The digital dividend is the spectrum that becomes available over and above that required to accommodate the existing analogue television services in a digital form (see Report ITU-R SM.2353-0). Part of that available spectrum can be used for additional television services and another part for the introduction of IMT services.

[29] The second digital dividend is made possible, partly, due to more advanced transmission standards (such as DVB-T2 and ATSC 3.0) and encoding technologies (such as AVC/H.264 and HEVC/H.265), reducing the required spectrum for DTTB.

studies of having IMT in the 700 MHz (and DTTB in 600 MHz band) or 800 MHz (and DTTB in the 700 MHz band), are mutually relevant.[30]

A debate is taking place in Region 1, as part of the preparations for WRC-23, to also review the use of (and allocations in) the 600 MHz band (TV channels 38-48). For more details see Section 9.

Table 4 provides an overview of the key IMT sharing and compatibility studies relevant for the 700 MHz band. The second column indicates the compatibility case under consideration in the study, i.e. the compatibility between IMT and an application for the other services (see Table 3).

Table 4: Overview of key IMT sharing and compatibility studies relevant for the 700 MHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Related key topics/results
1	IMT-other applications: – PPDR; – DTTB; – ARNS (not relevant for Africa, see footnote 5.312 in Table 2).	ITU-R	Report M.2241-0 (2011)	Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz.	• Theoretical compatibility scenarios between IMT systems in 790-862 MHz or 698-806 MHz band and systems of other services operating in the same or adjacent band; • Co-channel: distances to protect IMT-LTE BTS receivers from PPDR BTS transmitters 170-385 km and for protecting PPDR BTS receivers from IMT-LTE BTS transmitters 170-360 km.
2	IMT-fixed services	ITU-R	Report F.2331-0 (11/2014)	Sharing and compatibility between IMT systems and fixed service systems in the 470-694/698 MHz frequency range.	• Theoretical compatibility scenarios between IMT and fixed services. Two interference scenarios are considered: IMT base station into FS receiver station and IMT user equipment (UE) into FS receiver station; • Co-channel: required separation distance from 25-220 km, depending on the interference scenario and deployment environment; • Adjacent channel: under realistic pointing scenarios, the interference can be mitigated through a combination of geographic separation and frequency separation.

[30] Noting that different interference scenarios may have been addressed, the key difference is relatively small propagation differences between the 700 and 800 MHz band.

Table 4: Overview of key IMT sharing and compatibility studies relevant for the 700 MHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Related key topics/results
3	IMT-DTTB	ITU-R	Report BT.2339-0 (11/2014)	Co-channel sharing and compatibility studies between digital terrestrial television broadcasting and international mobile telecommunication in the frequency band 694-790 MHz in the GE-06 planning area.	• Theoretical compatibility scenarios between IMT and DTTB in the GE-06 planning area.[31] Interference scenario is co-channel interference with DTTB in the 700 MHz band; • IMT network into DTTB: required separation distance 200-1 000 km (depending on scenario); • A single IMT base station will need to be positioned 53 km (for land path) from the DTTB service edge, i.e. from the border of the affected administration in order not to exceed 23 dB(μV/m), the trigger value.
4	IMT – DTTB	ITU-R	Report BT.2337-1 (11/2017)	Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz.	• Theoretical compatibility scenarios between IMT and DTTB inside and outside the GE-06 planning;[32] • Results for DTTB inside the GE-06 planning area, the results of Report BT.2339-0 (11/2014) are reproduced; • Result for DTTB outside the GE-06 planning area not relevant for African countries (but similar in conclusion that sharing is difficult).

[31] This is relevant as the GE-06 Agreement specifies DTTB interference protection values, the so-called trigger values (the calculated medium interference field strength of IMT at the border).
[32] See footnote 30.

Table 4: Overview of key IMT sharing and compatibility studies relevant for the 700 MHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Related key topics/results
5	IMT – DTTB	ITU-R	Report BT.2301-2 (10/2016)	National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services.	• National field reports on the introduction of LTE in the 800 MHz band using the reverse duplex arrangement and DTTB in 700 MHz band; • Germany: Only 10 complaints of interference into the broadcasting service were identified as caused by LTE, due to thorough implemented methodology (i.e. potential interference was checked before IMT base station was approved); • France: LTE 800 MHz BS downlinks interfere with fixed roof-top DVB-T reception, despite 1 MHz guardband. Interference is, however, limited and can be mitigated (applying filters at DTTB RX); • The Netherlands: No reported interference from IMT into DTTB reception with a 1 MHz guardband; • Spain/Portugal: temporarily having DTTB (Spain) and IMT (Portugal) both in 800 MHz resulted in co-channel interference.
6	IMT-DTTB	ACMA	ACMA website[33]	DVB-T in 520-694 MHz (restacked) and LTE in 700 MHz band. DVB-T nationwide (i.e. around main cities) and IMT fully deployed (Optus and Telstra).	• No significant impact on DTTB. Some cases of TV distribution amplifiers being overloaded by LTE BS signals (within 1 km);[34] • No specific mitigation scheme for LTE 700 MHz interference. Hence no formal reporting. ACMA site provides DTTB viewers mitigation measures, to apply filters and change RX antenna.

[33] See https://www.acma.gov.au/700-mhz-technical-framework.

[34] See also BT.2296-0 (11/2013), including an example of application of Recommendation ITU-R BT.1895 and Report ITU-R BT.2265 to assess interference to the broadcasting service caused by the impact of IMT systems on existing head amplifiers of collective television distribution systems.

Table 4: Overview of key IMT sharing and compatibility studies relevant for the 700 MHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Related key topics/results
7	IMT-ATV	ITU-R	Report M.1023-1 (1990)	Frequency sharing between the land mobile service and the broadcasting service (television) below 1 GHz.	• Theoretical compatibility scenario between mobile and television services; • Television services typically operate with considerably larger radiated powers than mobile services. The total difference of 70 dB in the planning criteria of the two services suggests that sharing will be difficult.
8	IMT-SAB/SAP	ITU-R	Report BT.2338-0 (11/2014)	Services ancillary to broadcasting/ services ancillary to programme-making spectrum use in Region 1 and the implication of a co-primary allocation for the mobile service in the frequency band 694-790 MHz.	• Measurements show that a co-channel and co-location operation between SAB/SAP and IMT is not feasible; • IMT guardbands and duplex gaps could be used for certain SAB/ SAP applications, which can tolerate some levels of interference. Improvement of out-of-band performance of LTE devices can increase the potential utilization for SAB/SAP.

From Table 4, the following can be observed and concluded:

1) Sharing of IMT and PPDR[35] services in the same frequency band is, in most cases, not possible because:

   a. both applications are often deployed nationwide;

   b. as a number of studies have shown, the co-channel separation distances for protecting IMT-LTE BTS or PPDR BTS range from 170 to 385 km and from 170 to 360 km, respectively (see No. 1 in Table 4). This makes separating them geographically within the same country a less practical option.

2) Sharing of IMT and fixed services (P-P and P-MP) in the same frequency band requires separation distances ranging from 25 to 220 km, depending on the interference scenario and deployment environment. However, under realistic pointing scenarios, the interference can be mitigated through a combination of geographic separation and frequency separation (see No. 2 in Table 4).

3) Sharing of IMT and DTTB services in the same frequency band is, in most cases, not possible because:

   a. both applications are often deployed nationwide;

[35] It is noted that PPDR systems can be based on IMT/LTE. For PPDR-IMT, separate frequency arrangements are included in ITU Recommendation ITU-R M.2015-2 (01/2018).

b. studies have shown that the co-channel separation distances for protecting the DTTB services range from 200 to 1 000 km (see Nos. 3 and 4 in Table 4). This makes separating them geographically within the same country a less practical option.

4) Compatibility of IMT and DTTB services is possible when the applications are allocated in spectrum adjacent to each other (see Nos. 5 and 6 in Table 4). Technical conditions may apply, such as, applying guardbands, reverse IMT duplexing and filtering of IMT BTS/DTTB receivers (for more details see Section 1.3.2).
5) Sharing of IMT and ATV services in the same frequency band is not possible for the same reasons as for IMT/DTTB, and in many cases the interference situation is worse because of the higher radiated powers in ATV broadcasting (see No. 7 in Table 4).
6) Coexistence of IMT and SAB/SAP services at the same location is not possible. Sharing scenarios may exist for having certain SAB/SAP applications (i.e. those that can tolerate some levels of interference) in the IMT guardbands and duplex gaps. These possibilities for sharing may increase if the out-of-band performance of LTE devices improves (see No. 8 in Table 4).

1.3.2 Technical conditions for IMT sharing and compatibility

As concluded from Table 4, several compatibility and sharing options between IMT and other services have been identified. Table 5 provides an overview of technical conditions under which such options are technically feasible. It is noted that the specific local situation will dictate which and to what extent the listed technical conditions need to be applied.

For the technical conditions presented in Table 5, it is assumed that the radio equipment involved in the interference case complies with a minimal (least restrictive) and, preferably, a harmonized set of technical conditions. Such a set of minimum technical conditions may be checked as part of a type-approval procedure for granting the use of radio equipment in the national regulatory authority's (NRA) territory. Also, such a set of minimum criteria often include emission limits/spectrum masks and may be complemented with other conditions such as for human safety (EMC).[36]

Finally, the conditions included in Table 5 address the conditions for separating IMT from other non-IMT applications. Conditions for separating frequency blocks between IMT operators (such as guardbands, spectrum masks and radiated power level) are not addressed.

[36] For example, CEPT has identified common and minimal (least restrictive) technical conditions for the 790-862 MHz band for IMT (mobile/fixed communications networks - MFCN) equipment in the European Union. See CEPT Report 30. The technical conditions included in that report are based on block edge mask emission limits. See also ETSI EN 301 908-1 harmonized European standard for IMT cellular networks.

Table 5: Technical conditions for IMT sharing and compatibility in the 700 MHz band

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
IMT-DTTB[37]	Compatibility in adjacent bands	IMT in 700 MHz, DTTB in 600 MHz band[38]	Apply (preferably a harmonized) guardband at the IMT lower band edge. For example, for the CEPT area, 9 MHz (694-703 MHz) is recommended.	CEPT/ECC Decision (15)01[39]	Consideration should be given to the assumed IMT frequency arrangement. The ECC Decision (15)01 considers A7 (the lower duplexer from A5, see Table 1).
		IMT in 700 MHz, DTTB in 600 MHz band	Reverse the duplex direction (with the mobile terminal transmitting within the upper band and base station transmitting within the lower band), for example, in exceptional cases in which a minimum guardband cannot be implemented.	See Rec. ITU-R M.1036-6; See frequency arrangement A4 in Table 1 (or 3GPP band 13).	The AUC harmonized band plan recommends A7, which is not a reversed duplex arrangement.[40]

[37] Most documented technical conditions are for DTTB rooftop reception (as this is the applied reception mode in most countries). For indoor reception, the necessity to apply certain technical conditions may be different and should be investigated separately.

[38] The interference case of having IMT in the 700 MHz band and DTTB in the 800 MHz band is excluded for Region 1, as it assumed that IMT is first introduced in the 800 MHz band (first digital dividend) followed by an introduction in the 700 MHz band (second digital dividend).

[39] This decision is based on and further detailed in CEPT Report 053. CEPT Report 060 reviewed the findings of Report 053 and found no need to revise the channelling arrangement.

[40] See footnote 10.

Table 5: Technical conditions for IMT sharing and compatibility in the 700 MHz band (continued)

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
		LTE BTS transmitter (TX) in 700 MHz band into DTTB RX in 600 MHz band (overloading)[41]	Apply a filter at the DTTB receiver. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of technical conditions including: • Repositioning or replacement of the DTTB (rooftop) antenna; • Repositioning of the LTE BTS and/or changing antenna pattern. (includes a critical spectrum mask);[42] • Reduction of ERP of the LTE BTS TX.	See Rep. ITU-R BT.2215-7 (04/2018). See Rec. ITU-R M.2090-0 (10/2015); See Rec. ITU-R BT.2033-1 (02/2015); See also Nos. 4 and 5 in Table 4.	Anatel laboratory and field tests[43]
		LTE BTS TX in 700 MHz band into DTTB RX in 600 MHz band (unwanted emissions)[44]	Apply a filter at LTE-BTS transmitter. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of technical conditions including: • Repositioning or replacement of the DTTB (rooftop) antenna; • Repositioning of the LTE BTS and/or antenna pattern (includes a critical spectrum mask).	See Rec. ITU-R M.2090-0 (10/2015); See Rec. ITU-R SM.1541-6 (08/2015); See Rec. ITU-R BT.2033-1 (02/2015); See also Nos. 4 and 5 in Table 4.	Anatel laboratory and field tests

41 Overloading (DTTB and IMT/LTE receivers): the receiver begins to lose its ability to discriminate against interfering signals at frequencies differing from that of the wanted signal. In the case of DTTB receivers, overloading means in practice that usually all frequencies are interfered and hence all television services.

42 In this context a critical spectrum mask is a mask that is more restrictive than the minimum (least restrictive) spectrum mask conditions.

43 Anatel (the NRA of Brazil) compatibility study between LTE and DTTB (ISDB-T) in the 700 MHz Band. Both the laboratory and field test reports are available on the Anatel website: https://www.anatel.gov.br/Portal/verificaDocumentos/documento.asp?numeroPublicacao=311027.

44 Unwanted emissions: Consist of spurious emissions and out-of-band emissions.

Table 5: Technical conditions for IMT sharing and compatibility in the 700 MHz band (continued)

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
		DTTB in 600 MHz band into LTE BTS RX in 700 MHz band (overloading)	Apply a filter at LTE-BTS receiver. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of technical conditions including: • Repositioning of the DTTB TX antenna and/or antenna pattern (includes a critical spectrum mask); • Repositioning the LTE BTS and/or antenna pattern; • Reduction of ERP of the DTTB TX antenna.	See Rec. ITU-R M.1767 (03/2006); See Rec. ITU-R SM.1541-6 (08/2015); See Rec. ITU-R BT.1206-3 (04/2016).	Anatel laboratory and field tests
		DTTB in 600 MHz band into LTE BTS RX in 700 MHz band (unwanted emissions)	Use of critical spectrum mask at DTTB station TX. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of technical conditions including: • Repositioning of the DTTB TX antenna and/or antenna pattern; • Repositioning the LTE BTS and/or antenna pattern; • Reduction of ERP of the DTTB TX antenna.	See Rec. ITU-R BT.1206-3 (04/2016); See Rec. ITU-R M.1767 (03/2006); See Rec. ITU-R SM.1541-6 (08/2015).	Anatel laboratory and field tests
		DTTB in 600 MHz band into LTE UE RX in 700 MHz band (overloading)	Reposition or use more robust IMT UE. The practical and financial application of these technical conditions should be carefully considered.	None	Anatel laboratory and field tests
		DTTB in 600 MHz band into LTE UE RX in 700 MHz band (unwanted emission)	Use of critical spectrum mask at DTTB station TX. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of technical conditions including using more robust IMT UE (see also above).	See Rec. ITU-R BT.1206-3 (04/2016); See Rec. ITU-R SM.1541-6.	Anatel laboratory and field tests

Table 5: Technical conditions for IMT sharing and compatibility in the 700 MHz band (continued)

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
IMT- ATV	Compatibility in adjacent bands	In principle the same interference cases as for DTTB[45]	Any UHF ATV service cannot claim protection from and should not cause harmful interference to any assignments in conformity with the Agreement and its associated plans.[46]	GE-06 Agreement	The Agreement contains two plans: a digital plan and an analogue plan. The analogue plan expired by 17 June 2015 for the UHF band.[47]
IMT-SAB/SAP (i.e. wireless microphones)	Compatibility in adjacent bands	IMT in 700 MHz band and SAB/SAP in 600 MHz	Apply (preferably a harmonized) guardband at the IMT lower band edge, as SAB/SAP often operate in the same band as the broadcasting services (including DTTB). In such a case the guardband size will be determined based on the compatibility between IMT and DTTB. It is noted that SAB/SAP equipment includes unlicensed equipment and hence the NRA does not know the actual use (intensity and locations) of SAB/SAP equipment. For this reason, NRAs have decided to migrate SAB/SAP to other bands to exclude any risks of harmful interference.	See above	See above

45 For ATV, specific interference types may occur, i.e. loss of automatic gain controller and image channel interference. These interference types are deemed unlikely to occur for DTTB as DTTB receivers constantly improve and are well shielded. In planning ATV frequency, it is common to check for image channel interference but this is not common practice for planning DTTB frequency.

46 Article 12.8 of the GE-06 Agreement allows the continuation of analogue stations on a non-interference and non-protection basis.

47 Note 7, related to Article 12.6 of the GE-06 Agreement, lists countries where the transition period for Band III (VHF band) was to end on 17 June 2020.

Table 5: Technical conditions for IMT sharing and compatibility in the 700 MHz band (continued)

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
	Sharing in the same band	IMT in the 700 MHz band and SAB/SAP in guardbands and/or multiplexer gap	Set limits to the radiated power (and other specifications such as out-of-band and spurious emissions) of SAB/SAP applications in combination with type-approval of robust SAB/SAP equipment. A main concern is the unwanted emissions by an LTE UE to a SAB/SAP (PMSE) receiver as such equipment is of low complexity or has no error correction.	See ETSI EN 300 422 (parts 1 to 4); Rep. ITU-R BT.2338-0 (03/2015)	
IMT-fixed services (i.e. P-P and P-MP)	Sharing in the same band	IMT and fixed services in the 700 MHz band[48]	Any interference can be mitigated through a combination of geographic separation and frequency separation. This will require case-by-case approval of any fixed service by the NRA.	Rep. ITU-R F.2331-0 (11/2014)	
IMT- PPDR	Compatibility in adjacent bands	IMT in the 700 MHz band and PPDR in an adjacent band[49]	Apply (preferably a harmonized) guardband at the IMT upper band edge. However, specific frequency arrangements are identified for PPDR systems based on IMT/LTE.	Rec. ITU-R M.2015-2 (01/2018); Rec. ITU-R M.2009-2 (01/2019); Rep. ITU-R M.2291-1 (11/2016)	

From Table 5 the following can be observed and noted:

1) The technical conditions or measures listed are often applied in combination with each other, as well as in conjunction with regulatory conditions as outlined in Section 1.3.3. For example, the condition of applying guardbands is set in combination with an obligation for the IMT licensee to resolve any remaining harmful interference by filtering the IMT BTS.
2) Stricter applied technical conditions on the receiver/transceiver equipment may help reduce the guardband sizes (as guardbands for IMT systems should be minimized to avoid wasting spectrum).
3) The specific local situation will dictate which listed technical conditions need to be applied and to what extent.

48 It is noted, however, that fixed services (P-P/P-MP) are commonly operated in the bands 1-3 GHz. See also footnote 24.

49 It is assumed that PPDR would not be allocated in the 600 MHz band as this band is likely to be used for broadcasting services.

1.3.3 Regulatory conditions for IMT sharing and compatibility

NRAs or administrations may wish to complement the technical conditions under which they grant the IMT spectrum rights (see Section 1.3.2)[50] with specific IMT regulatory conditions (next to the general conditions for assigning spectrum rights[51]). These specific IMT-related conditions often arise from the situation that the IMT applications are introduced in bands with incumbent services that need to be protected.

Table 6 provides an overview of these IMT-specific regulatory conditions.

Table 6: Regulatory conditions specific for IMT licensees

No	Condition or requirement	Notes	References
1	The IMT licensee has the obligation to arrange for the provision of filters for DTTB receivers, for eligible households or all households with a television.	This can be a general provision in the IMT licence terms and conditions. In case the NRA receives complaints from DTTB households and assesses them eligible, the IMT licensee has an obligation to provide filters.	See the procedure as applied in the Netherlands (but also in other European countries), see No. 5 in Table 4. See also Rec. ITU-R SM.1603 (section 4.2.1 and 4.2.2).
2	The IMT licensee has the obligation to apply a critical spectrum mask at certain identified BTS or all BTS.	For example, the BTS can be identified in a frequency-assignment procedure in which the IMT licensee has to seek approval from the NRA before the IMT licensee can take the BTS into operation.	See the procedure as applied in Germany, see No. 5 in Table 4.
3	The IMT licensee has the obligation to reposition the BTS and/or change the antenna diagram/direction for certain identified BTS or all BTS.	Such a provision will require the IMT licensee to seek approval from the NRA before it can take any BTS into operation. The repositioning or change of the antenna diagram may be determined in consultation with the DTTB (or any other service) licensee (and may require a change of the DTTB network).	See above.

50 These spectrum rights may be assigned in a separate spectrum licence or part of a network or service licence, depending on the licensing framework of the different countries.

51 To comply with the assigned spectrum rights, including the guardbands, assigned spectrum blocks and duplex direction (for example, a reversed duplexing arrangement).

Table 6: Regulatory conditions specific for IMT licensees (continued)

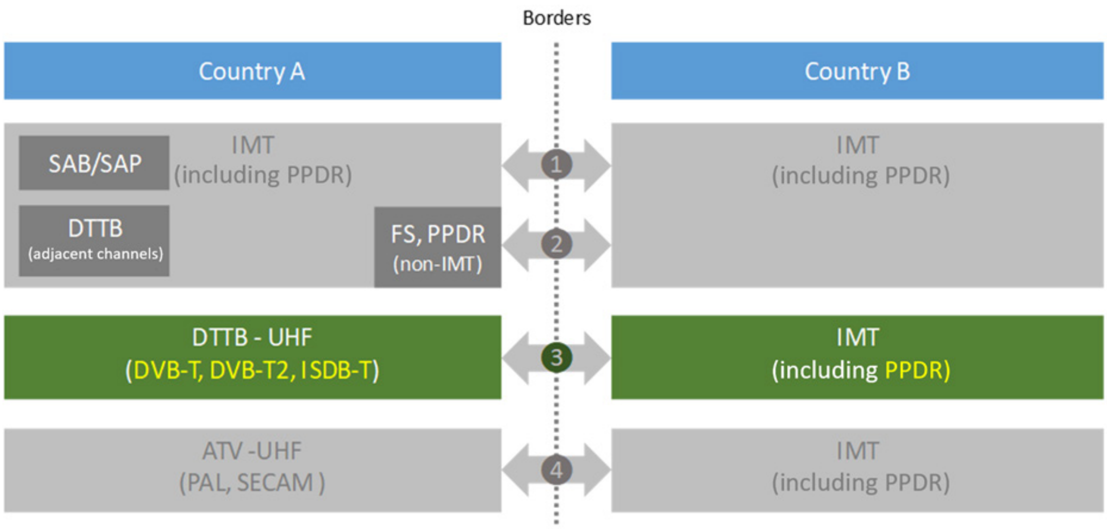
No	Condition or requirement	Notes	References
4	The IMT licensee has the obligation to compensate for any incurred costs by the incumbent service. Most commonly applied for DTTB. Here the IMT licensee must contribute to the costs of replanning and implementation of the revised DTTB networks, as well as the cost of retuning DTTB receivers and receiving antennas.	In case the DTTB networks had to vacate the band (i.e. refarming). Such an obligation to compensate for incurred costs may also be applied to other services (such as fixed services or SAB/SAP).	See for example the United Kingdom, the United States[52] and other countries (including for example Thailand).
5	The IMT licensee has the obligation to help investigate any complaints about interference of incumbent services (may include DTTB).	Such an obligation may come with the obligation to resolve the interference problem too (see above).	

1.3.4 Cross-border coordination aspects for IMT

Cross-border inference cases between countries are a subset of the interference cases within a country (as discussed in Section 1.3.1) as, in this frequency band, they mainly cover emissions located closer to the border.

Figure 1 shows a generic overview of the possible cross-border interference cases for the 700 MHz band.

Figure 1: Generic overview of possible cross-border interference cases for the 700 MHz band



[52] In the United States in the 600 MHz incentive auction, the IMT licensee also paid for the relinquishing of the broadcasting spectrum rights and organizing the auction (by having a reserve price that would at least cover these costs). See also Section 11.2.3.

First, it is noted that the potential interference case between FS/PPDR (non-IMT) and DTTB is not included in Figure 1. It is assessed that these cases are rare as it is assumed that such cases would have been resolved with the introduction of DTTB in the 700 MHz band.

The following interference cases are included in Figure 1:

1) Cross-border cases, numbers 1 and 2:

   a. Interference case 1: This may arise in the final stages when administrations have adopted IMT and their stations' emissions are within the coordination zone for these services. As references, the HCM[53], HCM4A[54], BKO-18[55] and the Vienna Agreement[56] provide procedures and parameters for managing possible cross-border interference between IMT services. It is noted that these agreements are based on a system of maximum permissible interference field strengths levels, and if the calculated interference level is higher (trigger value), coordination is needed. It is also noted that the HCM, HCM4A and Vienna Agreement cover both land mobile and fixed services.
   b. Interference case 1: Alternatively, and specifically for cross-border coordination of LTE and NR/5G applications, a system of physical cell identity (PCI) can be used. A PCI is an identification of an IMT cell at the physical layer and represents a specific frequency which can be used in cross-border coordination. ECC Rec. (15)01[57] provides guidance for cross-border coordination on the basis of PCI. The recommendation provides the following on cross-border coordination for the band 694-790 MHz:

      i. A system by dividing preferential and non-preferential PCIs between administrations, on the basis of equitable spectrum access whereby administrations should share PCIs in border areas and have equitable distribution of available 504 (LTE) or 1008 (NR/5G) PCIs, for preferential and non-preferential PCIs.
      ii. Preferential and non-preferential PCIs have different trigger values (expressed in dBμV/m/5 MHz). Coordination is needed if the interfering field strength is higher (Annex 1). The interfering field strength is calculated on the basis of defined propagation models (Annex 2).
      iii. A procedure for the exchange of data between the requesting and the affected administrations (Annex 3).
      iv. A detailed system for assigning PCIs to countries. The system is based on a cell-colouring system[58] for the CEPT countries. However, African countries can adapt the proposed system for their local situation.

53 Harmonized Calculation Method Agreement between the Administrations of Austria, Belgium, the Czech Republic, Germany, France, Hungary, the Netherlands, Croatia, Italy, Liechtenstein, Lithuania, Luxembourg, Poland, Romania, the Slovak Republic, Slovenia and Switzerland on the coordination of frequencies between 29.7 MHz and 43.5 GHz for the fixed service and the land mobile service (HCM Agreement), dated 2018.

54 HCM for Africa (HCM4A) agreement was developed under the harmonization of ICT policies project for sub-Saharan Africa. The agreement has been endorsed/implemented, partly, by some of the regional economic communities (RECs) of the African Union. PRIDA will update the agreement and will provide technical support to foster its adoption and implementation.

55 Agreement between the administrations of eight west African countries (Burkina Faso, the Gambia, Guinea, Guinea-Bissau, Côte d'Ivoire, Mali, Niger and Senegal) covering 87.5 MHz to 30 GHz and radiocommunication services such as sound broadcasting service, land mobile service and fixed service.

56 See ITU-R SM.1049-1, Annex 2, example 3.

57 ECC Recommendation (15)01, Cross-border coordination for MFCN in the frequency bands 694-790 MHz, 1 427-1 518 MHz and 3 400-3 800 MHz, approved on 13 February 2015 and last amended on 14 February 2020.

58 A system whereby countries are assigned to groups and each group has a unique colour. On a map the same colour should not touch and should be separated as far possible. The same colour implies the same frequencies and co-channel interference can be best achieved when colours are separated as far as possible.

c. Interference cases 2: Fixed services (FS) and PPDR (not based on IMT but on other applications such as TETRA or APCO Project 25) may be incompatible with IMT. As mentioned before, PPDR systems may be based on IMT (see Table 3), as for such systems separate frequency arrangements have been agreed.[59] Also, administrations may have agreed shared frequencies for these systems, allowing for cross-border operations. For the cross-border coordination of land mobile services (non-IMT PPDR) also the HCM, HCM4A, BKO-18 and Vienna Agreements as mentioned above, can be used as reference. Cross-border coordination of fixed services (P-P) are likely to be incidental and a case-based coordination can be used where any harmful interference can be mitigated by applying technical measures (see Report ITU-R F.2331-0 and Table 5).

2) Cross-border case 3: This case entails the possible incompatibilities between IMT and DTTB, the latter including the three different transmission standards applied in Africa. These transmission standards are important as their transmitters have different frequency characteristics, bandwidth and modulation schemes. Consequently, they have different interference potential.

3) Cross-border case 4: This case entails the possible incompatibilities between IMT and ATV services. Again, the latter includes the two different ATV systems which may still be in operation in Africa in the UHF band. It is noted that in the cross-border coordination between countries, both interference cases number 3 and number 4 may need to be addressed, if analogue switch-off (ASO) has not yet taken place.[60]

For mitigating any identified interference cases between countries, two basic approaches exist:

1) case-based coordination; and
2) agreement-based coordination.

Case-based frequency coordination is, in principle, applied in the absence of bi- or multi-lateral agreements. Case-based refers to the situation of one country (i.e. administration) in need of coordinating a frequency (or a set of frequencies) that it would like to protect from harmful interference or which it expects could cause harmful interference. Case-based coordination would ultimately result in an agreement on the frequency usage of the frequencies involved in the case.

Bilateral or multilateral agreements are agreed well in advance of the actual (detailed) planning and assignment of frequencies. These agreements include, in varying degrees, the process or method of frequency coordination (such as procedures, datasets, registers, propagation models and planning software) and the key applied parameters (such as specified levels of harmful interference, coordination zones and distances).

In Appendix A: Cross-border frequency coordination, more details can be found on case-based and agreement-based coordination.

In the case of cross-border interference cases numbers 3 and 4 (see Figure 1), the African countries should follow the procedures included in the GE-06 Agreement. This would also be the same for any potential interference case between FS/PPDR (non-IMT) and DTTB-UHF. As indicated earlier, these cases are not included in Figure 1. It is assessed that these cases are

[59] See ITU-R Recommendation M.2015-2 (01/2018).
[60] According to the PRIDA Explanatory Memorandum, the digital switchover in the 700 MHz and 800 MHz bands has been completed in 40 per cent of the 54 countries.

rare as it is assumed that such cases would have been resolved with the introduction of DTTB in the 700 MHz band.

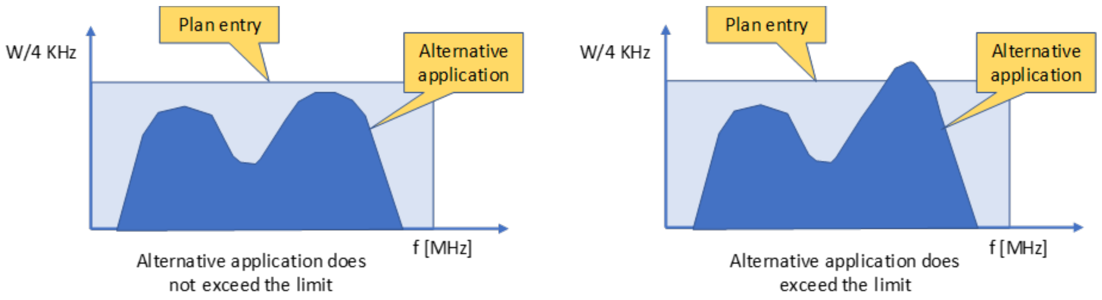
The procedures as included in the GE-06 Agreement can be summarized as follows:

1) First, IMT stations should be coordinated by using the existing digital plan entries for that country in the GE-06 Agreement (see also Table 2).
2) Second, if the IMT stations cannot be coordinated by using the existing digital plan entries (such as when a satisfactory IMT service cannot be obtained by using a plan entry), the country concerned could consider modifying the plan entry in accordance with the provisions of Article 4 of GE-06. It is important to note that the IMT service shall not cause unacceptable interference to, nor claim protection from, stations of the broadcasting service of administrations operating in conformity with the GE-06 Agreement. Also, the Article 4 procedure should be completed in about 27 months and if no agreement has been reached within that time, the request for modification lapses.

If a plan entry is used for an alternative application, such as IMT, GE-06 Article 5.1.3 allows such an entry under the condition of complying with the spectral power density check, whereby three conditions are verified:[61]

1) The frequency band should be allocated in ITU-RR.
2) The peak power density in any 4 kHz part of the alternative application should not exceed the spectral power density in the same 4 kHz part of the plan entry (see Figure 2).
3) The alternative application should not claim more protection than is provided by the plan entry.

Figure 2: Application of the GE-06 spectral power density check



Source: ITU

1.4 Best practices and methods for refarming other services in the 700 MHz band

Refarming in the context of this report means the replanning of incumbent services is deemed incompatible with the introduction of IMT services. In other words, the spectrum needs to be freed up or cleared for IMT. From Tables 4 and 5, it can be concluded that the following services or applications may have to be replanned or reallocated to adjacent or other bands:

1) DTTB;
2) ATV; and
3) wireless microphones (SAB/SAP).

[61] For more detailed information, see ITU Guideline for the transition from analogue to digital broadcasting, edition 2014, Annex A.

The financial funding of these refarming efforts is addressed in Section 11. It is noted that Recommendation ITU-R SM.1603 also covers general approaches to spectrum redeployment and refarming, guidelines for calculating refarming (or redeployment) costs, as well as examples of country experiences with refarming.

1.4.1 Refarming DTTB services

Refarming of DTTB services involves migrating a set of DTTB services, broadcasted on a given set of frequencies, to another set of frequencies in the band adjacent to the IMT services. This process should be well planned as it often involves a large audience of DTTB viewers having to retune their DTTB receivers (including set-top boxes and integrated digital television sets: STB and IDTVs, respectively) at a given date. After retuning, these DTTB viewers should be able to continue enjoying their DTTB services without service interruption.

Refarming of DTTB services may involve the introduction of a new transmission standard (e.g. DVB-T2) and encoding technology (e.g. H.265/HEVC), so as to reduce the number of frequencies needed to broadcast the defined set of DTTB services (which may include ultra-high-definition/4K services). Such a transition would often require the replacement of existing DTTB receiver equipment (which may be based on DVB-T and H.264/AVC).[62] Replacement of broadcasting receiving equipment is also part of the process of refarming ATV services as described in Section 9.

The following paragraphs describe the process of refarming DTTB services without the need to replace DTTB receiver equipment. Commonly the process involves four parts:

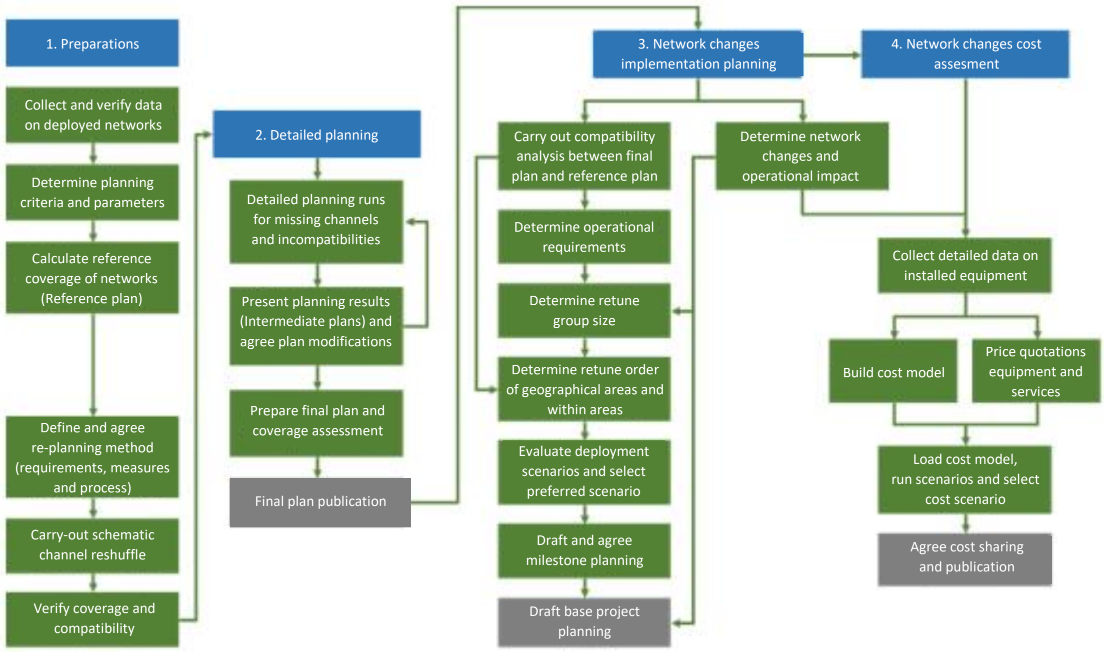
1) Preparing and calculating current coverage, including:
    a. determining planning criteria and parameters for calculating rooftop (and indoor) reception;
    b. calculating the reference coverage of the DTTB networks (reference plan);
    c. defining and agreeing the planning method for the new frequency plan (including how channels will be restacked/reshuffled);
    d. carrying out a schematic channel reshuffle and verifying the coverage and compatibility of this initial new plan.
2) Carrying out detailed planning in several runs for any missing channels and finding incompatibilities, resulting in a final plan.
3) Drafting an implementation plan for carrying out the necessary DTTB network changes including:
    a. a compatibility analysis between the final plan and the reference plan;
    b. determining the retune groups and their order (avoiding any found incompatibilities);
    c. drafting a milestone plan;
    d. determining the necessary equipment and operational changes (by comparing the reference plan and final plan).

[62] For example, as was the case in the United Kingdom when IMT was introduced in the 700 MHz band DVB-T2 was introduced. The United Kingdom, like many other European countries, started DTTB with DVB-T.

4) Assessing the costs of the required network changes. This may also include the costs of informing viewers about the necessary equipment retuning and providing installation aid (in case DTTB receiver antennas need to be replaced).

Figure 3 shows an overview of the process described above.

Figure 3: Process of refarming DTTB services



For the implementation of the new frequency plan, several factors can be considered, which are included in Table 7.

Table 7: Key implementation factors

Item	Rationale
Ordering lead time for equipment (e.g. filter sections or transmitter parts)	A longer ordering lead time is better for: – Absorbing delivery eventualities; – Preparatory and communications activities; – Preparing and agreeing implementation.
Lead time between retune phase	A longer lead time between phases is better for: – Absorbing retune eventualities and roll-back; – Carrying out finalizing activities; – Less risks of (foreign) expert unavailability; – Changing the retune calendar for remaining regions.
Number of retune phases	A higher number of phases reduces strain on: – The retune capacity of network operators and facility providers (e.g. tower companies); – Supplier/expert capacity.

Table 7: Key implementation factors (continued)

Item	Rationale
Roll-back and mitigation	Roll-back and mitigation plan should cover several elements, including: – Checking compatibility of intermediate networks for failed and other sites: if one or more sites failed to retune, new intermediate network configurations may be needed; – Finding a compatible insert for failed sites in later phases: the failed sites in a new network configuration in the reference situation need to be inserted in the remaining retune phases; – the retune dates of the remaining retune phases may need to be changed. A first priority should be to avoid changing the retune calendar (current region and/or next regions).

1.4.2 Refarming ATV services

Refarming ATV services is a process of migrating ATV services to a DTTB platform. In the context of introducing IMT services, this would entail migrating the ATV services to a DTTB platform in an adjacent band to the IMT service. The process of migrating ATV services to a DTTB platform includes some unique planning aspects, such as:

1) Simulcasting (whereby the same TV service is available on the analogue and digital platforms for a limited period) and infrastructure availability (as equipment for ATV and DTTB has to be facilitated at the same site and time).
2) Switching off the ATV services (ASO) and informing the ATV viewer.
3) Replacing ATV receiving equipment with DTTB receivers, along with the associated costs and viewer support.

An overview of this process and the associated guidelines are provided in Section 9.

1.4.3 Refarming SAB/SAP

Many refarming options can be considered for clearing SAB/SAP usage. Considering the options as shown in Table 4, three basic migration scenarios exist:

1) Migrating all SAB/SAP usage outside the 700 MHz band, for both licensed and unlicensed equipment/low power.
2) Migrating defined SAB/SAP usage (e.g. licensed usage, professional digital equipment which is robust for IMT interference) into the guardbands and multiplexer gaps and the remaining SAB/SAP usage outside the 700 MHz band (e.g. unlicensed usage/low power).
3) Migrating defined SAB/SAP usage (e.g. licensed usage, professional digital equipment) into the guardbands and multiplexer gaps and keeping other defined SAB/SAP usage (e.g. low-power equipment in combination with type approval) in the 700 MHz band.

The local situation at hand will demand which of these basic options are most feasible in terms of:

1) Avoiding harmful interference and the extent to which the NRA will be able to mitigate any occurring interference. Factors that could be considered in assessing the associated risks include:

a. the licensing regime (including the licence conditions, such as technical conditions as discussed in Table 5);
b. licence period and terms for (automatic) renewal;
c. the number of assigned licences for SAB/SAP (which may be recorded in the NTFA or a national frequency register);
d. procedure for type approval and registration of SAB/SAP equipment;
e. enforcement regulations;
f. deployment of SAB/SAP equipment and the ability to retune this equipment to other frequencies.

2) Compatibility with the introduction of IMT and other services in the longer term (five to 10 years). Factors that could be considered in assessing this long-term compatibility and drafting a long-term scenario include:

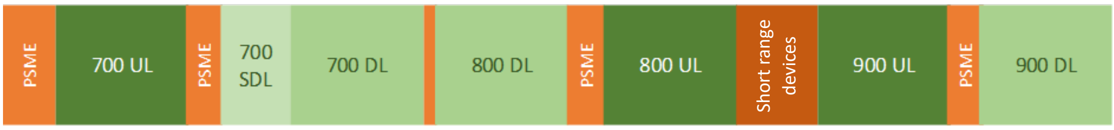
    a. The demand for IMT spectrum in the longer term and which bands will be needed to meet this demand.
    b. The applied IMT system (including TDD, FDD, FDD with reversed duplexing, supplemental downlinks).
    c. The actual and planned frequency assignments for IMT and other services (which may be recorded in the NTFA or a national frequency register).
    d. The (planned) IMT assignment procedure. This may include auction or public tender. Such assignment procedures may have conditions that conditionalize access to new spectrum rights. For example, a combination of different spectrum bands is auctioned at once or spectrum-aggregation rules for incumbents are stipulated (whereby the number of frequency blocks incumbent operators can acquire in the auction is limited, depending on the amount of spectrum they may already have in other bands).

3) Options for financing the migration of different SAB/SAP licence holders. Limited financial resources may require longer migration periods. For example, because SAB/SAP licence holders that should relinquish their spectrum rights (before their licence expires) cannot be compensated. Factors that could be considered for assessing the financial resources include:

    a. The (planned) IMT assignment procedure. An IMT licensee may have the obligation to contribute financially towards the cost of migrating incumbent licence holders (see also Table 6).
    b. The SAP/SAB licence period and renewal clauses.
    c. The number of SAB/SAB licence holders and their equipment (for example, whether or not the equipment can be retuned).
    d. The number and type of unlicensed SAB/SAP equipment deployed.

As discussed above, an example of a long-term IMT scenario (across multiple bands) is provided in Figure 4. It is noted that the category for short-range devices includes assistive listening devices (ALD, as part of PSME, see also Table 3), metering devices and active implantable medical devices.

Figure 4: Example of long-term scenario for IMT and PMSE or SAB/SAP



Source: Ofcom

For the migration of SAB/SAP devices, factors to be considered include:

1) The final date by which defined SAB/SAP usage should cease. Different dates may have to be communicated to the users for different SAB/SAP categories (e.g. between licensed and unlicensed equipment users).
2) Early band clearing (before the final date). The NRA may have arranged for a procedure whereby IMT licensees (or other licence holders for services such as PPDR) may introduce its services before the final date in certain areas. Under such an arrangement, the SAB/SAP users in the affected areas will get a notice to vacate the band within a number of days.
3) Modification of SAB/SAP licences. NRAs can change the licence conditions (which specify the frequency band), allowing these licence holders to operate their equipment in another specified band without having to file applications to modify their licences.
4) Transition period measures. SAB/SAP users may continue their operations during the transition period under (different) specified criteria, which may include:

   a. high-power and licensed SAB/SAP equipment may continue on the basis of the technical conditions set for lower-power/unlicensed equipment;
   b. any (new) SAB/SAP equipment should have type approval (and comply with a set of technical conditions);
   c. SAB/SAP users should not cause harmful interference (to the IMT service or any other primary service) and accept any interference from primary services;
   d. SAP/SAP users need to cease operations, pursuant to the early band-clearance rules (see above).

5) Communications and equipment labelling. This includes a communication programme during the transition period, targeting the SAB/SAP users as well as the public, who may purchase licensed and unlicensed equipment. Labelling should help SAB/SAP users to identify which equipment is permitted to operate in the new frequency bands.
6) Financial compensation schemes and SAB/SAP retuning aid. The inclusion of financial compensation will be dependent on the factors discussed above.

1.5 Guidelines and recommended actions for the 700 MHz band

Sections 1.1 to 1.4 cover the spectrum allocations for IMT and other services in the 700 MHz band, the technical and regulatory conditions facilitating the IMT introduction in this band, as well as best practices and methods for refarming the other services, if deemed necessary.

Table 8 provides a comprehensive list of guidelines as included in these sections.

Table 8: Spectrum management guidelines for IMT introduction in the 700 MHz band

No	Guideline	Applies to	Ref. Section(s)
1.1	As the frequency arrangement for IMT (Table 1) and frequency allocations for the other services can vary between countries, as well as the applied technology standard for these services (Table 3), administrations are advised to determine what applications are used in their territory. A market inventory or consultation may be necessary before selecting frequency arrangements. In selecting this frequency arrangement, due consideration should be given to the AUC guidelines on the harmonized use of the digital dividend in Africa.	All applications	Sections 1.1 and 1.2
1.2	Administrations are advised to interpret the sharing and compatibility study results, as included in Section 1.3.1, with caution as their local situation may differ from the situation covered in the studies. Case-by-case calculation may be needed to determine possibilities for sharing and compatibility of services. For this purpose, various ITU-R Recommendations and Reports are available, as specified in Table 4 and Table 5. Also, a comprehensive list of relevant ITU-R Recommendations and Reports is provided in Appendix B: ITU Recommendations and Reports.	All applications	Sections 1.3.1 and 1.3.2 Appendix B: ITU Recommendations and Reports
1.3	For introducing IMT in the specified frequency bands (see Table 1), administrations may have to set a range of technical and regulatory conditions. Technical conditions can include the application of guardbands, reverse duplexing, filtering of transmitters/receivers and critical spectrum masks. Regulatory conditions such as an obligation to provide filters to spectrum users, to compensate for migration costs and to follow station-approval procedures are set in combination with the technical conditions.	All applications	Sections 1.3.2 and 1.3.3

Table 8: Spectrum management guidelines for IMT introduction in the 700 MHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
1.4	Cross-border coordination may be needed for mitigating co-channel interference for the potential interference cases as included in Figure 1. For resolving interference between IMT and DTTB, the procedures of the GE-06 Agreement should be followed (as explained in Section 1.3.4). For resolving other interference cases (e.g. between IMT and fixed service) case-by-case coordination may be needed. For resolving IMT-IMT interference, the procedures and technical conditions of the HCM4A Agreement or ECC Rec. 15/01 may form a good reference.	Cross-border coordination for: GE-06 for IMT-DTTB (and DTTB-DTTB); HCM4A Agreement for IMT-IMT; ECC Rec. 15/01 for LTE/NR-LTE/NR coordination cases.	Section 1.3.4, Appendix A: Cross-border frequency coordination
1.5	From Tables 4 and 5, it was concluded that the following services or applications may have to be replanned or reallocated to adjacent or other bands: • DTTB and ATV; • SAB/SAP.	Refarming DTTB, ATV and SAB/SAP.	Section 1.4
1.6	Refarming DTTB services involves migrating a set of DTTB services, broadcasted on a given set of frequencies, to another set of frequencies in the adjacent band to the IMT services. This process should be well planned and can include a process as described in Figure 3.	Refarming DTTB	Section 1.4.1
1.7	Refarming ATV services entails the migration of these services to a DTTB platform. This process of migrating ATV services to a DTTB platform includes some unique planning aspects (such simulcasting and ASO). This is described separately in Section 9.	Refarming ATV	Section 1.4.2 See also Section 9
1.8	Refarming of SAB/SAP services can be carried out under three basic migration scenarios as provided in Section 1.4.3. Various factors should be considered when migrating SAB/SAP devices, including: • The final date by which defined SAB/SAP usage should cease; • Early band-clearing (before the final date); • Modification of SAB/SAP licences; • Transitional measures; • Communications and equipment labelling; • Financial compensation schemes and SAB/SAP retuning aid.	Refarming SAB/SAP	Section 1.4.3

2 IMT sharing and compatibility with other services in the 800 MHz band

This section addresses the sharing and compatibility of IMT services in the 800 MHz band (i.e. allocated according to frequency arrangements as detailed by ITU-R and as identified in the ITU-RR) with other primary services in the same band or adjacent bands.

2.1 IMT frequency arrangements in the 800 MHz band

Table 9 shows the IMT frequency arrangements in the 800 MHz band as included in Recommendation ITU-R M.1036-6. Table 9 shows frequency division duplex (FDD) and time division duplex (TDD) arrangements. It is noted that administrations may implement a part of each frequency arrangement. The recommended frequency arrangement by the African Union Commission (AUC) is highlighted in grey.[63]

Table 9: IMT frequency arrangements in the 800 MHz band

Frequency arrangement	Paired arrangements (FDD)				Unpaired arrangements (TDD) (MHz)
	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
A1	824-849	20	869-894	45	None
A2	880-915	10	925-960	45	None
A3	832-862	11	791-821	41	None

From Table 9 the following can be observed and concluded:

1) Three IMT frequency arrangements are identified in the 800 MHz band.
2) These three arrangements range from 791-960 MHz.
3) Frequency arrangement A1, including 3GPP bands 5, 18, 26, are often referred to as band plans for the 850 MHz band.
4) Frequency arrangement A2 or band 8 is often referred to as a band plan for the 900 MHz band (as most of the arrangement sits in the 900 MHz band). Although strictly speaking this arrangement falls (partly) in the 800 MHz band, this arrangement is not considered any further in this section;
5) Frequency arrangement A3 (3GPP band 20) is the most commonly applied frequency arrangement in the 800 MHz band around the world.[64]
6) Frequency arrangement A3 is a reversed duplex arrangement, with the mobile terminal transmitting within the upper band and base station transmitting within the lower band.

[63] See footnote 10.
[64] Source: Halberd Bastion, mobile networks deployment database. See https://halberdbastion.com/intelligence/mobile-networks/

Such an arrangement provides better protection against harmful interference from broadcasting services allocated in the lower adjacent band.[65]

2.2 Other services allocated in the 800 MHz band and adjacent bands

The frequency range of 791-894 MHz (i.e. the range of the lowest to the highest frequency of arrangements in Table 9) corresponds with the following (adjacent) parts of the ITFA for Region 1, as depicted in Table 10. Table 10 also includes the footnotes as included in the ITFA. Footnotes not relevant for the African countries or not relevant for the introduction of IMT are in brackets. Footnotes referring to IMT identifications are in blue.

Table 10: ITFA corresponding with the identified IMT frequency arrangements for the 800 MHz band (Region 1)

790-862 MHz		
Services:	Footnote number:	Footnote:
Fixed, mobile except aeronautical mobile, broadcasting	5.316B	For countries party to the GE-06 Agreement, the use of stations of the mobile service is also subject to the successful application of the procedures of that Agreement. (See Resolution 224 above.)
	5.317A	The frequency bands 694-790 MHz and 790-960 MHz in Region 1, which are allocated to the mobile service on a primary basis, are identified for IMT.
	(5.312)	See Table 1
	(5.319)	Additional allocation in the 806-840 MHz and 856-890 MHz bands to the mobile-satellite (except aeronautical mobile-satellite) service in Belarus, the Russian Federation and Ukraine.
862-890 MHz		
Services:	Footnote number:	Footnote:
Fixed mobile except aeronautical mobile, broadcasting	5.317A	See above.

65 As noted in Section 1.3.1, this follows from the order of the first and second digital dividend in Region 1. IMT is first introduced in the 800 MHz band followed by an IMT introduction in the 700 MHz band.

Table 10: ITFA corresponding with the identified IMT frequency arrangements for the 800 MHz band (Region 1) (continued)

	5.322	In Region 1, in the band 862-960 MHz, stations of the broadcasting service shall be operated only in the African Broadcasting Area, excluding Algeria, Burundi, Egypt, Spain, Lesotho, Libya, Malawi, Morocco, Namibia, Nigeria, South Africa, Tanzania, Zimbabwe and Zambia, subject to agreement obtained under No. 9.21.[66]
	(5.319)	Additional allocation in the 806-840 MHz and 856-890 MHz bands to the mobile-satellite (except aeronautical mobile-satellite) service in Belarus, the Russian Federation and Ukraine.
	(5.323)	Additional allocation to the aeronautical radio-navigation service on a primary basis for countries outside the African Broadcasting Area.
890-942 MHz		
Services:	Footnotes number:	Footnote:
Fixed Mobile except aeronautical mobile, broadcasting radiolocation	5.317A	See above
	5.322	See above
	(5.323)	See above

From Table 10 the following can be observed and concluded:

1) The non-IMT spectrum allocations in the range of 791-960 MHz and in adjacent bands include the following primary services:
    a. mobile except aeronautical mobile;
    b. broadcasting;
    c. fixed.
2) Only a limited number of footnotes are relevant for the African countries and the introduction of IMT:
    a. In the band 790-862 MHz:
        i. 5.316B: IMT stations are subject to the successful application of the procedures of the GE-06 Agreement (see Section 1.3.4);
        ii. 5.317A: IMT identification;

[66] That is to say, obtaining agreement for a terrestrial station operating in the bands mentioned in a footnote to the Table of Frequency Allocations of RR Article 5, following a prescribed procedure. The procedure describes the coordination steps between the requesting and affected administrations, as well as the involvement of ITU BR.

b. In the bands 862-890 MHz and 890-942 MHz:

   i. 5.322: For some African countries, broadcasting stations can operate in the band 862-960 MHz (this is not the case for most countries in Region 1).
   ii. 5.317A: IMT identification.

Table 11 provides and overview of the applications and technology standards commonly applied[67] in Region 1 for the non-IMT services as included in Table 9. The applications in Table 11 include the same applications as Table 3. However, the frequency ranges and footnotes in the table are different. Also, Table 11 includes land mobile services.

Table 11: Common applications and technology standards per ITU-RR service for Region 1

Radio service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Mobile except aeronautical mobile, 790-862 MHz, 862-890 MHz, 890-942 MHz	Services ancillary to broadcasting and services ancillary to programme-making (SAB/SAP)	Programme-making and special events (PMSE)[68]	Wireless microphones, wireless cameras and microwave links (for outdoor newsgathering), assistive listening devices (ALD).	Various, for professional licensed and unlicensed (lower-power) equipment.	ETSI
	Public protection and disaster relief (PPDR)	Public protection and disaster relief (PPDR)[69]	Two-way mission critical narrow and broadband communication systems with specific requirements. The legacy narrowband systems are also referred to as PMR/PAMR	APCO Project 25	The Association of Public-Safety
				DMR	ETSI
				TETRA	ETSI

[67] This does not exclude the possibility that country-specific applications exist in the band, such as land and maritime military systems, alarms, remote controllers and radio-frequency identification (RFID).

[68] According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), in the bands 790-862 MHz and 862-870 MHz, wireless microphones and ADL are designated in 823-832 MHz (in the centre gap of frequency arrangement A3) and 863-865 MHz (at the upper band edge of A3), respectively.

[69] According to ATU recommendations in ITU-R M.2015-2, there are no broadband PPDR allocations in the 800 MHz band. According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), PPDR is not allocated in the band 790-942 MHz. According to the SADC harmonized Radio Frequency Spectrum Allocation Plan, PMR and PAMR are designated in 876-880 MHz, 915-921 MHz and 921-925 MHz.

Table 11: Common applications and technology standards per ITU-RR service for Region 1 (continued)

Radio service	Application		Application examples	Tech-nology standard	References
	ITU name	CEPT name			
				(broad-band) LTE/LTE-A[70]	3GPP, ITU
	Land mobile	Land mobile	Legacy cellular mobile communication net-works, often referred to as 2G and 3G.	GSM(-R)	ETSI
				UMTS (HSPA)	ETSI
				CDMA-850[71]	IEEE
Broad-casting 790-862 MHz, 862-890 MHz, 890-942 MHz	Digital terrestrial television broad-casting (DTTB)[72]	Digital terrestrial television	Digital terrestrial tele-vision	DVB-T/ DVB-T2	ITU, DVB con-sortium
				ISDB-T	ITU, Digital Broadcasting Experts Group (DiBEG)
	Analogue tele-vision (ATV) broadcasting	Analogue television	Analogue terrestrial television	PAL (G/H)	ITU, ETSI
				SECAM	ETSI

70 See ITU Recommendation ITU-R M.2015-2 (01/2018), Frequency arrangements for public protection and disaster relief radiocommunication systems in accordance with Resolution 646 (Rev.WRC-15).
71 According to the AUC guidelines on the harmonized use of the digital dividend in Africa, CDMA-850, UMTS and GSM systems are still in use in some African countries. In the CEPT table of harmonized frequency allocations, only GSM-R is allocated in the band 876-880 MHz and 921-925 MHz.
72 According to the SADC harmonized Radio Frequency Spectrum Allocation Plan, there is no primary designation for broadcasting in the band 790-942 MHz. This is different from other African countries.

Table 11: Common applications and technology standards per ITU-RR service for Region 1 (continued)

Radio service	Application		Application examples	Tech-nology standard	References
	ITU name	CEPT name			
Fixed 790-862 MHz, [73] 862-890 MHz, 890-942 MHz	Fixed and nomadic wireless access (FWA/NWA)	Broadband wireless access	Public and private wireless broadband systems (for at home, shopping centres, air-ports, schools, etc.).	IEEE 802.16 (WiMAX)	IEEE
	Point-to-point (P-P)[74]	P-P	Backhaul radio links in IMT networks, wireless metropolitan area net-works (Wi-MAN) and corporate networks.	Various, including proprietary solutions.	ETSI
	Point-to-multipoint (P-MP)[75]	(P-MP)	As above	As above	ETSI

From Tables 10 and 11, the following can be concluded:

1) The following potential incompatibilities could occur in the 791-894 MHz (see Table 9) between IMT and:

   a. DTTB/ATV in the bands 790-862 MHz, 862-890 MHz and 890-942 MHz;
   b. SAP/SAB and PPDR (narrowband PMR/PAMR) in the bands 790-862 MHz, 862-890 MHz and 890-942 MHz;
   c. FWA/NWA, P-P and P-MP in the bands 790-862 MHz, 862-890 MHz and 890-942 MHz;
   d. CDMA-850[76] in the 790-862 MHz, 862-890 MHz and 890-942 MHz. As noted in Section 2.1, the frequency arrangement A2 (band 8) is outside the scope of this section. This excludes the GSM and UMTS (HSPA) systems as they are allocated in the frequency range of A2 (880-915 MHz and 925-960 MHz).[77]

2) The NTFA will indicate whether any of the applications in Table 11 are assigned and in use in a specific African country. Consequently, such use should be considered in assessing the compatibility with an IMT deployment in the 800 MHz band in that country.

[73] According to the SADC harmonized Radio Frequency Spectrum Allocation Plan, any fixed link deployments (in South Africa and Botswana) in the band 790-862 MHz should be migrated in order to introduce IMT.
[74] These types of applications (P-P and P-MP) are commonly allocated in the higher spectrum bands. For example, in the CEPT countries, P-P and P-MP is used in frequency bands above 1 GHz. See ECC Report 173, Fixed Service in Europe - Current use and future trends post 2016, dated 27 April 2018. In the SADC harmonized Radio Frequency Spectrum Allocation Plan several designations exist for fixed services below 1 GHz, see footnote SADC13 and SADC14 (bands 790-862 MHz and 862-890 MHz).
[75] See footnote 73.
[76] CDMA (code-division multiple access) refers to any of several protocols used in second-generation (2G) and third-generation (3G) wireless communications. As the term implies, CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth.
[77] See AUC guidelines on the harmonized use of the digital dividend in Africa, p 19-27.

2.3 Sharing/compatibility between IMT and the other services in the 800 MHz band

Again, as indicated in Section 1.3, considering Tables 9 and 11, many sharing and compatibility studies can, in theory, be carried out as the frequency arrangement for IMT (Table 9) and the other services can vary, as can the applied technology standard for IMT and the other services (Table 11).

In this report, only the key IMT sharing and compatibility studies and their results are covered. Administrations are advised to interpret these study results with caution as their local situation (including the actual frequency allocations/assignments reflected in their NTFA, the applied technologies and interference scenario) may differ from the situation covered in the studies.

2.3.1 Overview of IMT sharing and compatibility studies

As discussed in Section 1.3, in Region 1 the IMT introduction follows the clearance of the first and second digital dividend spectrum, i.e. first the 800 MHz band followed by the 700 MHz band. However, the results of the compatibility studies of having IMT in the 700 MHz (and DTTB in 600 MHz band) or 800 MHz (and DTTB in the 700 MHz band), are mutually relevant[78].

As indicated in the AUC guidelines on the harmonized use of the digital dividend in Africa, CDMA-850 is still in use in some African countries. As this system is considered a legacy system and to be replaced by LTE, incompatibilities with IMT/LTE can only occur in the adjacent bands between the IMT/LTE allocation and any residual use of the CDMA-850 system. Any co-channel interference between CDMA-850 and IMT/LTE could only occur in cross-border interference situations.

Table 12 provides an overview of the key IMT sharing and compatibility studies relevant for the 800 MHz band. The second column indicates the compatibility case under consideration in the study, i.e. the compatibility between IMT and an application for the other services (see Table 11). Table 12 shares some fields with Table 4 (and hence the reader is referred to this table), with the exception of the addition for CDMA-850 and the removal of ARNS.

Table 12: Overview of key IMT sharing and compatibility studies relevant for the 800 MHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
1	IMT-other services: – PPDR – DTTB	ITU-R	Report M.2241-0 (2011)	Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz.	• See Table 4

[78] Noting that different interference scenarios may have been addressed, the key difference is relatively small propagation differences between the 700 and 800 MHz bands.

Table 12: Overview of key IMT sharing and compatibility studies relevant for the 800 MHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
2	IMT-DTTB	ITU-R	Report BT.2339-0 (11/2014)	Co-channel sharing and compatibility studies between digital terrestrial television broadcasting and international mobile telecommunication in the frequency band 694-790 MHz in the GE-06 planning area.	• See Table 4
3	IMT-DTTB	ITU-R	Report BT.2301-2 (10/2016)	National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services.	• See Table 4
4	IMT-DTTB	ACMA	ACMA website	DVB-T in 520-694 MHz (restacked) and LTE in 700 MHz band. DVB-T nationwide (i.e. around main cities) and IMT fully deployed (Optus and Telstra).	• See Table 4
5	IMT-ATV	ITU-R	Report M.1023-1 (1990)	Frequency sharing between the land mobile service in the broadcasting service (television) below 1 GHz.	• See Table 4
6	IMT-SAB/SAP	ITU-R	Report BT.2338-0 (11/2014)	Services ancillary to broadcasting/ services ancillary to programme-making spectrum use in Region 1 and the implication of a co-primary allocation for the mobile service in the frequency band 694-790 MHz.	• See Table 4

Table 12: Overview of key IMT sharing and compatibility studies relevant for the 800 MHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
7	IMT-CDMA-850	AUC	Guidelines on the harmonized use of the digital dividend in Africa, 26 December 2016	Guidelines on the harmonized use of the digital dividend in Africa – policy, technical and regulatory procedures	• CDMA-850 is considered a legacy system that is to be replaced by IMT/LTE. A transition period is foreseen with residual use and reduced bandwidth for CDMA-850; • CDMA-850 initial deployment (2x25 MHz) in 824-849 MHz (uplink) and 869-894 MHz (downlink); • Reduced bandwidth (2x8 MHz) in 824-832 MHz (uplink) and 869-877 MHz (downlink); • With the recommended frequency arrangement A3, this would leave a guardband of 3 MHz between DL/UL and UL/DL of IMT and CDMA-850, respectively[79].

From Table 12, the following can be observed and concluded (only the last item in the list is additional to the conclusions and observations from Table 4):

1) Compatibility of IMT and PPDR[80] services in the same frequency band is usually not possible because:

    a. both applications are often deployed nationwide;

    b. studies have shown that the co-channel separation distances for protecting IMT-LTE BTS or PPDR BTS range from 170 to 385 km and from 170 to 360 km, respectively (see No. 1 in Table 12). This makes separating them geographically within the same country a less practical option.

2) Sharing of IMT and fixed services (P-P and P-MP) in the same frequency band requires separation distances ranging from 25 to 220 km, depending on the interference scenario and deployment environment. However, under realistic pointing scenarios,

[79] Still subject to ongoing studies to establish if this guardband is sufficient. Also, it is noted that this residual use of 2x8 MHz for CDMA is not compatible with the frequency arrangement A1, in the sense that the A1 frequency arrangement can only be implemented partly. Also, the A1 arrangement is not proposed by AUC.

[80] It is noted that PPDR systems can be based on IMT/LTE. For PPDR-IMT, separate frequency arrangements are included in ITU Recommendation ITU-R M.2015-2 (01/2018). According to the ATU recommendation in ITU-R M.2015-2, there are no broadband PPDR designations in the 800 MHz band. However, according to the SADC harmonized Radio Frequency Spectrum Allocation Plan, PMR and PAMR can be assigned in 876-880 MHz, 915-921 MHz and 921-925 MHz.

the interference can be mitigated through a combination of geographic separation and frequency separation (see No. 2 in Table 12).

3) Compatibility of IMT and DTTB services in the same frequency band is in most cases not possible because:

   a. both applications are often deployed nationwide;

   b. as a number of studies have shown, the co-channel separation distances for protecting the DTTB services range from 200 to 1 000 km (see Nos. 3 and 4 in Table 12.This makes separating them geographically within the same country a less practical option.

4) Compatibility of IMT and DTTB services is possible when the applications are assigned in spectrum adjacent to each other (see Nos. 5 and 6 in Table 12). Technical conditions may apply, such as applying guardbands, reverse IMT duplexing and filtering of IMT BTS/DTTB receivers (for more details, see Section 2.3.2).

5) Compatibility of IMT and ATV services in the same frequency band is not possible for the same reasons as for IMT/DTTB, and the interference situation is often worse because of the higher radiated powers in ATV broadcasting (see No .7 in Table 12).

6) Compatibility of IMT and SAB/SAP services in the same frequency band and at the same location is not possible. Sharing scenarios may exist for having certain SAB/SAP applications (i.e. those that can tolerate some levels of interference) in the IMT guardbands and duplex gaps. These possibilities for sharing may increase if the out-of-band performance of LTE devices improves (see No. 8 in Table 12).

7) Compatibility of IMT and CDMA-850 services in the same frequency band is excluded as the legacy systems are expected to be replaced by IMT/LTE. Sharing of the residual use of CDMA-850 with a reduced bandwidth (2 x 8 MHz) with IMT in the adjacent bands is deemed possible, under the application of a guardband of 3 MHz (see No. 9 in Table 12).[81]

2.3.2 Technical conditions for IMT sharing and compatibility

As concluded from Table 12, several compatibility and sharing options between IMT and other services have been identified. Table 13 provides an overview of technical conditions under which such options are technically feasible. It is noted that the specific local situation will dictate which and to what extent the technical conditions listed need to be applied.

For the technical conditions presented in Table 13, it is assumed that the radio equipment involved in the interference case, complies with a minimal (least restrictive), and preferably, a harmonized set of technical conditions. Such a set of minimum technical conditions may be checked as part of a type-approval procedure for granting the use of radio equipment in the NRA's territory. Also, such a set of minimum criteria often include emission limits/spectrum masks and may be complemented with other conditions such as for human safety (EMC).[82]

Finally, the conditions included in Table 13 address the conditions for separating IMT from non-IMT applications. Conditions for separating frequency blocks between IMT operators (such as guardbands, spectrum masks, radiated power level) are not addressed.

It is noted that Table 13 is in some fields the same as Table 5 (and hence the reader is referred to this table). Please also note the addition for CDMA-850, textual edits and different footnotes

[81] See footnote 77.
[82] See footnote 35.

Table 13: Technical conditions for IMT sharing and compatibility in the 800 MHz band

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
IMT-DTTB[83]	Compatibility in adjacent bands	IMT in 800 MHz - DTTB in 700 MHz band[84]	Apply (preferably a harmonized) guardband at the IMT lower band edge. For example, for the CEPT area 1 MHz (790-791 MHz) is recommended for FDD arrangements and 7 MHz (790-797 MHz) for TDD arrangement (which is not the AUC-recommended arrangement).	CEPT Decision ECC (09)03	Consideration should be given to the assumed IMT frequency arrangement. The ECC Decision (09)01 considers A3 (band 20), see Table 9).
		IMT in 800 MHz - DTTB in 700 MHz band	Reverse the duplex direction (with the mobile terminal transmit within the upper band and base station transmit within the lower band). CEPT, ECC (see above) and AUC all recommend the reversed duplex arrangement A3.[85]	See Rec. ITU-R M.1036-6. See frequency arrangement A3 (or 3GPP band 20) in Table 9.	

[83] See footnote 36.
[84] It assumed that IMT is first introduced in the 800 MHz band (first digital dividend) then in the 700 MHz band (second digital dividend).
[85] See footnote 10.

Table 13: Technical conditions for IMT sharing and compatibility in the 800 MHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
		LTE BTS TX in 800 MHz band into DTTB RX in 700 MHz band (overloading)[86]	Apply a filter at the DTTB receiver. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of other technical conditions, including: • Repositioning or replacement of the DTTB (rooftop) antenna; • Repositioning of the LTE BTS and/or change antenna pattern (includes a critical spectrum mask);[87] • Reduction of ERP of the LTE BTS TX.	See Table 5	See Table 5
		LTE BTS TX in 800 MHz band into DTTB RX in 700 MHz band (unwanted emissions)[88]	Apply a filter at LTE-BTS transmitter. Application is often considered case-by-case (and can be specific to certain geographical areas). Application may also be dependent on the application of other technical conditions: • Repositioning or replacement of the DTTB (rooftop) antenna; • Repositioning of the LTE BTS and/ or antenna pattern (includes a critical spectrum mask).	See Table 5	See Table 5

86 See footnote 40.
87 In this context, a critical spectrum mask is a mask that is more restrictive than the minimum (least restrictive) spectrum mask conditions.
88 Unwanted emissions: Consist of spurious emissions and out-of-band emissions.

Table 13: Technical conditions for IMT sharing and compatibility in the 800 MHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
		DTTB in 700 MHz band into LTE BTS RX in 800 MHz band (overloading)	Apply a filter at LTE-BTS receiver. Application is often considered case-by-case (and can be specific to certain geographical areas). Application may also be dependent on the application of other technical conditions including: • Repositioning of the DTTB TX antenna and/or antenna pattern (includes a critical spectrum mask); • Repositioning the LTE BTS and/or antenna pattern; • Reduction of ERP of the DTTB TX antenna.	See Table 5	See Table 5
		DTTB in 700 MHz band into LTE BTS RX in 800 MHz band (unwanted emissions)	Use of critical spectrum mask at DTTB station TX. Application is often considered case-by-case (and can be specific to certain geographical areas). Application may also be dependent on the application of other technical conditions including: • Repositioning of the DTTB TX antenna and/or antenna pattern; • Repositioning the LTE BTS and/or antenna pattern; • Reduction of ERP of the DTTB TX antenna.	See Table 5	See Table 5
		DTTB in 700 MHz band into LTE UE RX in 800 MHz band (overloading)	Reposition or use of more robust IMT UE. The practical and financial application of these technical conditions should be carefully considered.	See Table 5	See Table 5

Table 13: Technical conditions for IMT sharing and compatibility in the 800 MHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
		DTTB in 700 MHz band into LTE UE RX in 800 MHz band (unwanted emissions)	Use of critical spectrum mask at DTTB station TX. Application is often considered case by case (and can be specific to certain geographical areas). Application may also be dependent on the application of other technical conditions: • Use of more robust IMT UE (see also above).	See Table 5	See Table 5
IMT-ATV	Compatibility in adjacent bands	In principle the same interference cases as for DTTB[89]	Any UHF ATV service cannot claim protection and should not cause harmful interference.[90]	See Table 5	See Table 5
IMT-SAB/ SAP (i.e. wireless microphones)	Compatibility in adjacent bands	IMT in 800 MHz band and SAB/ SAP in 700 MHz	Apply (preferably a harmonized) guardband at the IMT lower band edge. As SAB/SAP often operate in the same band as the broadcasting services (including DTTB). In such a case the guardband size will be determined on the basis of the compatibility between IMT and DTTB. It is noted that SAB/SAP equipment includes unlicensed equipment and hence the NRA does not know the actual use (intensity and locations) of SAB/ SAP equipment. For this reason, NRAs may decide to migrate SAB/SAP to other bands to exclude any risks of harmful interference.	See above	See above

89 See footnote 44.

90 Article 12.8 of the GE-06 Agreement allows the continuation of analogue stations on a non-interference and non-protection basis.

Table 13: Technical conditions for IMT sharing and compatibility in the 800 MHz band (continued)

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
	Sharing in the same band	IMT in 800 MHz band and SAB/SAP in guard-bands and/or multiplexer gap	Set limits to the radiated power (and other specification such as out-of-band and spurious emissions) of SAB/SAP applications in combination with type approval of robust SAB/SAP equipment. A main concern is the unwanted emissions by an LTE UE to a SAB/SAP (PMSE) receiver as SAB/SAP equipment is low complexity or has no error correction.	See Table 5	See Table 5
IMT-fixed services (i.e. P-P and P-MP)	Sharing in the same band	IMT and fixed services in 800 MHz[91]	Any interference can be mitigated through a combination of geographic separation and frequency separation. This will require case-by-case approval of any fixed service by the NRA.	See Table 5	See Table 5
IMT-PPDR	Compatibility in adjacent bands	IMT in 800 MHz and PPDR in adjacent band	Apply (preferably a harmonized) guardband at the IMT upper band edge. However, for PPDR systems based on IMT/LTE, specific frequency arrangements are identified.	See Table 5	See Table 5

[91] It is noted, however, that fixed services (P-P/P-MP) are commonly operated in the bands 1 to 3 GHz. See also footnote 24. However, in some African countries, fixed services are allocated below 1 GHz and in the 800 MHz band. See footnote 73.

Table 13: Technical conditions for IMT sharing and compatibility in the 800 MHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
IMT-CDMA-850	Compatibility in adjacent bands	IMT in 800 MHz band and CDMA-850 in 800 MHz band	Reduce the bandwidth to (2x8 MHz) in 824-832 MHz (uplink) and 869-877 MHz (downlink), with the CDMA uplink in the centre gap of IMT frequency arrangement A3 and the downlink in the gap between CDMA-850 (downlink) and GSM/ UMTS in the band 880-915 MHz (uplink) allocations. This would allow a guard-band of 3 MHz between DL/UL and UL/DL of IMT and CDMA-850, respectively.[92] Local circumstances may dictate further measures to protect the IMT services, such as filtering or limiting the radiated power of the CDMA BTS TX. These measures are deemed possible as ultimately the CDMA service would be phased out.	See AUC guidelines on the harmonized use of the digital dividend in Africa, 26 December 2016. See also Rep. ITU-R M.2045.	For the filtering of the CDMA BTS, see CEPT ECC Report 41[93]

2.3.3 Regulatory conditions for IMT sharing and compatibility

Administrations may wish to complement the technical conditions under which they grant IMT spectrum rights (see Section 2.3.2)[94] with specific IMT regulatory conditions (next to the general conditions for assigning spectrum rights[95]). These specific IMT-related conditions often arise from the situation that the IMT services are introduced in bands with incumbent services which need to be protected.

Table 14 provides an overview of these IMT-specific regulatory conditions. Table 14 shares some fields with Table 6 (and the reader is referred to this table). Please note the additions for aiding the CDMA migration.

[92] See footnote 77.
[93] It is noted that this report considers GSM base station (BS) receivers deployed below 915 MHz and CDMA-PAMR in the band 917-921 MHz and considers a frequency separation of 2.15 MHz.
[94] See footnote 49.
[95] See footnote 50.

Table 14: Regulatory conditions specific for IMT licensees

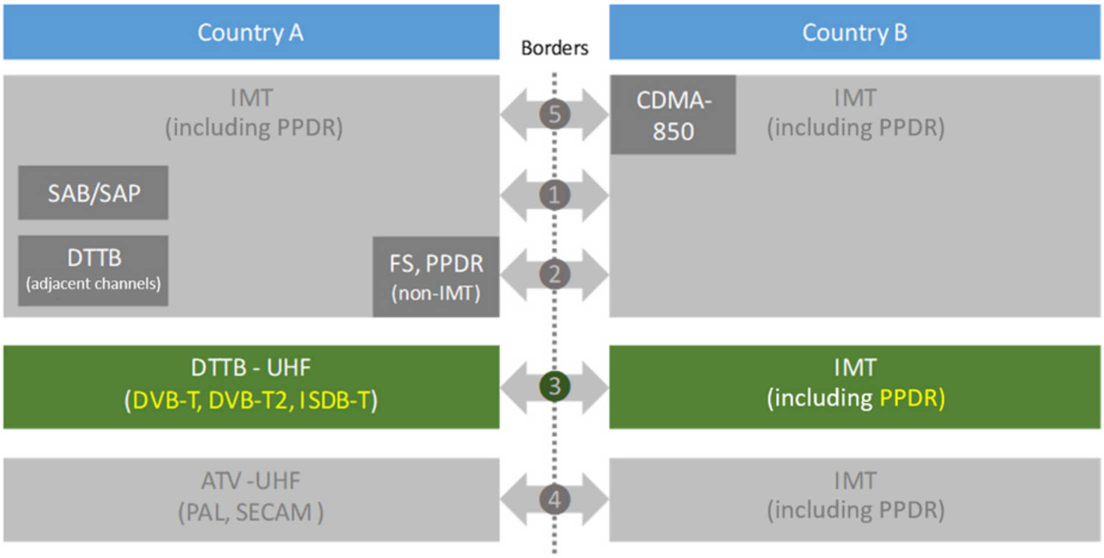
No	Condition or requirement	Notes	References
1	The IMT licensee has the obligation to arrange for the provisioning of filters for DTTB receivers, for eligible households or all television households.	See Table 6	See Table 6
2	The IMT licensee has the obligation to apply a critical spectrum mask at certain identified BTS or all BTS.	See Table 6	See Table 6
3	The IMT licensee has the obligation to reposition the BTS and/or change the antenna diagram/direction for certain identified BTS or all BTS.	See Table 6	See Table 6
4	The IMT licensee has the obligation to compensate for any incurred costs by the incumbent service.	See Table 6	See Table 6
5	The IMT licensee has the obligation to help investigate any complaints about interference of incumbent services.	See Table 6	See Table 6
6	The IMT licensee has the obligation to facilitate the migration of legacy CDMA-850 users to the new IMT/LTE platform. This requirement may be stipulated in various ways, for example: • A some or all of the available IMT/LTE blocks have an attached condition for facilitating CDMA-850 users (as per a pre-defined transition period); • IMT/LTE spectrum is set aside in the auction for the CDMA-850 network operator and the CDMA operator has an obligation to migrate its users (as per a pre-defined transition period). This obligation on (only) the CDMA operator can be part of the auction's qualifying criteria for bidders. Whether or not the CDMA operator is allowed to aggregate more IMT/LTE blocks needs to be defined in the auction rules; • Depending on the CDMA operator's other IMT/LTE spectrum assets/networks, its CDMA licence conditions and expiration date, the CDMA operator can only acquire a CDMA licence renewal (for a limited period) by accepting: o A reduced bandwidth; o The obligation to migrate the CDMA users to existing IMT/LTE capacity.	These constructions for migrating users from legacy systems to new systems is also used in other industries, such as broadcasting.	See also ITU-R Rec. SM.1603 See also Section 2.4.1
7	The regulator may facilitate the migration from legacy CDMA-850 to the new IMT/LTE platform by differentiating the spectrum or licence fees to be paid by the network operator.	Spectrum pricing is used in many countries to encourage spectrum users to vacate a frequency band voluntarily.	See ITU-R Rec. ITU-R SM.1603-2

2.3.4 Cross-border coordination aspects for IMT

Cross-border inference cases between countries are a subset of the interference cases within a country (as discussed in Section 2.3.1) as, in this frequency band, they mainly cover emissions located closer to the border.

Figure 5 shows a generic overview of the possible cross-border interference cases for the 800 MHz band. It is noted that Figure 5 is the same as Figure 1, with the exception of an additional potential interference case No.5 (IMT- CDMA).

Figure 5: Generic overview of possible cross-border interference cases for the 800 MHz band



First, it is noted that cross-border case DTTB-CDMA is not included in Figure 4 as it is assumed that the CDMA system was already in use before the introduction of DTTB. Hence, any such interference cases would have been addressed with the introduction of DTTB in the 800 MHz band.

The cross-border cases 1 to 4 in Figure 5 are addressed in Section 1.3.4. The interference case No. 5 is applicable to countries that may still have this legacy system in operation near the border.[96] Any such cases would likely require cross-border coordination (see also Appendix A: Cross-border frequency coordination).

Such cases can make use of the calculation methods as defined in existing agreements for coordinating land mobile services along borders, such as the HCM4A Agreement and the Vienna Agreement (see Section 1.3.4).

[96] According to the AUC guidelines on the harmonized use of the digital dividend in Africa, the following countries may still have CDMA in operation: Nigeria, Madagascar, Mauritania, Republic of the Congo, Democratic Republic of the Congo, Burkina Faso, Benin, Lesotho, Nigeria, Gambia, Togo, and Senegal.

2.4 Best practices and methods for refarming other services in the 800 MHz band

As discussed in Section 1.3, the IMT introduction in Region 1 follows the clearance of the first and second digital dividend spectrum: first the 800 MHz band then the 700 MHz band. Consequently, an introduction of IMT in the 800 MHz band should also consider the longer-term clearance of the 700 MHz band.

Likewise, the refarming of non-compatible services in the 800 MHz should therefore also consider the future refarming of those services in the 700 MHz band. For example, if broadcasting services are to be cleared from the 800 MHz, the new frequency plan for those broadcasters may have to consider migrating the services outside the 700 MHz band too. Alternatively, a staged refarming of broadcasting services can be developed.

It should be noted that a debate is taking place in Region 1, as part of the preparations for WRC-23, about also reviewing the use (and allocations) of the 600 MHz band (TV channels 38-48). For more details, see Section 9.

Tables 12 and 13 show that the following services or applications may have to be replanned or reallocated to adjacent or other bands:

1) DTT;
2) ATV;
3) wireless microphones (SAB/SAP);
4) CDMA-850.

Best practices and methods for refarming the first three above-listed applications are described in Sections 1.4.1, 1.4.2 and 1.4.3, respectively.

2.4.1 Refarming CDMA-850

Refarming an incumbent legacy service and ultimately replacing it with IMT is different from refarming DTTB, ATV and SAP/SAB. For the latter, the incumbent service is cleared for another use or application without migration of the legacy system's users to the new IMT platform. In the steps presented below, it is assumed that the CDMA platform will continue on a reduced bandwidth until it is eventually phased out:

1) In close collaboration with industry, the administration should establish a common understanding and agreement on refarming principles including:
    a. size and distribution (between operators and users) of the residual CDMA spectrum;
    b. compensation of the incumbent CDMA network operators by assigning (or giving access to) alternative spectrum;
    c. protection of CDMA subscribers on the legacy networks, so as to ensure the continuation of their communication needs and services;
    d. planning (in stages) of when to switch off (parts of) these legacy networks;
    e. regulatory policies for encouraging the migration of CDMA users to the new (LTE) platforms.
2) Adopting a new comprehensive band plan for the incumbent service and for the new IMT/LTE system. For phasing out CDMA-850, the AUC proposed a harmonized band plan in

which IMT frequency arrangement A3 (band 20) is combined with a reduced bandwidth (2 x 8 MHz) for residual use of the system (see Sections 2.3.1 and 2.3.2).

3) Carrying out network planning for the residual CDMA network.[97] Administrations adopting the AUC harmonized band plan must then assure that the network planning for the residual CDMA network is within this restricted bandwidth. For this network planning, the following sub-steps can be included:

   a. Determining planning criteria, such as minimum coverage, service quality and traffic load. In this context, the quality of services should encourage users of legacy systems to migrate to the new IMT/LTE system.
   b. Determining planning parameters, including system variants.
   c. Carrying out a schematic channel reshuffle with the aim to minimize frequency changes and verify the coverage and compatibility of any new plan with the old plan for CDMA.
   d. Several new plans can be developed using different criteria and parameters, from which a selection can be made.

4) Drafting an implementation plan for changing the incumbent CDMA network to the reduced network, giving due consideration to:

   a. The retune groups (i.e. clusters of CDMA sites) and their order (as to avoid any found incompatibilities). It is assumed that the existing CDMA sites do not change and that no new sites are added.
   b. Operational changes and the sourcing of any new equipment necessary.

5) Assessing the costs of the required changes, to include:

   a. Costs for changing the existing CDMA network(s).
   b. Accelerated depreciation of the CDMA network operator's network equipment.
   c. Compensation for the CDMA to relinquish its spectrum rights. This will be dependent on the CDMA licence conditions and renewal clauses.
   d. Migrating CDMA users to the new platform. The cost for this category is critically dependent on the timeline for migration. If CDMA users are forced to migrate within the economic life of their mobile terminals, the cost can be high (also dependent on the number of CDMA users and also the legislation on the infringement of people's property rights).
   e. Communication and marketing costs for informing CDMA users and encouraging them to migrate to the new platform. This may include discounted subscription or usage tariffs or other promotional costs.

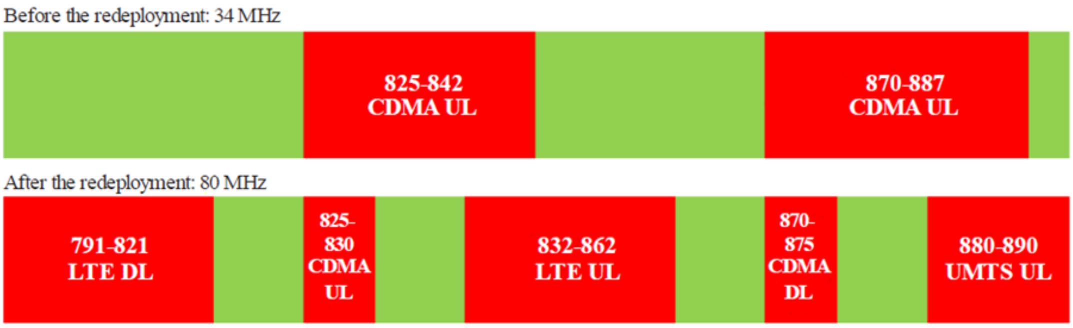
6) Preparing legislation to support the migration. See numbers 7 and 8 in Table 14.

Recommendation ITU-R SM.1603 includes the experience of refarming the CDMA-850 service in Benin, where that network operator is a public entity. The options for refarming may be different where the CDMA network operator is a private entity. This difference should be considered when observing the regulatory options included in Table 14.

Figure 6 shows the spectrum allocation before and after refarming CDMA-850. According to the AUC guidelines on the harmonized use of the digital dividend in Africa, the situation after refarming is temporary until CDMA is phased out.

[97] Network planning of the IMT network is not addressed here.

Figure 6: Refarming of the CDMA service in Benin, spectrum allocation before and after refarming



Source: ITU

The following points in this ITU-R Recommendation warrant attention:

1) The involvement of all stakeholders in the redeployment;
2) Service continuity for the CDMA users, including a detailed communication plan to subscribers, as well as a detailed schedule for changing user equipment;
3) Financial assessments, which proved difficult due to the lack of documentation on which to base equipment depreciation and residual value;
4) It was shown that it is crucial to identify and secure redeployment funding early on.

2.5 Guidelines and recommended actions for the 800 MHz band

Sections 2.1 to 2.4 cover the spectrum allocations for IMT and other services in the 800 MHz band, the technical and regulatory conditions facilitating the IMT introduction in this band, as well as best practices and methods for refarming the other services, if deemed necessary.

Table 15 provides a comprehensive list of guidelines as included in these sections, many of which are the same as included in Table 8 (the guidelines for the 700 MHz band), although all the references to sections, tables and figures are different, as are some text edits. Also, a guideline is added for the refarming of CMDA-850 legacy systems.

Table 15: Spectrum management guidelines for IMT introduction in the 800 MHz band

No	Guideline	Applies to	Ref. Section(s)
2.1	As the frequency allocations for IMT (Table 9) and other services can vary between countries, as can the applied technology standard for these services (Table 11), administrations are advised to determine what applications are used in their territory. A market inventory or consultation may be necessary before selecting frequency arrangements, while due consideration should also be given to the AUC Guidelines on the harmonized use of the digital dividend in Africa.	All applications	Sections 2.1 and 2.2

Table 15: Spectrum management guidelines for IMT introduction in the 800 MHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
2.2	Administrations are advised to interpret the sharing and compatibility study results contained in Section 2.3.1 with caution as their local situation may differ from that covered in the studies. Case-by-case calculation may be needed to determine possibilities for the sharing and compatibility of services. For this purpose, several ITU Recommendations and Reports are available, as specified in Tables 12 and 13. Also, a comprehensive list of relevant ITU Recommendations and Reports is provided in Appendix B: ITU Recommendations and Reports.	All applications	Sections 2.3.1 and 2.3.2, Appendix B: ITU Recommendations and Reports.
2.3	For introducing IMT in the specified frequency bands (see Table 9), administrations may have to set a range of technical and regulatory conditions. Technical conditions can include the application of guardbands, reverse duplexing, filtering of transmitters/receivers and critical spectrum masks. Regulatory conditions such as an obligation to provide filters to spectrum users, to compensate for migration costs and follow station-approval procedures, are set in combination with the technical conditions.	All applications	Sections 2.3.2 and 2.3.3
2.4	Cross-border coordination may be needed for mitigating co-channel interference for the potential interference cases as included in Figure 5. For resolving interference between IMT and DTTB, the procedures of the GE-06 Agreement should be followed (as explained in Section 1.3.4). ATV services in the UHF cannot claim protection any longer and should not cause harmful interference to other primary services (including IMT). For resolving other interference cases (e.g. between IMT and fixed service), case-by-case coordination may be needed. For resolving IMT-IMT interference, the procedures and technical conditions of the HCM4A Agreement or ECC Rec. 15/01 may form a good reference.	Cross-border coordination for: GE-06 for IMT-DTTB (and DTTB-DTTB); HCM4A Agreement for IMT-IMT coordination cases. It is noted that ECC Rec. 15/01 does not include the 800 MHz band, however the PCI method can be used.	Section 2.3.4, Appendix A: Cross-border frequency coordination.

Table 15: Spectrum management guidelines for IMT introduction in the 800 MHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
2.5	From Tables 12 and 13, it was concluded that the following services or applications may have to be replanned or reallocated to adjacent or other bands: • DTTB and ATV; • SAB/SAP; • CDMA-850.	Refarming DTTB, ATV, SAB/SAP and CDMA-850	Section 2.4
2.6	Refarming DTTB services involves migrating them from one set of frequencies to another located in the adjacent band to the IMT services. This process should be well planned and can include a process as described in Figure 3 in Section 1.4.1.	Refarming DTTB	Section 1.4.1
2.7	Refarming ATV services entails the migration of these services to a DTTB platform. This process of migrating ATV services to a DTTB platform includes some unique planning aspects (such simulcasting and ASO). These are described separately in Section 9.	Refarming ATV	Section 1.4.2 See also Section 9
2.8	Refarming of SAB/SAP services can be carried out under three basic migration scenarios as provided in Section 1.4.3. For the actual migration of SAB/SAP devices, it is recommended to consider a range of factors, including: • The final date by which defined SAB/SAP usage should cease; • Early band clearing (before the final date); • Modification of SAB/SAP licences; • Transition period measures; • Communications and equipment labelling; • Financial compensation schemes and SAB/SAP retuning aid.	Refarming SAB/SAP	Section 1.4.3

Table 15: Spectrum management guidelines for IMT introduction in the 800 MHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
2.8	Refarming an incumbent legacy CMDA-850 service is different from refarming DTTB, ATV and SAP/SAB. Migration of the legacy system's users to the new IMT platform is needed. It is recommended to consider the unique elements of this migration process, including: • Accelerated depreciation of the CDMA network equipment; • Compensation for the CDMA to relinquish its spectrum rights; • Migrating CDMA users to the new platform (which may include infringement of people's property rights); • Marketing costs for informing and encouraging CDMA users to migrate to the new platform; • Drafting a comprehensive marketing campaign and communication plan; • Preparing legislation in support of the migration.	Refarming CDMA-850	Section 2.4.1

3 IMT sharing and compatibility with other services in the 1.4 GHz band

This section addresses the sharing and compatibility of IMT services in the 1.4 GHz band (i.e. allocated according to frequency arrangements as detailed by ITU-R and as identified in the ITU-RR) with other primary services in the same band or in adjacent bands.

3.1 IMT frequency arrangements in the 1.4 GHz band

Table 16 shows the IMT frequency arrangements in the 1.4 GHz band as included in Recommendation ITU-R M.1036-6. It is noted that administrations may implement a part of each frequency arrangement.

Table 16: IMT frequency arrangements in the 1.4 GHz band

Frequency arrangement	Paired arrangements (FDD)				Unpaired arrangements (TDD) (MHz)
	Mobile station trans-mitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
G1	External	-	1 427-1 517	-	None
G2	1 427-1 470	5	1 475-1 518	48	None
G3	-	-	-	-	1 427-1 517

From Table 16 the following can be observed and concluded:

1) The frequency range 1 427 MHz to 1 518 MHz is also known as the L-band[98] or the 1 500 MHz band;
2) Frequency arrangement G1 is a supplemental downlink and can work when carrier aggregation is configured in a network with the uplink;[99]
3) In the harmonized European table of frequency allocations and applications, frequency arrangement G1 (SDL) is included (1 427-1518 MHz);[100]
4) The number of IMT/LTE deployments in the L-band (1 427 MHz-1 518 MHz) are relatively low:
   a. no deployments in Africa;
   b. a number of G1 (SDL) deployments in Europe (e.g. in Italy and the United Kingdom);
   c. frequency arrangement G2 (3GPP bands 50 and 51) is deployed in Japan.

[98] It is noted that in digital radio broadcasting (to include T-DAB and S-DAB), the L-band is also defined as the sub-band 1 452-1 492 MHz.
[99] It is noted that carrier aggregation (CA) is possible from 3GPP release 10 and onwards (LTE-Advanced).
[100] The band is designated to IMT SDL in two consecutive steps. First, the sub-band 1 452-1 492 MHz as per CEPT/ECC Decision (13)03. Secondly, the sub-bands 1427-1452 MHz and 1492-1518 MHz as per Decision (17)06.

3.2 Other services allocated in the 1.4 GHz band and adjacent bands

The frequency range of 1 427-1 517 MHz (i.e. the range of the lowest to the highest frequency of arrangements in Table 16) corresponds with the following (adjacent) parts of the ITFA for Region 1, as depicted in Table 17. Table 17 also includes the footnotes as included in the ITFA. Footnotes that are not relevant for the African countries or not relevant for the introduction of IMT are in brackets. Footnotes referring to IMT identifications are in blue.

Table 17: ITFA corresponding with the identified IMT frequency arrangements for the 1.4 GHz band (Region 1)

1 400-1 427 MHz		
Services:	Footnote number:	Footnote:
Earth exploration-satellite (passive), radio astronomy, space research (passive)	5.340	All emissions are prohibited in this band (1 400-1 427 MHz).
	5.341	In this band (1 400-1 727 MHz), passive research is being conducted by some countries in a programme search for intentional emissions of extraterrestrial origin.
1 427-1 429 MHz		
Services:	Footnote number:	Footnote:
Space operation (earth-to-space), fixed,mobile except aeronautical mobile	5.341A	The frequency bands 1 427-1 452 MHz and 1 492-1 518 MHz in Region 1 are identified for IMT. For these bands, Recommendation ITU-R M.1036-6 provides the frequency arrangements (see Table 16). IMT use is subject to agreement obtained under No. 9.21 (with respect to the aeronautical mobile service used for aeronautical telemetry).[101]
	(5.341B)	In Region 2, the band 1 427-1 518 MHz is identified for IMT.
	(5.341C)	In Region 3, the bands 1 427-1 452 MHz and 1 492-1 518 MHz are identified for IMT.

[101] The aeronautical mobile allocation is limited to some European countries and does not apply to African countries.

Table 17: ITFA corresponding with the identified IMT frequency arrangements for the 1.4 GHz band (Region 1) (continued)

	5.338A	In the band (1 427-1 452 MHz) Resolution 750 applies. Resolution 750: Given various considerations, recognitions and notes, WRC-19 resolved to urge administrations to take measures to prevent unwanted emissions from active services (including mobile/IMT) causing unacceptable interference to EESS (Earth exploration-satellite service) sensors. Limits of unwanted emission power from active service stations in specified bandwidths within the EESS (passive) frequency band are included in Table 1 to that resolution.
	5.341	See above
1 429-1 452 MHz		
Services:	Footnotes number:	Footnote:
Fixed, mobile except aeronautical mobile	5.341A	See above
	5.338A	See above
	5.341	See above
	(5.342)	Additional allocation in the band 1 429-1 535 MHz to the aeronautical mobile service for Armenia, Azerbaijan, Belarus, the Russian Federation, Uzbekistan, Kyrgyzstan and Ukraine.
1 452-1 492 MHz		
Services:	Footnotes number:	Footnote:

Table 17: ITFA corresponding with the identified IMT frequency arrangements for the 1.4 GHz band (Region 1) (continued)

Fixed, mobile except aeronautical mobile, broadcasting, broadcasting-satellite	5.346	The band 1 452-1 492 MHz is identified for IMT for many African countries[102] in accordance to Resolutions 223 (WRC-19) and 761. IMT use is subject to agreement obtained under number 9.21 (with respect to the aeronautical mobile service used for aeronautical telemetry).[103] Resolution 223: Given various considerations, recognitions and notes, WRC-19 resolves that administrations are invited to implement IMT on the basis of user demand and other national considerations. In addition, ITU-R is to conduct compatibility studies for IMT-MSS. Resolution 761: Establishes a power flux-density (pfd) limit at the border of the territory of an administration using broadcasting-satellite service (BSS) sound network. Coordination of IMT stations with respect to BSS-receiving earth stations (typical) also applies.
	5.341	See above
	(5.342)	See above
	5.345	The use of band 1 452-1 492 MHz by the BSS, and by the broadcasting service, is limited to digital audio broadcasting. This is subject to: Resolution 528: Given a number of considerations, WRC-19 resolves that a conference should be convened for the planning of BSS (sound) in the bands allocated to this service in the range 1-3 GHz and the development of procedures for the coordinated use of complementary terrestrial broadcasting.
	1 492-1 518 MHz	
Services:	Footnotes number:	Footnote:
Fixed, mobile except aeronautical mobile	5.341A	See above
	5.341	See above
	(5.342)	See above
	1 518-1 525 MHz	
Services:	Footnotes number:	Footnote:

[102] Excepting Cabo Verde, Comoros, Equatorial Guinea, Eritrea, Ethiopia, Libya, Sao Tome and Principe, Sierra Leone and Somalia.

[103] See footnote 99.

Table 17: ITFA corresponding with the identified IMT frequency arrangements for the 1.4 GHz band (Region 1) (continued)

Fixed, mobile except aero-nautical mobile, mobile-satellite (space-to-Earth)	5.348	The use of band 1 518-1 525 MHz by the MSS is subject to coordination under No. 9.11A.[104] Also, MSS stations in this band should not claim protection from the stations in the fixed service.
	(5.348A)	For the band 1 518-1 525 MHz a coordination threshold stipulation for Japan only.
	(5.348B)	A provision in the band 1 518-1 525 MHz for the United States only.
	(5.351A)	For the use of the bands 1 518-1 544 MHz by the MSS, see Resolutions 212 (Rev WRC-15, Implementation of IMT in the bands 1 885-2 025 and 2 110-2 200 MHz) and 225 (Rev-WRC-12, the use of additional frequency bands for the satellite component of IMT and the invitation to carry out sharing studies).
	5.341	See above
	(5.342)	See above

From Table 18 the following can be observed and concluded:

1) The non-IMT spectrum allocations in the range 1 427-1 518 MHz and in adjacent bands include the following primary services:

   a. In the adjacent band 1 400-1 427 MHz, it is noted that all the primary services listed are passive (i.e. not emitting radio frequencies), as radio astronomy is also defined as a service that only receives radio waves:

      i. Earth exploration-satellite (passive);
      ii. Radio astronomy;
      iii. Space research (passive).

   b. In the band 1 427 to 1 518 MHz:

      i. Space operation (Earth-to-space);
      ii. Fixed;
      iii. Mobile except aeronautical mobile;
      iv. Broadcasting;
      v. Broadcasting-satellite.

   c. In the adjacent band 1 518-1 525 MHz:

      i. Fixed;
      ii. Mobile except aeronautical mobile;
      iii. Mobile-satellite (space-to-Earth).

[104] An ITU-defined procedure for coordinating with or obtaining agreement of other administrations.

2) Several footnotes are relevant for the African countries and the introduction of IMT:

   a. In the band 1 400-1 427 MHz:

      i. 5.340: All emissions are prohibited in this band (1 400-1 427 MHz).

   b. In the bands 1 427-1 429 MHz and 1 429-1 452 MHz:

      i. 5.341A: IMT identification for these bands;
      ii. 5.338A: In these band Resolution 750 applies. IMT services do not cause unacceptable interference to EESS. IMT unwanted emissions should be below the limits as included in the enclosed table.

   c. In the band 1 452-1 492 MHz:

      i. 5.346: IMT identification for this band in many African countries;
      ii. 5.345: This band for the BBS and broadcasting service is limited to digital audio broadcasting and is subject to Resolution 528 (a conference should develop procedures for the coordinated use of the BBS).

   d. In the band 1 492-1 518 MHz:

      i. 5.341A: IMT identification for this band.

   e. In the band 1 518-1 525 MHz:

      i. 5.348: The use of this band by the MSS is subject to international coordination.

Table 18 provides an overview of the applications and technology standards commonly applied in Region 1 for the non-IMT services as included in Table 17. The passive services Earth exploration-satellite, radio astronomy and space research are not included in Table 18, although Section 3.3.1 does address the IMT compatibility with these passive services. Also, aeronautical telemetry systems are not included in Table 18, however Section 3.3.4 addresses the cross-border coordination of such systems with IMT.

Table 18: Common applications and technology standards per ITU-RR service for Region 1

ITU-RR service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Space operation (Earth-to-space) 1 427-1 429 MHz	Space operation service	Space operation service.	Communication service exclusively for the operation of spacecrafts (in particular space tracking, space telemetry and space telecommand).	Dedicated	NTFA[105]

105 The NTFA (and possibly a frequency register) needs to be checked for any applications under space operation services.

Table 18: Common applications and technology standards per ITU-RR service for Region 1 (continued)

ITU-RR service	Application		Application examples	Tech-nology standard	Refer-ences
	ITU name	CEPT name			
Fixed 1 427-1 518 MHz 1 518-1 525 MHz	Point-to-Point (P-P)	P-P[106]	Backhaul radio links in IMT net-works, wireless metropolitan area networks (Wi-MAN) and corporate net-works.	Various, including proprietary solutions.	ETSI
	P-MP	P-MP	As above	As above	ETSI
Mobile except aeronautical mobile 1 427-1 518 MHz, 1 518-1 525 MHz	Programme SAB/SAP	Programme PMSE[107]	Wireless microphones, wireless cameras and microwave links (for outdoor newsgather-ing), ALD.	Various, for pro-fessional licensed and unli-censed (low-er-power) equipment.	ETSI
Broadcasting[108] 1 452-1 492 MHz	Broadcasting service, digital sound broad-casting	Broadcasting (terrestrial)	Terrestrial digital sound broadcasting.	T-DAB and T-DAB+[109]	ETSI
Broadcasting-satellite 1 452-1 492 MHz	Broadcasting-satellite service, digital sound broad-casting	Broadcasting (satellite)	Radio broad-casting services by means of satellite trans-mission, often to feed a ter-restrial radio network.	S-DAB[110]	ETSI

106 In ECC Report 173, Fixed Service in Europe – Current use and future trends post 2016, dated 27 April 2018, a number of CEPT countries use for fixed services (P-P and P-MP) the two harmonized bands 1 350-1 375 MHz paired with 1 492-1 517 MHz and 1 375-1 400 MHz paired with 1 427-1 452 MHz (see Rec. T/R 13-01). However, fixed services are also used outside these harmonized bands. SADC's harmonized Radio Frequency Spectrum Allocation Plan has designations for fixed links in the bands 1 427-1 452 MHz, 1 492-1 518 MHz and 1 518-1 525 MHz (paired or single arrangements).

107 According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), the bands 1492-1518 MHz and 1 518-1 525 MHz are designated to radio microphones and ALD (on a tuning range basis). SADC harmonized Radio Frequency Spectrum Allocation Plan does not indicate any designations for SAB/SAP (radio microphones or ALD).

108 Handheld reception of TV, audio, data-cast and multimedia services (on systems like DVB-H, Media FLO and T-DMB) are not included as these services have almost all ceased to operate.

109 According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), T-DAB is designated in the band 1 452.0-1 479.5 MHz. The SADC harmonized Radio Frequency Spectrum Allocation Plan has designations for T-DAB and S-DAB in the bands 1 452-1 467 MHz and 1 467-1 492 MHz.

110 See footnote 108.

Table 18: Common applications and technology standards per ITU-RR service for Region 1 (continued)

ITU-RR service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Mobile-satellite (space-to-Earth) 1 518-1 525 MHz	Mobile satellite services (MSS) – with mobile earth stations	MSS	Communication systems with a mobile earth station, intended to be used while in motion or during halts at unspecified points. For example, for news reporting and data/voice communication.	Solutions offered by traditional telecom operators and specialized resellers.	Inmarsat, Iridium, Globalstar and Thuraya.

From Tables 17 and 18, the following can be concluded and noted:

1) The following potential incompatibilities could occur between IMT in the band 1 427-1 517 MHz (see Table 16) and:

   a. Earth exploration-satellite (EESS), radio astronomy (RAS) and space research services in the band 1 400-1 427 MHz.
   b. Space operation services in the 1 427-1 429 MHz.
   c. P-P and P-MP in the bands 1 427-1 518 MHz and 1 518-1 525 MHz.
   d. SAB/SAP, wireless microphones (and ALD) in the bands 1 427-1 518 MHz and 1 518-1 525 MHz.
   e. T-DAB and S-DAB in the band 1 452-1 492 MHz. In most European countries this band has remained unused for the past decade. In Africa, DAB usage of this band is probably also very limited to non-existent. According to WorldDAB, the only regular deployment of DAB is in Tunisia (but in the VHF band not in the L-band). Algeria and South Africa are conducting trials with DAB (also in the VHF band).
   f. MSS in the band 1 518-1 525 MHz.

2) The National Table of Frequency Allocations (NTFA) will indicate whether any of the applications in Table 18 are assigned and in use in a specific African country. Consequently, such use should be considered in assessing the compatibility with an IMT allocation in the 1.4 GHz band in that country.

3.3 Sharing/compatibility between IMT and the other services in the 1.4 GHz band

In this report, only the key IMT sharing and compatibility studies and their results are covered. Administrations are advised to interpret these study results with caution as their local situation (including the actual frequency allocations/assignments as reflected in their NTFA, the applied technologies and interference scenario) may differ from those covered in the studies.

3.3.1 Overview of IMT sharing and compatibility studies

Table 19 provides an overview of the key IMT sharing and compatibility studies relevant for the 1.4 GHz band. The second column indicates the compatibility case under consideration in the study, i.e. the compatibility between IMT and an application for the other services (see Table 18).

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
1	IMT-EESS	ITU	ITU-RR, Resolution 750 (Rev. WRC-19)[111]	Compatibility between the Earth exploration-satellite service (passive) and relevant active services	• Unwanted emissions from active services (including mobile/IMT) do not cause unacceptable interference to EESS (Earth exploration-satellite service) sensors. Unwanted emissions limits per active service and per frequency band are included in the enclosed table; • Limits of IMT unwanted emission power: o –72 dBW in the 27 MHz of the EESS (passive) band for IMT base stations; o –62 dBW in the 27 MHz of the EESS (passive) band for IMT mobile stations (EU).

[111] See Final Acts of WRC-19, Resolution 750.

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
2	IMT-EESS	CEPT/ ECC	ECC Decision (17)06 (2 March 2018)	The harmonized use of the frequency bands 1 427-1 452 MHz and 1 492-1 518 MHz for mobile/ fixed communications networks supplemental downlink (MFCN SDL)	• ECC Decision (17)06 establishes conditions of IMT operation in the whole 1 427-1 518 MHz band to ensure continued operation of passive services below 1 427 MHz and of MSS above 1 518 MHz • The unwanted emission limits as in Resolution (Rev. WRC-15)[112] may not be sufficient and at a national level there is a need to consider relevant separation distances around radio telescopes, and other mitigation techniques such as additional filtering and/or a guardband for IMT stations; • This Decision provides the unwanted emission limit (–72 dBW/27MHz for base stations), which correspond with Res.750 (Rev. WRC-19).
3	IMT-EESS	ITU	ITU-R Report RS.2336-0 (2014)	Consideration of the frequency bands 1 375-1 400 MHz and 1 427-1 452 MHz for the mobile service – Compatibility with systems of the Earth exploration-satellite service within the 1 400-1 427 MHz frequency band	• This report also includes the unwanted emission limit corresponding with Res. 750 (-75 dBW/27MHz) for IMT in the band 1 427-1 452 MHz;[113] • This report also indicates that additional mitigation measures may be needed to reduce unwanted emissions of IMT systems. These additional measures are included in Annex 1 of the Report (see Section 3.3.2).

112 It is noted that the unwanted emission limits for IMT in the band 1 427-1 452 MHz have not changed between Resolution 750 (Rev. WRC-15) and (Rev. WRC-19).

113 The Report includes a stricter unwanted emission limit of –80 dBW/27MHz that applies when the two frequency bands 1 427-1 452 MHz and 1 375-1 400 MHz are used for IMT. However, the frequency band 1 375-1 400 MHz has no IMT identification so far.

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
4	IMT-RAS	ITU	ITU-R Rec. RA.769 (2003)	Protection criteria used for radio astronomical measurements	• Sharing RAS frequencies with any other service (including IMT) in which direct line-of-sight paths from the transmitters to the observatories are involved is very difficult; • Above 40 MHz, frequency difference sharing may be practicable with services in which the transmitters are not in direct line-of-sight of the observatories, but coordination may be necessary, particularly if the transmitters are of high power; • Annex 1 provides interference calculation aids (and tables with interference threshold levels) for various types of RAS applications.
5	IMT-RAS	CEPT/ ECC	ECC Decision (17)06 (2 March 2018)	The harmonized use of the frequency bands 1 427-1 452 MHz and 1 492-1 518 MHz for mobile/ fixed communications networks supplemental downlink (MFCN SDL)	• This ECC Decision refers to Rec. ITU-R RA.769 (see above) and sets the threshold input power into the RAS frequency band 1 400-1 427 MHz to –205 dBW for broadband RAS observations and to –220 dBW/20 kHz for narrow band observations (from Tables 1 and 2 in the Annex 1 of Rec. ITU-R RA.769); • Additional mitigation methods may be required at the location of RAS stations, such as setting adequate separation distances between RAS stations and IMT BTS. The size of these separation distances will be determined on an individual basis for the affected RAS stations (Annex 1 of Rec. ITU-R RA.769 can be used).

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
6	IMT-FS	ITU	ITU-R Report F.2333-0 (11/2014)	Sharing and compatibility study between international mobile telecommunication and the fixed service in the frequency band 1 350-1 527 MHz	• This report presents an analysis of the feasibility of co-channel compatibility/sharing between IMT and FS (P-P) operating in the frequency band 1 350-1 527 MHz; • The geographic separation required between an IMT BTS and a co-channel fixed link is highly dependent on the orientation of the fixed link antenna, the TX and RX antenna heights relative to the clutter/terrain, the power transmitted, and fixed link RX antenna performance; • In deployment cases where a terrain database is available, a more accurate case-specific separation distance may be calculated for the IMT BTS; • Mitigation factors associated with many deployment scenarios could significantly decrease separation distances for the IMT BTS; • Compatibility of FS with IMT uplinks (UE) will be possible provided that the radio links are not located close to major population centres where UE are likely to be used in close proximity.

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
7	IMT-other services	CEPT/ ECC	ECC Decision (13)03 (8 November 2013 and amended on 02 March 2018)	The harmonized use of the frequency band 1 452-1 492 MHz for mobile/fixed communications networks supplemental downlink (MFCN SDL)	• OOBE limits for MFCN SDL have been defined to address compatibility between MFCN SDL in the 1 452-1 492 MHz frequency band and other applications in adjacent bands but in the same geographical area. See table 3 in this Decision; • The Decision leaves room for administrations to implement terrestrial digital sound broadcasting (including T-DAB) networks in part of the frequency band 1 452-1 492. However, T-DAB implementation in the L-band is rare to non-existent, as are applications for handheld reception of multimedia services (like DVB-H, Media FLO and T-DMB); • Administrations could restrict base stations in-band equivalent isotropically radiated power (e.i.r.p.) at a national level.
8	IMT-other services	CEPT/ ECC	ECC Report 188 February 2013	Future Harmonized Use of 1 452-1 492 MHz in CEPT	• Report studies alternative band allocations (as the band is hardly used), such as IMT, IMT SDL, DAB, PMSE; • As Decision (13)03 shows it was decided to allocate to MFCN(IMT) SDL; • In Section 6, a methodology is proposed to consider that some of these applications may share the spectrum with other applications through band segmentation or through solutions at a national level.

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
9	IMT-MSS	CEPT/ ECC	ECC Decision (17)06 (2 March 2018)	The harmonized use of the frequency bands 1 427-1 452 MHz and 1 492-1 518 MHz for mobile/ fixed communications networks supplemental downlink (MFCN SDL)	• This Decision establishes conditions of operation in the whole 1 427-1 518 MHz to ensure continued operation of MSS above 1 518 MHz; • This Decision provides IMT in-block and out-of-block emission limits for the compatibility with MSS (not unwanted emission limits):[114] o IMT in-block (1 512-1 517 MHz): max e.i.r.p. 58 dBm/5 MHz; o Out-of-block: max e.i.r.p –0.8 dBm/1 MHz for MSS in 1 518-1 520 MHz; o Out-of-block: max e.i.r.p –30 dBm/1MHz for MSS in 1 520-1 559 MHz; • It also proposes a guard-band of 1 MHz (1 517-1 518 MHz); • Additional measures may be necessary and administrations may restrict the power of IMT BTS (below the maximum in-block emission limit as set in this Decision).

[114] It is noted that in-block and out-of-block emission limits (BEM) should be considered in combination with the associated (harmonized) band plan.

Table 19: Overview of key IMT sharing and compatibility studies relevant for the 1.4 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
10	IMT - MSS	CEPT/ ECC	ECC Report 263	Adjacent band compatibility studies between IMT operating in the frequency band 1 492-1 518 MHz and the MSS operating in the frequency band 1 518-1 525 MHz	• This report studied under 3 different guardband scenarios (1, 3 and 6 MHz): o the out-of-band emissions (OOBE)[115] from IMT BTS to mobile Earth station (MES) in 1 518 MHz; o Receiver-blocking of the MES in 1 518 MHz. • It concluded that with a 1 MHz guardband, the OOBE and MES blocking interference was high. For the 3 and 6 MHz guardbands, the OOBE interference is limited and the MES blocking remain high; • However, with future improved MES, the MES receiver blocking is reduced to the levels of OOBE; • Report provides mitigation techniques that could further improve the compatibility between IMT and MSS around 1 518 MHz (see Section 3.3.2).

Table 19 tells us the following:

1) Compatibility of IMT with EESS in the adjacent band (1 400-1 427 MHz) is possible under the following conditions:

   a. Observing the unwanted emissions limits for IMT in the band above 1 427 MHz as stipulated in Resolution 750 (see No. 1 in Table 19);

   b. Applying additional measures if these unwanted emission limits don't suffice, such as additional filtering and/or a guardband for IMT stations (see Nos. 2 and 3 in Table 19).

2) Sharing of IMT and RAS using the same frequency (in which a direct line-of-sight path from the IMT transmitter to the observatories is involved) is not possible (see No. 4 in Table 19).

3) Compatibility of IMT with RAS in the adjacent band (1 400-1 427 MHz) is possible under the following conditions:

[115] Unwanted emissions: Consist of spurious emissions and out-of-band emissions.

   a. Observing the threshold input power into the RAS frequency band (1 400-1 427 MHz) from ITU-R Rec. RA.769 and ECC Decision (17)03 (see Nos. 4 and 5 in Table 19);
   b. Applying additional measures if such threshold input power doesn't suffice, such as setting adequate separation distances between RAS stations and IMT BTS (see No 5. In Table 19).

4) Compatibility of IMT and FS (P-P) in the same band is possible by having the appropriate (calculated) geographical separation distance (in case of co-channel). Mitigation measures could significantly decrease these separation distances (see No. 6 in Table 19).
5) Compatibility of IMT in the band 1 452-1 492 MHz and other services in adjacent bands is possible under the following conditions:
   a. Observing the OOBE limits for MFCN SDL (in the band 1 452-1 492 MHz), as defined in table 3 from ECC Decision (13)03 (see No. 7 in Table 19);
   b. Applying additional measures if such limits do not suffice (such as restricting the power of IMT BTS).
6) Any compatibility of IMT with T-DAB/S-DAB in the band 1 452-1 492 MHz are considered not likely to be relevant given that this band is not used for this application in Africa and that future T-DAB/S-DAB implementation in the L-band are also unlikely as many African countries had identified the band for IMT.
7) Compatibility of IMT in the band 1 492-1 518 MHz and MSS in the adjacent band 1 518-1 525 MHz is possible under the following conditions:
   a. Observing the in-block and out-of-block emission limits, as given in ECC Decision (17)06 (see Nos. 9 and 10 in Table 19);
   b. Applying additional measures if such limits do not suffice (such as restricting the power of IMT BTS).

3.3.2 Technical conditions for IMT sharing and compatibility

As concluded from Table 19, several compatibility and sharing options between IMT and the other services have been identified. Table 20 provides an overview of technical conditions under which such options are technically feasible. It is noted that the specific local situation will dictate which and to what extent the technical conditions listed need to be applied.

For the technical conditions presented in Table 20, it is assumed that the radio equipment involved in the interference case complies with a minimal (least restrictive), and preferably, a harmonized set of technical conditions.[116] Such a set of minimum technical conditions may be checked as part of a type-approval procedure for granting the use of radio equipment in the NRA's territory. Also, such a set of minimum criteria often include emission limits/spectrum masks and may be complemented with other conditions such as for human safety (EMC).

Finally, the conditions included in Table 20 address the conditions for separating IMT from other non-IMT applications. Conditions for separating frequency blocks between IMT operators (such as guardbands, spectrum masks, radiated power level) are not addressed.

[116] For the bands 1 427-1 452 MHz and 1 492-1 518 MHz, see ECC Decision (17)06, Annex 2. For the band 1 452-1 492 MHz, see ECC Decision (13)03, Annex 2.

Table 20: Technical conditions for IMT sharing and compatibility in the 1.4 GHz band

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
IMT-EESS	Compatibility in adjacent bands	IMT in the band above 1 427 MHz and EESS in 1 400-1 427 MHz	A number of measures can be applied (in combination): • Increase separation distances around radio telescopes; • Apply additional filtering at IMT stations; • Enlarge the guard-band for IMT stations.	ITU-R Report RS.2336-0 (2014); ECC Decision (17)06 (2 March 2018)	Rep. ITU-R RS.2336-0: the table in Annex 1 includes possible mitigation measures to be applied to IMT systems to protect EESS.
IMT-RAS	Compatibility in adjacent bands	IMT in the band above 1 427 MHz and RAS in 1 400-1 427 MHz	A number of measures can be applied (in combination): • Increase separation distances around radio telescopes; • Apply additional filtering at IMT stations; • Enlarge the guard-band for IMT stations.	ITU-R Rec. RA.769 (2003); ECC Decision (17)06 (2 March 2018)	ITU-R Rec. RA.769, Annex 1 provides interference calculation aids (and tables with interference threshold levels) for various types of RAS applications. The size of separation distances will be determined on an individual basis for the affected RAS stations (Annex 1 of Rec. ITU-R RA.769 can be used).

Table 20: Technical conditions for IMT sharing and compatibility in the 1.4 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
IMT-other services	Compatibility in adjacent bands	IMT in the band 1 452-1 492 MHz and other services in adjacent bands (above and below)	These measures can be applied (in combination): • Restrict the power of the IMT base stations; • Apply band segmentation between IMT and the other services.	ECC Decision (13)03; ECC Report 188	In ECC Report 188, section 6, a methodology is included to determine band segmentation.
	Sharing in the same band	IMT in the band 1 427-1 518 MHz band and PMSE (wireless microphones) in the same band	Although not included in Table 19, such sharing may need to be catered for as in the CEPT frequency allocation table, PMSE can be allocated in the bands 1 492 MHz-1 518 MHz and 1 518-1 525 MHz. For this IMT/PMSE sharing, please refer to Table 5.	See Table 5	See Table 5
IMT-MSS	Compatibility in adjacent bands	IMT in the band 1 492-1 518 MHz and MSS in the band 1 518-1 525 MHz (unwanted emissions)	Additional measures may be necessary and administrations may restrict the power of IMT BTS (below the maximum in-block emission limit as set in the ECC Decision (17)06.	ECC Decision (17)06	

Table 20: Technical conditions for IMT sharing and compatibility in the 1.4 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
	Compatibility in adjacent bands	IMT in the band 1 492-1 518 MHz and MSS in the band 1 518-1 525 MHz (blocking of MES)	ECC Report 263 found that for avoiding the blocking of the MES, a higher guardband may be needed (higher than needed for reducing unwanted emissions). However, with future improved MES, the MES receiver-blocking is reduced to the levels of OOBE (this excludes spurious emissions). Hence the ECC Decision (17)06 in-band and out-of-band emission limits may suffice.	ECC Report 263	Administration implementing IMT in the 1.4 GHz band should check the latest blocking performance of MES.

3.3.3 Regulatory conditions for IMT sharing and compatibility

Administrations may wish to complement the technical conditions under which they grant the IMT spectrum rights (see Section 3.3.2)[117] with specific IMT regulatory conditions (next to the general conditions for assigning spectrum rights[118]). These specific IMT-related conditions often arise from the situation that the IMT services are introduced in bands with incumbent services that need to be protected.

Table 21 provides an overview of these IMT-specific regulatory conditions.

Table 21: Regulatory conditions specific for IMT licensees

No	Condition or requirement	Notes	References
1	For protecting the passive services (such as EESS and RAS) in the band 1 400-1 427 MHz, the unwanted emission limits (as stipulated in ITU Resolution 750 WRC-19) should be observed by the IMT licensee. However, complying with these limits does not exclude the NRA imposing additional measures if deemed necessary.	The additional measures are described in Table 20	See Section 3.3.2
2	The IMT licensee has the obligation to compensate for any incurred costs by the incumbent service.	See also Table 6	See Section 1.3.3

[117] See footnote 49.
[118] See footnote 50.

Table 21: Regulatory conditions specific for IMT licensees (continued)

No	Condition or requirement	Notes	References
3	The IMT licensee has the obligation to help investigate any complaints about interference of incumbent services.	See also Table 6	See Section 1.3.3
4	To protect the mobile satellite service (MSS) in the band 1 518-1 525 MHz, a defined set of in-band and out-of-band emission limits should be observed by the IMT licensee. However, complying with these limits does not exclude the NRA imposing additional measures if deemed necessary.	This set of in-band and out-of-band emission limits could be derived from ECC Decision (17)06	See Section 3.3.2

3.3.4 Cross-border coordination aspects for IMT

Cross-border inference cases between countries are a subset of the interference cases within a country (as discussed in Section 3.3.1) as, in this frequency band, they mainly cover emissions located closer to the border.

Figure 7 shows a generic overview of the possible cross-border interference cases for the 1.4 GHz band.

Figure 7: Generic overview of possible cross-border interference cases for the 1.4 GHz band

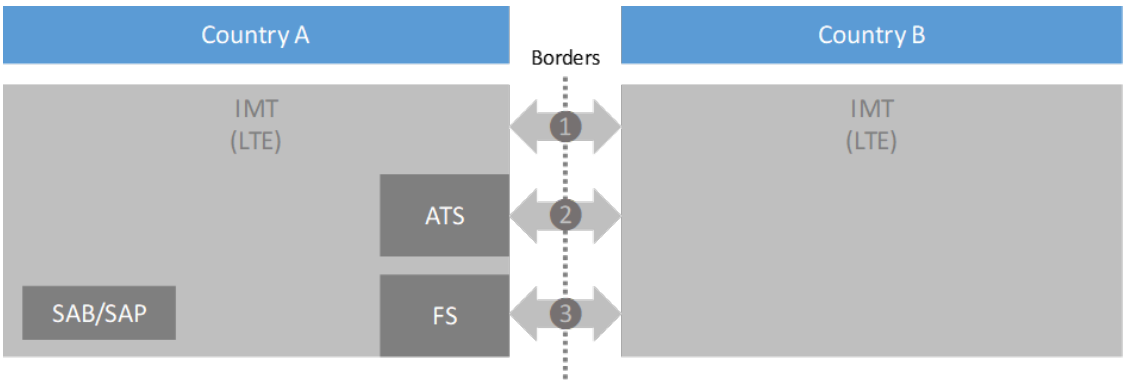


Figure 7 illustrates the following:

1) PPDR (broadband or narrowband) is not included in Figure 7 (see also Table 18) because:
   a. In the CEPT table of harmonized frequency allocations, PPDR is not identified or deployed in the band 1 427- 1 518 MHz;
   b. In the SADC table of harmonized frequency allocations, PPRD is not identified or deployed in the band 1 427- 1 518 MHz;
   c. ITU-R M.2015-2 (Frequency arrangement for PPDR), the ATU has neither recommended any allocations for PPDR in the band 1 427-1 518 MHz.
2) T-DAB/S-DAB (as well as any systems for handheld multimedia delivery) is not included in Figure 7 (see also Table 19) because:

a. The band 1 452-1 492 MHz is not used for these applications in Africa and that future T-DAB/S-DAB implementation in the L-band is also unlikely;
b. Even more so, given the IMT identification for a large number of African countries.

3) Cross-border case 1: Interference case 1 may arise in the final stages when administrations have adopted IMT and their stations' emissions are within the coordination zone for these services:

a. As referred to in Section 1.3.4, the HCM, HCM4A, BKO-18 and the Vienna Agreement can be referred to for procedures and parameters for managing possible cross-border interference between IMT services;
b. Alternatively, and specifically for the cross-border coordination of LTE and NR/5G applications a system of physical cell identity (PCI) can be used (also discussed in Section 1.3.4). A PCI is an identification of an IMT cell at the physical layer and represents a specific frequency which can be used in cross-border coordination. ECC Rec. (15)01 provides guidance for cross-border coordination on the basis of PCI. The recommendation provides the following on cross-border coordination for the band 1 427-1 518 MHz:

i. A system for dividing preferential and non-preferential PCIs between administrations on the basis of equitable spectrum access. In other words, administrations should share PCIs in border areas and have equitable distribution of 504 (LTE) or 1008 (NR/5G) available PCIs, for preferential and non-preferential PCIs.
ii. Preferential and non-preferential PCIs have different trigger values (expressed in dBμV/m/5 MHz). Coordination is needed if the interfering field strength is higher (Annex 1). The interfering field strength is calculated on the basis of defined propagation models (Annex 2).
iii. A procedure for the exchange of data between the requesting and the affected administrations (Annex 3).
iv. A detailed system for assigning PCIs to countries, based on a cell-colouring system[119] for the CEPT countries. However, African countries can adapt the proposed system for their local situation.

4) Cross-border case 2: According to footnote No. 5.342 (see Table 17) the bands 1 427-1 452 MHz and 1 492-1 518 MHz is also allocated to the aeronautical mobile service on a primary basis exclusively for the purposes of aeronautical telemetry services (ATS) within the national territory of some Region 1 countries. Country B implementing IMT and country A having ATS in the bands 1 427-1 452 MHz and 1 492-1 518 MHz may require coordination of their IMT and ATS use. The following is noted on this cross-border coordination:

a. ECC Report 295[120] provides interference scenarios and calculation methods for determining interference to the ATS;
b. possible technical measures to eliminate harmful interference from MFCN to ATS stations were also considered in this report.

5) Cross-border case 3: Cross-border coordination of fixed services (P-P) are likely to be incidental and a case-based coordination can be used where any harmful interference found can be mitigated by applying technical measures (see Report ITU-R F.2331-0 and Table 5 in Section 1.3.4).

119 See footnote 57.
120 ECC Report 295, Guidance on cross-border coordination between MFCN and aeronautical telemetry systems in the 1 429-1 518 MHz band (March 2019).

3.4 Best practices and methods for refarming other services in the 1.4 GHz band

Refarming in the context of this report means the replanning of incumbent services is deemed incompatible with the introduction of IMT. In other words, the spectrum needs to be freed up or cleared for IMT. From Tables 19 and 20 it can be concluded that some services or applications may have to be replanned or reallocated to adjacent or other bands.

It is noted that a number of non-IMT services or applications are likely not deployed or planned:

1) PPDR is not identified or deployed in the band 1 427-1 518 MHz, according to the CEPT and SADC table of harmonized frequency allocations, nor does ITU-R M.2015-2 (i.e. the ATU) recommend PPDR deployments in this band.
2) T-DAB/S-DAB (as well as any systems for handheld multimedia delivery) is not identified or deployed in the band 1 452-1 492 MHz and it is unlikely that this will happen in the near future.

Some non-IMT service or applications are likely deployed and may have to be refarmed:

1) Fixed services, P-P and P-MP are allocated in the 1.4 GHz band, according to the CEPT and SADC frequency allocation tables;[121]
2) SAB/SAP, wireless microphones and ALD are planned in the band 1 492-1 518 MHz, according to CEPT frequency allocation table. However, the SADC frequency allocation table does not have any entries in the band 1 427-1 518 MHz.[122]

For refarming SAB/SAP applications, the reader is referred to Section 1.4.3. The refarming of P-P/P-MP radio links is addressed in the next Section 3.4.1.

The financial funding of refarming efforts is addressed in Section 11. It is noted that Rec. ITU-R SM.1603 also covers general approaches to refarming, guidelines for calculating refarming (or redeployment) costs, as well as examples of country experiences with refarming.

3.4.1 Refarming P-P/P-MP radio links

The spectrum claim of radio links may be local, in small, scattered pockets. In such a case it may not be necessary to refarm the whole band nationally for the reassignment of radio links. Figure 8 shows a possible approach for preparing a refarming plan.

[121] See footnote 105 for the exact bands.
[122] See footnote 106.

Figure 8: Possible approach to preparing the refarming of FS

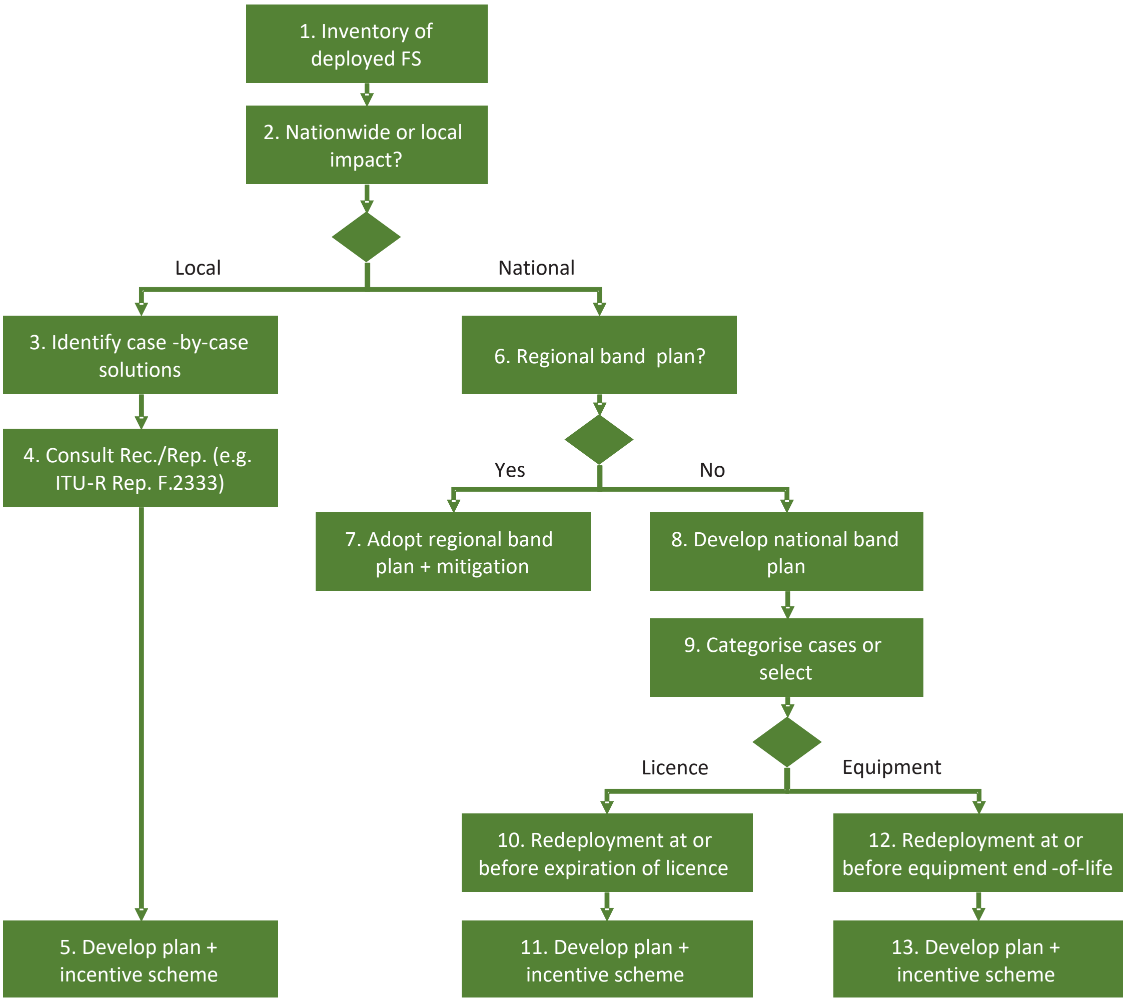


Figure 8 shows the following steps:

1) Carry out a detailed inventory of the numbers, locations and site characteristics of the deployed P-P/P-MP microwave links in the country. This task should not be underestimated as records may not be available and may be difficult to reconcile with each other. A public consultation may be needed to acquire such information.
2) Assess the scale and impact of a potential IMT-FS incompatibility. It may be that the number of deployed radio links is limited and that it is confined to some local areas in the country. This may open up the opportunity to address these local potential incompatibilities with a case-by-case approach.
3) If the scale is local, identify case by case whether mitigation is possible, while keeping the deployed radio links in operation as much as possible. Interference could be mitigated through a combination of geographic and frequency separation. This will also require a case-by-case approval procedure for any fixed service in the country.
4) The identification of mitigation solutions may be assisted by considering relevant ITU documents. For example, Report ITU-R F.2333 or other ITU-R Recommendations and Reports from the F-series (fixed services).
5) A plan, including timescales and technical solutions, should be developed and agreed with (a limited number) FS operators involved. Depending on the IMT implementation planning, a voluntary incentive scheme may suffice. In such a scheme, the FS operators are encouraged (e.g. by providing licence-fee reductions and/or offering a technological

better solution) to adopt the mitigation solution before the expiration date of their licence or before the end-of-life of their FS equipment.

6) If the scale is national, the administration is advised to check if a regional band plan is available or should be developed.[123]
7) If a regional band plan is available or should be developed, administrations are recommended to encourage the adoption and implementation of such a band plan.[124] It should be noted that the adoption of such a regional band plan will have to be accompanied with minimum (least restrictive) technical conditions and that these may not be adequate to resolve all harmful interference cases. Mitigation techniques may be necessary by setting additional technical conditions.
8) If no regional band plan is available and applicable, administrations are recommended to develop a national band plan. Such a new national band plan can entail that fixed links needs to be replanned in spectrum that would require replacing (or modifying) equipment.
9) Consequently, such a national band plan may have to consider either categorizing or selecting a method and planning based on the redeployment of FS at or before the expiration date of the assigned FS licences, and/or at or before the equipment's end of life.
10) Under the redeployment of FS at or before the expiry date of the assigned FS licences, administrations base their plan on the possibilities the legislative framework in force provides.
11) A new national band plan, including timescales and technical solutions, should be developed and agreed with all FS operators. Organizing a public consultation may be necessary. Depending on the IMT implementation planning, a voluntary incentive scheme may suffice. In such a scheme, the FS operators are encouraged (e.g. by providing licence-fee reductions and/or offering a technological better solution) to adopt the mitigation solution before the expiry date of their licence.
12) Under the redeployment of FS at or before equipment becomes redundant, administrations base their plan on giving due consideration to the economic life of FS equipment. Obliging FS operators to shorten the useful life of their equipment may have a severe economic impact on the operator, market or regulator.
13) A new national band plan, including timescales and technical solutions, should be developed and agreed with all FS operators. Depending on the IMT implementation planning, a voluntary incentive scheme may suffice. In such a scheme, the FS operators are encouraged (e.g. by providing licence-fee reductions and/or offering a technological better solution) to adopt the mitigation solution before their equipment's end of life.

3.5 Guidelines and recommended actions for the 1.4 GHz band

Sections 3.1 to 3.4 cover the spectrum allocations for IMT and other services in the 1.4 GHz band, the technical and regulatory conditions facilitating the IMT introduction in this band, as well as best practices and methods for refarming the other services, if deemed necessary.

Table 22 provides a comprehensive list of guidelines as included in these sections.

[123] Such a regional plan may exist for a situation in which a country is, for example, surrounded by another country (such as the Gambia and Senegal) and fixed links can cross over the enveloped country.
[124] It is noted that ITU Recommendations on FS band plans, such as ITU-R F.385-10, ITU-R F.636-5 and ITU-R F.637-4, cover different spectrum bands (not the 1.4 GHz band).

Table 22: Spectrum management guidelines for IMT introduction in the 1.4 GHz band

No	Guideline	Applies to	Ref. Section(s)
3.1	Administrations are advised to interpret the sharing and compatibility study results (contained in Section 3.3.1) with caution as their local situation may differ from the situation covered in the studies. Case-by-case calculation may be needed to determine possibilities for sharing and compatibility of services. For this purpose, various ITU-R Recommendations and Reports are available, as specified in Table 19. Also, a comprehensive list of relevant ITU Recommendations and Reports is provided in Appendix B: ITU Recommendations and Reports	All applications	Section 3.3.1 Appendix B: ITU Recommendations and Reports
3.2	For introducing IMT in the specified frequency bands (see Table 16), administrations may have to set a range of technical and regulatory conditions. Technical conditions can include the application of guardbands, filtering of transmitters/receivers and critical spectrum masks. Regulatory conditions such as an obligation to compensate for migration costs and follow station-approval procedures, are set in combination with the technical conditions.	All applications	Sections 3.3.2 and 3.3.3
3.3	Cross-border coordination may be needed for mitigating co-channel interference for the potential interference cases as included in Figure 7. For resolving interference between IMT and IMT, the procedure and calculation methods as included in the HCM4A can be used. Alternatively, and exclusively for LTE/NR-LTE/NR cross-border coordination the PCI method as included in ECC Rec. (15)01 can be used. ECC Report 295 provides interference scenarios and calculation methods for determining interference to the ATS.	Cross-border coordination of: HCM4A agreement; LTE/NR-LTE/NR (ECC Rec. 15/01).	Section 3.3.4 Appendix A: Cross-border frequency coordination
3.4	From Table 19 and Table 20 it was concluded that the following services or applications may have to be replanned or reallocated to adjacent or other bands: • SAB/SAP (radio microphones and ALD) • FS (P-P/P-MP radio links)	Refarming SAB/SAP and FS	Section 3.4 Section 1.4.3 (for refarming SAB/SAP)
3.5	Carry-out a detailed inventory of the numbers, locations and site characteristics of the deployed P-P/P-MP microwave links in the country. Assess the relocation impact. If the impact is limited to local areas with a limited number of involved FS operators, a case-by-case approach is preferred over a nationwide approach whereby a national band-plan should be developed.	Refarming FS	Section 3.4.1

4 IMT sharing and compatibility with other services in the 2.3 GHz band

This section addresses the sharing and compatibility of IMT services in the 2.3 GHz band (i.e. allocated according to frequency arrangements as detailed by ITU-R and as identified in the ITU-RR) with other primary services in the same band or in adjacent bands.

4.1 IMT frequency arrangements in the 2.3 GHz band

Table 23 shows the IMT frequency arrangements in the 2.3 GHz band as included in Recommendation ITU-R M.1036-6. Table 23 shows only one recommended frequency arrangement in this band. It is also noted that administrations may implement a part of this frequency arrangement.

Table 23: IMT frequency arrangements in the 2.3 GHz band

Frequency arrangement	Paired arrangements (FDD)				Unpaired arrangements (TDD) (MHz)
	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
E1	-	-	-	-	2 300-2 400

From Table 23 the following can be observed and concluded:

1) E1, 3GPP band 40, is a popular band for LTE-A deployments around the world. It is noted that those countries having LTE implementations in this band (2.3 GHz), commonly needed to reallocate fixed wireless access applications. Fixed wireless applications are common in this band[125].
2) Most 3GPP band 40 deployments are partial deployments (of E1).
3) The 3GPP band 30, although in the 2.3 GHz band, is an FDD arrangement (2 x10 MHz) and is rarely deployed.
4) TDD is recommended for this band, because LTE BTS deployed in this spectrum range are often intended for providing high traffic rates rather than cell coverage. Also, TDD systems are applied in cases where (paired) spectrum is not sufficiently available.

4.2 Other services allocated in the 2.3 GHz band and adjacent bands

The frequency range of 2 300-2 400 MHz (i.e. the range of the lowest to the highest frequency of arrangements in Table 23) corresponds with the following (adjacent) parts of the ITFA for Region 1, as depicted in Table 24. Table 24 includes also the footnotes as included in the ITFA. Footnotes not relevant for the African countries or not relevant for the introduction of IMT are between brackets. Footnotes referring to IMT identifications are in blue.

[125] See footnote 15.

Table 24: ITFA corresponding with the identified IMT frequency arrangements for the 2.3 GHz band (Region 1)

2 290-2 300 MHz		
Services:	Footnote number:	Footnote:
Fixed mobile except aeronautical mobile, Space research (deep space) (space-to-Earth)	None	None
2 300-2 450 MHz		
Services:	Footnote number:	Footnote:
Fixed mobile amateur radiolocation	5.384A	The band 2 300-2 400 MHz is identified for use by administrations wishing to implement IMT.
	5.150	The band 2 400-2 500 MHz is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating in this band must accept harmful interference which may be caused by ISM applications. ISM equipment operating in these bands is subject to the provisions of No. 15.13.[126]
	(5.282)	In the band 2 400-2 450 MHz (in Regions 2 and 3 only), the amateur-satellite service may operate subject to not causing harmful interference to other services.
	(5.395)	In France and Turkey, the use of the band 2 310-2 360 MHz by the aeronautical mobile service for telemetry has priority over other uses by the mobile service.

From Table 24 the following can be observed and concluded:

1) The non-IMT spectrum allocations in the range of 2 300 to 2 400 MHz and in adjacent bands include the following primary services:

   a. In the adjacent band 2 290-2 300 MHz:

      i. fixed;
      ii. mobile except aeronautical mobile;
      iii. space research (deep space) (space-to-Earth).

[126] This provision stipulates that administrations must ensure that radiation from ISM equipment is minimal and that, outside the bands designated for use by ISM equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service.

b. In the band 2 300 to 2 450 MHz:

   i. fixed;
   ii. mobile.

2) Two footnotes are relevant for the African countries and the introduction of IMT:

   a. 5.384A: IMT identification for the band 2 300 to 2 400 MHz;
   b. 5.150: non-ISM application in the band 2 300 to 2 400 MHz must accept harmful interference from ISM applications.

Table 25 provides and overview of the applications and technology standards commonly applied[127] in Region 1 for the non-IMT services as included in Table 24.

Table 25: Common applications and technology standards per ITU-RR service for Region 1

ITU-RR service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Fixed 2 290-2 300 MHz 2 300-2 450 MHz	Broadband fixed wireless access (BFWA)	Broadband fixed wireless access	BFWA networks are based on a central radio base station, which communicates with subscriber equipment in the surrounding area. They can rapidly extend fibre-optic networks. Referred to as P-MP systems or local multipoint distribution service (LMDS).[128]	802.16 (WiMAX)	IEEE
				HiperMAN	ETSI
	Point-to-Point (P-P)	Point-to-Point (P-P)	Backhaul radio links in IMT networks, wireless metropolitan area networks (Wi-MAN) and corporate networks.[129]	Various, including proprietary solutions	ETSI
	Point-to-MultiPoint (P-MP)	Point-to-MultiPoint (P-MP)	As above	As above	ETSI
Mobile except aeronautical mobile 2 290-2 300 MHz	SAB/SAP	PMSE	Portable or mobile wireless video links, cordless cameras, as well as temporary P-P links [130] Also referred to as electronic news gathering/outside broadcasting (ENG/OB) links.	Various, including proprietary solutions	ETSI

127 This does not exclude the possibility that country-specific applications exist in the band such as land and maritime military systems.

128 According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), there are no designations for BFWA in the bands 2 290-2 300 MHz and 2 300-2 400 MHz. The SADC harmonized Radio Frequency Spectrum Allocation Plan does have a designation for BFWA in the band 2 285-2 300 MHz.

129 According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), there are no designations for FS in the band 2 290-2 450 MHz. The SADC table does have FS (P-P/P-MP) in the band 2 300-2 400 MHz.

130 The SADC harmonized Radio Frequency Spectrum Allocation Plan does not have PMSE designation in the band 2 290-2 450 MHz. The European table does have PMSE in the band 2 290-2 450 MHz.

Table 25: Common applications and technology standards per ITU-RR service for Region 1 (continued)

ITU-RR service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Mobile 2 300-2 450 MHz	SAB/SAP	PMSE	As above	As above	ETSI
	Radio-telemetry	Aeronautical (and terrestrial) telemetry	Telemetry signals are transmitted by airborne stations (e.g. aircraft, missile) to ground stations. Telecommand can be associated to telemetry systems. Telecommand signals are transmitted by ground stations to airborne stations in another frequency band.[131]	IRIG standard 106	IRIG
Space research 2 290-2 300 MHz	Space research	Space research	Satellite payload and platform telemetry for space research (deep space). Continuum observations, very long baseline interferometry.[132]	Dedicated	ETSI
Industrial, scientific and medical (ISM) 2 400- 2 500 MHz[133]	ISM	ISM	ISM applications are applications for non-communications purpose such as drying, melting, heating, welding, thawing, cooking, tempering and soldering.[134]	Various, including proprietary solutions	ITU
Short-range devices (SRD) 2 400- 2 450 MHz[135]	None	SRD	SRDs include a wide range of applications such as broadband wireless access systems (RLAN/WLAN), radio frequency identification (RFID), car door openers, Bluetooth, near-field communications (NFC) and alarms.[136]	802.11 (for Wi-Fi/RLAN/WLAN) [137] Bluetooth	IEEE

131 In the CEPT countries aeronautical telemetry uses the band 2 310-2 400 MHz.
132 According to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), the band 2 290-2 300 MHz is allocated to space research. The SADC harmonized Radio Frequency Spectrum Allocation Plan does not have a designation in this band for space research.
133 Several bands in the ITU-RR are designated for ISM use, including the band 2 400-2 500 MHz. ISM applications do not fall under any of the radiocommunication services as defined in the ITU-RR. Radio communication services operating in the designated ISM bands shall accept harmful interference from ISM applications. But administrations must also take measures to limit the interference from ISM applications to radiocommunication services.
134 The European harmonized table has ISM in the band 2 400-2 500 MHz. No allocation in the SADC table.
135 SRDs do not have an allocation in the ITU-RR. SRDs operate in and outside ISM designated bands in the ITU-RR. SRDs in general operate in shared bands and are not permitted to cause harmful interference to radio services and cannot claim protection from radio services.
136 The European and SADC harmonized table has SRD in the band 2 400.0-2 483.5 MHz.
137 Fourteen channels are designated in the 2 400-2 500 MHz range (802.11b/g/n/ax).

From Table 24 the following can be observed and concluded:

1) The following potential incompatibilities could occur between IMT in the band 2 300-2 400 MHz (see Table 23) and:

   a. broadband fixed wireless access (BFWA) applications in the band 2 290-2 450 MHz;
   b. P-P and P-MP applications in the band 2 290-2 450 MHz;
   c. SAB/SAP (PMSE) applications in the band 2 290-2 450 MHz;
   d. aeronautical telemetry applications in the band 2 300-2 450 MHz;
   e. space research applications in the band 2 290-2 300 MHz;
   f. ISM applications in the band 2 400-2 500 MHz;
   g. SRD applications in the band 2 400-2 450 MHz.

2) The National Table of Frequency Allocations (NTFA) will indicate whether any of the applications in Table 25 are assigned and in use in a specific African country. Consequently, such use should be considered in assessing the compatibility with an IMT allocation in the 2.3 GHz band in that country.

4.3 Sharing and compatibility between IMT and other services in the 2.3 GHz band

In this report, only the key IMT sharing and compatibility studies and their results are covered. It is noted that administrations are advised to interpret these study results with caution as their local situation (including the actual frequency allocations/assignments as reflected in their NTFA, the applied technologies and interference scenario) may differ from the situation as covered in the studies.

4.3.1 Overview of IMT sharing and compatibility studies

Table 26 provides an overview of the key IMT sharing and compatibility studies relevant for the 2.3 GHz band. The second column indicates the compatibility case under consideration in the study, i.e. the compatibility between IMT and an application for the other services (see Table 25)

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
1	IMT (LTE TDD) – other services: – BFWA (WiMAX) – SAB/SAP (ENG/OB links) – Aeronautical telemetry – Space research – SRD (Bluetooth and WLAN)	CEPT/ECC	ECC Report 172 (March 2012)	Broadband wireless systems usage in 2 300-2 400 MHz	• This report defines two broadband wireless systems (LTE TDD and WiMAX TDD[138]). • The report provides compatibility studies between broadband wireless systems and other services, but also between broadband wireless systems. • The main conclusions per study are as follows: o BFWA: two BTS, operating in close proximity and in adjacent frequency blocks, should be synchronized[139] as to be able to use high power amplifiers and antennas. In case of non-synchronized systems, the frequency separation will be large or the output power will be very low.

[138] It is noted that WiMAX can be used for (a) providing a wireless alternative to cable and digital subscriber line (DSL) for "last mile" broadband access (BFWA) or (b) for providing portable mobile broadband connectivity across cities and countries through various devices. The latter is labelled as mobile WiMAX in this report.

[139] Network synchronization, as a technical measure to have two TDD systems coexist in adjacent blocks/bands, is addressed in Section 4.3.2.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
					o ENG/OB: the interference scenarios do not assume coordination between system operators nor the application of power limitation or cognitive technologies (i.e. worst case): – *Cordless camera link*: Compatibility can be feasible in the adjacent and alternate channel, since the required separation distance is moderate.[140] On a case-by-case basis, it must be decided if additional protection and sharing mechanisms have to be employed. In the co-channel case, dedicated protection and compatibility mechanisms would be required.

[140] An alternate channel is an adjacent channel with a guardband in-between. The guardband is assumed to be sufficiently large so that received out-of-band emissions are in the spurious domain.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
					– *Mobile video link*: further protection and compatibility mechanisms are probably required except in the presence of a guardband of more than 20 MHz between the systems. The special propagation case (RX antenna mounted on a helicopter) calls for dedicated coordination measures. – *Portable video link*: Compatibility based on geographical separation is feasible at least in the alternate channel case if on a case-by-case basis, some additional protection measures are deployed. In the co-channel case, additional dedicated protection/compatibility mechanisms are required due to large required separation distances.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
					o Telemetry (TLM): In case of co-channel configuration, large separation distances are needed to avoid harmful interference on telemetry system from LTE (and vice versa). In adjacent channel, the separation distances decrease drastically so that the operation of TLM and LTE is possible. Some mitigation techniques may however be needed to ensure that no interference occurs when the airborne TLM is in the main lobe of the LTE base station antenna. In practice, depending on the trajectory of the aircraft, an airborne TLM might not stay in the LTE base station main beam for a long time. o Space research: Having a very sensitive deep space earth station receiver close to a broadband wireless system such as LTE TDD might require some mitigation measures.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
					o Bluetooth: Bluetooth operating close to the 2 400 MHz band edge can cause interference. However, the LTE UE has full control over the choice of Bluetooth channels and avoids such situation by adaptive frequency-hopping. This will greatly alleviate interference from Bluetooth to LTE. Also, the ISM band filter on the LTE UE has ample margin to suppress the Bluetooth signal. Interference from LTE to Bluetooth could be an issue without power restrictions of the LTE channel. A regulatory solution could be to employ restrictions in that channel (to be below 15 dBm). o WLAN: In the case of macro (i.e. cell radius of 1 km) LTE BTS interfering WLAN, coexistence is feasible for indoor WLAN systems at antenna height of 1.5 m with an interference probability smaller than one per cent. The outdoor placed WLAN systems at 10 m height (worst case) will have very high interference probability. For the indoor case, WLAN access point interfering the Pico LTE TDD BS, there is a degradation in average bit rate. Frequency offset of LTE TDD decreases the bit rate degradation significantly.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
2	IMT-BFWA (WiMAX)	ITU	ITU-R M.2374-0 (07/2015)	Compatibility of two TDD networks in the 2 300-2 400 MHz band	• Although the report covers only compatibility between LTE-A TDD systems operating in adjacent blocks, the proposed mitigation measures may also be useful for mitigating IMT- BFWA (WiMAX) interference. • LTE-A TDD networks operating in adjacent channels with insufficient guardband and without inter-operator network synchronization, will cause severe mutual interference. • Network synchronization will resolve most interference. For unsynchronized networks, these reports offer mitigation measures for resolving interference.
3	IMT-BFWA (WiMAX)	CEPT/ ECC	ECC Report 216	Practical guidance for TDD networks synchronization (August 2014).	• This report addresses specifically the network synchronization between LTE TDD and WiMAX • Network synchronization is feasible through standardized techniques, most notably GNSS, IEEE-1588v2 and HeNB: o Outdoor cells: can be synchronized by all considered techniques. GNSS is generally the most used and mature solution for this scenario. o Indoor micro/pico-cells: IEEE-1588v2.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
4	IMT-FS	ITU	ITU-R Report F.2333-0 (11/2014)	Sharing and compatibility study between international mobile telecommunication and the fixed service in the frequency band 1 350-1 527 MHz.	• This report presents an analysis of the feasibility of co-channel compatibility/sharing between IMT and FS (P-P) operating in the frequency band 1 350-1 527 MHz. Although this band is outside the 2.3 GHz band the conclusions of the report are deemed applicable (as no definite separation distances are provided). • The geographic separation required between an IMT BTS and a co-channel fixed link is highly dependent on the orientation of the fixed link antenna, the TX and RX antenna heights relative to the clutter/terrain, the power transmitted, and fixed link RX antenna performance. • In actual deployment cases where a terrain database is available, a more accurate case-specific separation distance may be calculated for the IMT BTS.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
					• Mitigation factors associated with many deployment scenarios could significantly decrease separation distances for the IMT BTS. • Compatibility of FS with IMT uplinks (UE) will be possible provided that the radio links are not located close to major population centres where UE are likely to be used in close proximity.
5	IMT-ISM	ITU	Report ITU-R SM.2180 (09/2010)	Impact of industrial, scientific and medical (ISM) equipment on radiocommunication services.	• Radiocommunication services can be protected from harmful interference from ISM equipment if the radiation limits for ISM equipment are obeyed. These limits are set by CISPR.[141] • Initially the CISPR emission limits have been developed to protect analogue services rather than digital services. Hence revision is needed.

141 International Special Committee on Radio Interference, CISPR Publication 11 defines the ISM emission limits. The European equivalent of CISPR 11 is EN 55011 which is produced by the European Committee for Electrotechnical Standardization (CENELEC).

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

		ITU	Rec. ITU-R SM.1056-1	Limitation of radiation from industrial, scientific and medical (ISM) equipment.	• Administrations may use the latest edition of CISPR Publication 11, including amendments, as a guide for the application of limits and methods of measurements for ISM devices, in order to protect radiocommunications. • Continued cooperation with the CISPR is needed to ensure that the radiocommunication needs are fully taken into consideration.
6	IMT-SRD	CEPT/ ECC	ERC Rec. 70-03 (7 June 2019)	Relating to the use of short-range devices (SRD)	• The Recommendation describes the spectrum management requirements for SRDs relating to allocated frequency bands, maximum power levels, channel spacing or modulation/maximum occupied bandwidth and duty cycle.[142] • The annexes define this spectrum management requirements for various SRDs in a number of bands. For the band 2 400.0-2 483.5 MHz: o Annex 1. Non-specific short-range devices o Annex 3. Wideband data transmission systems o Annex 6. Radiodetermination applications.

[142] A duty cycle is used as a specific restriction on the radio usage of SRDs (e.g. 5 transmissions of 0.72 seconds within one hour) next to other measures such as 'listen before transmit' and 'adaptive power control'.

Table 26: Overview of key IMT sharing and compatibility studies relevant for the 2.3 GHz band (continued)

		Ofcom	Ofcom MC/174 (May 2013)	The effect of TDD LTE signals in the 2.3 to 2.4 GHz band on Bluetooth equipment operating in the 2.4 GHz ISM band	• This report offers an analysis of different interference cases, especially considering the different operational modes of Bluetooth, basic rate, enhanced data rate and low-energy mode. • Like ECC Report 172, the report concludes that adaptive frequency-hopping employed by Bluetooth is very effective way of combating interference on the lower Bluetooth channels (i.e. closer to LTE TDD in the 2 300-2 400 MHz band).

From Table 26 the following can be observed and concluded:

1) Compatibility of IMT and BFWA (WiMAX) in adjacent bands is possible under the following conditions (see Nos.1, 2 and 3 in Table 26):
   a. Applying network synchronization between network operators;
   b. In case of unsynchronized networks, the frequency separation will have to be large or the output power will have to be very low.
2) Compatibility of IMT and ENG/OB in adjacent bands is possible for the following sub-applications, under a number of conditions (see No.1 in Table 26):
   a. Cordless camera link: compatibility can be feasible in the adjacent and alternate channel, since the required separation distance is moderate. Additional measures may be necessary;
   b. Mobile video link: protection measures are required except in the presence of a guardband of more than 20 MHz between the systems;
   c. Portable video link: compatibility based on geographical separation is feasible at least in the alternate channel case, if on a case-by-case basis, some additional protection measures are deployed.
3) Sharing of IMT and telemetry in the same frequency band are only possible if large separation distances are applied (see No.1 in Table 26).
4) Compatibility of IMT and telemetry in adjacent bands is possible under the conditions of (see No.1 in Table 26):
   a. Applying separation distances;
   b. Additional measures may be necessary (especially in the case if the airborne telemetry station is in the main lobe of the LTE base station antenna).
5) Compatibility of IMT and space research in the adjacent band (2 290-2 300 MHz) will require mitigation measures (see No.1 in Table 26).

6) Sharing of IMT and FS (P-P) in the same (or adjacent band) is possible if a case-by-case approach is applied whereby the required geographic separation distance is calculated taking into account the orientation of the fixed link antenna, the TX and RX antenna heights relative to the clutter/terrain, the power transmitted, and fixed link RX antenna performance (see No.4 in Table 26).
7) Compatibility of IMT and SRD (Bluetooth) in the adjacent band (above 2 400 MHz) is possible under the following conditions (see Nos.1 and 6 in Table 26):
   a. Applying adaptive frequency hopping (by the Bluetooth application), and/or;
   b. Applying an ISM band filter on the LTE UE;
   c. In the case of interference from LTE to Bluetooth, LTE power restrictions may be necessary.
8) Compatibility of IMT and SRD (WLAN) in the adjacent band (above 2 400 MHz) is possible for the following cases and under a number of conditions (see Nos.1 and 6 in Table 26):
   a. Compatibility is feasible for indoor WLAN systems at antenna height of 1.5 m;
   b. Compatibility is deemed not possible for outdoor-placed WLAN systems at 10 m height (worst case);
   c. Compatibility is possible for indoor WLAN system interfering into the Pico LTE TDD cell if frequency off-set is applied.
9) Compatibility of IMT and ISM in the adjacent band (above 2 400 MHz) is possible if the latest radiation limits of CISPR (Publication 11) or CENELEC (EN 55011) are obeyed (see No.5 in Table 26).

4.3.2 Technical conditions for IMT sharing and compatibility

As concluded from Table 26, various coexistence and sharing options between IMT and the other services have been identified. Table 27 provides an overview of technical conditions under which such options are technically feasible. It is noted that the specific local situation will dictate which and to what extent the technical conditions listed need to be applied.

For the technical conditions presented in Table 27, it is assumed that the radio equipment involved in the interference case, complies with a minimal (least restrictive), and preferably, a harmonized set of technical conditions.[143] Such a set of minimum technical conditions may be checked as part of a type-approval procedure for granting the use of radio equipment in the NRA's territory. Also, such a set of minimum criteria often include emission limits/spectrum masks and may be complemented with other conditions such as for human safety (EMC).

Finally, the conditions included in Table 27 address the conditions for separating IMT from other non-IMT applications. Conditions for separating frequency blocks between IMT operators (such as guardbands, spectrum masks, radiated power level) are not addressed.

143 The least restrictive technical conditions for LTE TDD systems operating in the band 2 300- 2 400 MHz band are specified in Annex 2 of CEPT/ECC Decision (14)02.

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
IMT-BFWA (WiMAX)	Compatibility in adjacent bands	IMT and BFWA in adjacent blocks in the band 2 300-2 400 MHz	Apply network/time synchronization. For legacy IMT systems (3G) frequency synchronization was sufficient. For TDD LTE and LTE-A systems, network synchronization is more critical as these systems also require phase and time synchronization. Network synchronization is normally between two adjacent cells of the same operator (inter-operator). However, network synchronization can also be used between two different operators of TDD systems (intra-operator). Network synchronization is feasible through standardized techniques, most notably GNSS, IEEE-1588v2 and HeNB: • Outdoor cells: can be synchronized by all considered techniques. GNSS is generally the most used and mature solution for this scenario. • Indoor micro/pico-cells: IEEE-1588v2.	ECC Report 172 ECC Report 216	Network/time synchronization should be considered as an initial measure for avoiding interference between TDD network operators.

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
			Technical measures for unsynchronized TDD networks: • for the BS-BS interference case: o Frequency separation: interference into the networks of adjacent operators may be decreased by introducing guardbands (applied as stand-alone solution is not recommended as it is spectrum-inefficient); o Additional filtering and appropriate guardband: Additional filters may substantially reduce interference by decreasing the unwanted emissions from the transmitter and improving the selectivity on the receiver side;	ITU-R Report M.2374	Due consideration should be given that the provided measures are for mitigating interference between LTE TDD systems.

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
			o Coordination among network operators: Site engineering techniques such as transmitter antenna tilting, selection of antenna direction and careful deployment planning. However, it could be very difficult to implement practically. • For the UE-UE interference case: o interference may occur when the UEs are in close proximity but that for most scenarios this interference will occur rarely. For UEs, additional filters are not a realistic means for reducing interference.		
IMT-other services: – ENG/OB – Aeronautical telemetry – Space research	Compatibility in the same band	IMT and ENG/ OB in the same band	Dedicated protection and interference mitigation mechanisms would be required if IMT and video links are used at the same time in the same area. In a scenario involving a video link to a helicopter, a guardband between IMT and the video link is likely to be required (if no further coordination measures are implemented).	ECC Report 172	More interference cases and mitigation measures can be found in this report

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band (continued)

Sharing and compatibility case	Option	Interference type/case	Technical conditions	Reference documents	Notes
	Compatibility in the same band	IMT and telemetry in the same band	The compatibility between IMT and telemetry systems is not ensured in the case of co-channel/co-location. Adjacent channel operation, geographical separation, time sharing or a combination of the previous may help to ensure compatibility.	As above	As above
	Compatibility in adjacent band	IMT in	Deep space earth station receiver installed close to an LTE TDD base station might require additional solutions including: • Frequency separation; • Additional filtering; • Site engineering techniques such as transmitter antenna tilting, and antenna direction and careful deployment planning; • A combination of the above.	As above	As above

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
IMT-FS (P-P)	Compatibility in the same band	IMT and FS in the same band	On the basis of applying a case-by-case approach compatibility is possible. In this case-by-case approach calculations for the required geographical separation distance are carried out, taken into consideration the following: • Orientation of the fixed link antenna; • TX and RX antenna heights relative to the clutter/terrain; • Power transmitted; • Fixed link RX antenna performance.	ITU-R Report F.2333-0 (11/2014)	Due consideration should be given that this report covers the frequency band

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
IMT-SRD	Compatibility in adjacent band	IMT in	The Recommendation includes the technical conditions for SRDs relating to: • Allocated frequency bands; • Maximum power levels; • Channel-spacing or modulation/ maximum occupied bandwidth; • Spectrum access and duty cycle (including frequency-hopping, spread spectrum, listen before talk and adaptive frequency agility[144]). The annexes define these conditions in detail for the various SRDs in a number of bands. For the band 2 400.0–2 483.5 MHz: • Annex 1. Non-specific short-range devices; • Annex 3. Wideband data transmission systems; • Annex 6. Radiodetermination applications.	ERC Rec. 70-03 (7 June 2019)	It is noted that the technical conditions included are imposed on the SRDs.

[144] Adaptive frequency agility is a technique used by radio transmitters to avoid transmission in channels that are already occupied.

Table 27: Technical conditions for IMT sharing and compatibility in the 2.3 GHz band (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
IMT-ISM	Compatibility in adjacent band	IMT in	Compatibility is possible if the latest radiation limits of CISPR (Publication 11) or CENELEC (EN 55011) are obeyed.	EN 55011 publication 2016 (the latest)	It is noted that the radiation limits included are imposed on the ISM equipment.

4.3.3 Regulatory conditions for IMT sharing and compatibility

Administrations may wish to complement the technical conditions under which they grant the IMT spectrum rights (see Section 4.3.2) with specific IMT regulatory conditions (next to the general conditions for assigning spectrum rights). These specific IMT-related conditions often arise from the situation that the IMT services are introduced in bands with incumbent services which need to be protected.

Table 28 provides an overview of these IMT-specific regulatory conditions.

Table 28: Regulatory conditions specific for IMT licensees

No	Condition or requirement	Notes	References
1	For protecting the space research and telemetry services, administrations may wish to include a regulatory condition that on a case-by-case basis additional measures may be necessary, such as IMT BTS power reductions, additional filtering and site engineering measures (such as tilting and redirection antennas).	These regulatory requirements are additional to general technical conditions (such as least restrictive technical conditions).	See ECC Report 172
2	Administrations may wish to include that the latest version of the SRD/ ISM technical conditions apply to this radio equipment. These SRD/ ISM conditions may change during the IMT licence duration. When these SRD/ISM conditions are relaxed (less stringent), such changes may have an adverse impact on the performance of the IMT network.	IMT licences last commonly 10 years or more. SRD/ISM technical conditions change over such periods. Also new SRDs may be introduced.	ERC Rec. 70-03 for SRD CISPR (Publication 11) or CENELEC (EN 55011) for ISM

Table 28: Regulatory conditions specific for IMT licensees (continued)

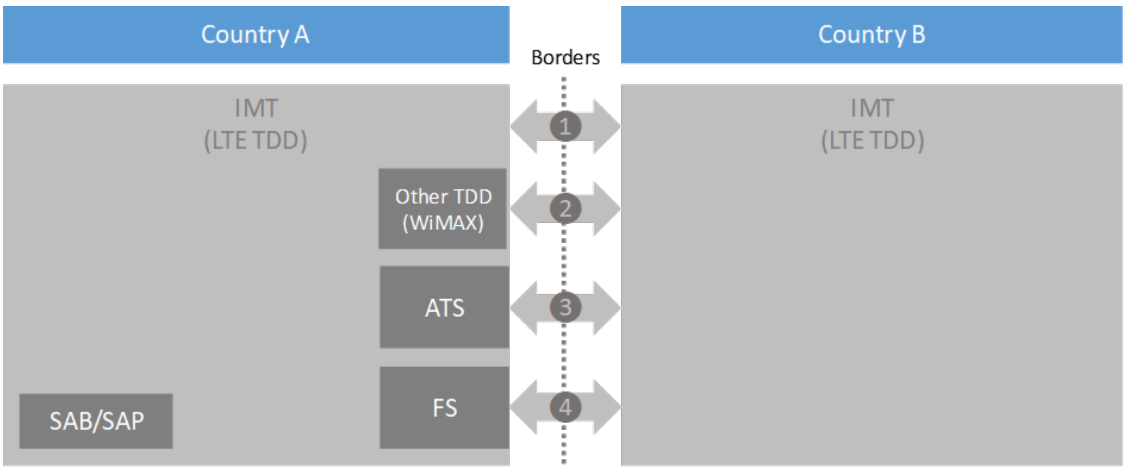
No	Condition or requirement	Notes	References
3	For the coordination between ENG/OB and IMT services, Administrations may wish to include that the IMT licensee will collaborate with the ENG/OB licensees to find (dedicated) solutions in resolving any identified case of harmful interference.	Depending on the specific ENG/OB application these identified interference cases may be temporary and the applied mitigation measures are also temporary. It is noted that a similar requirement should be included in the ENG/OB licence (which may be a licence per event).	See ECC Report 172
4	The IMT licensee(s) has the obligation to compensate for any incurred costs by the incumbent service.	See also Table 6	See Section 1.3.3
5	The IMT licensee(s) has the obligation to help investigate any complaints about interference of incumbent services.	See also Table 6	See Section 1.3.3

4.3.4 Cross-border coordination aspects for IMT

Cross-border inference cases between countries are a subset of the interference cases within a country (as discussed in Section 4.3.1) as, in this frequency band, they mainly cover emissions located closer to the border.

Figure 9 shows a generic overview of the possible cross-border interference cases for the 2.3 GHz band.

Figure 9: Generic overview of possible cross-border interference cases for the 2.3 GHz band



From Figure 9 the following can be observed and concluded:

1) SRD and ISM applications are not included in Figure 9 because both emit at very short distances and are not considered in cross-border coordination.
2) ENG/OB applications are also not included in Figure 9 because those cases which may cause cross-border interference (such as helicopter-mounted mobile video links) are temporary and would be coordinated on a case-by-case basis with dedicated measures.
3) Cross-border case 1: Interference case 1 may arise in the final stages when administrations have adopted IMT and their stations' emissions are within the coordination zone for these services:

    a. As referred to in Section 1.3.4, the HCM, HCM4A, BKO-18 and the Vienna Agreement provides procedures and parameters for managing possible cross-border interference between IMT services.
    b. Alternatively, and specifically for the cross-border coordination of LTE and NR/5G applications a system of physical cell identity (PCI) can be used. For the band 2 300- 2 400 MHz, CEPT/ECC issued Recommendation 14(04) which, in set-up, is the same as Recommendation (15)01 for cross-border coordination in the frequency bands 694-790 MHz, 1 427-1 518 MHz and 3 400-3 800 MHz (as discussed in 1.3.4). The key difference is Annex 1, including the field strength levels (trigger values) for coordination:

        i. Recommendation (15)01 provides the trigger values for FDD and SDL systems.
        ii. Recommendation (14)04 provides the trigger values for TDD systems.

4) Cross-border case 2: Recommendation (14)04 can be used in concluding a coordination agreement between neighbouring administrations.
5) Cross-border case 3: Country B implementing IMT and country A having ATS in the band 2 300-2 450 MHz may have to coordinate their IMT and ATS use. ECC Report 295[145] provides interference scenarios and calculation methods for determining interference to the ATS.
6) Cross-border case 4: Cross-border coordination of IMT with fixed services (P-P) are likely to be incidental and a case-based coordination can be used where any found harmful interference can be mitigated by applying technical measures (see ITU Report F.2331-0 and Table 5 in Section 1.3.4).

4.4 Best practices and methods for refarming other services in the 2.3 GHz band

Refarming in the context of this report means the replanning of incumbent services is deemed incompatible with the introduction of IMT services. In other words, the spectrum needs to be freed up or cleared for IMT. However, refarming is not always possible because incumbent users cannot be moved (in the short run), for example military or other governmental use.[146]

ECC Decision (14)02, on harmonized conditions for the use of the 2 300-2 400 MHz band for MFCN, an alternative approach to spectrum refarming is proposed; licensed shared access (LSA). This regulatory concept is the recognized approach by CEPT for administrations wishing

[145] Although ECC Report 295 provides guidance on cross-border coordination between MFCN and aeronautical telemetry systems in the 1429-1518 MHz band, the interference scenarios and calculation methods can be considered.

[146] It is noted that according to the harmonized European Table of Frequency Allocations and Applications (CEPT/ECC), the 2 300-2 400 MHz band has designations for aeronautical military systems, land military systems, maritime military systems and telemetry/telecommand (military).

to introduce IMT while maintaining the current incumbent use in the 2 300-2 400 MHz band. LSA is explained in Section 4.4.1.

In addition, the concept of shared access licensing of the UK regulator Ofcom is addressed in Section 4.4.2. This licensing concept is meant to provide access to spectrum by non-IMT users, to spectrum that is already licensed to IMT operators but which is not being used or planned for use in a particular area within the foreseeable future (i.e. a number of years). This concept is similar to the CEPT/ECC LSA concept, although the IMT spectrum user is considered the incumbent user in the Ofcom approach.[147]

It is noted that, if such alternative regulatory approaches are not considered and refarming of services is deemed necessary, the refarming approaches as included in the previous Sections 1.4, 2.4 and 3.4 can be consulted. It is noted that Rec. ITU-R SM.1603 also covers general approaches to refarming, guidelines for calculating refarming (or redeployment) costs, as well as examples of country experiences with refarming. The financial funding of refarming efforts is addressed in Section 11.

4.4.1 Refarming alternative through licensed shared access

Licensed share access (LSA) is a spectrum management instrument under an individual licensing regime, whereby spectrum rights are assigned to individual licence holders with terms and conditions which are applicable to only these individual licence holders.[148] It is noted that the LSA concept avoids the situation that the (LSA) licence holder has no protection from primary (incumbent) users. CEPT expects that the first practical implementations will be with the incumbent user being a government body.[149]

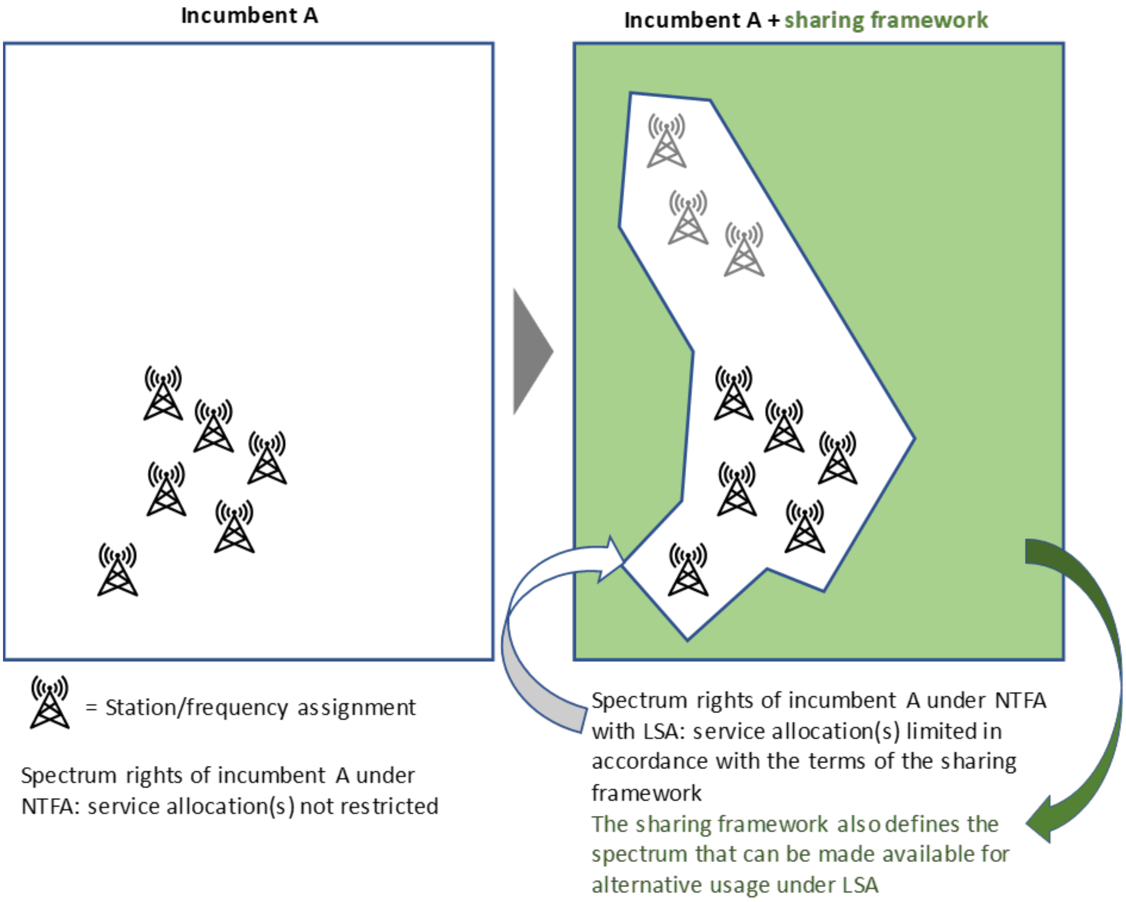
The *sharing framework* is the core of the LSA concept. This sharing framework is depicted in Figure 10.

[147] The shared access licensing concept is not confined to IMT use (as the incumbent user), but it is the main focus of Ofcom to introducing such a new licensing concept.

[148] The concept of LSA is detailed in ECC Report 205. Due consideration should be given to the fact that this LSA concept is provided in the context of the EU regulatory framework.

[149] See also footnote 146.

Figure 10: Sharing framework as the core of the LSA concept



Source: CEPT/ECC.

From Figure 10 the following can be observed and noted:

1) Sharing can be arranged for in the three dimensions, time, frequency and area. The sharing framework can also account for future needs of an incumbent, as depicted with grey stations in Figure 10.
2) Agreeing a sharing framework with the incumbent user will require negotiations between the regulator and the incumbent and future LSA spectrum users. For the incumbent spectrum user, the LSA sharing framework can be an alternative to spectrum refarming. Also, LSA can be combined with partial spectrum refarming.
3) From the perspective of market regulations, it is important to note that LSA would be applied when the incumbent users and the LSA licensees operate in separated markets. This would be for example the case if they are of different nature (e.g. governmental versus commercial) or operate different types of applications with different clients or users. What should be avoided is that incumbent and LSA licensees operate in the same market and they have different regulatory requirements to comply with. This would disturb fair competition in the relevant market. For regulators to determine what the different relevant markets are, the Small but Significant Non-transitory Increase in Price (SSNIP)[150] test a commonly used instrument.

[150] Defining relevant markets is an important task for regulators because market parties in the same relevant market should have the same regulatory burden. For an overview of the steps in the SSNIP test, see https://www.cococo.tv/wp-content/uploads/2020/04/Exhibit-4.1.2-SSNIP-test.pdf

4) Finally, it is important to note that the LSA concept should not be confused with spectrum-sharing between primary and secondary users. Both the incumbent and LSA licensee are primary users.

4.4.2 Shared access licensing for sharing spectrum with IMT

This new regulatory concept of shared access licensing is applied by Ofcom in the bands 1 800 MHz, 2 300 MHz (i.e. 2 390-2 400 MHz) and 3.8-4.2 GHz. Shared Access Licensing is considered a next step in further utilizing spectrum in heavily congested spectrum bands.[151] IMT spectrum licensees have spectrum rights that are deployed in stages, span a long period and cover the whole country. In other words, IMT-assigned spectrum rights may not be fully utilized all the time and at every location. Within this IMT-assigned spectrum, Ofcom considers it possible to allow other users to access the same spectrum on a shared and temporary basis.

The shared access licences are assigned on the basis of FCFS for a short period (with a default period of three years) and are categorized for two types of potential use:

1) Low power licence (per area licence). This type of licence allows users to deploy a number of stations in a circular area with a 50-metre radius without further authorization from Ofcom. For larger areas, applicants can apply for multiple licence areas to achieve the required coverage area.[152]
2) Medium power licence (per base station licence). This type of licence is for stations having a larger potential interference area. This type of licence will be assigned on a per-station basis and, generally, for deployments in rural areas where they are unlikely to cause harmful interference to other low power users.

Applicants for shared access licences will have to provide Ofcom with the necessary information for Ofcom to assess if temporary shared access use is possible. For granting the licence Ofcom's key considerations will be to confirm or verify that:

1) the spectrum under consideration is not being used in that location;
2) the shared spectrum use in that area will not interfere with existing or planned use of the band;
3) the licensed operator in the band (the incumbent) does not raise reasonable objections for the proposed shared use.

Upon confirmation that shared spectrum use is technically possible and the incumbent user has not raised reasonable objections, Ofcom assigns the shared access licence for the default period of three years. The attached technical conditions for the low and medium power shared access licences can be found in Tables 3.1 and 3.2 of the Ofcom publication.[153]

Finally, it is noted that, like with the LSA concept of CEPT/ECC (see Section 4.4.1), the Ofcom shared access licences are individual licences and are different from the more conventional sharing arrangements.

[151] See Ofcom statement "Enabling wireless innovation through local licensing, Shared access to spectrum supporting mobile technology", dated 25 July 2019, in which Ofcom considers a number of applications, including Internet of Things (IoT) applications, suitable for this new licensing concept.
[152] Several licence use and application scenarios are provided in the Ofcom publication, see section "Low power area licence".
[153] See footnote 151.

4.5 Guidelines and recommended actions for the 2.3 GHz band

Sections 4.1 to 4.4 cover the spectrum allocations for IMT and other services in the 2.3 GHz band, the technical and regulatory conditions facilitating the IMT introduction in this band, as well as best practices and methods for refarming the other services, if deemed necessary.

Table 29 provides a comprehensive list of guidelines as included in these sections.

Table 29: Spectrum management guidelines for IMT introduction in the 2.3 GHz band

No	Guideline	Applies to	Ref. Section(s)
4.1	Administrations are advised to interpret the sharing and compatibility study results, as included in Section 4.3.1 with caution as their local situation may differ from those covered in the studies. Case-by-case calculation may be needed to determine possibilities for sharing and compatibility of services. Relevant ITU Recommendations and Reports are specified in Table 26. Also, a comprehensive list of relevant ITU Recommendations and Reports is provided in Appendix B: ITU Recommendations and Reports.	All applications	Section 4.3.1 Appendix B: ITU
4.2	For introducing IMT in the specified frequency bands (see Table 23), administrations may have to set a range of technical and regulatory conditions. Technical conditions can include the application of guardbands, filtering of transmitters/receivers and critical spectrum masks. Regulatory conditions, such as an obligation to compensate for migration costs and follow station-approval procedures, are set in combination with the technical conditions.	All applications	Sections 4.3.2 and 4.3.3
4.3	To protect space research and telemetry services, administrations may wish to include specific regulatory condition that additional measures may be necessary on a case-by-case basis, such as IMT BTS power reductions, additional filtering and site-engineering measures (such as antenna-tilting and antenna redirection).	Space research (in the band 2 290-2 300 MHz) and telemetry services (in the band 2 300-2 450 MHz)	Section 4.3.3
4.4	Administrations may wish to stipulate that the latest version of the SRD/ISM technical conditions apply and to note that these conditions may change during the IMT licence duration. Relaxing these SRD/ISM conditions may have a negative impact on the performance of the IMT network.	IMT and SRD (in the band above 2 400 MHz)	Section 4.3.3

Table 29: Spectrum management guidelines for IMT introduction in the 2.3 GHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
4.5	Cross-border coordination may be needed for mitigating co-channel interference for the potential interference cases as included in Figure 9. For resolving interference between IMT and IMT, the procedure and calculation methods included in the HCM4A Agreement can be used. Alternatively, and exclusively for LTE/NR-LTE/NR cross-border coordination, the PCI method included in ECC Rec. (14)04 can be used, although the methods of that Recommendation may also be used for cross-border coordination between LTE TDD and WiMAX TDD. ECC Report 295 provides interference scenarios and calculation methods for determining interference to the ATS.	Cross-border coordination of: IMT-IMT (HCM4A Agreement); LTE/NR-LTE/NR (ECC Rec. (14)04); LTE TDD- WiMAX TDD (also Rec. (14)04); IMT-ATS (Report 295).	Section 4.3.4 Appendix A: Cross-border frequency coordination
4.6	Administrations may consider alternative regulatory approaches to refarming. Such alternative approaches are deemed applicable in cases where spectrum bands are not fully utilized and where incumbent spectrum users cannot be reallocated. The spectrum band 2 300-2 400 MHz is one such band in the CEPT area, and this may also be the case in some African countries. The regulatory alternative approaches presented include: • Licensed shared access (CEPT/ECC approach) • Shared access licensing (Ofcom approach).	All applications	Sections 4.4.1 and 4.4.2

5 IMT sharing and compatibility with other services in the 2.6 GHz band

The Radio Regulations establish that the band 2 500-2 690 MHz is allocated to mobile service and identified for IMT under RR No. 5.384A for all the three Regions, therefore including Africa.

5.1 IMT frequency arrangements in the 2.6 GHz band

Table 30 shows the IMT frequency arrangements in the 2.6 GHz band (2 500-2 690 MHz) as included in Recommendation ITU-R M.1036-6. It is also noted that administrations may implement all or part of each frequency arrangement.

Table 30: IMT frequency arrangements in the 2.6 GHz band

Frequency arrangement	Paired arrangements (FDD)				Unpaired arrangements (TDD) (MHz)
	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
C1	2 500-2 570	50	2 620-2 690	120	2 570-2 620
C2	2 500-2 570	50	2 620-2 690	120	
	External		2 570-2 620		
C3	2 595-2 615 MHz			Flexible FDD/TDD	

The following is noted in Table 30:

1) In C1, in order to facilitate deployment of FDD equipment, any guardbands required to ensure adjacent band compatibility at the 2 570 MHz and 2 620 MHz boundaries will be decided on a national basis and will be taken within the band 2 570-2 620 MHz and should be kept to the minimum necessary, based on Report ITU-R M.2045.
2) In C3, administrations can use the band solely for FDD or TDD or some combination thereof. Administrations can use any FDD duplex spacing or FDD duplex direction. However, when administrations choose to deploy mixed FDD/TDD channels with a fixed duplex separation for FDD, the duplex separation and duplex direction as shown in C1 are preferred. This option is the preferred implementation in Europe (ERC/DEC/(05)05.

As a reference for specific frequency-channelling within this band and further to the identification of the band for IMT services, CEPT's ERC/DEC/(05)05 proposes specific channel arrangements, which can be considered:

1) The frequency band 2 500-2 570 MHz is paired with 2 620-2 690 MHz for FDD operation with the mobile transmit within the lower band and base transmit within the upper band.
2) Administrations may assign the frequency band 2 570-2 620 MHz either to TDD or to FDD downlink (external). Any guardbands required to ensure adjacent band compatibility at

the 2 570 MHz and 2 620 MHz boundaries will be decided on a national basis and taken within the band 2 570-2 620 MHz.

3) Assigned blocks shall be in multiples of 5.0 MHz.
4) The upper and lower frequency edges of FDD uplink and downlink blocks are also specified.
5) For 5 MHz UTRA FDD, the block-edge frequency is defined with an offset of 2.5 MHz from the nearest carrier-centre frequency.
6) For other IMT-2000 radio interface, the block edge is to be defined on a case-by-case basis depending on receiver and transmitter characteristics of the radio interface in adjacent channels.

5.2 Other services allocated in the 2.6 GHz band and adjacent bands

Table 31 provides an overview of the Radio Regulations provisions applicable to each segment of spectrum in this band. The bands identified are those associated to the IMT identifications, but it should be noted that other services operate in adjacent bands outside the IMT band. The technical compatibility studies have considered such other adjacent band operations, particularly the use of the band 2 483.5-2 500 MHz by radiodetermination-satellite and the band 2 690-2 700 MHz for the Earth exploration-satellite (passive), radio astronomy and space research (passive). Radio Regulations provisions less relevant for IMT are indicated in round brackets while IMT identifications provisions are highlighted in blue.

Table 31: ITFA corresponding with the identified IMT frequency arrangements for the 2.6 GHz band (Region 1)

2 500-2 520 MHz		
Services:	Footnote number:	Footnote:
Fixed	(5.410)	Possible, not recommended used for tropospheric links.
Mobile except aeronautical mobile	5.384A	Identification, without priority, for IMT of 2 500-2 690 MHz in accordance with Resolution 223 (WRC-19).
2 520-2 655 MHz		
Services:	Footnote number:	Footnote:
Fixed	(5.140)	Possible, not recommended used for tropospheric links.
Mobile except aeronautical mobile	5.384A	Identification, without priority, for IMT of 2 500-2 690 MHz in accordance with Resolution 223 (WRC-19).
Broadcasting-satellite	(5.413)	Not relevant for IMT.
Other provisions	(5.416)	The band 2 520-2 670 MHz could be used for sound satellite broadcasting for community reception.
	(5.339)	Not relevant.
	(5.412)	Not relevant.

Table 31: ITFA corresponding with the identified IMT frequency arrangements for the 2.6 GHz band (Region 1) (continued)

	(5.418B)	Non-geo stationary orbit (NNGSO) systems to apply RR 9.12.
	(5.418C)	Requirements for GSO and NGSO.
2 655-2 670 MHz		
Services:	Footnotes number:	
Fixed	(5.140)	Possible, not recommended for tropospheric links.
Mobile except aeronautical mobile	5.384A	Identification, without priority, for IMT of 2 500-2 690 MHz in accordance with Resolution 223 (WRC-19).
Broadcasting-satellite	(5.413)	Not relevant for IMT.
	(5.416)	The band 2 520-2 670 MHz could be used for sound satellite broadcasting for community reception.
	(5.208B)	Resolution 739 applies for space services towards radioastronomy.
Other provisions	5.149	Administrations should make efforts to protect radio astronomy service when making assignments in the band 2 655-2 690 MHz for any other service.
	(5.412)	Not relevant
2 670-2 690 MHz		
Fixed	(5.140)	Possible, not recommended used for tropospheric links.
Mobile except aeronautical mobile	5.384A	Identification, without priority, for IMT of 2 500-2 690 MHz in accordance with Resolution 223 (WRC-15).
Other provisions	5.149	Administrations should make efforts to protect radio astronomy service when making assignments in the band 2 655-2 690 MHz.
	(5.412)	Not relevant.

Table 31 lets us observe and conclude the following:

1) The non-IMT spectrum allocations in the range 2 500-2 690 MHz include the following primary services:

   a. mobile;
   b. fixed;
   c. broadcasting-satellite.

2) In addition, the non-IMT spectrum allocations in the adjacent bands to 2 500-2 690 MHz include the following primary services:

   a. radiodetermination-satellite (space-Earth). RR 5.398A. Not relevant for Africa;
   b. mobile-satellite. RR 5.351A. Restrictions for MSS;
   c. ISM. RR 5.150. Operate under non protection basis;
   d. radiolocation. RR 5.399. Not relevant for Africa;
   e. radiodetermination by satellite. RR 5.401. Primary in 2 483.5-2 500 MHz in Angola, Eritrea, Ethiopia, Liberia, Libya, Mali, Republic of the Congo, Sudan, Eswatini, Togo and Zambia;
   f. RR 5.401. Not relevant for IMT in Africa;
   g. Earth exploration-satellite (passive), radio astronomy, space research (passive):
      i. RR 5.340. Emissions prohibited, except No. RR 5.422;
      ii. RR 5.422. Emissions in 2 690-2 700 MHz from fixed and mobile service are allowed if operation started prior to 1 January 1985.

Table 32 provides an overview of the applications and technology standards commonly applied in Region 1 for the non-IMT services as included in Table 30 in the same and adjacent bands. For the list of applications indicated, due account has been taken of available information about deployment of services in Africa, like the SADC Table of Frequency Allocations.

Table 32: Common applications and technology standards per ITU-RR service for Region 1

ITU-RR service	In-band or adjacent	Application		Application examples	Technology standard	References
		ITU name	CEPT name			
Mobile	In-band			No specific usage identified in Africa	N/A	
	In-band	BSS	BSS	TV broadcasting	DVB-S DVB-S2	DVB project
Fixed	In-band	Fixed and nomadic wireless access	Broadband wireless access	WiMAX	IEEE 802.16 (WiMAX)	IEEE 802.16e
Radio astronomy	In-band	Radio astronomy		Radio astronomy		Affects to 2 655-2 690 MHz
Radio determination-satellite	adjacent	Radio determination		No specific usage identified in Africa	N/A	Affects to 2 483.5-2 500 MHz several countries

Table 32: Common applications and technology standards per ITU-RR service for Region 1 (continued)

ITU-RR service	In-band or adjacent	Application		Application examples	Technology standard	References
		ITU name	CEPT name			
Earth exploration-satellite	adjacent	Earth exploration-satellite		No specific usage identified in Africa	N/A	Prohibited emissions unless operation started prior to 1 January 1985

From Tables 31 and 32, the following can be further concluded and noted:

1) The following potential incompatibilities could occur between IMT in the 2.6 GHz:

   a. mobile IMT/mobile;
   b. mobile IMT/broadcasting-satellite;
   c. mobile IMT/fixed;
   d. mobile IMT/radio astronomy in the band 2 655; 2 690 MHz;
   e. mobile IMT/radiodetermination-satellite in adjacent band 2 483.5-2 500 MHz;
   f. mobile IMT/Earth exploration-satellite in adjacent band 2 690-2 700 MHz.

2) The NTFA will indicate whether any of the applications are assigned in any given African country. Consequently, such assignments should be considered in assessing the compatibility with an IMT allocation in the 2.3 GHz band in that country.

5.3 Sharing/compatibility between IMT and the other services in the 2.6 GHz band

In spectrum management, the terms sharing and compatibility studies are about investigating mechanisms to facilitate the efficient use of spectrum by different services in-band or in adjacent bands, considering the expected deployment of each service as well as the applied technology standards.

In this section, the most relevant sharing and compatibility studies are identified with the aim of helping administrations to implement measures to avoid incompatible operation of different services as well as harmful interference.

Administrations are advised to interpret these study results with caution as their local situation (including the actual frequency assignments as reflected in their NTFA, the applied technologies and interference scenario) may differ from those situations covered in the studies. Most of the sharing and compatibility studies are based on typical scenarios which represent reasonably the deployment scenario of each service under study, although the singularities of a specific deployment of services would require adequate interpretation of the sharing environment.

5.3.1 Overview of IMT sharing and compatibility studies

As indicated in Section 5.2, the 2.6 GHz band is shared by IMT with other mobile applications (except aeronautical mobile), broadcasting by satellite and fixed services. In addition, radio astronomy, radiodetermination by satellite are operating in adjacent bands. The sharing studies conducted so far are listed in Table 33.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
1	IMT and radio-determination	ITU-R	Rec. M.1464-2 (2015)	Characteristics of non-meteorological radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and radars in the radiodetermination service operating in the frequency band 2 700-2 900 MHz.	• This Recommendation helps performing analyses between systems operating in the radiodetermination service and systems operating in other services. • It provides the technical and operational characteristics of the aeronautical radionavigation radars operating in the frequency band 2 700-2 900 MHz.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
2	IMT versus BSS (sound)	ITU-R	Rec. M.1646-0 (2003)	Parameters to be used in co-frequency sharing and pfd threshold studies between terrestrial IMT-2000 and BSS (sound) in the 2 630-2 655 MHz band,	• In this Recommendation, receiving parameters for IMT-2000 mobile stations and base stations are recommended for use when assessing interference from BSS (sound) systems operating in the 2 630-2 655 MHz band. • It is also recommended that interference should be assessed in terms of the level of aggregate interference from BSS (sound) systems against the thermal noise at the IMT-2000 receiver. • It sets the value for Isat/Nth[154] of –10 dB at any IMT-2000 mobile or base station receiver, which should be used as the trigger value for the sharing studies with a view to protecting IMT-2000 from BSS stations.

[154] Isat being the level of aggregate interference from BSS (sound) systems and Nth being the thermal noise at the IMT-2000 receiver.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
		ITU-R	Rec M.1654 (2003)	A methodology to assess interference from broadcasting satellite service (sound) into terrestrial IMT-2000 systems intending to use the band 2 630-2 655 MHz.	• This Recommendation is an example methodology to assess the interference from BSS (sound) into terrestrial IMT-2000 systems intending to use the band 2 630-2 655 MHz and which could be used to determine the impact of BSS (sound) on terrestrial IMT-2000 in the context of co-frequency sharing through the development of pfd masks[155] where applicable.

[155] This methodology contains an algorithm that can be used to calculate a single entry pfd mask for BSS (sound) satellites for a given scenario to meet an Isat/Nth criterion within a tolerance of 1 dB at any location on the Earth.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
3	IMT versus satellite IMT (MSS)	ITU-R	Report M.2041-0 (2003)	Sharing and adjacent band compatibility in the 2.5 GHz band between the terrestrial and satellite components of IMT-2000.	• This report uses the relevant parameters needed in interference studies at the date of publication. • It should be noted that the parameters assumed in this report for the IMT-2000 terrestrial system are those of IMT-2000 CDMA direct spread/CDMA TDD (referred to hereafter in this report as T IMT-2000); no other terrestrial IMT-2000 radio interfaces have been considered because the current studies only consider that interface. • The interference problems are investigated by deterministic and statistical approaches for the different scenarios. • This report gives technical conclusions regarding the necessary guardbands between T IMT-2000 and the MSS in the band 2 500-2 690 MHz.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
4	IMT versus IMT	ITU-R	Report M.2045-0 (2004)	Mitigating techniques to address compatibility between IMT-2000 time division duplex and frequency division duplex radio interface technologies within the frequency range 2 500-2 690 MHz operating in adjacent bands and in the same geographical area.	• This report considers techniques to mitigate this interference and hence to improve compatibility between TDD and FDD mobile networks in adjacent frequency bands and in the same geographic area. • The analysis in this report considers the following IMT-2000 radio interfaces operating within the 2 500-2 690 MHz band: o FDD: IMT-2000 CDMA Direct Spread: (WCDMA or UTRA FDD); o TDD: IMT-2000 CDMA TDD (UTRA TDD) with its two modes: o high chip rate (HCR, 3.84 Mchip/s[156]) TDD and; o low chip rate (LCR, 1.28 Mchip/s) TDD, known also as TD-SCDMA.

[156] For more details on the chip rate details, see 3GPP TS 25.104 v3.4.0, 3GPP TS 25.105 v3.4.0 and 3GPP TS 25.101 v3.4.0 on Universal Mobile Telecommunications System (UMTS); radio transmission and reception.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
5	IMT versus broadband wireless access systems	ITU-R	Report M.2113-1 (2008)	Report on sharing studies in the 2 500-2 690 MHz band between IMT-2000 and fixed broadband wireless access systems including nomadic applications in the same geographical area.	It addresses co-channel and adjacent channel interference between IMT-2000 systems and other systems in the band, for example, broadband wireless access systems such as MMDS or IEEE 802.16. This report addresses compatibility between the following: • 802.16 TDD, which is based on the IEEE 802.16 series of standards, and IMT-2000 CDMA-DS; • 802.16 TDD, and IMT-2000 CDMA-TDD; • MMDS and CDMA-DS; • MMDS and CDMA-TDD. Mobile applications of IEEE 802.16 are not addressed in this report. The feasibility of coexistence of certain scenarios is subject to a trade-off between technical, regulatory and economic factors.
6	IMT versus IMT	ITU-R	Report M.2146-0 (2009)	Compatibility between IMT-2000 CDMA-DS and IMT-2000 OFDMA TDD WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area.	This report addresses compatibility between the OFDMA-TDD-WMAN and CDMA-DS components of IMT-2000, thus complementing previous Reports M.2030, M.2045 and M.2113. The feasibility of certain scenarios is subject to a trade-off between technical, regulatory and economic factors.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
7	IMT versus radio astronomy	ITU-R	Report RA.2332-0 (2014)	Compatibility and sharing studies between the radio astronomy service and IMT systems in the frequency bands 608-614 MHz, 1 330-1 400 MHz, 1 400-1 427 MHz, 1 610.6-1 613.8 MHz, 1 660-1 670 MHz, 2 690-2 700 MHz, 4 800-4 990 MHz and 4 990-5 000 MHz.	Studies in preparation of WRC 15, mostly addressing other bands than 2.6 GHz.
8	IMT and fixed service	ITU-R	Rec. F.2119-0	Guidance on technical parameters and methodologies for sharing and compatibility studies related to fixed and land mobile services in the frequency range 1.5-30 MHz.	It provides a generic list of parameters which should be used as guidance on characteristics of systems in the fixed and land mobile services appropriate for use in sharing studies in the frequency range of 1.5-30 MHz.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
9	IMT versus IMT and other services	CEPT	ECC Report 045 (2004)	Sharing and adjacent band compatibility between UMTS/ IMT-2000 in the band 2 500-2 690 MHz and other services.	Provides detailed spectrum arrangements for the band as well as the utilization of the frequency ranges 2 500-2 520 MHz and 2 670-2 690 MHz. The report shows that co-frequency sharing between BFWA and UMTS/IMT-2000 services is feasible but only with relatively large separation distances (up to 70 km for macro cells) to minimize mutual interferences. In the studied configuration, the victim receiver is either FDD/ TDD BS or UE. The simulations indicate that co-frequency sharing may prove to be difficult due to the large separation distances required between the two services. Due to the high front-to-back ratio of BFWA receivers, it may be possible to reduce the interference into BFWA receivers for co-channel sharing by ensuring that they are pointing away from IMT service areas. The report also shows that for adjacent channel operation between BFWA and terrestrial IMT services operating in geographically separate locations, a minimum frequency separation of 15 MHz will be necessary for macro and micro cell deployment of IMT.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
					For pico-cell deployment no guardband is necessary. Due to the high front-to-back ratio of BFWA receivers, it may be possible to reduce the interference into BFWA receivers for adjacent channel-sharing by ensuring that they are pointing away from IMT service areas. For adjacent band compatibility, for each possible combination of FDD and TDD / MSS adjacent band-sharing, the overall requirements in terms of the frequency carrier spacing or guardbands between these systems will need to ensure protection of both FDD/TDD and MSS victim stations in both systems or ensure compatible operation of these systems. The results of the studies show that for adjacent channel operation between MMDS and terrestrial UMTS services operating in geographically separate locations, a minimum frequency separation of 15 MHz will be necessary for macro and micro cell deployment of UMTS. For pico-cell deployment, no guardband is necessary. Due to the high front-to-back ratio of MMDS receivers, it may be possible to reduce the interference into MMDS receivers for adjacent channel-sharing by ensuring that they are pointing away from UMTS service areas.

Table 33: Overview of key IMT sharing and compatibility studies relevant for the 2.6 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
10	IMT versus IMT	CEPT	ECC Report 119	Compatibility between mobile systems in the 2.6 GHz frequency band at the FDD/ TDD boundary.	This report investigated compatibility between FDD and TDD networks in adjacent channels. It identifies several scenarios of interfer-ence between base stations, between base station and terminal and between terminals. Some scenarios could raise severe interfer-ence problems. The main element to achieve compatibility is by imple-menting guardbands, additional front-end fil-ters, restricted channels, deployment restrictions and special site engi-neering (for co-siting case), although other more complex mitiga-tion techniques are also studied.
11	IMT versus other services	CEPT	CEPT Report 019	Report from CEPT to the European Commission in response to the mandate to develop least restrictive tech-nical conditions for frequency bands addressed in the context of WAPECs.	It addresses compat-ibility of IMT with all other services in oper-ation, co-channel or in adjacent bands for all spectrum of IMT up to 3.8 GHz. The report develops the concept of block edge mask (BEM) to facilitate compatibility. In its Annex 4, a set of BEMs are proposed for several scenarios.
12		CEPT	ECC/REC/ (11)05	ECC Recommenda-tion of 26 May 2011 on cross-border coordination for mobile/fixed communications networks (MFCN) in the frequency band 2 500-2 690 MHz, amended on 3 February 2017.	It recommends technical conditions for operation of FDD or TDD systems and set field strength limits for several cases. Very useful Recommendation to address in frequen-cy-planning and cross-border coordina-tion of IMT services.

Further interpretation of the results of the above compatibility studies is summarized in the following section, identifying the technical conditions for IMT compatibility with other services. As described in the previous table, compatibility between IMT and other services can be achieved by observing the technical conditions to avoid harmful interference.

5.3.2 Technical conditions for IMT sharing and compatibility

As shown in Table 33, a number of sharing and compatibility options between IMT and the other services have been identified. Table 34 provides an overview of technical conditions under which such options are technically feasible, although it is the specific local situation that will dictate which conditions need to be applied and to what extent.

For the technical conditions presented in Table 34, it is assumed that the radio equipment involved in the interference case complies with a minimal (least restrictive), and preferably, a harmonized set of technical conditions. Such a set of minimum technical conditions may be checked as part of a type-approval procedure for granting the use of radio equipment in the NRA's territory. Also, such a set of minimum criteria often include emission limits/spectrum masks and may be complemented with other conditions such as for human safety (EMC).

Finally, the conditions included in Table 34 address the conditions for separating IMT from other non-IMT applications. Conditions for separating frequency blocks between IMT operators (such as guardbands, spectrum masks, radiated power level) are not addressed, although various reports (ITU-R M.2030, M.2045, M.2146) address recommendations for several cases of compatibility of different IMT technologies, usually in adjacent channelling.

Table 34: Technical conditions for IMT sharing and compatibility in the 2.6 GHz band

No	Interference type / case	Technical conditions	Reference documents	Notes
1	BSS sound into IMT	It sets the value for Isat/Nth of –10 dB at any IMT-2000 mobile or base station receiver, which should be used as the trigger value for the sharing studies with a view to protecting IMT-2000 from BSS stations. The following receiving parameters should be used when assessing the interference into IMT-2000 mobile stations: • maximum noise figure: 9 dB; • thermal noise level at the receiver: –135 dB(W/MHz); • antenna gain: 0 dBi; • polarization: linear. The following receiving parameters should be used when assessing the interference into IMT-2000 base stations: • typical noise figure: 5 dB; • thermal noise level at the receiver: –139 dB(W/MHz); • feeder loss: 2 dB; • polarization: linear; • typical antenna: 120° sector, max antenna gain of 18 dBi.	ITU-R Rec M.1446	This Recommendation sets protection criteria and methodology to compute interference.
	BSS sound into IMT	This methodology contains an algorithm that can be used to calculate a single entry pfd mask for BSS (sound) satellites for a given scenario to meet an Isat/Nth criterion within a tolerance of 1 dB at any location on the Earth. The methodology is recommended for the assessment of interference from new BSS (sound) systems into IMT.	Rec ITU-R M.1654	This Recommendation is an example methodology to assess the interference from BSS (sound) into terrestrial IMT 2000 systems intending to use the band 2 630-2 655 MHz and that could be used to determine the impact of BSS (sound) on terrestrial IMT 2000 in the context of co-frequency-sharing through the development of pfd masks where applicable.

Table 34: Technical conditions for IMT sharing and compatibility in the 2.6 GHz band (continued)

No	Interfer-ence type / case	Technical conditions	Reference docu-ments	Notes
2	IMT versus satellite IMT	For the downlink band (around 2 520 MHz), the compatibility results depend to a large extent on the environment in which the MESs will operate and the terrestrial system is deployed: • If IMT-2000 CDMA TDD systems are deployed in the adjacent band, it would not be feasible to operate MESs in the same geographical areas. • If IMT-2000 CDMA direct spread downlink is deployed in the adjacent band, under the baseline assumptions a minimum guardband of 6 MHz would be needed for the pedestrian micro environment and 5 MHz for rural environments, and it would not be possible to operate MES in macro vehicular environment. However, if the MSS accepts some extra risk of interference, a guardband of 1 MHz would be sufficient in all environments based on the more optimistic assumptions, the appropriateness of which is neither guaranteed nor agreed. • If IMT-2000 CDMA direct spread uplink is deployed in the adjacent band, under the baseline assumptions, no guardband is needed for vehicular macro and rural environment and it may not be possible to operate MESs in the pedestrian micro areas.	Rec ITU-R M.2041	Note should be taken that MSS allocation is only in the adjacent band, below 2 500 MHz.

Table 34: Technical conditions for IMT sharing and compatibility in the 2.6 GHz band (continued)

No	Interference type / case	Technical conditions	Reference documents	Notes
		For the uplink band (around 2 670 MHz) the compatibility results are generally favourable: • If IMT-2000 CDMA TDD operates in the adjacent band, no guardband or a small guardband is necessary. • If IMT-2000 CDMA direct spread downlink operates in the adjacent band, under the baseline assumptions, the guardband exceeds 7 MHz. However, if the MSS operator accepts some extra risk of interference, a guardband of 1.5 MHz would be sufficient based on the more optimistic assumptions, the appropriateness of which is neither guaranteed nor agreed. • If IMT-2000 CDMA direct spread uplink operates in the adjacent band, a guardband of 1 MHz may be necessary. For other types of satellite radio interface, the conclusion is that simultaneous operation with IMT would be possible if a frequency separation distance of 5 MHz is observed.		

Table 34: Technical conditions for IMT sharing and compatibility in the 2.6 GHz band (continued)

No	Interference type / case	Technical conditions	Reference documents	Notes
3	IMT versus IMT	This report investigates techniques to improve compatibility between the two radio interfaces for the problematic scenarios identified in Report ITU-R M.2030. Application of these mechanisms would reduce the size of, and may in some cases eliminate, the guardband and/or isolation distances that might otherwise be required. This report has identified techniques that can provide significant mitigation of interference between TDD and FDD networks in the scenarios investigated operating in adjacent bands. A single technique will not provide full mitigation in all scenarios. However, a combination of techniques can provide a solution to mitigate TDD/FDD interference in many situations. Some of the techniques need to be implemented through coordination of network deployments. Some techniques are only applicable to specific scenarios, and/or require the technique to be implemented by the BS manufacturer. Nonetheless, these mitigation techniques could be considered in determining if there are guardband requirements between the two systems. The techniques studied are: • Equipment performance (supplier improving the equipment performance); • Site engineering on single site; • Deployment relationship between sites.	Report ITU-R M.2045	Study based on 3GPP specifications for the 2 GHz band.

Table 34: Technical conditions for IMT sharing and compatibility in the 2.6 GHz band (continued)

No	Interference type / case	Technical conditions	Reference documents	Notes
	IMT versus IMT	Compatibility between IMT-2000 CDMA-DS and IMT-2000 OFDMA TDD WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area, based on the IEEE 802.16 series of standards, and the CDMA-DS component of IMT-2000 in the band 2 500-2 690 MHz. The feasibility of certain scenarios is subject to a trade-off between technical, regulatory and economic factors.	Report ITU-R M.2146	A planning scenario is required to ensure that the identified cases of excessive interference, as reported in this ITU-R Report, are duly taken into consideration. Several tables identify the cases of interference, and methodology to mitigate cases of excessive interference is provided.
	IMT versus IMT	The coexistence issue considered is adjacent-channel interference between FDD and TDD systems. The coexistence between two TDD unsynchronized systems is not strictly assessed in the report; however, since most parameters are similar, most of the results of the FDD/TDD scenario can be extended to two unsynchronized TDD systems scenario. Co-channel interference between geographically adjacent areas (cross-border coordination) has not been studied. Various scenarios are considered, and conclusion are provided in terms of required guard-bands, additional front-end filters, restricted channels, deployment restrictions and special site engineering (for co-siting cases), although other more complex mitigation techniques are also studied.	CEPT report 119	Relevant for cross-border coordination. Relevant for cross-border coordination. Considered technologies are: Draft ETSI EN 301 908-3 V3.2.1 (2006-12), harmonized EN for IMT-2000, CDMA FDD (UTRA FDD) (BS) and ETSI EN 301 908-2 V3.2.1 (2006-12), harmonized EN for IMT-2000, CDMA FDD (UTRA FDD) (UE), draft ETSI EN 301 908-7 V3.2.1 (2006-12), harmonized EN for IMT-2000, CDMA TDD (UTRA TDD) (BS) and ETSI EN 301 908-6 V3.2.1 (2006-12), harmonized EN for IMT-2000, CDMA TDD (UTRA TDD) (UE), draft ETSI EN 302 544, broadband radio access networks (BRAN), broadband data transmission systems in 2 500-2 690 MHz, harmonized EN.

Table 34: Technical conditions for IMT sharing and compatibility in the 2.6 GHz band (continued)

No	Interference type / case	Technical conditions	Reference documents	Notes
4	IMT versus other services	It introduces the concept of block edge mask to mitigate the interference to other services, both in co-channel and adjacent bands for several scenarios.	CEPT report 019	Relevant for cross-border coordination of IMT and for other services.
5	IMT versus broadband wireless access systems	Co-frequency-sharing between MMDS and terrestrial IMT-2000 requires: • 5 km separation distance to prevent interference from a CDMA-DS mobile station transmitting into a MMDS receiver, 70 km separation distance between a CDMA-DS base station transmitter and a MMDS receiver for macro cell deployment, 25 km for micro-cell deployment and 5 km for pico-cell deployment. • 70 km separation distance between a MMDS transmitter and a CDMA DS base station receiver, 25 km for micro cell deployment and 5 km for pico-cell deployment. • 5 km separation distance between a MMDS transmitter and a CDMA-DS mobile station receiver.	Report ITU-R M.2113	Additional considerations are required for wireless broadband access systems based on 802.16.

5.3.3 Regulatory conditions for IMT sharing and compatibility

Administrations may wish to complement the technical conditions under which they grant the IMT spectrum rights with specific IMT regulatory conditions (in addition to the general conditions for assigning spectrum rights). These specific IMT-related conditions often arise from the situation that the IMT services are introduced in bands with incumbent services that need to be protected.

Table 35 provides an overview of these IMT-specific regulatory conditions. It should be noted that the RR 5.384A provision refers to Resolution 223 (WRC-15). This resolution does not stipulate specific regulatory elements that might constrain IMT deployment.

Table 35: Regulatory conditions specific for IMT licensees

No	Condition or requirement	Notes	References
1	Implement the Radio Regulation footnote 5.384A applicable to the band 2 500-2 690 MHz, in the national tables of frequency allocations. The IMT identification of band 2 500-2 560 MHz applies to all African countries.	To ensure the implementation of ITU RR requirements.	See ITU RR footnote 5.884A
2	To protect existing fixed-service stations, observe the required separation distances.	Separation distances may differ depending on the specific interference environment.	See section 5.3.2
3	The IMT licensee has the obligation to compensate for any incurred costs by the incumbent service.	See also Table 34	See Section 5.3.2
4	The IMT licensee has the obligation to help investigate any complaints about interference of incumbent services.	See also Table 34	See Section 5.3.2
5	Implementation of regulation associated with the requirements of equipment to operate in IMT band 2 500-2 690 MHz, similarly as the European RTTE Directive, which defines the essential requirements for bringing radio equipment onto the market and deploying it into service. Article 3.2 of the Directive states that, "radio equipment shall be so constructed that it effectively uses the spectrum allocated to terrestrial/space radio communication and orbital resources so as to avoid harmful interference". However, it also contains provisions addressing the obligations of administrations and operators in relation to bringing radio equipment into service and allowing it to connect to compatible networks.	Compatibility studies were conducted assuming the given performance of equipment, but the conclusions may differ for other characteristics of equipment.	See CEPT Report 019

5.3.4 Cross-border coordination aspects for IMT

As described earlier, several studies have been developed to assist on the compatibility of different IMT technologies (see reports ITU-R M.2030, M.2045, M.2146 in Table 34). Those reports establish the conditions which must be met by the IMT systems to ensure operation free from harmful interference.

Interference cases may arise in the final stages when administrations have adopted IMT and their stations' emissions are within the coordination zone for these services. The HCM, HCM4A, BKO-18 and the Vienna Agreement provide procedures and parameters for managing possible cross-border interference between IMT services. It is noted that these agreements are based on a system of maximum permissible levels of interference field strength, and if the calculated interference level is higher (than the trigger value), coordination is needed. It is also noted that the HCM, HCM4A and Vienna Agreement cover both land mobile and fixed service.

Additionally, and specifically for cross-border coordination of LTE and NR/5G applications, a system of physical cell identity (PCI) can be used. A PCI is an identification of an IMT cell at the physical layer and represents a specific frequency which can be used in cross-border coordination. ECC Rec. (11)05 provides guidance for cross-border coordination on the basis of PCI. The recommendation provides the following on cross-border coordination for the band 2 500- 2 690 MHz:

1) A system of dividing preferential and non-preferential PCIs between administrations on the basis of equitable spectrum access. In other words, administrations should share PCIs in border areas and have equitable distribution of 504 (LTE) or 1008 (NR/5G) available PCIs, for preferential and non-preferential PCIs.
2) Preferential and non-preferential PCIs have different trigger values (expressed in dBµV/m/5 MHz). Coordination is needed if the interfering field strength is higher (Annexes 1 and 2). The interfering field strength is calculated on the basis of defined propagation models (Annex 3).
3) A procedure for the exchange of data between the requesting and the affected administrations (Annex 4).
4) A detailed system for assigning PCIs to countries (Annex 5). The system is based on a cell-colouring system for the CEPT countries. However, African countries can adapt the proposed system to their local situation.[157]

The ECC/REC/(11)05, updated in 2017, sets the recommended conditions for cross-border coordination of IMT systems (limits defined in Annexes 1 and 2), as listed below:

1) Field-strength levels for the cross-border operation between FDD MFCN systems in the frequency band 2 500-2 690 MHz:[158]

    a. Stations of FDD systems with centre frequencies not aligned on both sides of the borderline or with centre frequencies aligned using preferential PCI codes may be used without coordination with a neighbouring country if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 65 dBµV/m/5MHz at a height of 3 m above ground at the borderline between countries and does not exceed 49 dBµV/m/5MHz at a height of 3 m above ground at a distance of 6 km inside the neighbouring country.
    b. Stations of MFCN FDD systems with centre frequencies aligned on both sides of the borderline using non-preferential PCI codes given in Annex 5 may be used without coordination with a neighbouring country if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 49 dBµV/m/5 MHz at a height of 3 m above ground at the borderline between countries.
    c. As per ECC/REC/(11)01, and for the case of FDD, it is usually not considered necessary to define preferential frequencies. If administrations wish to agree on frequency coordination based on preferential frequencies, while ensuring a fair treatment of different operators, then they can do so based on mutual agreements. In this case, field-strength levels in paragraph 1 above may be applicable.

Table 36 gives an overview of the trigger values of the field strength.

[157] See also Section 1.3.4.
[158] See further explanations in CEPT ECC/REC/(11)05, updated in 2017.

Table 36: Trigger values at a height of 3 m above ground for MFCN FDD systems

Non-preferential frequency usage			Preferential frequency usage
Centre frequencies aligned		Centre frequencies not aligned	Based on bi-or multilateral agreements/ arrangements (paragraph 1c)
Using preferential PCI codes	Using non-preferential PCI codes	Using all PCI codes	
65 dBmV/m/5MHz@0 km and 49 dBmV/m/5MHz@6 km (paragraph 1a)	49 dBµV/m/5 MHz@0 km (paragraph 1b)	65 dBmV/m/5 MHz@0 km and 49 dBmV/m/5 MHz@6 km (paragraph 1a)	

From Table 36 it is noted that:

i. @ stands for "at a distance inside the neighbouring country".

ii. For field-strength predictions, the calculations should be made according to Annex 3. In cases of channel bandwidth other than 5 MHz, a factor of 10 x Log10 (channel bandwidth/5MHz) should be added to the field-strength values.

2) Field-strength levels for the cross-border operation between TDD MFCN and between TDD and FDD MFCN systems in the frequency band 2 500-2 690 MHz:

   a. In general, stations of MFCN systems may be operated without coordination if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 30 dBµV/m/5 MHz at 3 metres above ground level at the border;
   b. If administrations wish to agree on frequency coordination based on preferential frequencies, or MFCN TDD systems are in operation across both sides of a border and are synchronized across that border, or MFCN TDD systems are deployed as downlink only on both sides of the border, then field-strength levels such as those in Annex 1 may be applicable. If those values are not acceptable, field-strength levels should be agreed on a bilateral or multilateral basis.
   c. TDD operation within the bands 2 500-2 570 MHz and 2 620-2 690 MHz has not been studied with FDD operation. TDD operation within these bands will only occur if countries do not adopt the channelling arrangement in ECC/DEC/(05)05. In this case, the field-strength levels should be agreed on a bilateral or multilateral basis.

Table 37 gives overview of the trigger values of the field strength.

Table 37: Trigger values at a height of 3 m above ground between TDD systems

<table>
<tr><th colspan="5">Non-preferential frequency usage</th><th>Preferential frequency usage</th></tr>
<tr><td colspan="3">Centre frequencies aligned</td><td colspan="2">Centre frequencies not aligned</td><td rowspan="4">Based on bi-or multilateral agreements/ arrangements (paragraph 2c)</td></tr>
<tr><td colspan="2">Synchronized TDD, or DL only</td><td>Unsynchronized TDD</td><td>Unsynchronized TDD, or DL only</td><td>Unsynchronized TDD</td></tr>
<tr><td>Preferential PCI codes</td><td>Non-preferential PCI codes</td><td>All PCI codes</td><td>All PCI codes</td><td></td></tr>
<tr><td>65 dBmV/m/5MHz@0 km and
49 dBmV/m/5 MHz@6 km (paragraph 2b)</td><td>49 dBµV/m/5 MHz@0 km
(paragraph 2b)</td><td>30 dBµV/m/5 MHz@0 km
(paragraph 2a)</td><td>65
dBmV/m/5 MHz@0 km and
49 dBmV/m/5 MHz@6 km (paragraph 2b)</td><td>30 dBµV/m/5 MHz@0 km
(paragraph 2a)</td></tr>
</table>

From Table 37 it is noted that:

i. @ stands for "at a distance inside the neighbouring country".

ii. For field-strength predictions, the calculations should be made according to Annex 3. In the case of other channel bandwidths other than 5 MHz, a factor of 10 x Log10 (channel bandwidth 5 MHz) should be added to the field-strength values.

In addition, other services could be deployed in neighbouring countries, thus requiring cross-border coordination to achieve compatibility, notably with:

1) fixed service;
2) BSS sound;
3) radioastronomy.

For mitigating any identified interference cases between countries, two basic approaches exist:

1) case-based coordination;
2) agreement-based coordination.

Case-based frequency coordination is in principle applied in the absence of bilateral or multilateral agreements. Case-based refers to the situation of one country needing to coordinate a frequency (or a set of frequencies) it would like to protect from harmful interference or which it expects could cause harmful interference. Case-based coordination would ultimately result in an agreement on the frequency usage of the frequencies involved in the case.

Bilateral or multilateral agreements are agreed well in advance of the actual detailed planning and assignment of frequencies. These agreements include, in varying degrees, the process or method of frequency coordination (such as procedures, datasets, registers, propagation models and planning software) and the key applied parameters (such as specified levels of harmful interference, coordination zones and distances).

5.4 Best practices and methods for refarming other services in the 2.6 GHz band

Refarming in the context of this report means the replanning of incumbent services deemed incompatible with the introduction of IMT services. In other words, the spectrum needs to be freed up or cleared for IMT. From Tables 31 and 32, it can be concluded that several services or applications may have to be replanned or reallocated to adjacent or other bands.

It is noted that some fixed broadband wireless access (FBWA) services are deployed in some SADC countries, although how many countries and the density of deployment are not known.

The financial funding of refarming efforts is addressed in Section 11. It is noted that Recommendation ITU-R SM.1603 also covers general approaches to refarming, guidelines for calculating refarming (or redeployment) costs and examples of country experiences with refarming.

5.4.1 Refarming fixed broadband wireless access service links

The uniquely identified incumbent service having been deployed in African SADC countries is fixed service, for broadband wireless access applications. This similar application of the fixed service may have been also deployed in other African countries.

Although not automatically applicable for FBWA, some relevant references on potential refarming of FBWA are developed for point to point and point-to-multipoint systems in Section 3.4.1.

5.5 Guidelines and recommended actions for the 2.6 GHz band

Table 38 provides a summary of the main guidelines associated with measures to facilitate IMT introduction.

Table 38: Spectrum management guidelines for IMT introduction in the 2.6 GHz band

No	Guideline	Applies to	Ref. Section(s)
5.1	Advanced frequency-planning coordination is recommended at the earliest stage of the frequency-assignment process, as there would be technical elements strongly associated with the technologies being deployed for IMT systems in each country. This work could also include preparatory coordination work among operators concerned. However, in the ideal case, the frequency assignments should be coordinated with neighbouring countries at earlier stages, even when the specific frequency assignments to each operator would have not been concluded. The cross-border coordination can be undertaken on a bilateral or a multilateral level between administrations.	IMT services	Section 5.3.4

Table 38: Spectrum management guidelines for IMT introduction in the 2.6 GHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
5.2	The bilateral or multilateral agreement should define the coordination methods encompassing all wireless broadband mobile service radio interfaces present on each side of the border.	IMT services	Section 5.3.4
5.3	The cross-border coordination between IMT FDD or IMT TDD systems can take as a reference the limits defined in CEPT ECC/REC/(11)05.	IMT services	Section 5.3.4
5.4	Based on the recommendations from ECC/REC/(11)05, stations of TDD systems, in general, may be operated without coordination with a neighbouring country if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 30 dBµV/m/5 MHz at an antenna height of 3m above ground at the border between countries. If administrations wish to agree on frequency coordination based on preferential frequencies or if IMT TDD systems are in operation either side of a border are synchronized, then higher field-strength levels at the borderline can be allowed.	IMT services	Section 5.3.4
5.5	Based on the recommendations from ECC/REC/(11)05, stations of FDD systems with centre frequencies not aligned on both sides of the border or with centre frequencies aligned using preferential PCI codes may be used without coordination with a neighbouring country if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 65 dBµV/m/5MHz at a height of 3 m above ground at the border and does not exceed 49 dBµV/m/5MHz at 3 m above ground at a distance of 6 km inside the neighbouring country. Stations of FDD systems with centre frequencies aligned on both sides of the border using non-preferential PCI codes may be used without coordination with a neighbouring country if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 49 dBµV/m/5 MHz at 3 m above ground at the border. In the case of cross-border operations between TDD systems and FDD systems, the field-strength levels should be agreed on a bilateral basis. Stations of IMT systems may be operated without coordination if the mean field strength produced by the cell (all transmitters within the sector) does not exceed 15 dBµV/m/5MHz for 10 per cent of the time at half of the locations 3 m above ground level at the border.	IMT services	Section 5.3.4

Table 38: Spectrum management guidelines for IMT introduction in the 2.6 GHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
5.6	Promote agreement for a harmonized regional or African table of frequency allocation under the aegis of ATU, which should include the frequency range 2 500-2 690 MHz as identified for wireless broadband mobile services. This agreement should include the specific recommended methodologies to reach cross-border agreements depending on the specific technologies deployed by each administration, as well as the regulatory framework to undertake diligently the necessary cross-border coordination processes.	Compatibility of IMT services and Compatibility of IMT with FBWA.	Section 5.3.4
5.7	For countries that have already deployed some WiMAX systems, detailed analysis should be undertaken for each sharing scenario including the trade-off between technical, regulatory and economic factors. The mitigation techniques, as recommended by ITU-R Report M.2113 should be considered as a way to allow coexistence of IMT and WiMAX systems.	Compatibility of IMT with FBWA.	Section 5.3.4
5.8	In order to achieve compatibility, even temporary, between the introduction of IMT services and existing FBWA services, the report ITU-R M.2113 provides technical elements regarding the required separation distances for different technologies. For countries that have implemented FBWA services, the earliest frequency coordination process would facilitate the appropriate frequency assignments to IMT. The CEPT report ECC 045 also provides the mitigation techniques to achieve compatibility between BFWA and IMT through separation distances, guardbands or proper pointing of BFWA.	Compatibility of IMT with FBWA.	Section 5.3.4
5.9	Consider industry recommendations about synchronized operation between countries. This should be encouraged as much as possible as synchronized operation between countries is also very important for simplifying cross-border coordination, especially between smaller countries and for countries with cities at their borders.	IMT services.	Sections 5.3.2 and 5.3.4

6 IMT sharing and compatibility with other services in the 3.5 GHz band

The Radio Regulations establish that the band 3 400-3 600 MHz is allocated to mobile service and identified for IMT under RR No. 5.430A for Region 1.

Under footnote RR 5.429, 31 African countries have also identified the band 3 300-3 400 MHz for IMT. WRC-23 will also study possible ways to simplify the current existing footnotes associated with this band, under Resolution 245 of WRC-19.

The segment 3 600-3 800 MHz is subject to further review by WRC-23 (Resolution 246 of WRC-19).

6.1 IMT frequency arrangements in the 3.5 GHz band

Table 39 shows the IMT frequency arrangements in the 3.5 GHz band (3 300-3 700 MHz) as included in Recommendation ITU-R M.1036-6. It is also noted that administrations may implement all or part of each frequency arrangement.

Table 39: IMT frequency arrangements in the 3.5 GHz band

Frequency arrangement	Paired arrangements (FDD)				Unpaired arrangements (TDD) (MHz)
	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
F1					3 400-3 600
F2	3 410-3 490	20	3 510-3 590	100	None
F3					3 300-3 700

The following is noted from Table 39:

1) Frequency arrangement F3 could enable administrations to implement IMT in the whole or parts of the bands identified in the RR (3 300-3 400 MHz, 3 400-3 600 MHz and 3 600-3 700 MHz), with any possible frequency separation, if required, taking into account the use of the bands by other services and applications. The frequency arrangement F1 is harmonized with F3. This frequency arrangement F1 has been implemented by some administrations.
2) 3GPP bands are: n77 (3 300-4 200 MHz) and n78 (3 300–3 800 MHz).

6.2 Other services allocated in the 3.5 GHz band and adjacent bands

The allocation table applicable to Region 1 is described in Table 40, which provides an overview of the Radio Regulations provisions applicable to each segment of spectrum in this band. The bands identified are those associated to the IMT identifications. No specific technical conditions have been identified for the operation of adjacent services outside the range 3 300-4 200 MHz). Radio Regulations provisions less relevant for IMT are indicated in round brackets while IMT identifications provisions are highlighted in blue.

Table 40: ITFA corresponding with the identified IMT frequency arrangements for the 3.5 GHz band (Region 1)

3 300-3 400 MHz		
Services:	Footnote number:	Footnote:
Radiolocation		
Mobile	5.429	Identification for fixed and mobile services on primary basis in several African countries: Benin, Cameroon, Republic of the Congo, Côte d'Ivoire, Egypt, Kenya, Libya, Uganda, Democratic Republic of the Congo and Sudan. The countries bordering the Mediterranean shall not claim protection for their fixed and mobile services from the radiolocation service.
	5.429A	In Angola, Benin, Botswana, Burkina Faso, Burundi, Djibouti, Eswatini, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Malawi, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sudan, South Sudan, South Africa, Tanzania, Chad, Togo, Zambia and Zimbabwe, the frequency band 3 300-3 400 MHz is allocated to the mobile service (except aeronautical mobile) on a primary basis. Stations in the mobile service operating in the frequency band 3 300-3 400 MHz shall not cause harmful interference to, or claim protection from, stations operating in the radiolocation service.
	5.429B	In the following countries of Region 1 south of 30° parallel north: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Republic of the Congo, Côte d'Ivoire, Egypt, Eswatini, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Malawi, Mauritania, Mozambique, Namibia, Niger, Nigeria, Uganda, the Democratic Republic of the Congo, Rwanda, Sudan, South Sudan, South Africa, Tanzania, Chad, Togo, Zambia and Zimbabwe, the frequency band 3 300-3 400 MHz is identified for the implementation of IMT. This is primary but not priority versus other services, and agreement with neighbouring countries is required for the radiolocation service.
	Resolution 245 (WRC19)	Studies are being undertaken for possible modification of footnotes at WRC-23.
3 400-3 600 MHz		
Services:	Footnote number:	Footnote:

Table 40: ITFA corresponding with the identified IMT frequency arrangements for the 3.5 GHz band (Region 1) (continued)

Fixed		
Fixed satellite (space to Earth)		
Mobile, except aeronautical mobile	5.430A	Identification without priority for IMT of 3 400-3 600 MHz. RR 9.17, RR 9.18 and RR 9.21 apply. Before an administration brings into use a (base or mobile) station of the mobile service in this frequency band, it shall ensure that the pfd produced at 3 m above ground does not exceed −154.5 dB(W/(m2 at 4 kHz)) for more than 20 per cent of the time at the border of the territory of any other administration. This limit may be exceeded on the territory of any country whose administration has so agreed.
Radiolocation		
Amateur	(5.431)	On secondary basis (Germany, Israel) the segment 3 400-3 475 MHz
3 600-4 200 MHz		
Services:	Footnote number:	Footnote:
Fixed		
Fixed satellite (space to Earth)		
Mobile	Resolution 246 (WRC19)	Conduct-sharing and compatibility studies in time for WRC-23 between the mobile service and other services allocated on a primary basis within the frequency band 3 600-3 800 MHz and adjacent frequency bands in Region 1.

From Table 40 the following aspects can be noted:

1) 3 300-3 400 MHz: This band is allocated to mobile service as primary in several countries of Region 1 through footnotes 5.429 and 5.429A. The band is also identified for IMT in 31 countries in Africa with requirements to protect the radiolocation service.
2) 3 400-3 600 MHz: This band is identified for IMT and includes a mechanism to facilitate cross-border coordination by establishing a limit on the pfd produced by any IMT base or user terminal at 3 m above ground which shall not exceed −154.5 dB(W/(m2 at 4 kHz)) for more than 20 per cent of the time at the border of the territory of any other administration. This limit may be exceeded on the territory of any country whose administration has so agreed.
3) 3 600-3 800 MHz: Further studies are ongoing in preparation of WRC-23 for possible mobile allocation in this band as primary.

Table 41 provides and overview of the applications and technology standards commonly applied in Region 1 for the non-IMT services as included in Table 40 in the same and in adjacent bands. For the list of applications indicated, due account has been taken of available information about deployment of services in Africa, such as the SADC Table of Frequency Allocations.

Table 41: Common applications and technology standards per ITU-RR service for Region 1

ITU-RR service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Fixed	FS	FS	FBWA (the band 3 400-3 600 MHz is also used for BFWA in some SADC countries). The sub-band 3 600-3 800 MHz could be used for BFWA where frequency-sharing with FS PTP and/or FSS is feasible.)	IEEE 802.16 (WiMAX) LTE	IEEE 802.16e
	FS	FS	Fixed links	The channelling arrangement for PTP links in this band is based on ITU-R Recommendation F.635 Annex 1.	
Radiolocation	Government-related radar systems in European countries, but no details are available about the use of the band in Africa for radiolocation.				
Mobile	No information about specific use in Africa, although LTE deployment is expected.				
Fixed satellite	FSS	FSS	VSAT	Proprietary satellite, and DVB-S, DVB-S2	

From the above information about specific allocations and deployment, compatibility issues may arise with respect to fixed service and fixed-satellite service in the upper part of the frequency range and with radiolocation in the 3 300-3400 MHz band.

6.3 Sharing and compatibility between IMT and other services in the 3.5 GHz band

In spectrum management, sharing and compatibility studies are about investigating mechanisms to facilitate the efficient use of spectrum by different services in-band or in adjacent bands, considering the expected deployment of each service as well as the applied technology standards.

In this section, the most relevant sharing and compatibility studies are identified with the aim of helping administrations to implement measures to avoid incompatible operation of different services and avoidance of harmful interference.

Administrations are advised to interpret these study results with caution as their local situation (including the actual frequency allocations/assignments as reflected in their NTFA, the applied technologies and interference scenario) may differ from those studied. Most of the sharing and compatibility studies are based on typical scenarios representing the reasonable deployment scenario of each service under study, although the singularities of specific deployment of services would require adequate interpretation of the sharing environment.

6.3.1 Overview of IMT sharing and compatibility studies

The main sharing and compatibility studies conducted so far in the frequency range of 3 300-3 600 MHz and adjacent bands are reported in Table 42.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
1	IMT versus fixed service	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.	This report examines the required frequency rejection as a function of separation distance for compatible operation of IMT and FS systems. Two interference scenarios are considered: IMT base station into FS receiving station and IMT user equipment (UE) into FS receiving station. The main results, for co-channel interference, require the following separation distances between IMT base station and FS receiving station: • Macro suburban 50.4-92.0 km • Macro urban 41.7-81.0 km • Small cell outdoor 13.4-45.0 km • Small cell indoor 1.0-10.0 km; And between IMT UE into FS receiving station: • Macro suburban 1.0-24.0 km • Macro urban 1.0-31.0 km • Small cell outdoor 1.0-25.0 km • Small cell indoor < 1.0 km. For the adjacent channel separation, the separation distance varies from 1 to 30 km and 27.7 MHz to 0 MHz.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
2	IMT versus fixed-satellite service	ITU-R	Report M.2109-0	Sharing studies between IMT-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.	This report presents the results of the sharing studies performed between the FSS networks using the geostationary satellite orbit (GSO) and IMT-Advanced systems. These studies have been based upon: • The current band usage by GSO-FSS and the associated generalized characteristics, which could evolve during the period while IMT-Advanced is being further developed and implemented; • Assumptions on the future characteristics of IMT-Advanced. To provide protection of the FSS receiving earth stations, some separation distance relative to the stations of the mobile terrestrial network is required. The magnitude of this separation distance depends on the parameters of the networks and the deployment of the two services. The minimum required separation distances from IMT-Advanced base stations, when using the long-term interference criterion derived in the studies to date, are at least in the tens of kilometres. The minimum separation distances associated with short-term interference criterion, generally, but not in all cases, exceed 100 km in the considered cases with similar assumptions as the ones used for the long term.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
		ITU-R	Report S.2368-0	Sharing studies between IMT-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.	• Complements results of report M.2109. • The study analyses various interference cases and derives the necessary separation distances between stations of IMT and FSS to avoid harmful interference.
		ITU-R	Rec ITU-R S.1856-0	Methodologies for determining whether an IMT station at a given location operating in the band 3 400-3 600 MHz would transmit without exceeding the pfd limits in the Radio Regulations Nos. 5.430A, 5.432A, 5.432B and 5.433A	The report provides the methodology to compute the required pfd limit. The reason is to protect earth stations in the band 3 400-3 600 MHz from cross-border interference by stations in the mobile service, as provided by RR Nos. 5.430A, 5.432A, 5.432B and 5.433A (WRC 07) which state that, before an administration specified in these footnotes brings into use a (base or mobile) station of the mobile service in this band, it shall ensure that the pfd produced at 3 m above ground does not exceed −154.5 dB(W/(m2 * 4 kHz)) for more than 20per cent of the time at the border of the territory of any other administration.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
3	IMT versus radiolocation	ITU-R	Report M.2111-0	Sharing studies between IMT-Advanced and the radiolocation service in the 3 400-3 700 MHz bands.	• This report provides sharing studies between radar systems and IMT-Advanced systems in the bands 3 400-3 700 MHz, and potential interference mitigation techniques. • The studies show that co-frequency-sharing between radiolocation services and IMT devices is not feasible in the same geographic area without the application of mitigation techniques. • Separation distances and frequency-separation are required to protect victim systems.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
		ITU-R	Report M.2481-0	In-band and adjacent band compatibility and compatibility studies between IMT systems in 3 300-3 400 MHz and radiolocation systems in 3 100-3 400 MHz.	This report provides guidance for operational measures to enable the compatibility of IMT and radiolocation service in the frequency band 3 300-3 400 MHz, and in adjacent bands between IMT systems and radiolocation operating below 3 300 MHz. The results of the in-band and adjacent band compatibility studies give generic values of separation distances obtained with models from ITU-R Recommendations for compatibility of future IMT deployment in the band 3 300-3 400 MHz. The studies show clearly that mitigation techniques and measures are necessary for the compatibility of future deployment of IMT systems with incumbent radar systems in these bands. Administrations preparing future deployment of IMT systems in the band 3 300-3 400 MHz would have to consider mitigation techniques.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
4	IMT versus IMT	CEPT	ECC Report 281	Analysis of the suitability of the regulatory technical conditions for 5G MFCN operation in the 3 400-3 800 MHz band (2018).	It contains harmonized technical conditions contained in this Decision to ensure their suitability for 5G, including: • Development of the most suitable frequency arrangement for 5G in the 3 400-3 800 MHz band; • Compatibility with other services below 3 400 MHz (radiolocation services in particular) and above 3 800 MHz (FSS and FS services); • Management of interference between MFCNs with particular emphasis on the "synchronization framework" to support the operation of MFCNs based on the TDD access scheme in outdoor deployment scenarios.
5	IMT versus IMT	CEPT	ECC Decision (11)06	Harmonized frequency arrangements and least restrictive technical conditions (LRTC) for mobile/fixed communications networks (MFCN) operating in the band 3 400-3 800 MHz (2018).	CEPT administrations designate the frequency band 3 400-3 800 MHz on a non-exclusive basis to MFCNs, without prejudice to the protection and continued operation of other existing users. The Decision further sets: • Frequency arrangement (in Annex 1); • The least restrictive technical conditions suitable for MFCN(Annex 2); • The migration within the frequency band 3 400-3 800 MHz of existing terrestrial networks; • Key principles related to the compatibility with services other than MFCN.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibil-ity case	Source	Reference no.	Document title/ scope	Key topics/results
		CEPT	ECC Report 287	Guidance on defragmentation of the frequency band 3 400-3 800 MHz (2018).	The report provides guidelines to help admin-istrations in defragmenting the 3.4-3.8 GHz band, in which there are existing licences in many CEPT countries. It also refers to possible ways to refarm existing FS and FSS services.
		CEPT	ECC Report 296	National syn-chronization regulatory frame-work options in 3 400-3 800 MHz: a toolbox for compatibil-ity of MFCNs in synchronized, unsynchronized and semi-syn-chronized operation in 3 400-3 800 MHz (2019).	This report provides guid-ance to Administrations on the regulatory options for synchronization in the band, in particular, to enable unsynchronized and semi-synchronized operation of IMT systems in multi-operator environ-ment. It extends upon previous ECC Reports 216 and 281 to account for the following new aspects: • 5G-NR new frame structures bring new compatibility and per-formance aspects to be considered in the case of synchronized oper-ation between 5G-NR and LTE-TDD, thus prompting consider-ation of unsynchronized operation; • The adoption of active antenna system (AAS) technology to IMT base stations brings new challenges for unsyn-chronized operation (in terms of cost-effec-tiveness and spectrum efficiency of the LRTC's implementation), which makes synchronized operation worthy of consideration; • Semi-synchronized operation as a new mode of operation.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
6	IMT versus IMT and other services	CEPT	ECC Report 254	Operational guidelines for spectrum sharing to support the implementation of the current ECC framework in the 3 600-3 800 MHz range (2016).	It provides operational guidelines for spectrum-sharing to support the implementation of the ECC framework in the 3 600-3 800 MHz range.
		CEPT	ECC Report 203	Least restrictive technical conditions suitable for MFCNs, including IMT, in the frequency bands 3 400-3 600 MHz and 3 600-3 800 MHz (2014).	CEPT has carried out studies to determine appropriate least restrictive technical conditions (LRTC) for IMT. The BEM was derived through minimum coupling loss (MCL) analysis and simulations.
		EU	Decision 2008/411/EC and 2014/276/EU	Commission Implementing Decision of 2 May 2014 on amending Decision 2008/411/EC on the harmonization of the 3 400-3 800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community.	Without prejudice to the protection and continued operation of other existing use in this band, Member States shall designate and subsequently make available, on a non-exclusive basis, the 3 400-3 800 MHz frequency band for terrestrial electronic communications networks. It also sets the parameters for the BEM to facilitate multi-operator environment. The same parameters can be taken as reference for cross-border coordination.

Table 42: Overview of key IMT sharing and compatibility studies relevant for the 3.5 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
		EU	EU Decision 2019/235	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.	Simplifies the regulatory wording of Article 2 previous Decision 2014/276 in its leaving only the essential elements of the designation of the band 3 400-3 800 MHz for terrestrial electronic communication networks.
		CEPT	ECC/REC/ (15)01	Cross-border coordination for MFCNs in the frequency bands: 694-790 MHz, 1 427-1 518 MHz and 3 400-3 800 MHz (2020).	This Recommendation contains provisions for cross-border coordination between MFCNs in order to avoid harmful interference and provide guidance in cases of synchronized and unsynchronized MFCN TDD systems operation in the 3 400-3 800 MHz frequency band. This Recommendation covers wideband (WB) vs wideband systems cross-border coordination scenarios but does not address cross-border coordination of MFCN vs other systems in these bands. In this Recommendation, wideband systems include LTE and new radio (NR).

The results of the above sharing and compatibility analysis as well as the regulations applied in other Regions are summarized in Section 6.3.2 with an indication of the resulting desirable technical conditions for operation of IMT.

6.3.2 Technical conditions for IMT sharing and compatibility

Based on the studies available, reference is made to the ECC/DEC(11)06, which recommends a TDD arrangement based on a block size of 5 MHz starting at the lower edge of the band at 3 400 MHz. This arrangement also provides flexibility for accommodating other services/users, which may be necessary in the frequency-coordination process, noting the deployment of radiolocation and fixed-satellite services in this band. If blocks need to be offset to accommodate other users, the raster should be 100 kHz while maintaining the IMT block of 5 MHz. Narrower blocks can be defined adjacent to other users, to allow full use of spectrum. It should be noted that in one extreme case TDD also covers downlink-only operation. Multiple adjacent blocks of 5 MHz can be combined to obtain wider channels.

The Annex 2 of the ECC Decision (11)06 sets the least restrictive technical conditions suitable for AAS (active antenna systems) and non-AAS (non-active antenna systems) mobile/fixed communications networks (MFCNs) in this frequency range (3 400-3 800 MHz).

The least restrictive technical conditions are in the form of block-edge masks (BEMs) applicable to AAS and non-AAS MFCN base stations. The BEMs have been derived to allow compatibility between MFCN applications in the 3 400-3 800 MHz band. In addition, these conditions include "additional baseline" power limits for protection of military radiolocation systems below 3 400 MHz. Additional baseline power limits are also identified for the protection of FSS/FS systems above 3 800 MHz.

Regarding the harmonized introduction of IMT with a view to facilitating cross-border coordination, administrations may wish to consider the BEM requirements to ensure compatibility between neighbouring networks in the absence of bilateral or multilateral agreements between operators of such neighbouring networks.

A BEM is an emission mask that is defined as a function of frequency, relative to the edge of a block of spectrum that is licensed to an operator. It consists of in-block and out-of-block components which specify the permitted emission levels over frequencies inside and outside the licensed block of spectrum, respectively.

Accordingly, the BEM levels are built up in such a way that the limit at any frequency is given by the highest (least stringent) value of the transition requirements and the in-block requirements (where appropriate).

The BEM is applied as an essential component of the necessary conditions for compatibility in the absence of bilateral or multilateral agreements between mobile networks in adjacent frequency blocks, without precluding less stringent technical parameters if agreed among the operators of such networks.

An administration should ensure that operators to which it has granted authorizations in this band are free to enter into bilateral or multilateral agreements to develop less stringent technical parameters and, if agreed among all affected parties, these less stringent technical parameters may be used, if the level of protection for other networks (not party to the agreement) is not affected.

Table 43 provides a summary of the main technical conditions for operation of IMT resulting from sharing and compatibility with the fixed service, radiolocation service and fixed-satellite service.

Table 43: Technical conditions for IMT sharing and compatibility in the 3.5 GHz band

No	Interference type/case	Technical conditions	Reference documents	
1	IMT versus fixed service	The co-frequency channel results show that the required separation distance can range from less than one kilometre to nearly 100 km, depending on the interference scenario and deployment environment. These results are based on worst-case assumptions including the pointing direction of the IMT station and the application of the propagation model. Furthermore, mobile operators can determine which locations are most suitable for the deployment of IMT base stations in terms of meeting any required separation distances. The adjacent channel results show that in the worst-case scenarios (i.e. FS receiving station pointing directly toward a macro deployment of IMT base stations), the separation distance needed to protect the FS station exceeds 30 km. The required geographic and frequency separations are significantly reduced for the scenario of deploying small-cell indoor base stations. For this case, the separation distance between small-cell base stations and FS receiving stations is of the order of either one kilometre coupled with a frequency separation of about one channel bandwidth or a few kilometres with no frequency separation, depending on the relative pointing directions of the IMT and FS stations. These results also show that the interference from the IMT UE is relatively low. This interference can be mitigated by either a frequency separation of about one channel or a geographic separation of a few kilometres.	ITU-R Report F.2328-0 (2014)	None

Table 43: Technical conditions for IMT sharing and compatibility in the 3.5 GHz band (continued)

No	Interference type/case	Technical conditions	Reference documents	
2	IMT versus FSS	Protection of the FSS receiving earth stations requires some separation distance relative to the stations of the mobile terrestrial network. The extent of this separation distance depends on the parameters of the networks and the deployment of the two services. In band co-channel: o The minimum required separation distances from IMT-Advanced base stations, when using the long-term interference criterion derived in the studies to date, are at least in the tens of kilometres. o The minimum separation distances associated with short-term interference criterion, generally, but not in all cases, exceed 100 km in the considered cases with similar assumptions as used for the long-term scenario. • Adjacent band: o Concerning interference from unwanted emissions arising from out-of-band and spurious domains of IMT-Advanced base station transmitters and falling within the band used by the FSS receiver, the minimum required separation distances, when using the long-term interference criterion derived in the studies to date, are up to tens of kilometres (with no guardband) and decreasing as the guardband increases.	ITU-R Report M.2109-0 (2017), CEPT Report 254, CEPT/ECC Report 287	None
		Cross-border coordination between IMT base or terminal stations and earth stations of the mobile service in this band requires that the pfd produced at 3 m above ground does not exceed −154.5 dB(W/(m2 * 4 kHz)) for more than 20 per cent of time at the border of the territory of any other administration.	Radio Regulations RR Nos. 5.430A, 5.432A, 5.432B and 5.433A (WRC-07) and methodology proposed in Rec S.1856	None

Table 43: Technical conditions for IMT sharing and compatibility in the 3.5 GHz band (continued)

No	Interference type/case	Technical conditions	Reference documents	
3	IMT versus radiolocation	Sharing studies between airborne radar and IMT-Advanced have concluded that: • The required separation distance is approximately 360 km in co-channel cases; • Using non-overlapping adjacent channel analysis, the required separation distance is approximately 0 km, depending on the radar type and antenna type; No interference problem when radiolocation operates in 3.3-3.4 GHz and IMT operates in 3.4-3.8 GHz. Sharing studies between land-based/shipborne radar and IMT-Advanced have concluded that: • The required separation distance is approximately 70 km in co-channel cases; • Using non-overlapping adjacent-channel analysis, the required separation distance is less than 1 km, depending on the types of radar and antenna; The frequency-separation analyses concluded that: • The frequency separations vary between 13 and 136 MHz when interference is from IMT-Advanced to radar; • Based on a worst-case analysis, the frequency separation is greater than 1GHz when interference is from radar to IMT-Advanced. These results show that co-frequency-sharing between radiolocation services and IMT devices could be difficult in the same geographical area within the application of mitigation techniques. Potential mitigation techniques shown in Annex 3 of ITU-R Report M.211 may reduce the interference and may facilitate sharing between IMT-Advanced systems and radiolocation systems.	ITU-R M.2111-0 (2007)	None

From Table 43, and upon reviewing the conclusions of the relevant studies for sharing IMT and FSS, it can be noted that:

1) An administration intending to bring IMT systems into use, and whose territory falls within the coordination contours of the earth stations under the coordination or notification procedure or notified under Articles 9 and 11 of the ITU Radio Regulations, shall coordinate with other administrations having these earth stations.

2) Although the studies have differing assumptions and methodologies, they all show that sharing between IMT-Advanced and an FSS earth station is not feasible within the area delineated by the minimum required separation distances for each azimuth to protect that specific FSS earth station, as explained above. Therefore, sharing is feasible only when the receiving earth station is specifically under the condition that the required permissible interference level (which can be translated into appropriate transmission parameters for the IMT-Advanced stations such as maximum power or minimum separation distance between the stations concerned, taking into account propagation environment) within individual administrations is observed, and any coordination agreements that may have been reached between the concerned administrations are also observed.
3) If FSS is deployed in a ubiquitous manner and/or with no individual licensing of earth stations, sharing is not feasible in the same geographical area since no minimum separation distance can be guaranteed.
4) Studies have also shown that the use of local terrain information, including clutter losses, will reduce the separation distance. The degree of this reduction will depend on the specific circumstances. However, the reliability of local terrain information has not been proven for all countries.
5) Site-shielding for FSS earth stations, where possible, would mitigate interference from IMT-Advanced systems. Other mitigation techniques for IMT-Advanced systems, such as narrow-beam transmission based on sectorized- or adaptive-beamforming antenna, sector-disabling and antenna down-tilting will reduce the required minimum separation distance where they are effective. Some of these mitigation techniques could increase the deployment density of IMT-Advanced base stations in a given area. The impact of this increase in the number of IMT-Advanced cells as well as the reduction of the transmission power per IMT-Advanced base station should be taken into consideration when computing the aggregate interference.
6) With respect to interference from FSS into IMT-Advanced, studies have provided a range of margins relative to the required interference-to-noise ratio (I/N) criterion (from 9 to –11 dB) depending on the assumptions (particularly the type of IMT-Advanced base station considered and the FSS space station e.i.r.p. density). As a result, the IMT-Advanced base and mobile stations may experience interference from emissions of authorized satellite networks.

Similarly, for the case of sharing between IMT and radiolocation, there are several mitigation techniques, as reported in ITU-R Report M.211, which could be used to facilitate sharing:

1) IMT station antenna vertical down-tilt;
2) lower IMT-Advanced antenna height;
3) IMT-Advanced antenna location, optimization of antenna directivity loss toward radar site;
4) IMT-Advanced antenna dynamic null steering;
5) IMT-Advanced dynamic frequency selection (DFS);
6) transmit power control;
7) forward error-correction and interleaving;
8) radar sector-blanking;
9) terrain-following;
10) radar signal-processing.

Also, ITU-R Report M.2481 provides more detailed recommendations on mitigation techniques for sharing IMT and radiolocation, and measures to remove the harmful interference. Among them:

1) Technical measures. Some technical measures, perhaps in combination, that could be considered to ensure compatibility between the two systems in coastal and in land-border areas, are for example:

a. Power reduction for IMT base stations.
b. Adjustment of radiating patterns of base stations' transmitting antennas to reduce the e.i.r.p. in the direction of all possible radar sites.
c. Possible frequency separation between IMT and radar systems.
d. Defining specific masks of out-of-band and spurious emissions of base stations, which could be achieved by using specific RF filters in BS transmitters (additional filters can be external for non-AAS and internal for AAS). In order to reach the required unwanted emission limits below 3 300 MHz, a frequency separation may be needed in order to implement the necessary filter at the IMT BS transmitter side.
e. Defining specific characteristics of IMT deployment in this band (i.e. BS density, cell radius).
f. Performing specific compatibility study for each IMT deployment project, considering its propagation characteristics (i.e. clutter losses, antenna heights, terrain relief and masking from buildings for specifying the most appropriate network topology of base stations).

2) Operational measures. Some operational measures for IMT deployment in the 3 300-3 400 MHz band, perhaps in combination, that could be studied to ensure compatibility with radar systems, are for example:

a. Restriction zones: the administration may define a zone around a specific radar location where a restriction to IMT deployment applies. The restriction could take the form of an exclusion zone, where no IMT BS can be deployed. However, a more efficient alternative could be to impose operational restrictions in IMT deployment to ensure that the IMT does not cause harmful interference. Examples of such restrictions could be some of the technical measures mentioned above, such as power reduction or an adjustment in the radiation pattern of the BS. Other examples of restrictions are indoor deployment only or reduced antenna height.
b. Power flux-density limits: For instance, cross-border protection, a limitation expressed as a pfd limit at the boundary between countries would in practice result in an exclusion or restriction zone along the border.
c. If the radar operates near the IMT system for only a limited period of time, it may be possible to put in place a compatibility regime where IMT is required to turn off, or to operate with restrictions such as lower power, when radar is active nearby, for example by using a network of sensors to detect the presence of the radars and to relay this information to the IMT networks.

6.3.3 Regulatory conditions for IMT sharing and compatibility

Administrations may wish to complement the technical conditions under which they grant the IMT spectrum rights with specific IMT regulatory conditions (in addition to the general conditions for assigning spectrum rights). These specific IMT-related conditions often arise from the situation that the IMT services are introduced in bands with incumbent services that need to be protected.

Table 44 provides an overview of these IMT-specific regulatory conditions. Note that the RR 5.429B provision refers to Resolution 223 (WRC-15). This resolution does not stipulate specific regulatory elements that might constrain the deployment of IMT.

Table 44: Regulatory conditions specific to IMT licensees

No	Condition or requirement	Notes	References
1	Implement the Radio Regulation footnote 5.429B applicable to the band 3 300-3 400 MHz, in the national tables of frequency allocations. The IMT identification of band 2 500-2 560 MHz applies to 33 African countries.	The wording in footnotes RR5.429, 429A, 429B, 429C, 429D, 429E, 429F raises complexity and Res 245 plans to review the wording.	See ITU-R footnote RR.5.429B
2	Consider the association to RR 429B by the rest of African countries.		See ITU-R footnote RR.5.429B
3	Implement the Radio Regulation footnote RR5.430A applicable to the band 3 400-3 600 MHz in the national tables of frequency allocations. The IMT identification of the band 3 400-3 600 MHz applies to all African countries.		See ITU-R footnote RR.5.430A
4	Implement measures to observe the limits of pdf as set in RR 5.430A to protect earth stations in neighbouring countries.	RR 5.430A	
5	Adopt the harmonized channelling plan with the associated least restrictive operational conditions, following, for example, the CEPT ECC Decision (11)06 and report ECC Report 281.	ECC Decision (11)06	Such regulatory instruments include; harmonized channelling plan, BEM, least restrictive conditions and limits to allow sharing with radiolocation.

6.3.4 Cross-border coordination aspects for IMT

Consideration of the following elements is recommended in order to facilitate the cross-border coordination with respect to fixed service, fixed-satellite service and radiolocation. These limits and considerations constitute the summary of the relevant aspects to be considered towards facilitating the cross-border coordination when one country introduces IMT and other neighbouring countries have deployed or plan to deploy other services:

1) Observe the maximum limits for emissions from base or mobile terminals of IMT services in the frequency band 3 400-3 600 MHz as mandated by RR 5.430A in order to protect earth stations of the fixed-satellite service. It shall ensure that the pfd produced at 3 m above ground does not exceed −154.5 dB(W/(m2 * 4 kHz)) for more than 20 per cent of the time at the border of the territory of any other administration.
2) Administrations wishing to implement IMT in the frequency band 3 300-3 400 MHz shall obtain the agreement of neighbouring countries to protect operations within the radiolocation service.
3) Administrations implementing IMT in the frequency band 3 400-3 600 MHz shall seek agreement under No. 9.21 of the ITU RR. The provisions of Nos. 9.17 and 9.18 of the ITU RR shall also apply in the coordination phase. Before an administration brings into use a (base or mobile) station of the mobile service in this frequency band, it shall ensure that the pfd produced at 3 m above ground does not exceed −154.5 dB(W/(m2 * 4 kHz)) for more than

20 per cent of the time at the border of the territory of any other administration. This limit may be exceeded on the territory of any country whose administration has so agreed. In order to ensure that the pfd limit at the border of the territory of any other administration is met, the calculations and verification shall be made, taking into account all relevant information, with the mutual agreement of both administrations (the one responsible for the terrestrial station and that responsible for the earth station) and with the assistance of the Radiocommunication Bureau if so requested. In case of disagreement, calculation and verification of the pfd shall be made by the Bureau, considering the information referred to above. Stations of the mobile service in the frequency band 3 400-3 600 MHz shall not claim more protection from space stations than that provided in Table 21-4 of the Radio Regulations (Edition of 2004).

4) Organize bilateral, or when feasible multilateral, cross-border frequency-coordination processes. Therefore, it is recommended that administrations consider having regular coordination frameworks. In this context, it is further recommended that countries should relook at the HCM4A agreement, which has been developed under the HIPSSA[159] project, and possibly embrace it as a continent-wide, cross-border frequency-coordination framework. Where such coordination processes are lacking, administrations should strengthen them to encompass key technologies, bands and services to ensure interference-free operation of systems along the borders.
5) Consider the adoption of least restrictive technical conditions suitable for wireless broadband systems, as for example, recommended by the CEPT Report 281 based on the concept of the block edge mask (BEM). This concept is illustrated in Table 45.

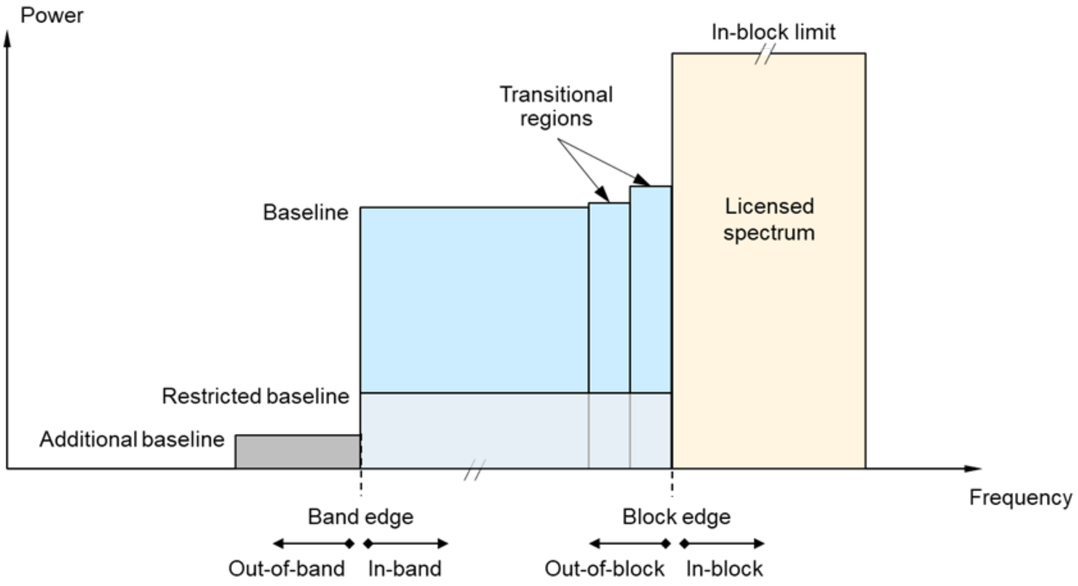
Table 45: CEPT/ECC concept of BEM

BEM elements	
In-block	Block for which the BEM is derived
Baseline	Spectrum used for TDD and FDD UL and DL, except from the operator block in question and corresponding transitional regions. For FDD DL blocks, the transitional region applies 0 to 10 MHz below and above the block assigned to the operator. For TDD blocks, the transitional region applies 0 to 10 MHz below and above the block assigned to the operator.
Transitional region	Transitional regions do not apply to TDD blocks allocated to other operators, unless networks are synchronized. The transitional regions do not apply below 3 400 MHz or above 3 800 MHz.
Guardbands	The following guardbands apply in case of an FDD allocation: 3 400-3 410, 3 490-3 510 (duplex gap) and 3 590-3 600 MHz In case of overlap between transitional regions and guardbands, transitional power limits are used.
Additional baseline	Below 3 400 MHz

The concept of BEM is further illustrated in Figure 11.

[159] The Support for the Harmonization of the ICT Policies in sub-Saharan Africa project promotes the use of harmonized ICT policies and regulatory frameworks and provides human and institutional capacity building in this sector. Launched in December 2008, the project is jointly funded by the European Commission and ITU.

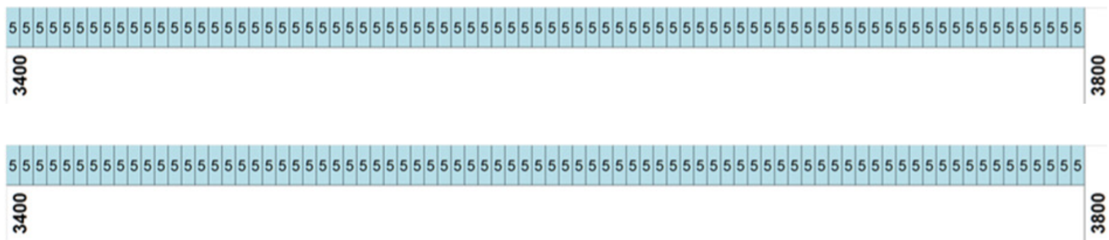
Figure 11: Concept of BEM elements



For the planning of the introduction of IMT multi-operator environment and facilitation of cross-border coordination, the CEPT Report 296 provides a full set of techniques allowing compatibility of IMT in synchronized, unsynchronized and semi-synchronized operations.

The CEPT/ ECC Report 281 proposes the following channelling for the band 3 400-3 600 MHz, which is depicted in Figure 12.

Figure 12: Preferred frequency arrangement for 3 400-3 600 MHz based on TDD



Source: CEPT/ ECC Report 281

CEPT Report 067 establishes the recommended conditions for deployment of IMT services. Among them:

1) There is no need to maintain FDD frequency arrangement. Moreover, the frequency separation at 3.6 GHz for the TDD frequency arrangement is no longer needed.
2) The proposed frequency arrangement will facilitate availability of larger contiguous frequency blocks to enable 5G, although this may require reorganization and defragmentation of the band.
3) In-block radiated power limits:
    a. ECC Decision (11)06 and EC Decision 2014/276/EU specify:
        i. a maximum BS in-block EIRP of 68 dBm/(5 MHz) per antenna (non-mandatory);
        ii. a maximum TS in-block TRP of 25 dBm.

b. CEPT confirms that BS in-block EIRP is not mandatory, therefore, there is no need to include a reference limit in the regulatory framework for either non-AAS or AAS systems. Administrations wishing to include a limit in their authorization or to use a limit for coordination purpose may define such limits on a national basis.

4) Out-of-block power limits – interference between operators in adjacent blocks.
5) Out-of-band power limits – interference to other services in adjacent bands.

It is particularly relevant to refer to the most recent recommendations for cross-border coordination, as per ECC/REC/(15)01, which sets a series of levels as follows:

The field-strength trigger values in case of synchronized and unsynchronized operations between MFCN TDD systems across the border should be:

1) In the synchronized case:

a. AAS and non-AAS base stations of synchronized TDD systems on both sides of the border in the frequency band 3 400-3 800 MHz with centre frequencies not aligned for all PCIs or with centre frequencies aligned for preferential PCIs may be used without coordination with a neighbouring country if the mean field strength of each cell produced by the base station does not exceed the values of:

i. 67 dBµV/m/5 MHz at a height of 3 m above ground at the border between countries, and;
ii. 49 dBµV/m/5 MHz at a height of 3 m above ground at a distance of 6 km inside the neighbouring country.

b. AAS and non-AAS base stations of synchronized TDD systems on both sides of the borderline in the frequency band 3 400-3 800 MHz with centre frequencies aligned and for non-preferential PCIs may be used without coordination with a neighbouring country if the mean field strength of each cell produced by the base station does not exceed the value of:

i. 49 dBµV/m/5 MHz at a height of 3 m above ground at the borderline between countries.

Table 46 gives an overview of the trigger values of the field strength.

Table 46: Trigger values at a height of 3 m above ground between synchronized MFCN TDD systems with AAS and non-AAS

Synchronized case		
Centre frequencies aligned		Centre frequencies not aligned
Preferential PCIs	Non-Preferential PCI	All PCIs
67 dBµV/m/5 MHz @ 0 km and 49 dBµV/m/5 MHz @ 6 km	49 dBµV/m/5 MHz @ 0 km	67 dBµV/m/5 MHz @ 0 km and 49 dBµV/m/5 MHz @ 0 km
@ stands for "at a distance inside the neighbouring country"		

2) In the unsynchronized case:

   a. AAS and non-AAS base stations of unsynchronized TDD systems on both sides of the borderline in the frequency band 3 400-3 800 MHz for all PCIs may be used without coordination with a neighbouring country if the mean field strength of each cell produced by the base station does not exceed a value of 0 dBμV/m/5 MHz at a height of 3 m above ground level at the border between countries.
   b. AAS and non-AAS base stations of unsynchronized TDD systems on both sides of the border in the frequency band 3 400-3 800 MHz with preferential frequency blocks and for preferential PCIs may be used without coordination with a neighbouring country if the mean field strength of each cell produced by the base station does not exceed the trigger values of:
      i. 45 dBμV/m/5 MHz at a height of 3 m above ground at the border between countries, and;
      ii. 27 dBμV/m/5 M Hz at a height of 3 m above ground at a distance of 6 km inside the neighbouring country.
   c. AAS and non-AAS base stations of unsynchronized TDD systems on both sides of the border in the frequency band 3 400-3 800 MHz with preferential frequency blocks and for non-preferential PCIs may be used without coordination with a neighbouring country if the mean field strength of each cell produced by the base station does not exceed the trigger values of 27 dBμV/m/5 MHz at a height of 3 m above ground at the border between countries.
   d. AAS and non-AAS base stations of unsynchronized TDD systems on both sides of the border in the frequency band 3 400-3 800 MHz with non-preferential frequency blocks and for all PCIs may be used without coordination with a neighbouring country if the mean field strength of each cell produced by the base station does not exceed the trigger values of 0 dBμV/m/5 MHz at a height of 3 m above ground level at the border between countries.

Table 47 gives an overview of the trigger values of the field strength.

Table 47: Trigger values at a height of 3 m above ground for preferential frequency blocks of unsynchronized MFCN TDD systems with AAS and non-AAS

Unsynchronized case		
Preferential frequency blocks		Non-preferential frequency blocks
Preferential PCIs	Non-preferential PCI	All PCIs
45 dBμV/m/5 MHz @ 0 km and 27 dBμV/m/5 MHz @ 0 km	27 dBμV/m/5 MHz @ 0 km	0 dBμV/m/5 MHz @ 0 km
@ stands for "at a distance inside the neighbouring country"		

6.4 Best practices and methods for refarming other services in the 3.5 GHz band

Refarming in the context of this report means the replanning of incumbent services is deemed incompatible with the introduction of IMT services. In other words, the spectrum needs to be freed up or cleared for IMT. From Tables 39 and 40 it can be concluded that several services or applications may have to be replanned or reallocated to adjacent or other bands.

It is noted that some FBWA services are deployed in some SADC countries. Also, earth stations of the FSS are deployed. The number of countries with such services in operation as well as the density of deployment is not known.

The financial funding of refarming efforts is addressed in Section 11. It is noted that Recommendation ITU-R SM.1603 also covers general approaches to refarming, guidelines for calculating refarming (or redeployment) costs, as well as examples of country experiences with refarming.

6.4.1 Refarming of fixed broadband wireless access service links

The identified incumbent service deployed in African SADC countries is fixed service for broadband wireless access applications.

Owing to the varying characteristics of different types of FS systems and their deployment, no single separation distance, guardband or signal-strength limit could be provided to guarantee coexistence with IMT systems. Coexistence can be achieved through national coordination on a case-by-case basis, although it introduces complexity at a national level. It is therefore recommended to assess to possibility to relocate the fixed service to another band in the areas intended for IMT, and to assess the impact to regulatory certainty this may cause.

Considering the similarity between BWA and IMT systems, CEPT/ECC Report 287 concluded that BWA can coexist under some conditions with IMT systems that are licensed under the new BEM licensing regime (ECC Decision (11)06 revised 2018) or the previous one (ECC Decision (11)06 revised 2014). It should be noted that various CEPT studies refer to the compatibility between BWA and IMT (see CEPT Report 281, for example).

In particular, CEPT Report 281 notes that BWA systems compliant with the previous framework may suffer from interference from IMT systems operating under the regulatory framework (ECC Decision (11)06, as updated in 2014). Either a frequency separation or the application of BEM elements (2014) has been recommended.

CEPT studies (CEPT Report 281) highlighted the compatibility issues between LTE and 5G NR systems in adjacent frequencies and the conditions to be fulfilled to ensure the compatibility between either synchronized operation for AAS or non-AAS systems or unsynchronized operation for AAS or non-AAS systems.

As a consequence, administrations should assess the need to reorganize the BWA usage in order to make sufficient contiguous spectrum available for high-throughput IMT applications. Synchronization between existing BWA networks and IMT are important for IMT introduction. The lack of synchronization of these BWA/IMT MFCN networks could imply the need of guardband between both networks.

Moreover, when necessary, administrations may also assess the opportunities in some geographical areas to share the spectrum between IMT LTE and IMT 5G systems on co-channel basis. See ECC Recommendation (15)01 for possible reuse of relevant cross-border coordination limits within a co-channel national context.

6.4.2 Refarming of satellite service

The sharing and compatibility difficulties with earth stations of the fixed-satellite service would depend on the density of deployment of the FSS in both countries. As determined by the sharing studies, a separation distance must be observed. While this mechanism may be valid for a transition period until the IMT service is deployed (IMT being introduced in one country, but not yet available in a neighbouring country where earth stations are deployed) in the region where the earth station is deployed, the longer term would require the refarming of the earth stations.

It is worth mentioning CEPT Report 287, which concluded that co-channel sharing is not possible between FSS and IMT in the same geographic area, and that sharing between FSS and IMT requires a sufficient separation distance between the services. The required distance varies considerably depending on system specifications (see ECC Report 203) and local geography.

In areas intended for IMT, such as urban, suburban areas, or along transport routes such as roads and railways, it is recommended that administrations consider relocation to a different geographical location or to a different band above 3 800 MHz, taking into account considerations such as the impact on the FSS business (the cost of physical relocation, the cost of changing equipment), its level of use of the spectrum, the high-level target of introduction of IMT and the opportunity cost of precluding IMT use in that area.

In areas not intended for IMT, administrations could consider maintaining existing FSS installations. These installations could be protected with spectrum-sharing mechanisms as described in ECC Report 254:

1) Approach A: Specifying the maximum permitted interference powers or electric-field strengths at the FS/FSS receivers and giving IMT operators full flexibility to comply with the specified limits. These may be expressed in terms of protection zones.
2) Approach B: Specifying explicit restrictions on the frequency, geographic location, or e.i.r.p. levels (or a combination thereof) for the IMT deployments. These restrictions can be expressed in terms of exclusion zones and/or restriction zones.

In areas where IMT is intended, administrations are recommended not to issue authorizations to new sites in this band for FSS and to consider the higher bands above 3 800 MHz for future FSS usage.

6.4.3 Specific refarming/sharing cases with satellite services

In this section, country cases are provided for refarming/sharing of satellite services.[160]

[160] Elements extracted from the GSA report on 3 300-4 200 MHz: A key frequency band for 5G. How administrations can exploit its potential.

Case study of France

In November 2006, the French regulator (ARCEP) provided the following feedback[161] from its public consultation on the prospects for the development of fixed-satellite service applications, accounting for the 11 comments received.

Respondents highlighted that compatibility between terrestrial access systems and FSS earth stations in the band 3 600-4 200 MHz (note: FSS earth stations at known locations) is possible on a geographic basis. Based on the feedback received, ARCEP announced the following conclusions aiming at the most efficient spectrum use:

1) Satellite players will be invited to consider the band 3 800-4 200 MHz for the development of new terrestrial base stations in urban areas and their future expansion.
2) The band 3 600-3 800 MHz will therefore be frozen for the fixed-satellite service and ARCEP will study the possibilities to migrate the FSS earth stations from the 3 600-3 800 MHz band to the 3 800-4 200 MHz band, as well as the implementation of mixed solutions (Ku-band and C-band) for the realization of satellite links.

In the context of the preparation of the licensing framework of the 3 490-3 800 MHz band in the French metropolitan areas, finalized in November 2019, the following decisions have been taken:

1) Clearing of the FSS assignments below 3 800 MHz.
2) Freezing of the FSS assignments between 3 800 and 3 840 MHz: these assignments will continue to be protected, but no new assignment will be allowed. The locations of five FSS earth stations fall into this category.
3) Generic protection of existing earth-station locations operating above 3 840 MHz, in order to allow future assignments at these locations. This situation refers to 17 earth-station locations, including the five operating at 3 800-3 840 MHz. At the request of ARCEP, ANFR conducted a study in 2019 on coexistence between 5G and FSS in the C-band10, based on these principles. The results of the study show that, for some of the ES locations, this would result in the need for coordination of 5G deployments in urban areas, with an impact on the deployment of 5G in these areas.

Case study of the Netherlands

As the use of the 3 400-3 800 MHz is currently precluded in the geographic region above the Amsterdam-Zwolle line due to the lawful interception facility at the Burum site (of crucial importance for national security), the Dutch Telecom Agency carried out an extensive impact assessment comparing the value from 5G use of the band against that associated with national security.

TNO further concludes that it is possible, with a combination of mitigation measures by mobile operators and the satellite earth station in Burum, to limit the production loss to one per cent for a period of five to seven years after the introduction of 5G in the 3 500 MHz band.

Since December 2019, the Ministries of the Interior and Kingdom Relations and Defense have been exploring the possibility of relocating (parts of) the satellite earth station in Burum to another European country. The following aspects are under discussion: possible alternative locations, legal and technical feasibility, duration and costs. Displacement within the Netherlands is, in principle, not an option because there are no disturbance-free locations. The change in

[161] http://www.arcep.fr.. L'Autorité publie la synthèse de la consultation publique sur le service fixe par satellite et se prononce sur l'organisation de la bande 3,4-4,2 GHz.

the National Frequency Plan that would allow introducing mobile services in the band from 1 September 2022 was suspended on 30 June 2021, following an appeal by Inmarsat which operates earth stations in Burum[162]. An advisory committee was set up by the Dutch government to advise the cabinet on the matter by 1 May 2022. On the basis of the advice, the Ministry of Economic Affairs and Climate Policy will take a new decision to amend the national frequency plan[163].

Case study of the United Kingdom

Ofcom, the UK regulator, started an assessment[164] in October 2016 of the possible use of 3 600-3 800 MHz for mobile services, in particular for 5G. Part of the band was already available for FWA, but 116 MHz within the band were allocated to fixed services (FS) and fixed-satellite services (FSS).

In July 2017, Ofcom published its decision to make the whole of 3 600-3 800 MHz available for mobile use as soon as possible.[165] Later that year,[166] they confirmed that they would revoke authorizations for fixed links and no longer take registered satellite earth stations into account for frequency-management purposes. In practice, receiving earth stations would be able to continue operation but they would not be protected from interference from mobile users. Ofcom awarded the remaining 120 MHz in the band for mobile operators in April 2021[167].

In parallel with this, Ofcom also started in 2016 a consultative process[168] on the possible use of 3 800-4 200 MHz for mobile, under the premise of sharing with incumbents. There are three main types of uses currently sharing this band in the United Kingdom: FS, FSS and FWA. The latter use is through a nationwide block licence of 84 MHz. All deployments in the band are technically coordinated by Ofcom in order not to cause undue interference between users. Ofcom's analysis in its consultation document indicates that the band is suitable for more intensive sharing while considering incumbent services.

Ofcom further developed its proposals for this band in December 2018.[169] It concluded that it will be possible to open the band for low- and medium-power localized use. Ofcom would grant individual licences valid only at the specific locations requested by the applicants, following an assessment of the interference to existing users – including incumbents (FS and FSS) and other mobile-use assignments. Ofcom clearly stated its intention to start assigning spectrum in this frequency range while preserving the ability of incumbents to continue using this band even if mobile use is allowed.

Case study of the United States of America

Another reference on a mechanism followed at a global level is the refarming in the United States. The 3 700-4 200 MHz band is allocated to the fixed service and fixed-satellite service. Four satellite operators (Intelsat, SES, Eutelsat and Telesat) hold licences that allow them to

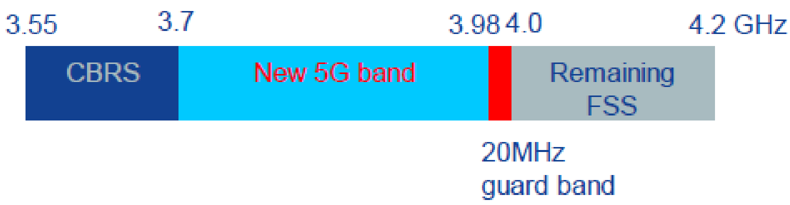
162 https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:RBROT:2021:6106.
163 https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/nieuws/2021/12/17/adviescommissie-verdeling-35-gigahertz-band-van-start.
164 https://www.ofcom.org.uk. Assessment of possible use of 3 600-3 800 MHz for mobile services.
165 https://www.ofcom.org.uk. Decision to make the whole of 3 600-3 800 MHz available for mobile use.
166 https://www.ofcom.org.uk/__data/assets/pdf_file/0019/107371/Consumer-access-3.6-3.8-GHz.pdf
167 https://www.ofcom.org.uk/about-ofcom/latest/features-and-news/spectrum-auction-principal-stage-results.
168 https://www.ofcom.org.uk/__data/assets/pdf_file/0031/79564/3.8-GHz-to-4.2-GHz-band-Opportunities-for-Innovation.pdf
169 https://www.ofcom.org.uk/__data/assets/pdf_file/0022/130747/Enabling-opportunities-for-innovation.pdf

exploit the band simultaneously in the United States. In August 2017, the FCC issued a Notice of Inquiry,[170] seeking comments on the feasibility of repurposing the 3 700-4 200 MHz block for 5G services in the United States. Then in July 2018, the FCC issued a Notice of Proposed Rulemaking to advance this goal.

The FCC received different proposals for sharing between 5G and FSS. The following seemed to be agreed by several parties:

1) FSS needs to be cleared from the portion of the band that will be made available for 5G in order to maximize use of the spectrum by 5G, avoiding large exclusion zones, restrictions on power transmission, antenna pointing, and so on; and a 20 MHz guardband is enough between the 5G and the remaining FSS spectrum blocks in conjunction with an out-of-band emission limit and/or other techniques to mitigate interference to FSS earth stations. FCC confirmed the 20 MHz guardband stating that it will conduct a public auction of the spectrum, repacking incumbent FSS to the upper 200 MHz portion of the band and then auction off 280 MHz for 5G, with a 20 MHz guardband to protect existing users as shown in the adjacent figure.[171]

Figure 13: Frequency arrangements of incumbent and 5G spectrum in the United States of America[172]



2) This 20 MHz guardband was provided in several filings to FCC based on compatibility simulations.[173] The 20 MHz was also affirmed by the C-Band Alliance, which consists of the major satellite operators who represent C-band services currently provided in continental United States.[174]
3) High EIRP for base stations of 65dBm/1MHz for rural areas (defined as any county with population density of 100 or fewer persons per square mile, based upon the most recent population statistics available from the Bureau of the Census) and 62dBm/1MHz for other areas.
4) Power of mobiles and portables: 1 Watt (30 dBm).

Different out-of-band emission (OOBE) levels needed to protect FSS have been proposed along with network-management techniques such as power control, putting users on a different band in proximity of the FSS earth stations, beam-nulling towards the FSS earth stations, etc. FCC is expected to clarify what OOBE levels and interference mitigation techniques they would adopt but, as explained above, clearing the band of FSS along with a 20 MHz guardband seem to be agreed upon.

The USA FCC issued an Order and Public Notices on 3 March 2020 on how the C-band auction will be managed and the implications for the affected satellite operators. There is compensation

170 https://ecfsapi.fcc.gov/file/0803116124915/FCC-17-104A1.pdf
171 https://docs.fcc.gov/public/attachments/DOC-360855A8.pdf
172 CBRS: Citizen Broadband Radio Services
173 https://ecfsapi.fcc.gov/file/102976959340/Nokia%20Comments%20on%203.7%2010-29-2018%20FINAL.pdf
174 https://c-bandalliance.com/

being paid to satellite operators that meet certain qualifications. A C-Band Alliance was formed including Intelsat, SES and Telesat. Eutelsat also joined later. Other operators could also qualify either by being part of C Band Alliance or independently. The target is the clearance of 300 MHz bandwidth.

The funds raised by an auction will be partly used to pay for upgrades and filters to be fitted to thousands of C-band dishes across the USA and also to order eight new satellites to replace the freed-up bandwidth. These measures are estimated to cost around USD 2.5-USD 3.5 billion.

The proposed 'incentive' payments are; Intelsat will qualify for a total of USD 4.865 billion while SES will receive USD 3.968 billion. Eutelsat gets USD 506.9 million, while Telesat's payment is USD 344.4 million. StarOne, the only small satellite operator which qualifies, gets USD 15.1 million. Additional compensation will be paid for the complex task of relocating client dishes, filters, and new satellites.

The FCC will appoint an independent body to supervise and act as a clearing house and to prevent waste, fraud and abuse as well as to distribute payments and mediate and rule on disputes. The satellite industry plus various other interested stakeholders will each appoint one individual to the nine-member search committee for the clearing house.

6.5 Guidelines and recommended actions for the 3.5 GHz band

Table 48 provides a summary of the main guidelines associated to measures to facilitate IMT introduction.

Table 48: Spectrum-management guidelines for IMT introduction in the 3.5 GHz band

No	Guideline	Applies to	Ref. Section(s)
6.1	Anticipated frequency-planning coordination is recommended at the earliest stage of the frequency-assignment process, as there would be technical elements strongly associated with the technologies being deployed for IMT systems in each country. This work could also include preparatory coordination work among operators concerned. However, in the ideal case, the frequency assignments should be coordinated with neighbouring countries at earlier stages, even when the specific frequency assignments to each operator have not been concluded. The cross-border coordination can be undertaken on bilateral or multilateral level between administrations. Obviously, for IMT assignments far from border areas, coordination may not be required.	IMT services	General
6.2	The bilateral or multilateral agreement should define the coordination methods which encompass all wireless broadband mobile service radio interfaces present on each side of the border. Consider adoption of the field strength trigger values set in the ECC/REC/(15)01, as the reference to facilitate coordination in multi-operator environments.	IMT services	Section 6.3.4

Table 48: Spectrum-management guidelines for IMT introduction in the 3.5 GHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
6.3	The cross-border coordination between IMT FDD or IMT TDD systems can take as a reference the limits defined in CEPT ECC Decision (11)06 by harmonizing the channelling plan, the masks, the least restrictive technical conditions as well as the conditions to protect other services such as radio-location.	IMT services and radiolocation	Sections 6.3.3 and 6.3.4
6.4	The frequency-coordination processes would identify whether earth stations of the fixed-satellite service are deployed and at what density, thus facilitating the adoption of a mechanism for refarming and/or agreeing on temporary roadmaps whenever compatibility becomes possible regarding the specific deployment of earth stations.	Fixed-satellite service	Sections 6.3.3, 6.3.4 and 6.4.2
6.5	Analyse the density of deployment of incumbent services, likely satellite-based, in the country in order to trade off options based on sharing or clearing spectrum.	Fixed-satellite service, FBWA	Sections 6.3.4 and 6.4.2
6.6	It is recommended that, when necessary, the current and future assignments be defragmented. Several assignments to IMT operators have been made for frequency blocks that are not contiguous. Defragmentation of current spectrum assignments to mobile services is rather appropriate. Existing mobile and BWA/FWA licences are mostly for a bandwidth of 30 MHz or lower and for paired blocks. These licences are not appropriate for 5G. In addition, some existing licensees may want to deploy 5G in the band, whilst others may prefer to continue using their existing technology (WiMAX, LTE) or to deploy something else (most likely LTE).	IMT services	Section 6.3.4
6.7	Consider industry recommendations about synchronized operation between countries, which should be encouraged as much as possible as international synchronized operation is also very important for simplifying cross-border coordination, especially between smaller countries and for countries with cities at borders.	IMT services	Sections 6.3.2 and 6.3.4

7 IMT sharing and compatibility with other services in the 26 GHz band

The band 24.25-27.5 GHz was identified by WRC-19 for IMT. The band provides over 3 GHz of contiguous spectrum. This band has a more favourable propagation than the higher frequency bands that have also been identified for IMT.

The band has been identified as part of the set of frequency bands above 24 GHz; 24.25-27.5 GHz, 37.0-43.5 and 66.0-71.0 GHz (a total bandwidth of 14.75 GHz). In addition, other IMT identifications at national level were adopted by WRC-19, mostly for African countries, in the bands 45.5-47.0 GHz and 47.2-48.2 GHz (2.5 GHz of aggregated bandwidth).

WRC-19 established special technical conditions to protect Earth exploration satellite service (EESS) in the adjacent band 23.6-24.0 GHz as stipulated in Resolution 750 (WRC-19).

7.1 IMT frequency arrangements in the 26 GHz band

Table 49 provides the proposed frequency arrangements in which the use of TDD is foreseen, consistent with ETSI TS 138 101-2 V15.2.0 (2018-07).

Table 49: IMT frequency arrangements in the 26 GHz band

Frequency arrangement	Unpaired arrangements (TDD) (MHz)
26 500 – 29 500 MHz	200
24 250 – 27 500 MHz	200

The recommended CEPT frequency arrangement is provided in ECC Decision (18)06, under the following scheme:

1) The frequency arrangement is a TDD arrangement with a block size of 200 MHz.
2) This block size could be adjusted to narrower blocks (multiples of 50 MHz) adjacent to other users, to allow full use of spectrum, if required.
3) If blocks need to be offset to accommodate other uses, this shift should be done in 10 MHz steps.

ITU-R is also conducting further studies on frequency arrangements in the 26 GHz band.

7.2 Other services allocated in the 26 GHz band and adjacent bands

Table 50 provides a comprehensive overview of the different services allocated in the 26 GHz band. Note should be taken that the frequency range 24.25-27.5 GHz is shared with several other services in different sub-bands within this band. Radio Regulations provisions less relevant for IMT are indicated between round brackets while IMT identifications provisions are highlighted in blue.

Table 50: ITFA corresponding with the identified IMT frequency arrangements for the 26 GHz band (Region 1)

24.25-24.45 GHz		
Services:	Footnote number:	Footnote:
Fixed		
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT
24.45-24.65 GHz		
Services:	Footnote number:	Footnote:
Fixed		
Inter-satellite		
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT
24.65-24.75 GHz		
Services:	Footnotes number:	
Fixed		
Fixed-SATELLITE (Earth to space)	5.532B	Limit of minimum antenna diameter of 4.5 m for FSS Earth-to-space) in the band 24.65-25.25 GHz in Region 1
Inter-satellite		
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT
24.75-25.25 GHz		
Services:	Footnote number:	Footnote:
Fixed		
Fixed-satellite	5.532B	Limit of minimum antenna diameter of 4.5 m for FSS Earth-to-space) in the band 24.65-25.25 GHz in Region 1
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT

Table 50: ITFA corresponding with the identified IMT frequency arrangements for the 26 GHz band (Region 1) (continued)

25.25-25.5 GHz		
Services:	Footnotes number:	
Fixed	(5.534A)	HAPS in Region 2 (HAPS to ground)
Inter-satellite	(5.536)	Limited for space research and Earth exploration-satellite
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT
25.5-27 GHz		
Services:	Footnotes number:	
Earth exploration-satellite (space-to-Earth)	5.536A 5.536B	Should not claim protection from mobile Should not claim protection from mobile
Fixed	5.534A	HAPS in Region 2 (ground to HAPS)
Inter-satellite	(5.536)	Limited for space research and Earth exploration-satellite
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT
Space research (space-to-Earth)	5.536C	In Algeria, Botswana, Cameroon, Djibouti, Egypt, Kenya, Morocco, Nigeria, Somalia, Sudan, South Sudan, Tanzania, Tunisia, Zambia and Zimbabwe, earth stations operating in the space research service in the band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services.
27.0-27.5 GHz		
Services:	Footnotes number:	
Fixed	5.534A	HAPS in Region 2 (HAPS to ground)
Inter-satellite	(5.536)	Limited for space research and Earth exploration-satellite
Mobile, except aeronautical mobile	5.338A	Resolution 750 (Rev.WRC-19) applies
	5.532AB	Identification for IMT

It is important to note the required operating conditions for IMT in the band 24.25-27.5 GHz to coexist with Earth exploration-satellite services in the adjacent band 23.6-24.0 GHz. Resolution 750 applies as per RR No.5.338A, which indicates that the unwanted emission power level is considered in terms of total radiated power (TRP). The TRP is to be understood here as the integral of the power transmitted from all antenna elements in different directions over the entire radiation sphere:

1) A limit of −39 dB(W/200 MHz) will apply to IMT base stations brought into use after 1 September 2027. This limit will not apply to IMT base stations brought into use prior to this date. For those IMT base stations, the limit of −33 dB(W/200 MHz) will apply.
2) A limit of −35 dB(W/200 MHz) will apply to IMT mobile stations brought into use after 1 September 2027. This limit will not apply to IMT mobile stations brought into use prior to this date. For those IMT mobile stations, the limit of −29 dB(W/200 MHz) will apply.

For the list of applications indicated, due account has been taken of available information about deployment of services in Africa, such as the SADC Table of Frequency Allocations. In addition, some SADC countries use the segment 27- 27.5GHz for government applications.

Table 51: Common applications and technology standards per ITU-RR service for Region 1

ITU-RR service	Application		Application examples	Technology standard	References
	ITU name	CEPT name			
Earth exploration-satellite service	EESS	EESS	Unknown services in Africa		
Fixed service	FS	FS	Channelling plan for 26 GHz (24.5-26.5 GHz)		ITU-R Rec. F.748 Annex 1.
	FS	FS	FBWA (24.5-26.5 GHz)		
Fixed-satellite service	FSS	FSS	No info about services deployed in Africa		

7.3 Sharing/compatibility between IMT and the other services in the 26 GHz band

The following sections review the sharing and compatibility studies available for the introduction of IMT services, allowing the identification of the technical conditions that will also serve as relevant tools for cross-border coordination and suggested approaches.

In spectrum management, terms-sharing and compatibility studies are about investigating mechanisms to facilitate the efficient use of spectrum by different services in-band or in adjacent bands, considering the expected deployment of each service as well as the applied technology standards.

In this section, the most relevant sharing and compatibility studies are identified with the aim of helping administrations to implement measures to avoid incompatible operation of different services and avoidance of harmful interference.

Administrations are advised to interpret these study results with caution as their local situation (including the actual frequency allocations/assignments as reflected in their NTFA, the applied technologies and interference scenario) may differ from the situations covered in the studies. Most of the sharing and compatibility studies are based on typical scenarios which represent reasonably the deployment scenario of each service under study, although the specificities of service deployments require adequate interpretation of the sharing environment.

7.3.1 Overview of IMT sharing and compatibility studies

Table 52 provides an overview of the main sharing and compatibility studies available to facilitate the introduction of IMT services. The studies are produced by ITU-R and also by CEPT and have been the basis for further decisions adopted by both CEPT and the European Union on the establishment of a set of technical conditions for operation of IMT services.

The studies conducted in this band were carried out by ITU-R in preparation for WRC-19. Summaries of those studies are included in the Conference Preparatory Meeting report. These studies served WRC-19 to resolve on the identification of this band as suitable for IMT.

In addition, CEPT and the European Union have developed regional decisions accommodating the results of WRC-19.

Table 52: Overview of key IMT sharing and compatibility studies relevant for the 26 GHz band

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
1	Frequency arrangements for fixed services in the band 24.25-27.5 GHz	ITU-R	ITU-R Rec. F.748 Annex 1.	Radio-frequency arrangements for systems of the fixed service operating in the 25, 26 and 28 GHz bands.	This Recommendation provides specifications for radio-frequency channel arrangements for systems in the fixed service with channel separations ranging from 2.5 to 112 MHz in the bands 24.5-26.5 GHz, 27.5-29.5 GHz, 24.25-25.25 GHz and 25.27-26.98 GHz. One annex includes block-based arrangements with bandwidths of 40 MHz and 60 MHz in the frequency range 24.25 to 26.98 GHz.
2	IMT versus other services	ITU-R	ITU-R CPM-2 report for WRC-19	CPM Report on technical, operational and regulatory/procedural matters to be considered by the World Radiocommunication Conference 2019. 2nd Session of the Conference Preparatory Meeting for WRC-19.	Sharing studies are reported under Agenda item 1.13 of WRC-19. The outcome of WRC-19 is reported in the Final Acts of WRC-19 and the modified and new provisions are to be included in the updated Radio Regulations.

Table 52: Overview of key IMT sharing and compatibility studies relevant for the 26 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
3	IMT versus EESS, SRS, FSS	ITU-R	Resolution 242 WRC-19	Terrestrial component of International Mobile Telecommunications in the frequency band 24.25-27.5 GHz.	It sets requirements for transmitting antennas of outdoor base stations which should normally point below the horizon. IMT base stations within the frequency band 24.45-27.5 GHz employing values of e.i.r.p. per beam exceeding 30 dB(W/200 MHz) should be selected so that the direction of maximum radiation of any antenna will be separated from the geostationary satellite orbit, within line-of-sight of the IMT base station, by ±7.5 degrees. Protection of EESS/ space research service (SRS) (space to Earth) earth stations in the frequency band 25.5-27 GHz and radio astronomy service (RAS) stations in the frequency band 23.6-24 GHz and compatibility between FSS earth stations in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz and IMT stations should be facilitated through bilateral agreements for cross-border coordination.

Table 52: Overview of key IMT sharing and compatibility studies relevant for the 26 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
4	IMT versus IMT and other services	CEPT/ ECC	ECC Decision (18)06	Harmonized technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz (2018)	The ECC recognizes that implementation of MFCN including IMT-2020/5G systems in CEPT countries providing high data rate applications in the band 24.25-27.5 GHz should be based on a harmonized frequency arrangement and least restrictive technical conditions for the introduction of 5G in the 26 GHz band.
5	IMT versus EESS and SRS (space-to-Earth)	CEPT/ ECC	ECC Recommendation (19)01	Technical toolkit to support the introduction of 5G while ensuring, in a proportionate way, the use of existing and planned EESS/ SRS receiving earth stations in the 26 GHz band and the possibility for future deployment of these earth stations.	Compatibility between IMT-2020 and space research service/Earth exploration-satellite service (SRS/ EESS) (space-to-Earth) earth stations operating in the frequency band 25.5-27 GHz can be achieved by using an appropriate coordination zone. Coordination zones within a radius of a few km for EESS earth stations and of a few tens of km for SRS earth stations (less numerous and more remote) are envisaged. The exact shape of the coordination zone will have to be calculated on a case-by-case basis.

Table 52: Overview of key IMT sharing and compatibility studies relevant for the 26 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
6	IMT versus FS	CEPT/ ECC	ECC Report 303	Guidance to administrations for compatibility between 5G and fixed links in the 26 GHz band ("Toolbox") (2019)	This ECC Report ("toolbox") is intended to help national administrations in the decision-making process supporting introduction of 5G systems in 26 GHz with mechanisms to allow for continued FS operation, where appropriate. This report has been developed under the assumption of an individual authorization framework for 5G IMT. Knowledge of the locations and parameters of the 5G base stations is necessary in order to manage national coordination with fixed services.
7	IMT versus IMT	CEPT/ ECC	ECC Report 307	Toolbox for the most appropriate synchronization regulatory framework including compatibility of MFCN in 24.25-27.5 GHz in unsynchronized and semi-synchronized mode (2020).	It provides solutions and develops regulatory options for synchronization, in particular, to enable unsynchronized and semi-synchronized operation of IMT in the 24.25-27.5 GHz band. In addition, the Report identifies the most appropriate synchronization regulatory framework at national level.

Table 52: Overview of key IMT sharing and compatibility studies relevant for the 26 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
8	IMT versus other services	CEPT/ ECC	CEPT Report 68	Report B from CEPT to the European Commission in response to the mandate "to develop harmonized technical conditions for spectrum use (of the 24.25-27.5 GHz ('26 GHz') frequency band) in support of the introduction of next-generation (5G) terrestrial wireless systems in the Union".	The technical conditions identified in this report address sharing and compatibility conditions to ensure protection of other users of spectrum in the 24.25-27.5 GHz frequency band (e.g. EESS/SRS and FSS earth stations) and in adjacent bands (EESS-passive).
9	IMT versus FSS (Earth-to-space)	CEPT/ ECC	ECC Recommendation (20)01	Guidelines to support the introduction of 5G while ensuring, in a proportionate way, the use of existing and planned FSS transmitting earth stations in the frequency band 24.65-25.25 GHz and the possibility for future deployment of these earth stations (2020).	Coordination zones and coordination contours may be required around FSS earth stations to achieve compatibility between 5G IMT systems and transmitting FSS earth stations operating in the frequency band 24.65-25.25 GHz. The exact coordination zone and contour will have to be calculated on a case-by-case, site-specific basis

Table 52: Overview of key IMT sharing and compatibility studies relevant for the 26 GHz band (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/ scope	Key topics/results
10	IMT versus IMT	EU	EU Decision 2019/784	Commission Implementing Decision (EU) 2019/784 of 14 May 2019 on harmonization of the 24.25-27.5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services in the Union.	It harmonizes the essential technical conditions for the availability and efficient use of the 24.25-27.5 GHz frequency band in the Union for terrestrial systems capable of providing wireless broadband electronic communications services. By 30 March 2020, EU Member States were to have designated and made available on a non-exclusive basis the 24.25-27.5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services.
11	IMT versus EESS (passive)	EU	EU Decision 2020/590	Commission Implementing Decision (EU) 2020/590 of 24 April 2020 amending Decision (EU) 2019/784 to update of relevant technical conditions applicable to the 24.25-27.5 GHz frequency band.	It updates the outcome of WRC-19 particularly regarding the protection of EESS in the 23.6-24.0 GHz and modifies the BEM least restrictive technical conditions.
12	IMT versus other services	CEPT/ ECC	ECC/DEC/ (18)06	ECC Decision of 6 July 2018 on the harmonized technical conditions for Mobile/Fixed Communications Networks (MFCN) in the band 24.25-27.5 GHz, corrected on 26 October 2018.	It sets the reference for least restrictive technical conditions, prior to WRC-19, which have been slightly amended by WRC-19 to protect EESS services.

Table 52 provides an overview of the main studies conducted to assess the sharing and compatibility of IMT versus other services in-band and in adjacent bands. It also provides an overview of the main services affected by the introduction of IMT services. Some studies have served to derive least restrictive technical conditions, mostly to facilitate compatibility among IMT services as well as incorporating the latest limits and resolution adopted by WRC-19 (which will be included in the next update of the Radio Regulations). Other studies are aimed at setting conditions to assess risks of interference between IMT and other services such as FSS and FS.

7.3.2 Technical conditions for IMT sharing and compatibility

As indicated in previous sections and specifically in Table 52, several studies have been conducted to check the compatibility of IMT with EESS, FSS and FS.

Table 53 provides a summary of the main relevant technical conditions which will facilitate the operation of IMT while ensuring compatible operation with other services. One of the most difficult sharing issues in this band has been the operation of IMT and protecting EESS (passive) services in the adjacent band.

As mandated by Resolution 242 (WRC-19), ITU-R is conducting studies to update existing Recommendations or develop a new one, as appropriate, to provide information and assistance to the administrations concerned on possible coordination measures to protect the RAS from IMT deployment in the 23.6-24 GHz band. The studies should also regularly review, as appropriate, the impact on sharing and compatibility of evolving technical and operational characteristics of IMT systems (including base-station density) and of space-services systems, and should take into account the results of these reviews in the development and/or revision of ITU-R Recommendations/Reports addressing, inter alia, if necessary, applicable measures to mitigate the risk of interference into space receivers.

Table 53: Technical conditions for IMT sharing and compatibility in the 26 GHz band

Sharing and com-patib-ility case	Option	Interfer-ence type/ case	Technical conditions	Reference documents	Notes
1	In-band and adjacent bands	IMT versus other ser-vices	It sets requirements for transmitting anten-nas of outdoor base stations which should normally point below the horizon. IMT base stations within the frequency band 24.45-27.5 GHz employing e.i.r.p. values per beam exceeding 30 dB(W/200 MHz) should be selected so that the direction of maximum radiation of any antenna will be separated from the geostationary satellite orbit, within line-of-sight of the IMT base station, by ±7.5 degrees. Bilateral agreements for cross-border coor-dination should be facilitated to protect EESS/space research service (SRS) earth sta-tions in the frequency band 25.5-27 GHz and radio astronomy service (RAS) stations in the frequency band 23.6-24 GHz and com-patibility between FSS earth stations in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz and IMT stations.	Resolution 242 WRC-19; Resolution 750 (WRC-19)	

Table 53: Technical conditions for IMT sharing and compatibility in the 26 GHz band (continued)

Sharing and com-patib-ility case	Option	Interfer-ence type/ case	Technical conditions	Reference documents	Notes
2	In-band and adjacent band	IMT versus IMT; IMT versus EESS	Harmonized tech-nical conditions in the band 24.25-27.5 GHz (2018). Concept of block edge mask (BEM). Frequency arrangement is a TDD with a block size of 200 MHz. This block size could be adjusted to narrower blocks (multiples of 50 MHz) adjacent to other users, to allow full use of spectrum.	CEPT/ECC Decision (18)06	It estab-lishes the concept of BEM although the spe-cific limits require updat-ing to consider the deci-sions of WRC-19, particu-larly for the pro-tection of EESS passive services in adjacent bands.

Table 53: Technical conditions for IMT sharing and compatibility in the 26 GHz band (continued)

Sharing and compatib-ility case	Option	Interfer-ence type/ case	Technical conditions	Reference documents	Notes
3	In-band and adjacent bands	IMT versus EESS (passive); IMT versus radio astronomy (23.6-24.0 GHz); IMT versus FSS in 24.65-25.25 GHz; FSS inter-satellite links in 24.45-24.75 GHz and 25.25-27.5 GHz.	Conditions to protect: (a) systems in adjacent bands, in particular in the Earth exploration-satellite service (passive) and in the radio astronomy service in the 23.6-24.0 GHz frequency band; (b) earth stations in the Earth exploration-satellite service and in the space research service for space-to-Earth communications operating within the 25.5-27.0 GHz frequency band; (c) satellite systems for Earth-to-space communications in the fixed-satellite service operating within the 24.65- 25.25 GHz frequency band; (d) satellite systems for inter-satellite communications operating within the 24.45-24.75 GHz and 25.25-27.5 GHz frequency bands.	EU decision 2019/784	Technical conditions required by EU Decision 2019/784 are same as ECC Decision (18)06.

Table 53: Technical conditions for IMT sharing and compatibility in the 26 GHz band (continued)

Sharing and com-patib-ility case	Option	Interfer-ence type/ case	Technical conditions	Reference documents	Notes
4	Adjacent bands	IMT versus EESS (pas-sive)	Conditions to protect: (a) systems in adja-cent bands, in particular in the Earth explora-tion-satellite service (passive) and in the radio astronomy service in the 23.6-24.0 GHz frequency band. The BEM least restrictive technical condi-tions are updated.	EU decision 2020/590	Updates EU Decision 2019/784 in the light of WRC-19 outcome for IMT versus EESS.
5	In-band and adjacent bands	IMT versus SRS/EESS (space-to-Earth)	Methodologies are described: • in Annex 1 to calculate the coordination zone around SRS earth stations operating in the frequency band 25.5-27 GHz; • in Annex 2 to calculate the coordination zone around NGSO EESS earth stations operating in the frequency band 25.5-27 GHz; • in Annex 3 to calculate the coordination zone around GSO EESS earth stations operating in the frequency band 25.5-27 GHz.	ECC Recommenda-tion (19)01	

Table 53: Technical conditions for IMT sharing and compatibility in the 26 GHz band (continued)

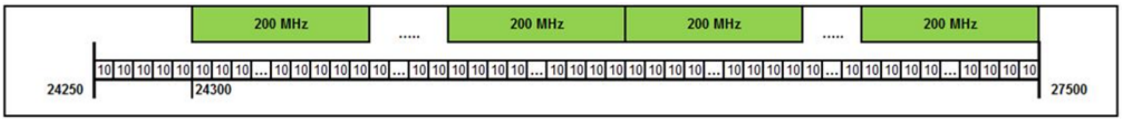
Sharing and com-patib-ility case	Option	Interfer-ence type/ case	Technical conditions	Reference documents	Notes
6	In-band	IMT versus FSS (Earth-to-space)	The Recommendation establishes a method-ology and examples of calculations of coordination zones (where further con-sideration may be needed if 5G IMT base stations were inside these zones) around FSS earth sta-tions transmitting to satellites in the GSO orbit in the frequency band 24.65-25.25 GHz. Such methodol-ogy can be used by administrations as a guideline to imple-ment coordination zones and support the compatibility between 5G IMT BS and FSS transmitting earth stations.	ECC Recommenda-tion (20)01	

In summary, Table 53 shows that with respect to EESS (passive), compatibility of IMT is achieved by respecting the limits associated with the least restrictive technical conditions (concept of block edge masks [BEMs]), while the compatibility with FSS and FS would be on a case-by-case basis, depending on the specific geographical zones and frequency ranges being proposed by IMT and those other characteristics of the deployed FSS and FS links. For in-band operation of IMT and EESS/SRS, a methodology to compute interference levels is recommended by

ECC Recommendation (19)01 (which is based on previous ITU-R Recommendations providing several elements to substantiate such methodology.[175]

The CEPT-recommended frequency plan is illustrated in Figure 14.

Figure 14: Example of possible frequency arrangements for MFCN in the 24.25-27.5 GHz band



The least restrictive technical conditions (LRTC) are here reported as a valid element to facilitate the introduction of IMT services. In most cases, the application of LRTC would be made through individual authorization regimes. However, administrations would consider other ways to refer to the LRTC in the case of different authorization regimes. These conditions include provisions related to the compatibility between IMT systems in the form of BEMs, i.e. related to spectrum licensing and the avoidance of interference between users of spectrum, as well as provisions related to the compatibility with EESS (passive) in the form of unwanted emission limits in the band 23.6-24 GHz.

As explained in Section 6.3.2, a BEM is an emission mask that is defined, as a function of frequency, relative to the edge of a block of spectrum that is licensed to an operator. It consists of components specifying the permitted emission levels in adjacent blocks (transitional region 0-50 MHz below or above operator block) and non-adjacent blocks in the band.

The technical conditions for the frequency range 24.25-27.5 GHz are optimized for, but not limited to, fixed/mobile communications networks (two-way). As such, they are derived both for base stations (BS) and terminal stations (TS). The BEMs have been developed to ensure compatibility with other IMT blocks, as well as other services and applications in adjacent bands. Additional measures may be required at a national level to achieve compatibility with other services and applications.

[175] The methodology developed by ERC Recommendation (19)01 is based on ITU-R Recommendations:

- Recommendation ITU-R M.2101-0: "Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies"
- Recommendation ITU-R P.452: "Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz"
- Recommendation ITU-R SA.609-2: "Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites"
- Recommendation ITU-R SA.1161-2: "Sharing and coordination criteria for data dissemination and direct data readout systems in the Earth exploration-satellite and meteorological-satellite services using satellites in geostationary orbit"
- Recommendation ITU-R SA.1027-5: "Sharing criteria for space-to-Earth data-transmission systems in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit"
- Recommendation ITU-R P.2108-0: "Prediction of Clutter Loss"
- Recommendation ITU-R P.525-3: "Calculation of free-space attenuation"
- Recommendation ITU-R P.526-14: "Propagation by diffraction"
- Recommendation ITU-R SA.509-3: "Space research earth station and radio astronomy reference antenna radiation pattern for use in interference calculations, including coordination procedures, for frequencies less than 30 GHz"

The following requirements apply for the IMT base station (BS):

1) the IMT BS BEM consists of a baseline level, designed to protect the spectrum of other IMT operators as well as emission limits to protect adjacent services (additional baseline level(s)), and;
2) transitional levels for compatibility between IMT networks in adjacent blocks.

Table 54 contains the different elements of the BS BEM, and Tables 55 to 57 contain the power limits for the different BEM elements.

To obtain a BS BEM for a specific block, the BEM elements that are defined in Table 54 are used as follows:

1) transitional regions are determined and corresponding power limits are used;
2) for the remaining spectrum assigned to IMT, baseline power limits are used;
3) for protection of services in adjacent bands, an additional baseline is used.

For IMT BSs, baseline requirements and requirements for transitional regions in Tables 55 and 56 assume synchronized operation. Operators of IMT (in the ECC Decision, they are referred to as MFCN) in the 24.25-27.5 GHz band may agree, on a bilateral or multilateral basis, less stringent technical parameters provided they continue to comply with the technical conditions applicable for the protection of other services, applications or networks and with their cross-border obligations. Administrations should ensure that these less stringent technical parameters can be used, if agreed among all affected parties.

Table 54: IMT BS BEM elements

BEM element	Definition
Baseline	Applies in spectrum used for IMT, except from the operator block in question and corresponding transitional regions.
Transitional region	These are the regions adjacent to an operator block.
Additional baseline	Additional baseline limits apply in adjacent bands where specific limits for other services are necessary.

Table 55: IMT BS transitional region requirements for coexistence between IMT networks in adjacent blocks (assuming synchronized operation)

Frequency range	Maximum total radiated power (TRP)	Measurement bandwidth
0-50 MHz below or above operator block	12 dBm	50 MHz

Table 56: IMT BS baseline requirements for coexistence with IMT networks in other (non-adjacent) blocks in the band (assuming synchronized operation)

Frequency range	Protected frequency range	Maximum total radiated power (TRP)	Measurement bandwidth
In-band baseline	24.25- 27.5 GHz	4 dBm	50 MHz

Note: Administrations may define appropriate mitigation measures to be applied in case of unsynchronized or semi-synchronized operations. Alternatively, administrations may further develop and use an appropriate BEM at national level.

Table 57: IMT BS additional baseline requirement: maximum emissions into the 23.6-24.0 GHz band (Updated after WRC-19)

Frequency range	Maximum total radiated power (TRP)	Measurement bandwidth
23.6-24.0 GHz	–33 dBW (a)	200 MHz
23.6-24.0 GHz	–39 dBW (b)	200 MHz

Note: This level of requirement applies to BS for all foreseen modes of operation (example: maximum in-band power, electrical pointing, carrier configurations).

(a) This limit applies to base stations before 1 January 2024. Administrations shall not allow new deployments of terrestrial systems capable of providing wireless broadband electronic communications services in the frequency range 22-23.6 GHz, so as to ensure the appropriate protection of the Earth exploration-satellite service (passive) and the radio astronomy service in the 23.6-24 GHz frequency band in conjunction with the limit applicable after 1 January 2024.

(b) This limit applies to base stations that will be brought into use after 1 January 2024. This limit does not apply to base stations brought into use before that date. For those base stations, the limit of –33 dBW/200 MHz will continue to apply after 1 January 2024. Administrations shall consider additional measures to assess and mitigate the aggregate impact of those base stations on the Earth exploration-satellite service (passive). Such measures include adaptation of the size of assigned blocks, the antenna configuration, the in-block power or the penetration of equipment.

There are also conditions applying to the elevation of the main beam from 5G AAS outdoor base stations which must be taken into account: When deploying outdoor base stations, it shall be ensured that each antenna is transmitting only with the main beam pointing below the horizon and, in addition, the antenna shall have mechanical pointing below the horizon except when the base station is only receiving.

The least restrictive conditions include requirement for the terminal station as described in Table 58.

Table 58: IMT terminal station maximum emissions into the 23.6- 24.0 GHz band

Frequency range	Maximum total radiated power (TRP)	Measurement bandwidth
23.6-24.0 GHz	–29 dBW (a)	200 MHz
	–35 dBW (b)	200 MHz

Note: This level of requirement applies to terminal stations for all foreseen modes of operation (example: maximum in-band power, electrical pointing, carrier configurations).

(a) Immediately

(b) This limit applies to terminal stations that will be brought into use after 1 January 2024. This limit does not apply to terminal stations brought into use before that date. For those terminal stations, the limit of –29 dBW/200 MHz will continue to apply after 1 January 2024.

The above least restrictive technical conditions have been derived based on several compatibility studies, taking into account the impact of an EESS/SRS and FSS earth station which will be limited to a specific sub-band: i.e. 1.5 GHz for EESS/SRS (25.5-27 GHz) and a maximum of 600 MHz for FSS (24.65-25.25 GHz). In order to ensure that existing and future earth station requirements could be accounted for when granting 5G authorizations, or after they have been granted, EU Member States need to include adequate provisions in their authorizations. However, since the regulatory solutions are likely to vary from country to country, a certain level of flexibility may be necessary.

If necessary, any impact could be mitigated by various measures (e.g. requiring an operator with fewer constraints to share access with others or ensuring frequencies in areas potentially impacted are distributed among operators appropriately). CEPT is developing relevant methodologies described in ECC Recommendations for national implementation to ensure compatibility between 5G networks and EESS/SRS and FSS earth stations.

Individual authorization can cover both nationwide licensing and on a smaller geographic basis. No specific technical conditions have been determined that would allow for the possibility of a general authorization regime under sharing conditions in a way to ensure protection of the other users of spectrum in this band (in particular EESS/SRS earth stations).

Finally, it is important to note the conclusions from WRC-19, notably Resolution 242 (WRC-19):

1) Transmitting antennas of outdoor base stations should normally point below the horizon; IMT base stations within the frequency band 24.45-27.5 GHz employing values of e.i.r.p. per beam exceeding 30 dB(W/200 MHz) should be selected so that the direction of maximum radiation of any antenna will be separated from the geostationary satellite orbit, within line-of-sight of the IMT base station, by ±7.5 degrees.
2) Protection of EESS/space research service (SRS) earth stations in the frequency band 25.5-27 GHz and radio astronomy service (RAS) stations in the frequency band 23.6-24 GHz and coexistence between FSS earth stations in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz and IMT stations should be facilitated through bilateral agreements for cross-border coordination.

7.3.3 Regulatory conditions for IMT sharing and compatibility

Table 59 provides a summary of the main requirements which will facilitate compatibility between IMT systems as well as with other services such as Earth exploration-satellite and fixed satellite.

Table 59: Regulatory conditions specific for IMT licensees

No	Condition or requirement	Notes	References
1	Implement regulation to mandate operation of IMT under the least restrictive technical conditions. Adopt the concept of BEM.	Described above, resulting from compatibility between IMT networks and the protection of EESS.	ECC Decision (18)06
2	In order to avoid harmful interference into the Earth exploration service and passive services, IMT should observe: • A limit of –33 dB(Wm/200 MHz) until September 2027 and of –39 dB(Wm/200 MHz) afterwards for IMT base stations; • A limit of –29 dB(W/200 MHz) until September 2027 and of –35 dB(W/200 MHz) afterwards for IMT mobile stations. These limits should be observed within the EESS passive band (23.6-24.0 GHz).	Limits to protect EESS passive service.	Resolution 750
3	Where feasible, administrations may wish to consider locating future FSS satellite earth stations away from populated areas where 5G IMT BS may operate. Consider implementing the mitigation techniques proposed in ECC Rec (20)01 to mitigate the interference from FSS earth stations into IMT.	A methodology to compute interference and coordination zones is defined in ECC Rec (20)01.	ECC Recommendation (20)01
4	The individual authorization process would allow definition of specific technical conditions in order to protect FS and mitigate interference from earth stations in the FSS, and apply case-by-case, mitigation techniques and, when necessary, refarming processes.	The restrictions for deployment of IMT would depend on the specific frequency ranges and geographical locations where FSS earth stations and FS links would have been deployed.	CEPT/ECC Report 303; CEPT/ECC Report 68

Note should also be taken that ITU-R is conducting studies to further assist administrations on several aspects related to the technical conditions for operation of IMT in the 26 GHz band. In particular, Resolution 242(WRC-19) foresees the following additional technical elements:

1) Harmonized frequency arrangements to facilitate IMT deployment in the frequency band 24.25-27.5 GHz, considering the results of sharing and compatibility studies conducted in preparation for WRC-19.
2) Further studies towards ITU-R Recommendation on methodologies for calculating coordination zones around EESS/SRS earth stations in order to avoid harmful interference from IMT systems in the frequency band 25.5-27 GHz.
3) Development of new ITU-R Recommendation(s) to assist administrations to mitigate interference from FSS earth stations into IMT stations operating in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz.

4) Further studies to update existing ITU-R Recommendations or develop a new one, as appropriate, to provide information and assistance to the administrations concerned on possible measures for coordination and protection from IMT deployment for the RAS in the frequency band 23.6-24 GHz.
5) Further review, as appropriate, of the impact of evolving technical and operational characteristics of IMT systems (including base-station density) and those of systems of space services on sharing and compatibility, and to take into account the results of these reviews in the development and/or revision of ITU-R Recommendations/Reports addressing, inter alia, if necessary, applicable measures to mitigate the risk of interference into space receivers.

The main conditions associated with the deployment of IMT are those based on compliance of the limits established by the concept of BEM and reported in Tables 54 to 58 above. These conditions set standard practices and common references, thus facilitating the process both in national spectrum planning and for cross-border coordination.

Regarding the compatibility with FS, assuming that the compatibility issue is dealt with at national level, the ECC Report 303 provides examples of methodologies to mitigate interference between these services. It sets a shared approach. In this shared approach, the fixed links will continue to operate in the 26 GHz band. Further different ways of sharing are possible, including:

1) sharing in frequency and space;
2) sharing in frequency, separation in space;
3) sharing in space, separation in frequency;
4) separation in space and frequency.

The shared approach requires interference calculations to determine the conditions for newly implemented applications. Therefore, information on incumbent applications (e.g. location, technical parameters of individual FS sites) must be available and might be provided in a database. Due to confidentiality requirements, in some cases it may not be possible to make data publicly available.

7.3.4 Cross-border coordination aspects for IMT

The international coordination of new IMT services in a country versus other IMT services planned or deployed in another country would be facilitated if there is compliance with the conditions set out in Tables 54 to 58.

The international coordination of IMT services with respect to FSS earth stations deployed in a neighbouring country can be facilitated by following similar schemes as described in Section 7.4.

Note should be taken of Resolution 242 (WRC-19), which indicates that bilateral agreements for cross-border coordination should facilitate protection, as necessary, of EESS/space research service (SRS) earth stations in the frequency band 25.5-27 GHz and radio astronomy service (RAS) stations in the frequency band 23.6-24 GHz and coexistence between FSS earth stations in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz and IMT stations.

7.4 Best practices and methods for refarming other services in the 26 GHz band

The main cases of potential refarming of services in the 26 GHz band have been identified for incumbent FSS earth stations and fixed service links.

For the refarming for FSS service, several approaches are considered below.

The measures to facilitate introduction of IMT in the 26 GHz when FSS services are deployed have been studied by CEPT and have led to recommendations included in the ECC Recommendation (20)01. Several mitigation techniques exist to mitigate the interference from FSS earth stations into IMT. However, when refarming of FSS would be required, several approaches are being followed by administrations.

Considerations followed by example Country A

FSS earth stations in this band will be subject to an individual licensing regime and due to restrictions on antenna size, there will be limited deployment in terms of the number of earth stations in any given country.

In the frequency band 24.65-25.25 GHz, IMT systems could be subjected either to an individual licensing regime (either per assignment or national/regional/local allotment) or a general authorization regime, according to market demand.

In order to assess prospective areas where FSS earth stations may be deployed, administrations could assess the IMT market demands in order to categorize the potential territory (rural, suburban and urban areas) where IMT BS could be rolled out. Further, based on national plans, administrations could define present and future areas of specific potential interest for IMT (stadiums, train stations, which may be in any of the above categories).

Based on the calculation results of the coordination areas, it would be up to each administration to identify the candidate locations for a limited number FSS earth stations in such a way that imposing disproportionate constraints on the IMT is avoided.

Subsequently, and via public consultation, administrations could assess the relevant market demand for FSS earth stations and confirm the result of that assessment where FSS satellite earth stations may be deployed in the short and medium term and in an appropriate and proportionate way.

Such location of FSS earth station and relevant coordination areas would be recorded and made available to potential FSS and IMT licence holders in the band. Within the relevant coordination zones, it would then be up to IMT network operators to mitigate interferences from FSS satellites earth stations (BS installation, managing the impact of FSS interference, etc.).

Outside such identified locations, in case of IMT individual authorizations, the licence framework should also leave an opportunity for IMT and FSS satellite operators to negotiate bilateral agreements in order to identify specific locations for earth stations on terms proportionate to the potential impact of the operation of the FSS earth station.

Considerations followed by example Country B

It should be noted that according to RR No. 5.532B, FSS earth stations in this band are used for feeder links and are required to have an antenna size of at least 4.5 m. This means that these earth stations will be large and sparsely distributed within a territory and limited in number. It is recommended that where feasible, administrations may wish to consider locating future FSS satellite earth stations away from populated areas where IMT BS may operate.

The envisaged deployment scenario of 26 GHz IMT will be largely in built-up urban areas and the coordination zones around FSS earth stations will be small (generally less than a couple of km). The deployment scenario of FSS will be largely in rural areas. It is likely that there are already FSS earth stations established in the band. The deployment scenarios alone would allow for continued deployment of FSS earth stations as there will continue to be locations where they can operate without causing interference to IMT.

The band should remain open for authorizing specific FSS earth stations but no additional or special provisions would be required. Authorization of FSS earth stations and IMT would be on a first-in-time basis where the system that is authorized first would get the right to transmit and/or be protected.

7.4.1 Refarming for FS service

ECC Report 303 proposes a phased approach, under which the FS will continue to operate in the 26 GHz band for a period of time. It is assumed, as per Table 51, that FS is also deployed in Africa. Gradually, the FS will be migrated out of the 24.25-26.5 GHz band to other frequencies. Wherever possible, the FS backhaul links to base stations could be exchanged by fibre-optic communication, so as to clear the band continuously from FS use.

Under the migration approach, the FS service will be migrated completely or partially out of the band before the introduction of 5G networks. Depending on the national situation and number of FS links deployed, such an approach could delay the availability of spectrum for 5G systems. It should be noted that some administrations may wish to consider a combination of the shared and clearance options. This includes, for example, establishing sharing approaches between 5G systems and FS within some areas and migration of FS to other frequency bands in other areas.

The studies included in ECC Report 303 assume a long-term protection criterion for FS as ratio of I/N = –10 dB, not exceeded for more than 20 per cent of the time.

7.5 Guidelines and recommended actions for the 26 GHz band

Table 60 summarizes the main guidelines to facilitate introduction of IMT in the 26 GHz band, noting the need to protect EESS (as defined by the conclusions of WRC-19). Table 60 includes also best practices to mitigate interference from FSS earth stations into IMT.

Table 60: Spectrum management guidelines for IMT introduction in the 26 GHz band

No	Guideline	Applies to	Ref. Section(s)
7.1	Advanced frequency-planning coordination is recommended at the earliest stage of the frequency-assignment process, as there would be technical elements strongly associated with the technologies being deployed for IMT systems in each country. This work could also include preparatory coordination among operators concerned. Ideally, however, the frequency assignments should be coordinated between neighbouring countries at earlier stages, even before the specific frequency assignments to each operator have been concluded. The cross-border coordination between administrations can be undertaken bilaterally or multilaterally.	IMT services	Section 5.3.4
7.2	Consider an individual authorization regime[176] to ensure that specific studies are conducted for each applicant (geographical zones affected, frequency range involved, etc.), allowing the definition of conditions suitable for the specificities of each case.	IMT versus EESS	Section 7.3.2
7.3	Apply the conditions derived from WRC-19 regarding protection of the passive EESS as stipulated by Resolution 750 (Rev. WRC-19), which are also included in the updated version of the EU Decision 2020/594, based on the concept of BEM and least restrictive technical conditions.	IMT versus EESS	Section 7.3.2
7.4	Consider the proposed approaches to compatibility and migration of FSS earth stations, when necessary, depending on required coordination zones in each case. These approaches mostly refer to coexistence with FSS by either limiting further deployment of FSS in specific areas or informing the deployment of FSS and IMT to concerned operators to help mitigate potential harmful interference cases.	IMT versus FSS	Section 7.4

[176] The term "individual authorization" is used to designate the licence which is issued by a national administration to an IMT operator for a given set of unique technical and regulatory operating conditions.

Table 60: Spectrum management guidelines for IMT introduction in the 26 GHz band (continued)

No	Guideline	Applies to	Ref. Section(s)
7.5	Consider the toolbox for the most appropriate synchronization regulatory framework, including compatibility of MFCN in 24.25-27.5 GHz in unsynchronized and semi-synchronized mode (2020). This toolbox offers guidance for: • Indoor deployments using adjacent channels. Unsynchronized operation is possible using equipment complying to the baseline requirements. For indoor deployments it is not necessary to synchronize two networks. This is under the assumption of an authorization regime whereby base station locations are planned and proper installation of indoor base stations can guarantee the assumed building entry loss of the interfering signal. The indoor installation should be professionally done to ensure sufficient isolation between indoor and outdoor systems; • For an outdoor network and an indoor network, it is possible to use the same channel if carefully planned and if the envisioned service is enhanced mobile broadband. For ultra-reliable low-latency communication services, it may be challenging to use the same channel; • For outdoor deployments of two geographically adjacent IMT networks, depending on the specific scenario (urban, suburban and open space) and on the co-channel or adjacent channel case, unsynchronized operation is feasible respecting certain minimum separation distances between the edges of the two networks.	IMT deployment	ECC Report 307

8 IMT sharing and compatibility with other services in the 37-71 GHz band

As result of WRC-19, several frequency bands have been identified for IMT:[177]

1) 40 GHz (37.0-43.5 GHz) on a worldwide basis;
2) 45.5-47.0, national footnotes, including a large number of African countries;
3) 47.2-48.2 GHz, national footnotes, including a large number of African countries;
4) 66 GHz (66.0-71.0 GHz) on a worldwide basis.

Because of the similar deployment status and available studies for this set of frequency bands, the analysis of the conditions for the IMT introduction is conducted for the whole frequency range 37-71 GHz. The analysis in this section will give an overall view on the sharing and compatibility issues for these higher frequencies.

Due to the early stage of service deployment in these bands, there are not many singularities or differences worthy of mention. Note should be made, though, that ITU-R is still conducting studies on the evolution of IMT, the development of harmonized frequency arrangements, as well as IMT identifications in these higher frequency ranges.

Further studies are under way regarding:[178]

1) Development of ITU-R Recommendations and/or Reports, as appropriate, to assist administrations in the efficient use of these frequency bands through compatibility mechanisms between IMT and other applications of the mobile service (including other wireless access systems, as well as between the mobile service and other services).
2) Reviewing, as appropriate, the impact of evolving technical and operational characteristics of IMT systems (including base-station density) and those of systems for space services, on sharing and compatibility, as well as measures to mitigate the risk of interference into space receivers.
3) Investigate measures to assist administrations in ensuring compatibility between IMT and BSS and FSS, including high-density applications in the fixed-satellite service (HDFSS), within the frequency ranges 37-43.5 GHz and 47.2-48.2 GHz.
4) Provide information and assistance to the administrations concerned on possible coordination and measures for protecting the RAS in the frequency band 42.5-43.5 GHz from IMT interference.

8.1 IMT frequency arrangements in the 37-71 GHz band

Table 61 provides the proposed frequency arrangements under which the use of TDD is foreseen, consistent with ETSI TS 138 101-2 V15.2.0 (2018-07) for the frequency range FR 2 (24.25-52.60 GHz). The frequency arrangements for the other identified IMT bands are still under development.

[177] The World Radiocommunication Conference 2019 (WRC-19) was held in Egypt from 28 October to 22 November 2019. 3 400 delegates participated representing 165 countries.
[178] See WRC-19 Resolutions 241, 242 and 244.

Table 61: IMT frequency arrangements in the 37-71 GHz band

Frequency arrangement	Unpaired arrangements (TDD) (MHz)
FR 2 (37-40 GHz)	50, 100, 200, 400
FR2 (39.5-40.5) GHz	50, 100, 200, 400

As the identification of several frequency bands for IMT applications is very recent (WRC-19), further work is still expected by ITU-R, regional organizations and industrial standardization bodies to develop suitable frequency-channelling for these bands. From Table 61, it can be observed that only one duplexing system is foreseen – TDD with several broadband channelling bandwidths.

It should be noted that Resolution 243 (WRC-19) encourages administrations of Region 1 to consider implementing IMT in the frequency band 40.5-43.5 GHz in order to better accommodate the needs of other services below 40.5 GHz, considering protection of the FSS within the frequency band 37.5-40.5 GHz in Region 1.

8.2 Other services allocated in the 37 to 71 GHz frequency range and adjacent bands

The four sets of frequency ranges identified for IMT, as result of WRC-19, also include a number of sub-bands sharing each sub-band with different services. The overall breakdown of the allocations for each segment of the band is described in Table 62. The following sub-bands are included:

1) 40 GHz (37.0-43.5 GHz) on a worldwide basis;
2) 45.5-47.0, national footnotes;
3) 47.2-48.2 GHz, national footnotes;
4) 66 GHz (66.0-71.0 GHz) on a worldwide basis.

Radio Regulations provisions less relevant for IMT are indicated in round brackets while IMT identifications provisions are highlighted in blue.

Table 62: ITFA corresponding with identified IMT frequency arrangements for the 37 to 71 GHz frequency range (Region 1)

37-43.5 GHz		
Services:	Footnote number:	Footnote:
37-37.5 GHz		
Fixed	5.547	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Mobile except aeronautical mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Space research (space-to-Earth)		

Table 62: ITFA corresponding with identified IMT frequency arrangements for the 37 to 71 GHz frequency range (Region 1) (continued)

37.5-38 GHz		
Fixed	(5.547)	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Fixed satellite (space-to-Earth)	(5.550C)	Application of No. 9.12 for coordination with other non-geostationary satellite systems in the fixed-satellite service but not with non-geostationary-satellite systems in other services. Resolution 770 (WRC-19) shall also apply, and No. 22.2 shall continue to apply.
Mobile except aeronautical mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Space research (space-to-Earth)		
Earth exploration-satellite (space-to-Earth)		
38-39.5 GHz		
Fixed (space-to-Earth)	5.550D	Band identified for worldwide use by administrations wishing to implement high-altitude platform stations (HAPS) (HAPS-to-ground direction). Resolution 168 (WRC-19).
	5.547	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Fixed satellite (space-to-Earth)	(5.550C)	Requirement for coordination of NGSO FSS but not required with NGSO other services. Resolution 770 of WRC-19.
Mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Earth exploration-satellite		
39.5-40 GHz		
Fixed	5.547	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Fixed satellite (space-to-Earth)	5.516B	Identification for HD FSS (space to Earth) in Region 1.
	(5.550C)	Requirement for coordination of NGSO FSS but not required with NGSO other services. Resolution 770 of WRC-19.

Table 62: ITFA corresponding with identified IMT frequency arrangements for the 37 to 71 GHz frequency range (Region 1) (continued)

	(5.550E)	The use of the frequency bands 39.5-40 GHz and 40-40.5 GHz by non-geostationary-satellite systems in the mobile-satellite service (space-to-Earth) and by non-geostationary-satellite systems in the fixed-satellite service (space-to-Earth) is subject to the application of the provisions of No. 9.12.
Mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Mobile satellite (space-to-Earth)	(5.550E)	The use of the frequency bands 39.5-40 GHz and 40-40.5 GHz by non-geostationary-satellite systems in the mobile-satellite service (space-to-Earth) and by non-geostationary-satellite systems in the fixed-satellite service (space-to-Earth) is subject to the application of the provisions of No. 9.12.
Earth exploration-satellite (space-to-Earth)		
	40-40.5 GHz	
Earth exploration-satellite (Earth-to-space)		
Fixed		
Fixed satellite (space-to-Earth)	5.516B	Identification for HD FSS (space to Earth) in all Regions.
	(5.550C)	Requirement for coordination of NGSO FSS but not required with other NGSO services. Resolution 770 (WRC-19).
	(5.550E)	The use of the frequency bands 39.5-40 GHz and 40-40.5 GHz by non-geostationary-satellite systems in the mobile-satellite service (space-to-Earth) and by non-geostationary-satellite systems in the fixed-satellite service (space-to-Earth) is subject to the application of the provisions of No. 9.12.
Mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Mobile satellite (space-to-Earth)	(5.550E)	The use of the frequency bands 39.5-40 GHz and 40-40.5 GHz by non-geostationary-satellite systems in the mobile-satellite service (space-to-Earth) and by non-geostationary-satellite systems in the fixed-satellite service (space-to-Earth) is subject to the application of the provisions of No. 9.12.
Space research (Earth-to-space)		
Earth exploration-satellite (space-to-Earth)		
	40.5-41 GHz	

Table 62: ITFA corresponding with identified IMT frequency arrangements for the 37 to 71 GHz frequency range (Region 1) (continued)

Fixed	5.547	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Fixed satellite (space-to-Earth)	(5.550C)	Requirement for coordination of NGSO FSS but not required with other NGSO services. Res. 770 (WRC-19).
Land mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Broadcasting		
Broadcasting satellite		
Aeronautical mobile		
Maritime mobile		
41-42.5 GHz		
Fixed	5.547	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Fixed satellite (space-to-Earth)	5.516B	Identification for HD FSS (space-to-Earth) in Region 2.
	(5.550C)	Requirement for coordination of NGSO FSS but not required with NGSO other services. Res 770 WRC-19.
Land mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Broadcasting		
Broadcasting satellite		
Aeronautical mobile		
Maritime mobile		
	(5.551F) (5.551H) (5.551I)	Not applicable for Africa; Requirements for FSS and BSS versus radio astronomy; Requirements for FSS and BSS versus radio astronomy.
42.5-43.5 GHz		
Fixed	5.547	The bands 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the fixed service (see Resolution 75).
Fixed satellite (Earth-to-space)	(5.552)	Requirements for paired spectrum for FSS in the band 47.2-49.2 GHz.

Table 62: ITFA corresponding with identified IMT frequency arrangements for the 37 to 71 GHz frequency range (Region 1) (continued)

Mobile except aeronautical mobile	5.550B	The frequency band 37-43.5 GHz is identified for IMT. Resolution 243 (WRC-19) applies (HDFSS).
Radio astronomy	5.149	Administrations should protect radio astronomy service in this band.
45.5-47 GHz		
Services:	Footnote number:	Footnote:
Mobile	5.553	In the bands 43.5-47 GHz and 66-71 GHz, stations in the land mobile service may be operated subject to not causing harmful interference to the space radiocommunication services to which these bands are allocated.
	5.553A	IMT identification in the following African countries: Algeria, Angola, Benin, Botswana, Burkina Faso, Cabo Verde, Côte d'Ivoire, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Sudan, South Africa, Tanzania, Togo, Tunisia, Zambia and Zimbabwe. IMT has to protect aeronautical mobile service and radionavigation; coordination under RR 9.21 is required. Resolution 244 (WRC-19) applies.
Mobile satellite	(5.554)	Flexibility for use of fixed links with MSS or radionavigation service.
Radionavigation		
Radionavigation satellite	(5.554)	Flexibility for use of fixed links with MSS or radionavigation service.
47.2-48.2 GHz		
Services:	Footnote number:	Footnote:
Fixed	5.552A	The allocation to the fixed service in the frequency bands 47.2-47.5 GHz and 47.9-48.2 GHz is identified for use by high-altitude platform stations (HAPS) in accordance with Resolution 122.
Fixed satellite	(5.550C)	Application of No. 9.12 for coordination with other non-geostationary satellite systems in the fixed-satellite service but not with non-geostationary-satellite systems in other services. Resolution 770 (WRC-19) shall also apply, and No. 22.2 shall continue to apply.
	(5.552)	Requirements for paired spectrum for FSS in the band 47.2-49.2 GHz.

Table 62: ITFA corresponding with identified IMT frequency arrangements for the 37 to 71 GHz frequency range (Region 1) (continued)

	5.516B	The band 47.5-47.9 GHz (space-to-Earth) is identified for HD FSS in Region 1.
	(5.554A)	The use of the bands 47.5-47.9 GHz, 48.2-48.54 GHz and 49.44-50.2 GHz by the fixed-satellite service (space-to-Earth) is limited to geostationary satellites.
Mobile	5.553B	IMT identification in the following African countries: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Comoros, Republic of the Congo, Côte d'Ivoire, Djibouti, Egypt, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Equatorial Guinea, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Morocco, Mauritania, Mozambique, Namibia, Niger, Nigeria, Uganda, Democratic Republic of the Congo, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, South Sudan, South Africa, Tanzania, Chad, Togo, Tunisia, Zambia and Zimbabwe. Resolution 243 (WRC-19) applies.
66-71 GHz		
Services:	Footnotes number:	
Inter-satellite		
Mobile	5.553	Mobile service should not cause interference to space services in this band.
	(5.558)	Obligations for aeronautical mobile to not cause interference to inter-satellite service.
	5.559AA	Identification for IMT, without priority. See also RR 5.553. Resolution 241 (WRC-19) applies.
Mobile satellite	(5.554)	Flexibility for use of fixed links with MSS or radionavigation service.
Radionavigation		
Radionavigation satellite	(5.554)	Flexibility for use of fixed links with MSS or radionavigation service.

From Table 62, it is concluded that operation of IMT will have to coexist with a number of services in-band as well as in adjacent bands. Note that identification for IMT in these bands is made without priority to other services. Consequently, respect of sharing conditions will be crucial to allow compatibility of several services and particularly, to facilitate the cross-border coordination because it would help achieving agreements at international level (note should be taken that national coordination of services could be undertaken based on separate sets of parameters agreed at national level). For the list of applications indicated, due account has been taken of available information about deployment of services in Africa, such as the SADC Table of Frequency Allocations.

Table 63: Common applications and technology standards per ITU-RR service for Region 1

ITU-RR service	Application		Application examples	Tech-nology standard	References
	ITU name	CEPT name			
Mobile	MS	MS	Multiple giga-bit wireless systems in 60 GHz.	WiGig	
FS	FS	FS	HDFS in the band 37-40 GHz.		Rec. ITU-R F.749 Annex 1
FS	HD FS	HD FS	BFWA or MWS (40.5-43.5 GHz). The bands 37-40 GHz and 40.5-43.5 GHz are identified for HDFS.		Resolution 75 WRC-12
FS	FS	FS	Government use in the band 40-40.5 GHz.		SADC Table
FS	HAPS	HAPS	The band 38-39.5 GHz is identified for HAPS (WRC-19).		Res 168 WRC-19, Res 243 WRC-19
Space research (space-to-Earth)	No specific services or applications have been identified as deployed in Africa.				
Fixed satellite (space-to-Earth)	FSS	FSS	The bands 39.5-40.0 GHz, 47.5-47.9 GHz and 48.2-48.54 are identified for HDFSS.		Resolution 143 WRC-03
Mobile satellite (space-to-Earth)	No specific services or applications have been identified as deployed in Africa.				
Earth exploration-satellite (Earth-to-space)	No specific services or applications have been identified as deployed in Africa.				
Broadcasting	No specific services or applications have been identified as deployed in Africa.				
Broadcasting satellite	No specific services or applications have been identified as deployed in Africa.				

Table 63: Common applications and technology standards per ITU-RR service for Region 1 (continued)

ITU-RR service	Application		Application examples	Tech-nology standard	References
	ITU name	CEPT name			
Radio astronomy	No specific services or applications have been identified as deployed in Africa.				
Radionavigation	No specific services or applications have been identified as deployed in Africa.				
Radionavigation satellite	No specific services or applications have been identified as deployed in Africa.				
Inter-satellite	No specific services or applications have been identified as deployed in Africa.				

As can be seen in Table 63, there are several potential compatibility issues with a number of other services which can be deployed in Africa or elsewhere in Region 1. Also, an IMT introduction may affect the space services.

8.3 Sharing/compatibility between IMT and the other services in the 37 -71 GHz frequency range

In spectrum management terms, sharing and compatibility studies are about investigating mechanisms to facilitate the efficient use of spectrum by different services in-band or in adjacent bands, considering the expected deployment of each service as well as the applied technology standards.

In this section, the most relevant sharing and compatibility studies are identified with the aim of helping administrations to implement measures to avoid incompatible operation of different services and avoidance of harmful interference.

Administrations should interpret these study results with caution as their local situation (including the actual frequency allocations/assignments as reflected in their NTFA, the applied technologies and interference scenario) may differ from the situations covered in the studies. Most of the sharing and compatibility studies are based on typical scenarios which represent reasonably the deployment scenario of each service under study, although the singularities of specific deployment of services would require adequate interpretation of the sharing environment.

8.3.1 Overview of IMT sharing and compatibility studies

The main sharing and compatibility studies conducted so far in the frequency range of 37-71 GHz and adjacent bands are reported in Table 64. As opposed to other lower frequency ranges, where many studies have been conducted by ITU-R and regional organizations such as CEPT, in this frequency range the industrial implementations are still immature. Therefore, the main references on sharing studies are those developed by ITU-R in the process of deciding frequency allocations, mostly in WRCs. Such studies have been conducted very recently and have led to Resolutions and Radio Regulations footnotes which administrations should observe when deciding on the deployment of IMT services.

The main sharing and compatibility studies in the upper frequency bands within this frequency range have been conducted within the WRC-19 study cycle and are included as part of the second meeting of the Conference Preparatory Meeting for WRC-19.

Table 64: Overview of key IMT sharing and compatibility studies relevant for the 37-71 GHz frequency range

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
1	Reference on frequency arrangements for FS.	ITU-R	Rec. ITU-R F.749 Annex 1	Radio-frequency arrangements for systems of the fixed service operating in sub-bands in the 36-40.5 GHz band.	Relevant to note for compatibility studies between FS and IMT.
2	Sharing and compatibility studies of IMT versus all other services sharing the candidate IMT bands as well as adjacent bands.	ITU-R	ITU-R CPM-2 Report WRC-19	CPM Report on technical, operational and regulatory/procedural matters to be considered by the World Radiocommunication Conference 2019. 2nd Session of the Conference Preparatory Meeting for WRC-19.	Sharing studies are reported under Agenda item 1.13 of WRC-19. The outcome of WRC-19 is reported in the Final Acts of WRC-19 and the modified and new provisions to be included in the Article 5 of the updated Radio Regulations.
3	IMT versus other services: EESS, FSS in the 37-43.5 GHz and 47.2-48.2 GHz.	ITU-R	Resolution 243 WRC-19	Terrestrial component of International Mobile Telecommunications in the frequency bands 37-43.5 GHz and 47.2-48.2 GHz.	Frequency arrangements for IMT are under study as per Resolution 243. Technical limits to ensure compatibility with EESS, SRS and FSS.
4	IMT versus HAPS in 38-39.5 GHz.	ITU-R	Resolution 168 WRC-19 on HAPS for the band 38-39.5 GHz	Use of the frequency band 38-39.5 GHz by high-altitude platform stations in the fixed service.	Sets the limits which HAPS should meet to trigger cross-border coordination and which IMT systems should consider. Compatibility studies cover the cross-border case but not the national scenarios of compatibility of IMT and HAPS.
5	Frequency arrangements for IMT in the 45.5-47 GHz.	ITU-R	Resolution 244 WRC-19	International Mobile Telecommunications in the frequency band 45.5-47 GHz.	ITU-R to develop the frequency arrangements for IMT in this band.

Table 64: Overview of key IMT sharing and compatibility studies relevant for the 37-71 GHz frequency range (continued)

No	Sharing and compatibility case	Source	Reference no.	Document title/scope	Key topics/results
6	IMT versus HAPS in the 38-39.5 GHz.	ITU-R	Report F.2475	Sharing and compatibility studies of high-altitude platform station systems in the fixed service in the 38-39.5 GHz frequency range.	This report includes the sharing and compatibility studies of HAPS systems in the 38-39.5 GHz frequency range with FS, MS and FSS to which the bands are allocated on a primary basis, and also with the SRS in the adjacent band. This report provides the sharing and compatibility studies referenced in Resolution 160 (WRC-15) to ensure the protection of the existing services allocated to the frequency range and considering relevant footnotes of Article 5 of the RR.
7	IMT versus HAPS in the 47.2-47.5 GHz.	ITU-R	Report F.2476	Sharing and compatibility studies of HAPS systems in the fixed service in the 47.2-47.5 GHz and 47.9-48.2 GHz frequency ranges.	This report includes the sharing and compatibility studies of HAPS systems in the 47.2-47.5 and 47.9-48.2 GHz frequency ranges with services to which the bands are allocated on a primary basis. It provides studies to ensure the protection of the existing services allocated to the frequency range, considering relevant footnotes of Article 5 of the RR.
8	IMT versus mobile.	ITU-R	Resolution 241 WRC-19	Use of the frequency band 66-71 GHz for IMT and compatibility with other applications of the mobile service.	Invites further studies on how to guide compatibility between IMT and other applications in the mobile service.

As can be seen, the operation of IMT in this frequency range must coexist with other incumbent services, specifically with EESS, SRS, FSS and HAPS. Several conclusions are derived from the sharing studies covered in the related Radio Regulations Resolutions. Also, further studies are under way regarding coexistence between IMT and other applications in the mobile service (for example, the multi-gigabit wireless systems WiGig technology).

In summary, the compatibility between services can be achieved via establishment of limits of the transmissions of IMT services, separation distances between interferer and victim stations as well as observing certain avoidance of transmissions through the geostationary orbital arc.

8.3.2 Technical conditions for IMT sharing and compatibility

As concluded from Table 64, a number of sharing and compatibility options between IMT and the other services have been identified. Table 65 provides an overview of technical conditions under which such options are technically feasible. It is noted that the specific local situation will dictate which and to what extent the technical conditions listed need to be applied.

As indicated above, the compatibility between services can be achieved via establishment of limits of the transmissions of IMT services, separation distances between interferer and victim stations as well as observing certain avoidance of transmissions through the geostationary orbital arc.

Table 65: Technical conditions for IMT sharing and compatibility in the 37 to 71 GHz frequency range

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
1	In-band sharing	IMT/IMT	Need for developing frequency arrangements for IMT in the bands 37-43.5 GHz and 47.2-48.2 GHz as well as 66-71 GHz band. Further studies are required.	Resolution 243 WRC-19, Resolution 241 WRC-19	
	Sharing in-band and adjacent band.	IMT/EESS, SRS, FSS.	Technical limits to ensure compatibility with EESS, SRS and FSS.	Resolution 243 WRC-19	Summary of limits are provided below.
	In-band sharing.	IMT/IMT.	Need to develop frequency arrangements for IMT in the bands 45.5-47.0 GHz. Further studies are required.	Resolution 244 WRC-19	

Table 65: Technical conditions for IMT sharing and compatibility in the 37 to 71 GHz frequency range (continued)

Sharing and compatibility case	Option	Interference type/ case	Technical conditions	Reference documents	Notes
2	In-band sharing.	IMT versus HAPS in 38-39.5 GHz.	Limits for HAPS to meet to trigger cross-border coordination and which IMT operators should consider.	Resolution 168 WRC-19	Compatibility studies cover the cross-border case but not the national scenarios of compatibility of IMT and HAPS.
	In-band sharing.	IMT versus HAPS in 38-39.5 GHz.	Results of compatibility studies are reported below.	Report F.2475	
	In-band sharing.	IMT versus HAPS in 47.2-47.5 GHz.	Results of compatibility studies are reported below.	Report F.2476	
3	In-band sharing.	IMT versus mobile.	Further studies are invited.	Resolution 241	

The studies, conducted mostly by ITU-R and the results of WRC-19, set conditions for sharing between IMT and other services; HAPS, EESS, space research and FSS. The main conclusions of those studies and the technical limits associated with the sharing of IMT and other services are reported below.

Coordination with HAPS in 38-39.5 GHz

Resolution 168 stipulates that for the purpose of protecting mobile-service systems operating in the frequency band 38-39.5 GHz in the territory of neighbouring administrations, coordination of a transmitting HAPS ground station is required when the pfd in dB(W/(m^2 · MHz)) at the border exceeds a pfd limit of −110.8 dB(W/(m^2 · MHz)). Also, the pfd values shall be verified one per cent of the time in the relevant propagation model of the most recent version of Recommendation ITU-R P.452 and at a mobile-station antenna height of 20 m.

ITU-R Report F.2475 contains several studies conducted on sharing between IMT and HAPS. One of these studies specifically provides an indication that sharing the band between a single HAPS ground station and a single mobile-service station is less challenging than sharing the band between a single conventional fixed-service station and a single mobile-service station. However, mobile-service deployment is expected to be based on a cluster of multiple base stations. The study provides sets of separation distances required to avoid harmful interference.

In some cases, mitigation techniques to avoid interference from IMT into HAPS stations could be considered to ease coordination and sharing feasibility, such as:

1) careful positioning of HAPS ground terminals with respect to incumbent systems;

2) applying site-shielding to the HAPS GW, when required and feasible, to reduce side-lobe radiation, while maintaining system performance.

The report also concluded that compliance with short-term-protection criteria is the most important factor, and that separation distances between MS and FS systems are higher than separation distances between MS and HAPS systems. The coordination areas for the protection of HAPS receiving ground stations will also be significantly smaller than coordination areas for HAPS receiving stations. Based on the results of this study, coordination between HAPS and IMT could be carried out with similar procedures as for coordination between HAPS and FS systems.

Another study cited in Report F.2475 concludes that, based on statistical analysis, the separation distance between a HAPS ground terminal and IMT-2020 UE is 0 km for less than 10 per cent of cases, and 2 km for 1 one in 100 000 cases. It also found that the separation distance between a HAPS ground terminal and an IMT 2020 BS is 0 km for less than 10 per cent of cases and 5 km for one in 100 000 cases (considering HAPS system six in a suburban deployment area with p = 0.01 for path loss and one per cent for clutter loss).

Another study cited in Report F.2475 concludes that in the worst case, separation distance (based on -minimum coupling losses [MCL]) between a HAPS gateway transmitter and an IMT-2020 base station receiver is between 0.25 km and 0.42 km. Also, the worst-case separation distance (based on MCL) between a HAPS gateway transmitter and a user terminal receiver, as derived in the form of graphs is from 0.2 km to 0.27 km with an elevation angle of 20 degrees for the HAPS gateway. These MCL) results are based on the maximum transmit power that will be transmitted during a small percentage of the time (such as during heavy rain).

Coordination with HAPS as results of compatibility studies reported in ITU-R Report F.2476 in the 47.2-47.5 GHz and 47.9-48.2 GHz bands

Two studies are reported for sharing HAPS and IMT in these bands.

Study A: The statistical analysis shows that the separation distance between a HAPS gateway and IMT-2020 UE is 0 km for less than 10 per cent of cases up to 1 km for one in 100 000 cases and that the separation distance between a HAPS gateway and IMT-2020 BS is 0 km for less than 10 per cent of cases up to 3 km for one in 100 000 cases (HAPS system six in a suburban deployment area with p = 0.01 for path loss and one per cent for clutter loss).

Study B. In this study, a sharing study between an IMT and HAPS ground stations operating in the 47.9-48.2 GHz frequency range is reported. Simulation results indicate that sharing is feasible under the assumptions and parameters that are described in this study. A summary of the most stringent margins show that the GW to HAPS (uplink) case indicates that the pfd mask (–116.8 dB(W/(m^2 · MHz)) can be met for 99.99 per cent of IMT base stations with a margin of at least 10.9 dB. This case represents a scenario that considers ubiquitous deployment of IMT networks and one HAPS gateway in the same geographical area.

Coordination with EESS

The compatibility between IMT and EESS has been studied by ITU-R and the technical conditions are established in Resolution 243 WRC-19, which resolves that in order to ensure compatibility between IMT in the frequency bands 37-40.5 GHz and the EESS (passive) in the frequency band 36-37 GHz, the following unwanted emissions of IMT stations operating in the frequency band 37-40.5 GHz apply as specified in Table 66.

Table 66: Unwanted emissions of IMT in the frequency band 37-40.5 GHz

Frequency band for the EESS (passive)	Frequency band for IMT stations	Unwanted emission mean power for IMT stations*	Recommended limits for IMT stations*
36-37 GHz	37-40.5 GHz	−43 dB(W/MHz) and−23 dB(W/GHz) within the frequency band 36-37 GHz	−30 dB(W/GHz)

* The unwanted emission power level is considered in terms of total radiated power (TRP). The TRP is to be understood here as the integral of the power transmitted from all antenna elements in different directions over the entire radiation sphere.

Compatibility with space research service (SRS) and radio astronomy

The compatibility between IMT and SRS has been studied by ITU-R and the technical conditions are established in Resolution 243 (WRC-19), which stipulates that protection of space research service (SRS) earth stations in the frequency band 37-38 GHz and RAS stations in the frequency band 42.5-43.5 GHz from IMT stations should be facilitated through bilateral agreements for cross-border coordination as necessary.

Compatibility with FSS

The compatibility between IMT and FSS has been studied by ITU-R and the technical conditions are established in Resolution 243 WRC-19, which resolves that:

1) When considering the spectrum to be used for IMT, due attention is paid to the need for spectrum for ubiquitous earth stations at unspecified points, as well as those used for gateways, taking into account spectrum identified in the frequency bands 39.5-40 GHz in Region 1, 40-40.5 GHz in all Regions, 40.5-42 GHz in Region 2 and 47.5-47.9 GHz in Region 1 for the HDFSS as per No. 5.516B.
2) Protection of and compatibility with fixed-satellite service (FSS) earth stations within the frequency ranges 37.5-43.5 GHz and 47.2-48.2 GHz should be facilitated through bilateral agreements for cross-border coordination as necessary.
3) Take practical measures to ensure the transmitting antennas of outdoor base stations are normally pointing below the horizon when deploying IMT base stations within the frequency bands 42.5-43.5 GHz and 47.2-48.2 GHz. The mechanical pointing needs to be at or below the horizon.
4) As far as practicable, sites for IMT base stations in the frequency bands 42.5-43.5 GHz and 47.2-48.2 GHz employing values of e.i.r.p. per beam exceeding 30 dB (W/200 MHz) should be selected so that the direction of maximum radiation of any antenna will be separated from the geostationary-satellite orbit, within line-of-sight of the IMT base station, by ±7.5 degrees.

8.3.3 Regulatory conditions for IMT sharing and compatibility

Table 67 provides a summary of the main regulatory elements to be observed in order to facilitate the deployment of IMT services in the range 37-71 GHz.

Table 67: Regulatory conditions specific for IMT licensees

No	Condition or requirement	Notes	References
1	Define frequency arrangements for IMT in the bands identified for IMT in the range 37-71 GHz.	Mandates from WRC-19 to ITU-R (WRC-19 Resolutions 243, 244)	ITU-R studies and WRC-19
2	Coordination of IMT and HAPS should be conducted similarly as IMT and FS.	Conclusions of compatibility studies ITU-R F.2475 and F.2476	ITU-R studies
3	Observe the pfd coordination triggers to ensure the protection of IMT from HAPS operating in the frequency band 38-39.5 GHz in a neighbouring country.	Regulatory provisions included in Resolutions 168 and 241 WRC-19	ITU-R studies and WRC-19
4	Protection of IMT from HAPS within a country developing both services in the band 38-39.5 GHz would require implementation of mitigation techniques (position of HAPS ground terminals, site-shielding for HAPS GW, etc.).	Recommendations from ITU-R Report F.2475	ITU-R studies
5	Set limits for IMT unwanted emissions in the frequency ranges 36-37 GHz resulting from IMT stations in the frequency range 37-40.5 GHz to protect EESS.	Resolution 243 WRC-19	ITU-R studies and WRC-19
6	Foresee the potential deployment of ubiquitous earth stations at unspecified points in the frequency bands 39.5-40 GHz in Region 1, 40-40.5 GHz in all Regions, 40.5-42 GHz in Region 2 and 47.5-47.9 GHz for HDFSS. Therefore Region 1 administrations are encouraged to use the upper band 40.5-43.5 GHz for IMT.	Resolution 243 WRC-19	ITU-R studies and WRC-19
7	Take practical measures to ensure the transmitting antennas of outdoor base stations are normally pointing below the horizon, when deploying IMT base stations within the frequency bands 42.5-43.5 GHz and 47.2-48.2 GHz. The mechanical pointing needs to be at or below the horizon.	Resolution 243 WRC-19	ITU-R studies and WRC-19

Table 67: Regulatory conditions specific for IMT licensees (continued)

No	Condition or requirement	Notes	References
8	As far as practicable, sites for IMT base stations in the frequency bands 42.5-43.5 GHz and 47.2-48.2 GHz employing values of equivalent isotropically radiated power (e.i.r.p.) per beam exceeding 30 dB (W/200 MHz) should be selected so that the direction of maximum radiation of any antenna will be separated from the geostationary-satellite orbit, within line-of-sight of the IMT base station, by ±7.5 degrees.	Resolution 243 WRC-19	ITU-R studies and WRC-19

8.3.4 Cross-border coordination aspects for IMT

As indicated in Sections 8.3.1 and 8.3.2, regarding technical conditions for operation, the coordination of IMT services at international level will require actions, including:

1) defining frequency arrangements for IMT services in order to facilitate sharing and compatibility with other IMT services in neighbouring countries;
2) applying the limits defined in Table 66 in order to protect EESS;
3) observing the limits defined by Resolutions 168 and 241 regarding maximum pfd values from HAPS which would trigger coordination;
4) applying coordination procedures for HAPS and IMT similar to those applicable for FS and IMT;
5) observing the recommended deployment practices of IMT services, as identified in Table 67 in order to protect FSS services.

8.4 Best practices and methods for refarming other services in the 37-71 GHz frequency range

The introduction of IMT services in the bands 37-71 GHz would not require refarming other services, as, so far, only conditions to protect other services have been identified and deployment for some other services has not yet happened. The identifications for IMT in this frequency range have been adopted based on studies showing compatibility with other services, for the typical scenarios and interference environment considered.

8.5 Guidelines and recommended actions for the 37-71 GHz frequency range

Sections 8.1 to 8.4 cover the spectrum allocations for IMT and other services in the frequency range 37-71 GHz, the technical and regulatory conditions facilitating IMT introduction in this band, as well as considerations on refarming the other services.

Table 68 provides a comprehensive list of guidelines as included in these sections.

Table 68: Spectrum-management guidelines for IMT introduction in the 37-71 GHz frequency range

No	Guideline	Applies to	Ref. Section(s)
8.1	Advanced frequency-planning coordination is recommended at the earliest stage of the frequency assignment process, as there would be technical elements strongly associated with the technologies being deployed for IMT systems in each country. This work could also include preparatory coordination work among operators concerned. However, in the ideal case, the frequency assignments should be coordinated with neighbouring countries at earlier stages, even before the specific frequency assignments to each operator have been concluded. The cross-border coordination between administrations can be undertaken bilaterally or multilaterally.	IMT services	Section 8.3.4
8.2	Apply the conditions derived from WRC-19, particularly Resolutions 168, 241, 242, 243, 244, particularly on limits to protect EESS and recommended practices to facilitate coexistence with HAPS, FSS and SRS.	IMT deployment and coexistence with other services	Section 8.3.2
8.3	Consider the gradual introduction of the IMT service in each of the identified bands for its deployment: • 37.0-43.5 GHz for all Africa, particularly in the range 40.5-43.5 GHz; • 45.5-47.0 GHz for most African countries; • 47.2-48.2 GHz for most African countries; • 66.0–71.0 GHz for all Africa.	IMT deployment	General

9 Guidelines for the transition from ATV to DTTB

To assist countries to transition from analogue television (ATV) to digital terrestrial television broadcasting (DTTB), ITU has developed a comprehensive framework and set of guidelines. Three editions of the *Guidelines for the transition from analogue to digital broadcasting* have been published, with the latest in 2014.[179]

Before addressing these guidelines in more detail, it is important to note that various elements have since changed, including:

1) The 2014 edition of the Guidelines, which covers all three ITU Regions and most guidance is applicable to all Regions. However, the guidance on the Geneva 2006 Agreement (GE-06) is only relevant for the planning area of this Agreement, which includes Region 1 and all African countries.[180] The GE-06 Agreement stipulates that the transition period with regard to VHF Band III ended on 17 June 2015 (or 17 June 2020 for some countries).[181] As indicated in Section 1.3.2, ATV services can no longer claim protection and must not cause harmful interference to any assignments in conformity with the GE-06 Agreement and its associated plans. Article 12.8 of that Agreement allows the continuation of analogue stations on a non-interference and non-protection basis. It is noted that, although these deadlines have passed, GE-06 is in force and arranges for the available spectrum in each country as well as for the cross-border coordination. As addressed in Section 1.3.4 the cross-border procedures of GE-06 should be followed, in case plan entries are used for IMT.
2) The 2014 edition of the Guidelines, which covers mobile TV (MTV) systems, defined as the delivery of linear television services to handheld devices over broadcasting networks. Although various transmission standards (such as DVB-H, T-DMB and Media FLO) have been developed and introduced, all these MTV services have been discontinued. They have been replaced by LTE evolved multimedia broadcast multicast services (eMBMS) and FeMBMS (further-evolved multimedia broadcast & multicast).[182] As part of the Release 16 framework, 3GPP will further develop LTE-based terrestrial broadcasting. The proposed solution, also known as 5G Broadcast, will be able to deliver linear broadcasting services from one or more transmitters in a single-frequency network (SFN) to multiple receivers. This SFN can be implemented on a dedicated broadcasting infrastructure (typically high-power high-tower) whereby the broadcasting signals are delivered to handsets having the LTE/5G chip sets. The following is noted for regulators considering LTE/NR based broadcasting solutions:

    a. The mobile network operator will have to balance its unicast traffic (i.e. data/voice communications with individual subscribers) against broadcast traffic. For broadcasting mode, the network operator will have to allocate a part of the available (aggregated)[183] bandwidth to the broadcasting service. Consequently, the operator will have less capacity available for unicast traffic. Such traffic-balancing will be driven by the

[179] The ITU guidelines on the transition from analogue to digital broadcasting are freely available on the ITU website.
[180] The GE-06 Agreement covers the frequency bands 174-230 MHz and 470-862 MHz.
[181] The countries with a prolonged transition period in Band III are listed in footnote 7 related to Article 12 of the GE-06 Agreement.
[182] FeMBMS was defined in 3GPP Release 14.
[183] Carrier aggregation will be needed.

profitability of both services. Hence, regulators considering such LTE/NR based solutions for free-to-air broadcasting will have to take this into account and arrange for it. Such regulatory arrangements may be too intrusive on the mobile network operator's operation.

b. LTE/NR broadcasting signals are primarily intended for delivery to handheld devices with relatively small screens. The feasibility of delivery to ultra-high-definition television (UHDTV) on large screens is questionable because the bandwidth claim may be too large (see below).

c. LTE/NR free-to-air broadcasting services (as a replacement for DTTB free-to-air services) are likely to come with a regulatory requirement to be available nationwide for a sustained period of many years. Although, LTE/NR-based solutions can technically arrange for this, they are designed to make broadcasting services temporarily available in selected areas of the network.

3) The 2014 edition of the Guidelines covers so-called first- and second-generation transmission standards[184], such as DVB-T and DVB-T2. At that time DVB-T2 was the only commercially available second-generation standard in the market. This has changed with the first major commercial introduction of ATSC 3.0 in the Republic of Korea.[185] Also, the high-efficiency video coding (HEVC/H.265) for DTTB receivers (and other devices) became commercially available, as opposed to the MPEG-4 coding (also referred to as MPEG-AVC/H.264). Second-generation transmission standards (ATSC 3.0 and DVB-T2) in combination with HEVC coding will substantially lower the required capacity in Mbit/s per service. Hence, the spectrum needed in MHz for delivering a same number of television services will also be lower.[186]

4) In 2014, the common market standard for video quality was high-definition television (HDTV). Nowadays ultra-HDTV (UHDTV, also known as 4k) with 5.1 or multichannel sound services are becoming the market standard.[187] Such a market requirement would, however, increase the required capacity in Mbit/s per service. Hence, the spectrum needed in MHz for delivering a same number of television services will also be higher.

5) Finally, the 2014 edition includes the results of WRC-12 but not of WRC-15 and WRC-19. However, the impact on the guidance as provided in the 2014 edition is minimal, other than that more bands have been identified for IMT in the broadcasting bands (see Sections 1.1, 2.1 and 3.1).

6) Furthermore, Resolution 235 of WRC-15 invited ITU-R, after WRC-19 and by the time of WRC-23, to:

a. review the spectrum use and spectrum needs of existing services, in particular the broadcasting and mobile services, within the frequency band 470-960 MHz in Region 1;

b. carry out sharing and compatibility studies between the broadcasting and mobile services in the band 470-694 MHz.

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184 The systems covered by Recommendation BT.1306 are also referred to as first-generation systems, and the systems covered by Recommendation BT.1877 as second-generation systems. The second generation of DTTB systems is meant as systems offering higher bit-rate capacity per Hz and better power efficiency in comparison to the systems described in Recommendation ITU-R BT.1306. It is noted that there is no backward compatibility with first-generation systems.

185 The first major deployment of ATSC 3.0 was in the Republic of Korea, with the country's major television networks launching terrestrial ATSC 3.0 services in May 2017 in preparation of the 2018 Winter Olympics.

186 Given other parameters being equal, such as population/area coverage, reception mode (indoor and outdoor) and the video definition (HDTV or UHDTV).

187 ITU defines 4k also as UHDTV-1 and 8k as UHDTV-2.

WRC-23 will consider the subject under agenda item 1.5 and decide accordingly on the possible regulatory actions in the frequency band 470-694 MHz in Region 1.

The band 470-694/698 MHz was a candidate band for IMT identification in the three ITU regions at WRC-15. While all countries of Region 1 agreed that no IMT identification in this band should be made at that conference and to reconsider the band at WRC-23, according to Resolution 235, countries of Regions 2 and 3 were divided into three groups:

- countries that identified the whole band (i.e. 470-608 and 614-698 MHz in Region 2 and 470-698 MHz in Region 3) for IMT;
- countries that only identified the upper part of the band (i.e. 614/610-698 MHz) for IMT; and,
- countries with no IMT identification in this band.

Given these above-listed changes, the functional framework as presented in the 2014 Guidelines has been adjusted and is presented in Section 9.1. Following this adjusted framework, three different transition statuses are identified for African countries. These three statuses will drive:

1) which parts of the functional framework are most relevant for the different groups;
2) the options for advancing the transition process, and;
3) the specific implementation aspects.

This tailoring of the functional framework for the different country groups is addressed in Section 9.2.

9.1 Adjusted functional framework for the ATV to DTTB transition

The functional framework included in the 2014 edition of the guidelines, comprises five functional layers. In turn, each layer includes several functional building blocks, each of which provides guidelines on key topics and choices. The functional blocks on MTV can be removed as well as the blocks on roadmap development (as most African countries have already commenced the transition, although have not yet switched off ATV). The resulting adjusted functional framework is presented in Figure 15.

Figure 15: Adjusted functional framework of the Guidelines on the transition from ATV to DTTB

Source: ITU

The following is noted on Figure 15:

1) The numbering of the functional building blocks, as included in Figure 15, has not changed. Hence the reader can refer to the same sections/blocks in the ITU Guidelines.
2) Functional building block 4.7 is missing as this block was addressing the shared and common design principle between the DTTB and MTV networks. For example, in selecting the transmitter sites and equipment, the network operator will consider both networks' requirements and possible cost savings when infrastructure is shared. Although the MTV technology is replaced by LTE FeMBMS and in the near future may be replaced by 5G broadcast, these sharing considerations may become relevant again. As 5G broadcast is intended to be deployed on typical broadcasting infrastructure (i.e. high-power high-tower) the DTTB network development may have to consider 5G broadcast too.
3) For the detailed considerations and guidelines as provided for each functional building block, the reader is referred to the ITU Guidelines. However, in Section 9.2, the following are addressed for the different groups of African countries:

   a. most-relevant building blocks;
   b. options for moving forward the transition process;
   c. specific key implementation aspects.

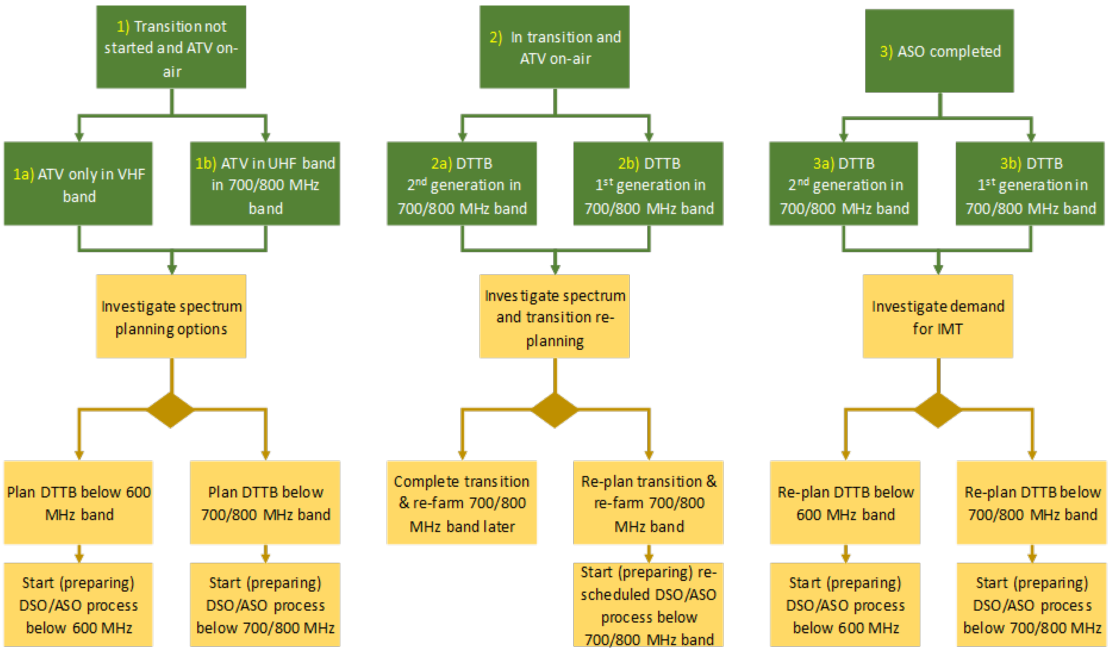
9.2 Functional blocks and implementation aspects per group of African countries

From the Explanatory Memorandum for PRIDA track 1, Action 1.2, it can be concluded that most African countries are in the transition process (i.e. DTTB and ATV services on-air), although some countries have completed the digital switch-over (DSO) and analogue switch-off (ASO) process[188], while others have not yet started the DSO/ASO process.

These three groups of African countries have different options for moving forward in the DSO/ASO transition, for the purpose of freeing up more spectrum for IMT. These different options are depicted in Figure 16.

The options that involve planning the DTTB services below 600 MHz are only applicable for countries that currently have low demand for terrestrial television broadcasting services. This does not imply freeing up the 600 MHz spectrum for the implementation of IMT services but to avoid the need for replanning the UHF band again, should WRC-23 decide on additional IMT identification and future demand for IMT spectrum exceed the available spectrum.

Figure 16: Different options for moving forward the DSO/ASO process



The following is noted on Figure 16:

1) African countries in group 1) can be split into two subgroups: 1a) countries with ATV services only in the VHF Band III[189] and 1b) other countries with ATV services (also) in the UHF band, and then most likely in 700/800 MHz band. For both subgroups, spectrum replanning options should be investigated:

   a. For group 1a), as the UHF band is not in use for television broadcasting, the option of planning DTTB services below the 600 MHz band may be feasible because:

[188] Digital switch-over (DSO) means that the incumbent ATV services are broadcast on the DTTB platform. In other words, the ATV services are simulcasted (or dual illumination) on the DTTB platform. Analogue switch-off means that after a simulcast period the ATV services are switched off.

[189] Such as Ivory Coast, see PRIDA Explanatory Memorandum.

i. The current demand for television broadcasting services was, up to now, catered for in the VHF band. Implying a relative low number of (national) television services with a low video quality.
ii. The choice for the DTTB transmission standard and coding may still be open. Countries yet to commence the transition can opt for the latest second-generation transmission standard and HEVC encoding. This would facilitate up to 12 HD television services in one multiplex (see Figure 17).[190]
iii. In deciding to replan below 600 MHz, also the future demand of UHDTV services should be considered, alongside the demand for IMT services. UHDTV (4k) services may take up the full capacity of a single multiplex (up to 40 Mbit/s, not shown in Figure 17). However, it is debatable if such high bit rate is necessary. In this context is important to note that services like Netflix already offer UHDTV services at a speed of 15 Mbit/s. Furthermore, it is noted that with the second-generation transmission standards, the Shannon limit has practically been reached.[191] With FeMBMS and 5G Broadcast, this limit cannot be passed because the applied transmission technologies are the same as for DVB-T2/ATSC 3.0 and the transmission efficiency is similar. Hence any future improvements may have to come from improved encoding technologies (beyond HEVC/ ITU H.265).[192]

b. For group 1b) the demand for television services is assessed to be higher. The feasibility of planning DTTB below 600 MHz will depend on:

   i. Under the assumption that the 600 MHz band comprises TV channels 38-48 and that the available channels would be 21-37, that would leave 17 channels in which to plan DTTB. DTTB network-planning in various countries has shown that, on average, four to five frequencies are needed to plan one multiplex for nationwide coverage. This would result in enough spectrum for three nationwide multiplexes with 12 HD services in each multiplex (see Figure 17), i.e. 36 television services in total.
   ii. If HD quality is not considered a long-term option and it is required to plan for UHDTV, two services could be fitted in one multiplex, resulting in a total of six services. Whether this number is considered too low will depend on what is considered to be a minimum number of television services to be available (possibly free-to-air) on the terrestrial platform (i.e. the universal service requirement). Other alternatives in the market for television viewers should be considered in this decision, for example satellite and LTE-based broadcasting, although such an alternative would not be free-to-air unless stipulated by the regulator. In this context, it is also noted that in most African countries, wired broadband infrastructure is limited (and is missing) and the importance of the terrestrial platform is therefore different from most countries in Europe.

2) African countries in group 2 can be split in two subgroups; 2a) countries in the transition of deploying second-generation DTTB receivers and 2b) countries with deploying first-generation receivers. For both groups it should be investigated what options exist for replanning the DTTB spectrum and transition process:

   a. Depending on the transition stage (at the beginning or at the end), for the group 2a countries, a more likely option is probably to replan the 700/800 MHz band after completing the DSO/ASO process because:

[190] It is noted that spectrum needed for deploying DTTB services is also dependent on coverage requirements, reception mode, possibilities for MFN/SFN, statistical multiplex gain.

[191] The Shannon limit or Shannon capacity of a communication channel refers to the maximum rate of error-free data that can theoretically be transferred over the channel.

[192] A new video compression standard, that will need half the bit rate of HEVC, was announced in July 2020 by the Joint Video Experts Team (JVET), a partnership of ITU, ISO and IEC. It is called the 'Versatile Video Coding' and will be published as ITU H.266.

i. Under the assumption that DVB-T2/MPEG4 is deployed, the spectrum efficiency gain is far less than in the case for countries deploying first-generation receivers (see Figure 17).
ii. Under the assumption that DTTB viewers are purchasing the receiver equipment (possibly with a form of subsidy), it would be a big ask for them to purchase a new HEVC receiver.
iii. However, the demand for IMT spectrum will also play a key role and may force regulators to replan the 700/800 MHz before completion of the running transition process.[193]
iv. For replanning the 700/800 MHz band, the approach as presented in Figure 3 in Section 1.4.1 could be followed.

b. For the group 2b countries, the situation may be assessed differently as the spectrum-efficiency gains can be very large. Depending on the transition stage, it may be possible to replan the process and the spectrum plan. The following is noted:

i. Such a replanning process is far more complex as it will require intense communication with viewers as two types of receivers are involved in the process. Also, the process will have to deal with the ASO as well as the phasing out of first-generation DTTB receivers.[194]
ii. As the spectrum-efficiency gains are potentially large, the digital dividend for IMT services may also be significant. Hence, under the assumption of an IMT auction, the regulator may reserve some of the auction proceeds to finance the replanning and to subsidize new DTTB receivers. It is noted that this option of using auction proceeds is also possible under the other options presented, although for the group 2b countries, the willingness for the IMT industry to cooperate is assessed to be greater.

3) African countries in group 3 can be split into two subgroups: 3a) countries with a completed DSO/ASO process and an installed base of second-generation DTTB receivers and 3b) countries with an installed base of first-generation receivers. For both groups it should be investigated what options exist for replanning the DTTB service below the 600 MHz band:

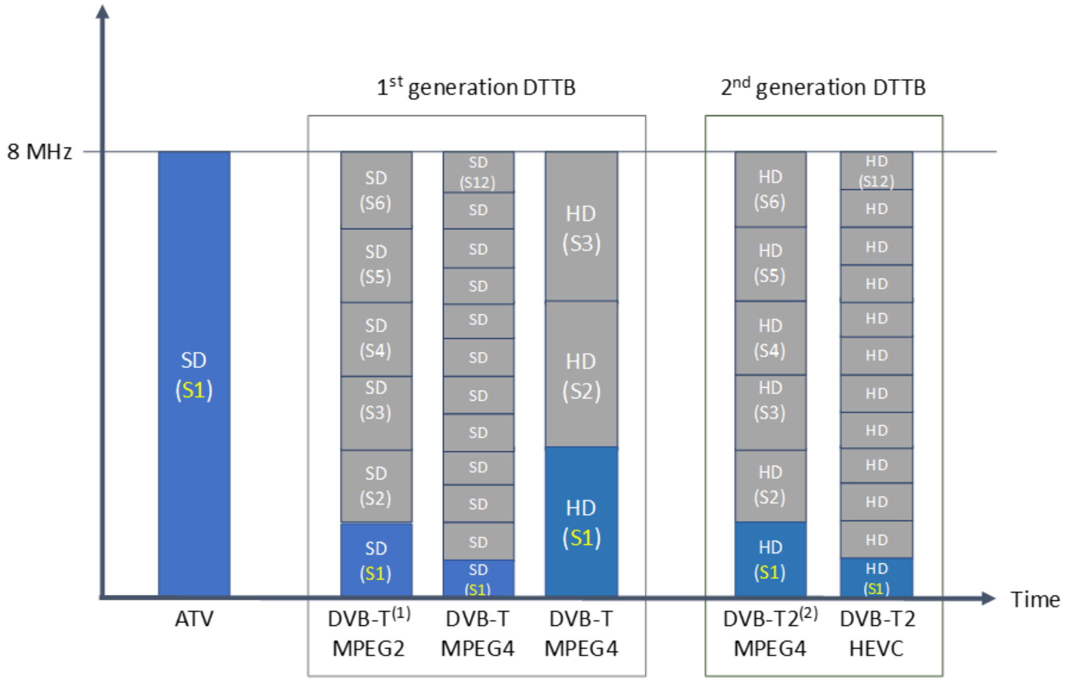
a. For both subgroups the demand for IMT and HD/UHDTV should be assessed (see above for more details on this assessment.

b. For replanning services either below 600 MHz or below 700/800 MHz, the approach as presented in Figure 3 in Section 1.4.1 could be followed.

[193] South Africa is currently still in transition with deploying DVB-T2/MPEG4 and has recently decided to restack (refarm) the 700 and 800 MHz bands so as to accelerate the introduction of IMT in these bands.

[194] The United Kingdom is an example of a country that went through such a complex process as the initial DSO started with DVB-T (first-generation DTTB receivers) and the transition process was replanned for the introduction of DVB-T2. It is noted that the transition of the United Kingdom was relatively long due to the country being an early-adopter (and hence starting with DVB-T) with a phased DSO/ASO approach and a requirement for simulcasting. The requirement for simulcasting may now be more relaxed because of the reliability of DTTB technology and the limited risk of viewers having to revert to the legacy technology.

Figure 17: Number of TV services per multiplex under different DTTB options



(1) Net bit rate: 24 Mbit/s (64QAM, CR 2/3)
(2) Net bit rate: 40 Mbit/s (256 QAM, CR 2/3)

Table 69 shows what the most relevant functional building blocks are for the different groups of African countries (as included in Figure 16), as well as some key implementation elements.

Table 69: Functional build blocks and implementation elements per group of African countries

	1) Transition not started and ATV on-air		2) In transition and ATV on-air		3) ASO completed	
	1a) ATV only in VHF band	1b) ATV in UHF band in 700/800 MHz band	2a) DTTB 2nd gen. in 700/800 MHz band	2b) DTTB 1st gen. in 700/800 MHz band	3a) DTTB 2nd gen. in 700/800 MHz band	3b) DTTB 1st gen. in 700/800 MHz band
Blocks	All	All	2.1, 2.4-2.13, 2.16-2.18, 4.1-4.9	2.1, 2.4-2.13, 2.16-2.18, 4.1-4.9	2.1, 2.4-2.13, 3.1, 3.2, 3.4, 3.5 2.16-2.18, 4.1-4.9	2.1, 2.4-2.13, 3.1, 3.2, 3.4, 3.5 2.16-2.18, 4.1-4.9
Elements	• Planning below 600 MHz band may be feasible; • ATV VHF rooftop antennas need to be replaced; • The selection of second-generation receivers with HEVC encoding is recommended; • Any support for viewers should consider installation aid for replacing rooftop antennas; • Simulcast period may be longer due to VHF antenna-replacement programme; • Alternatively, indoor reception could be planned for, avoiding the need for a DTTB rooftop antenna. More DTTB sites are likely to be necessary, depending on reception areas and modulation scheme • ATV viewers not served by the new DTTB network could be offered an LTE/NR solution, although this would require a significant regulatory intervention and the television services would be intended for smaller screens.	• Planning below 600 MHz may be feasible; • The selection of second-generation receivers with HEVC encoding is recommended; • ATV UHF antenna may be reused, depending on the state of the antenna; • Simulcast period may not be necessary (or very short), accelerating the DSO/ASO process • ATV viewers not served by the new DTTB network could be offered an LTE/NR solution, although this would require a significant regulatory intervention and the television services would be intended for smaller screens.	• Restacking below 700/800 MHz during transition may be possible but complex; • Viewers may have to retune their receivers and possibly redirect their DTTB antenna; • Alternatively, the current DSO/ASO process can be accelerated and completed, followed by restacking later; • A change to second-generation/HEVC could be considered, to enable refarming below the 600 MHz band.	• Restacking below 600 MHz during transition may be possible but more complex; • Viewers may have to retune their receivers and possibly redirect their DTTB antenna; • Phasing out of ATV and DTTB receivers; • Alternatively, the current DSO/ASO process can be accelerated and completed, followed by restacking later; • A change to second-generation/HEVC is a real option, to enable refarming below the 600 MHz band.	• Restacking below 600 MHz may be possible; • A change to second-generation/HEVC could be considered, to enable refarming below the 600 MHz band.	• Restacking below 600 MHz may be possible • A change to 2nd generation/HEVC is a real option, to enable refarming below the 600 MHz band.

9.3 Guidelines and recommended actions for the transition from ATV to DTTB

Table 70 provides a comprehensive list of guidelines as included in this Section 9.

Table 70: Guidelines for the transition from ATV to DTTB

No	Guideline	Applies to	Reference to Section(s)
10.1	Administrations or regulators addressing the transition from ATV to DTTB should give due consideration to the latest developments, including: • Passing of the GE-06 deadlines and no protection of ATV services; • MTV technologies being replaced by LTE/NR-based solutions. Such new solutions may not be able to replace nationwide free-to-air broadcasting to households (with large screens); • Second-generation/HEVC receivers may facilitate more restacking options for freeing up IMT spectrum; • The growth of UHDTV will require more DTTB spectrum, if considered necessary.	All African countries still to start the DSO/ASO transition, already in transition or having completed the transition (and considering restacking DTTB networks).	Introduction of Section 9
10.2	The ITU Guidelines for the transition from ATV to DTTB should be considered, in the light of the latest developments and the scope of the functional building blocks included, to have been adjusted.	As above	Section 9.1
10.3	African countries can be categorized in different groups, reflecting the different states of transition. These different groups have different options for moving forward the DSO/ASO transition, as included in Figure 16. Also, different key implementation aspects should be considered, as included in Table 69.	As above	Section 9.2

10 Technical conditions for IMT introduction in incumbent mobile bands

The purpose of this section is to identify which technical conditions will be required to make available the 900 MHz, 1 800 MHz and 2 GHz bands for the introduction of the latest wireless broadband technologies.

10.1 Background on the regulation and context of IMT use in the 900 MHz, 1 800 MHz and 2 GHz bands

Note should be made that the management of spectrum for compatibility among different IMT services within a country or the technology to be used (or alternatively, the technology-neutral regulation) is closely related to the national criteria for planning and managing the spectrum.

Consequently, understanding that the technical compatibility and sharing studies between IMT and other services have been already conducted by ITU-R, the principles associated with the specific usage of the IMT, including its efficient use for wireless broadband services, rely on the follow-up studies and regulation developed by national administrations and regional organizations.

This is the main reason why most of the references provided in this section rely on studies, recommendations, reports or regulatory decisions adopted by regional organizations or the European Union. It is considered that such European references on the regulatory measures to stimulate the implementation of wireless broadband services in incumbent frequency ranges identified for IMT could be a valuable reference to guide further decisions by African spectrum-regulatory authorities.

The frequency ranges under assessment are:

1) 900 MHz (880-915 and 925-960 MHz);
2) 1 800 MHz, B2 and B4: 1 710-1 785 MHz (UE Tx) and 1 805-1 880 MHz (BS Tx);
3) 1 900 MHz, B3, B4: 1 850-1 920 MHz (UE Tx) and 1 930-2 000 MHz (BS Tx);
4) 2 GHz, B1: 1 920-1 980 MHz (UE Tx) and 2 110-2 170 MHz (BS Tx).

A summary of the recommended frequency arrangements for implementation of IMT is duly reported in many documents.[195]

It is relevant to note the following definitions:

1) 'GSM system' means an electronic communications network as specified by ETSI standards, in particular EN 301 502, EN 301 511, and EN 301 908-18, also including Extended Coverage GSM IoT (EC-GSM-IoT);

[195] Documents of reference: ECC Report 082, ECC Report 096, CEPT Report 040, CEPT Report 041, CEPT Report 042, CEPT Report 019, ECC /DEC (06)01, ECC/REC/(01)01.

2) the '900 MHz band' means the 880-915 MHz and 925-960 MHz bands;
3) the '1 800 MHz band' means the 1 710-1 785 MHz and 1 805-1 880 MHz bands.

10.2 Summary of relevant studies on compatibility of IMT services with respect to other services

Several studies and regulatory decisions have been conducted or issued towards the implementation of advanced technologies in the GSM bands. Among them:

1) ECC Report 082 – Compatibility study for UMTS operating within the GSM bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz bands). This report gives the description of the sharing study methodology, coexistence scenarios, simulation assumptions, and the simulation results for the deployment of UMTS operating in the 900 MHz and in 1 800 MHz bands in urban and in rural areas. Based on the sharing study results and the analysis, it can be concluded that UMTS900/1800 can be deployed in urban, suburban and rural areas in coexistence with UMTS and/or GSM under the following conditions:

    a. UMTS900/1800 networks can coexist with other UMTS900/1800 networks in the same geographical area with a carrier separation of 5 MHz. The recommended carrier separation between two uncoordinated UMTS networks is 5 MHz or more. The recommended carrier separation in coordinated operation, for example, multiple carriers over the same UMTS network, is 5 MHz or less, in the same way as for the core band.
    b. UMTS900/1800 can be deployed in urban, suburban and rural areas in coexistence with GSM900/1800 macro-cells in coordinated operation and/or in uncoordinated operation. When UMTS900/1800 networks and GSM900/1800 networks are in uncoordinated operation, the recommended carrier separation between UMTS carrier frequency and the nearest GSM carrier frequency is 2.8 MHz or more. When UMTS900/1800 networks and GSM900/1800 networks are in coordinated operation (co-located sites), the recommended carrier separation between UMTS carrier frequency and the nearest GSM carrier frequency is 2.6 MHz or more.
    c. UMTS900/1800 can be deployed in urban, suburban areas in coexistence with GSM900/1800 microcell and/or picocell in uncoordinated (non-located sites between different networks) operation. The recommended carrier separation between the UMTS carrier frequency and the nearest GSM microcell and/or picocell carrier frequency is 2.8 MHz or more. It is suggested that the UMTS carrier should be placed as far as possible from GSM microcell and/or picocell carrier frequencies.
    d. One possible solution is for the operator to separate their UMTS carriers and their GSM microcell and/or picocell carrier frequency sub-band by the GSM macro-cell carrier frequency sub-band.

2) ECC Report 096 – Compatibility between UMTS 900/1800 and systems operating in adjacent bands. Further conclusions on this study are reported in the section dealing with adjacent band studies (see Section 10.5).
3) CEPT Report 040 – Compatibility study for LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz bands); the conclusions of the several scenarios studied rely on a certain frequency separation between LTE, WiMAX and UMTS/GSM carriers.
4) CEPT Report 041 – Compatibility between LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz

bands) and systems operating in adjacent bands. This report concludes that introducing LTE and WiMAX into the 900 and 1800 MHz bands should not cause any additional impact on adjacent services.

5) CEPT Report 042 – Compatibility between UMTS and existing and planned aeronautical systems above 960 MHz. This report investigates compatibility between UMTS and adjacent band systems above 960MHz. It reviews the risk of interference between UMTS and existing and planned aeronautical systems above 960 MHz, in order to enable the development of all systems below and above 960 MHz without taking a risk relating to aeronautical safety. The report focuses on the compatibility between UMTS 900 on the one hand, and the aeronautical systems (existing: DME and future: L-band digital aeronautical communication system (L-DACS)) in the band 960-1 215/1 164 MHz, on the other.
6) CEPT Report 019 – Report from CEPT to the European Commission in response to the mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS. This report addresses the BEM concept which consists of defining a power/frequency envelope within which radio emissions must remain. This is done by specifying in-block as well as out-of-block transmission power. It gives the operators the certainty of their transmission rights and freedom to choose mainly among three parameters:

   a. the EIRP in-block power;
   b. the minimum frequency separation from edge of outermost channels;
   c. the transmit spectrum mask-attenuation enhancements.

   The BEM is still valid without any coordination between operators for all applications whose characteristics are included in the WAPECS reference system. This concept allows operators to increase density of deployment, even without reducing transmission powers. For controlling the occurrence probability of worst cases caused by unforeseen new technologies, the BEM should be supplemented by a minimum antenna gain.
7) ECC /Decision (06)01 – (Reviewed in 2019.) – The harmonized utilization of the bands 1 920-1 980 MHz and 2 110-2 170 MHz for mobile/fixed communications networks (MFCN) including terrestrial IMT systems. This decision updates previous regulatory elements and introduces the flexibility for other frequency-channelling than 5 MHz by defining the block edge frequency instead of the carrier centre frequency, enabling the deployment of larger channel bandwidths.

10.3 Some considerations on relevant regulatory decisions in Europe regarding 900 MHz, 1 800 MHz and 2 GHz

As a worldwide reference on regulatory actions to promote the upgrade of the efficient use of the mobile-service bands, the European Commission adopted several decisions relevant for consideration in the process of making available the 900 MHz, 1 800 MHz and 2 GHz bands for the introduction of the latest wireless broadband technologies.

While the bands are kept for traditional GSM applications, the regulation requires administrations to designate and make available these bands for those other terrestrial systems capable of providing electronic communications services as listed in Table 71, subject to the conditions and implementation deadlines laid down therein. These include:

1) 2009/766/EC: Commission Decision of 16 October 2009 on the harmonization of the 900 MHz and 1800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community.
2) 2011/251/EU: Commission Implementing Decision of 18 April 2011 amending Decision 2009/766/EC on the harmonization of the 900 MHz and 1 800 MHz frequency bands for

terrestrial systems capable of providing pan-European electronic communications services in the Community.

3) Commission Implementing Decision (EU) 2018/637 of 20 April 2018 amending Decision 2009/766/EC on the harmonization of the 900 MHz and 1 800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community as regards relevant technical conditions for the Internet of Things.

4) EU Decision 2020/667: Commission Implementing Decision (EU) 2020/667 of 6 May 2020 amending Decision 2012/688/EU as regards an update of relevant technical conditions applicable to the frequency bands 1 920-1 980 MHz and 2 110-2 170 MHz.

Table 71 also includes the technical implementation parameters required for these other systems. These parameters shall be applied as an essential component of conditions necessary to ensure compatibility, in the absence of bilateral or multilateral agreements between neighbouring networks, without precluding less stringent technical parameters if agreed among the operators of such networks.

Table 71: List of terrestrial systems providing electronic communication services

Systems	Technical parameters	Implementation deadlines	Reference
UMTS complying with UMTS Standards, as published by ETSI, in particular EN 301 908-1, EN 301 908-2, EN 301 908-3 and EN 301 908-11,	1. Carrier separation of 5 MHz or more between two neighbouring UMTS networks 2. Carrier separation of 2.8 MHz or more between a neighbouring UMTS network and a GSM network.	To be determined by administrations. As reference, the European Union set 9 May 2010.	Decision European Union 2009/766/EC
LTE complying with LTE standards, as published by ETSI, in particular EN 301908-1, EN 301908-13, EN 301908-14, and EN 301908-11.	1. A frequency separation of 200 kHz or more between the LTE's and the GSM carrier's network channel edges. 2. No frequency separation is required between the channel edges of a neighbouring LTE and the UMTS carrier's networks. 3. No frequency separation is required between LTE channel edges of two neighbouring LTE networks.	To be determined by administrations. As reference, the European Union set 31 December 2011.	Decision European Union 2011/251/EU
WiMAX complying with WiMAX Standards, as published by ETSI, in particular EN 301908-1, EN 301908-21 and EN 301908-22.	1. A frequency separation of 200 kHz or more between the channel edges of WiMAX and the GSM carrier's neighbouring networks. 2. No frequency separation is required between the channel edges of WiMAX and the neighbouring UMTS carrier's network. 3. No frequency separation is required between the channel edges of two neighbouring WiMAX networks.	To be determined by administrations. As reference, the European Union set 31 December 2011.	Decision European Union 2011/251/EU

Table 71: List of terrestrial systems providing electronic communication services (continued)

Systems	Technical parameters	Implementation deadlines	Reference
Narrowband IoT (NB-IoT) as specified by ETSI standards, in particular EN 301 908-1, EN 301 908-13, EN 301 908- 14, EN 301 908-15, and EN 301 908-18.	1.Standalone mode: • A frequency separation of 200 kHz or more between the standalone NB-IoT channel edge of a network and the UMTS/LTE channel edge of the neighbouring network; • A frequency separation of 200 kHz or more between the channel edges of a standalone NB-IoT network and the neighbouring GSM network. 2. In-band mode: the same parameters apply as for LTE. 3. Guardband mode: a frequency separation of 200 kHz or more, between the NB-IoT channel edge and the edge of the operator's block, considering existing guardbands between operators' block edges or the edge of the operating band (adjacent to other services).	To be determined by administrations. As reference, the European Union set 30 September 2018.	Decision European Union 2018/637/EU

The use of the 900 MHz and 1 800 MHz bands for other terrestrial systems not listed in Table 71 is possible provided they ensure that:

1) such systems can coexist with GSM systems;
2) such systems can coexist with other systems listed in Table 71, both on their own territory and in neighbouring Member States.

10.4 Recommended technical conditions for operation of wireless broadband networks in-band with incumbent applications (in-band studies)

Based on studies conducted by CEPT, compatibility of operation of new wireless broadband systems and conventional GSM services has been assessed. CEPT Report 40 addresses technical coexistence within the 900/1 800 MHz bands (in-band studies). Its conclusions are summarized below.

Based on the analysis of the simulation results of the interference between LTE/WiMAX and GSM, the frequency separation between the LTE/WiMAX channel edge and the nearest GSM carrier's channel edge is derived as follows:

1) When LTE/WiMAX networks in 900/1 800 MHz band and GSM900/1800 networks are in uncoordinated operation, the recommended frequency separation between the LTE/WiMAX channel edge and the nearest GSM carrier's channel edge is 200 kHz or more.
2) When LTE/WiMAX networks in 900/1 800 MHz band and GSM900/1800 networks are in coordinated operation (co-located sites), no frequency separation is required between the channel edges of the LTE/WiMAX and the nearest GSM carrier.

The recommended frequency separation of 200 kHz or more for the uncoordinated operation can be reduced based on agreement between network operators, bearing in mind that the LTE/WiMAX wideband system may suffer some interference from GSM due to LTE/WiMAX BS/UE receiver narrowband blocking effect.

Based on the analysis of the simulation results of the interference between LTE/WiMAX and UMTS, there is no frequency separation required between the channel edge of the LTE/WiMAX and the UMTS carrier.

Based on the analysis of the simulation results of the interference between LTE systems with different channel bandwidths, there is no requirement on frequency separation between LTE channel edges for the different channel bandwidths.

Analysis of the simulation results of the interference between WiMAX systems with different channel bandwidths indicates there is no requirement on frequency separation between WiMAX channel edges for the different channel bandwidths.

A simple analysis of the system parameters led CEPT to conclude that the downlink interference from LTE to WiMAX and vice versa does not require frequency separation between channel edges. It is noted that the adjacent channel leakage ratio figures for LTE and WiMAX are similar. Although these figures are not directly applicable to the interference scenario between LTE and WiMAX since they refer to interference from LTE to LTE and WiMAX to WiMAX, respectively (with an assumed difference in channel occupation between LTE and WiMAX), this gives an indication that interference between LTE and WiMAX and vice versa will be limited.

As a result of these studies, to ensure compatibility between LTE/WiMAX and GSM/UMTS in the 900/1800 MHz bands, the following parameters in Table 72 shall be respected:

Table 72: Technical parameters for operation of IMT considering compatibility with other services

Systems	Technical Parameters	Reference
LTE complying with LTE Standards, as published by ETSI, in particular EN301908-1, EN301 908-13, EN301908-14, and EN301908-11.	1) A frequency separation of 200 kHz or more between the channel edges of the LTE network and that of a neighbouring GSM carrier; 2) No frequency separation required between the channel edges of the LTE network and that of a neighbouring UMTS carrier; 3) No frequency separation required between the channel edges of two neighbouring LTE networks, These recommended technical conditions could be relaxed at national level based on agreement between operators.	CEPT Report 040

Table 72: Technical parameters for operation of IMT considering compatibility with other services (continued)

Systems	Technical Parameters	Reference
WiMAX complying with harmonized standards EN301908-21 and EN301908-22 under development in ETSI.	1) A frequency separation of 200 kHz or more between the channel edges of a WiMAX network and that of a neighbouring GSM carrier; 2) No frequency separation required between the channel edges of a WiMAX network and that of a neighbouring UMTS carrier; 3) No frequency separation required between the channel edges of two neighbouring WiMAX networks. These recommended technical conditions could be relaxed at national level based on agreement between operators.	CEPT Report 040
Notes: It should be noted that EC Decision 2009/766/EC and ECC Decision (06)01 define the required frequency separation as the distance between the two carriers' centre frequencies. This approach is straightforward for both GSM and UMTS as those technologies have fixed carrier separations of 200 kHz and 5 MHz, respectively. Since both LTE and WiMAX have multiple possible channel bandwidths, the required frequency separation for those technologies is defined in a generic way based on the gap between the channel edges of the respective carriers. This generic edge-to-edge separation can then be converted into the appropriate separation of the carriers' centre frequencies considering the relevant channel bandwidths. For example, for a 5 MHz LTE/WiMAX system, the generic edge-to-edge separation (uncoordinated) of 200 kHz results in a separation between the LTE and GSM carriers' centre frequencies of 2.8 MHz, whereas for a 10 MHz LTE/WiMAX system the generic edge-to-edge separation (uncoordinated) of 200 kHz results in a separation between the LTE/WiMAX and GSM carriers' centre frequencies of 5.3 MHz.		

The ECC/Decision (06)01 updates the conditions for operation of the band 1 920-1 980 MHz and 2 110-2 170 MHz for IMT services. The technical conditions are based on the concept of BEM.

Although the BEM concept has been introduced already in Section 6.3.2, it is applicable to several frequency bands. A BEM is an emission mask defined as a function of frequency, relative to the edge of a block of spectrum licensed to an operator. It consists of in-block and out-of-block components specifying the permitted emission levels over frequencies inside and outside the licensed block of spectrum, respectively.

Accordingly, the BEM levels are built up by combining the values listed in the tables below in such a way that the limit at any frequency is given by the highest (least stringent) value of a) the transition requirements, and b) the in-block requirements (where appropriate). The BEMs are applicable only within the sub-band 2 110-2 170 MHz.

The BEM is applied as an essential component of the necessary conditions for compatibility in the absence of bilateral or multilateral agreements between mobile networks in adjacent frequency blocks in the 2 GHz band, without precluding less stringent technical parameters if agreed among the operators of such networks.

An administration should ensure that operators to which it has granted authorizations in this band are free to enter into bilateral or multilateral agreements to develop less stringent technical parameters that may be used, if agreed among all affected parties and if the level of protection for other networks not party to the agreement is not affected.

In-block limits for FDD IMT base station

In-block limits for non-AAS BS and AAS BS are not necessary as long as the BS FDD-to-BS TDD scenario does not need to be addressed. However, administrations may choose to set an e.i.r.p. limit for BS if needed on a national or local basis (e.g. to limit the risk of terminal-station receiver-blocking).

EU Decision 2020/667 defines further requirements:

1) Non-AAS EIRP limit. Not obligatory. In case an upper boundary is set by a Member State, a value of 65 dBm/5 MHz per antenna may be applied.
2) AAS TRP limit. Not obligatory. In case an upper boundary is set by a Member State, a value of 57 dBm/5 MHz per cell may be applied.

In a multi-sector base station, the AAS radiated power limit applies to each of the individual sectors.

The corresponding in-block TRP limit is determined following guidelines given in ETSI TS 138 104 V15.6.0, Annex F, Sections F.2 and F.3, on the basis of an antenna gain of 17 dBi and a total of eight beam-forming antenna elements (scaling factor of 9 dB): 65 dBm/(5 MHz) – 17 dBi + 9 dB = 57 dBm/(5 MHz).

Out-of-block limits for FDD IMT base station

Table 73 defines the baseline out-of-block power limits for non-AAS and AAS base stations. Table 74 defines the out-of-block BEM requirements for non-AAS MFCN base stations within the spectrum licensed to operators of MFCNs. Table 75 contains the corresponding out-of-block BEM requirements for AAS MFCN base stations (ECC Report 298 for more details).

It should be noted that for non-AAS BS these requirements have been derived from the characteristics of macro base stations, with the assumption of an in-block e.i.r.p. limit of 61 dBm/5 MHz and an antenna gain of 17 dBi.

Table 73: Baseline out-of-block power limits for non-AAS and AAS base stations

BEM element	Frequency range within FDD downlink	Non-AAS mean EIRP limit per antenna (a)	AAS mean TRP limit per cell (b)	Measurement bandwidth
Baseline	Frequencies spaced more than 10 MHz from the lower or upper block edge.	9 dBm	1 dBm	5 MHz

Notes:

1) The non-AAS BEM level is defined per antenna and applicable to base station configurations with up to four antennas per sector.
2) In a multi-sector base station, the AAS radiated power limit applies to each of the individual sectors.

Table 74: Transition requirements – non-AAS BS BEM out-of-block e.i.r.p. limits per antenna[196]

Frequency range of out-of-block emissions	Maximum mean out-of-block e.i.r.p.	Measurement bandwidth
–10 to –5 MHz from lower block edge	11 dBm	5 MHz
–5 to 0 MHz from lower block edge	16.3 dBm	5 MHz
0 to +5 MHz from upper block edge	16.3 dBm	5 MHz
+5 to +10 MHz from upper block edge	11 dBm	5 MHz
Other blocks	9 dBm	5 MHz

Table 75: Transition requirements – AAS BS BEM out-of-block TRP limits per cell[197]

Frequency range of out-of-block emissions	Maximum mean out-of-block TRP per cell	Measurement bandwidth
–10 to –5 MHz from lower block edge	3 dBm	5 MHz
–5 to 0 MHz from lower block edge	8 dBm	5 MHz
0 to +5 MHz from upper block edge	8 dBm	5 MHz
+5 to +10 MHz from upper block edge	3 dBm	5 MHz
Other blocks	1 dBm	5 MHz

Further limits have been defined by the European Union (EU Decision 2020/667).

10.5 Additional supporting compatibility studies of wireless broadband services and other incumbent applications (adjacent band studies)

For the benefit of having a full picture on the multiple studies undertaken in the 900 MHz, 1 800 MHz and 2 GHz, below is a summary of the main studies reported. Note should be made that this information would be useful for coordination of IMT versus other services, if the compliance against the BEM concept limits is not met or because administrations may wish to explore other, more relaxed parameters than those established by the BEM limits.

The CEPT Report 41 deals with the compatibility between LTE/WiMAX operating within the 900/1 800 MHz bands and systems operating in adjacent bands (adjacent band studies). Table 76 reports on the results of the compatibility studies.

196 The BEM level for base stations is defined as per antenna. It is applicable to base-station configurations with up to four antennas per sector

197 In a multi-sector base station, the radiated power limit applies to each of the individual sectors.

Table 76: Summary of compatibility studies of IMT versus other services

Band/scenario (interferer into victim)	Summary result
880 MHz/925 MHz LTE/WiMAX to GSM-R	In general, there is no need for an additional guardband between LTE/WiMAX900 and GSM-R whatever the channelization or bandwidth considered for LTE/WiMAX 900. ECC Report 096 concludes that a carrier separation of 2.8 MHz or more between the UMTS carrier and the nearest GSM-R carrier is sufficient. For LTE/WiMAX 900, the frequency separation between the nearest GSM-R channel centre frequency and LTE/WiMAX channel edge should be at least 300 kHz (at least 200 kHz between channel edges).
925 MHz – LTE/WiMAX BS to GSM-R MS	For some critical cases (e.g. with antenna located at high altitudes, or open and sparsely populated areas served by high-power LTE/WiMAX BS close to railway tracks, which would lead to assumption of possible direct line-of-sight coupling) the MCL calculations demonstrate that coordination is needed for a certain range of distances (up to 4 km or more from railway tracks) when the GSM-R signal is close to the sensitivity level. In order to protect GSM-R operations, LTE/WiMAX operators should take care when deploying LTE/WiMAX in the 900 MHz band, where site-engineering measures and/or better filtering capabilities (providing additional coupling loss in order to match the requirements defined for the critical/specific cases) may be needed in order to install LTE/WiMAX sites close to a railway track when the LTE/WiMAX network is using the channel adjacent to the GSM-R band. The deployment criteria of the GSM-R network such as the field-strength level at the GSM-R cell edge could be also strengthened in order to improve that network's immunity to emissions from other systems.
880 MHz – GSM-R MS to LTE/WiMAX BS	It is beneficial to activate GSM-R uplink power control, especially for the train-mounted MS, otherwise the impact on LTE/WiMAX capacity could be important when the LTE/WiMAX network is using the 10 MHz of spectrum adjacent to the GSM-R band. However, it has to be recognized that this is only applicable in low-speed areas as elsewhere the use of uplink control in GSM-R will cause significantly increased call drop-out rates. Another solution would be to introduce a higher frequency separation between the GSM-R channel and the 900 MHz allocation by allowing transmission in the extended GSM-R band. However, this solution should be counterbalanced by the potential impact on the upper part of the 900 MHz allocation. Due to the blocking-response profile of LTE, the base station deployed above 890 MHz may also suffer from desensitization due to E-GSM-R BS emissions.

Table 76: Summary of compatibility studies of IMT versus other services (continued)

Band/scenario (interferer into victim)	Summary result
915 MHz – LTE/WiMAX MS to E-GSM-R MS (CEPT has adopted amendments to ECC Decisions (02)05 on GSM-R and (04)06 on wideband PMR/PAMR. The amended Decisions provide a possibility for GSM-R extension (E-GSM-R) into the bands 873-876 MHz and 918-921 MHz on a national basis under the PMR/PAMR umbrella.)	The LTE/WiMAX UE transmitting power is relatively limited, at 23 dBm. In reality, mobile terminals rarely emit a maximum power of 23dBm (in 90 per cent of cases they emit 14 dBm or less. By considering that the minimum coupling loss between UE and E-GSM-R BS is relatively large (80 dB is used in ECC Report 082 between UE and BS in rural areas) compared to the MCL between LTE/WiMAX BS and GSM-R train-mounted MS, and since the UE is moving, the interference from LTE/WiMAX UE to E-GSM-R MS should not lead to interference. For detailed analysis of interference between LTE/WiMAX UE to E-GSM-R MS, Monte-Carlo simulations should be performed, but this is not covered in this report.
915 MHz – E-GSM-R BS to LTE/WiMAX BS (CEPT has recently adopted amendments to ECC Decisions (02)05 on GSM-R and (04)06 on wideband PMR/PAMR. The amended Decisions provide a possibility for GSM-R extension (E-GSM-R) into the bands 873-876 MHz and 918-921 MHz on a national basis under the PMR/PAMR umbrella.)	The worst interference case is the interference from E-GSM-R BS to LTE/WiMAX BS. The interference from E-GSM-R BS operating at frequencies above 918 MHz may cause receiver desensitization and blocking of LTE/WiMAX900 BS operating below 915 MHz. The specifications of the GSM-R BTS characteristics in the expected extension band are assumed to be the same as those of GSM-R in the primary band. It is assumed the GSM-R BTS for the extension band will be designed to protect efficiently the upper part of the uplink 900 MHz band, in particular the spurious emissions will be aligned to the current levels as defined to protect the 900 MHz receiving band. The main challenge would be to achieve this level in a 3 MHz offset instead of 6 MHz. However, as it would not be sufficient to prevent blocking of LTE/WiMAX base stations, the utilization of interference-mitigation techniques should be assessed in order to protect LTE/WiMAX900 BS efficiently.
915 MHz – LTE/WiMAX MS to PMR/PAMR MS	The LTE/WiMAX UE transmitting power is relatively small, at 23 dBm. In reality, mobile terminals rarely emit a maximum power of 23dBm (in 90 per cent of cases they emit 14 dBm or less. By considering that the minimum coupling loss between UE and PMR/PAMR BS is relatively large (80 dB is used in ECC Report 082 between UE and BS in rural areas) compared to the MCL between LTE/WiMAX BS and GSM-R train-mounted MS, and since the UE is moving, the interference from LTE/WiMAX UE to PMR/PAMR MS should not lead to interference. For detailed analysis of interference between LTE/WiMAX UE and PMR/PAMR MS, Monte-Carlo simulations should be performed, but this is not covered in CEPT Report 41. The worst interference case is the interference from PMR/PAMR BS to LTE/WiMAX BS (see next section).

Table 76: Summary of compatibility studies of IMT versus other services (continued)

Band/scenario (interferer into victim)	Summary result
915 MHz – PMR/PAMR BS to LTE/WiMAX BS	The interference from PMR/PAMR (CDMA PAMR, TETRA, TAPS) BS operating at frequencies above 915 MHz will cause receiver desensitization of LTE/WiMAX900 BS operating below 915 MHz. In order to protect LTE/WiMAX900 BS, the use of interference-mitigation techniques is necessary: 1) Reduced PMR/PAMR BS Tx power; 2) Spatial separation by coordination between operators; 3) External filters applied to the PMR/PAMR BS; 4) Sufficient guardband between the 900 MHz mobile allocation and the first PMR/PAMR channel in use. It is more likely that a combination of these interference-mitigation techniques should be used to ensure the compatibility of LTE/WiMAX900 operating below 915 MHz and PMR/PAMR (CDMA PAMR, TETRA, TAPS) operating above 915 MHz.
960 MHz – LTE/WiMAX BS to DME/L-DACS	The LTE and WiMAX BS masks for the 900 MHz bands are aligned with the UMTS900 mask for all the LTE/WiMAX channelization bandwidth available and are expected to have similar characteristics in terms of average power. Similarly, the protection criteria of LTE and WiMAX terminals is aligned with that of UMTS, and hence the conclusions regarding interference between UMTS and DME/L-DACS should be applicable to the scenarios involving LTE/WiMAX on one side and DME/L-DACS on the other, for the same signal bandwidth. When considering LTE/WiMAX with higher carrier bandwidth (> 5MHz), the compatibility results should be improved. With a large number of interferers with lower bandwidths (<5MHz), the aggregate interference from LTE would increase. However, it is not expected that LTE will be deployed with lower bandwidth. Bandwidth different from 5 MHz for LTE/WiMAX has not been addressed in detail.

Table 76: Summary of compatibility studies of IMT versus other services (continued)

Band/scenario (interferer into victim)	Summary result
	The results of the studies are as follows: • L-DACS 2 airborne transmitters will not cause any interference to LTE/WIMAX terminals when the distance between the aircraft and an outdoor LTE/WIMAX terminal is greater than 8.6 km, with an L-DACS 2 transmitting frequency of 960.1 MHz. For an L-DACS 2 transmitting frequency of 962.6 MHz, this distance becomes 6.5 km. The limiting factor is currently the selectivity of the LTE/WIMAX UE. • L-DACS 2 ground stations could cause desensitization to LTE/WIMAX terminals at a distance up to 17.5 km, depending on the propagation characteristics in the area considered and L-DACS 2 ground-station antenna height, with an L-DACS 2 transmitting frequency of 960.1 MHz. For an L-DACS 2 transmitting frequency of 962.6 MHz, this distance becomes 14.7 km. The limiting factor is currently the selectivity of the LTE/WIMAX UE. • No interference from LTE/WIMAX base stations to DME airborne receivers is expected above 972 MHz. Below 972 MHz some interference, in the order of 3 to 4 dB, may occur at low altitudes for the mixed-urban case. • L-DACS airborne receivers are no more sensitive to interference than DME. • LTE/WIMAX base-station transmissions may cause interference to L-DACS ground stations, if these stations are deployed in the lowest part of the band, and if the L-DACS TDD option is selected, in the order of 17- 25 dB, depending on the distance from the ground station to the nearest base station. If the FDD (LDACS-1) option is chosen and the associated ground stations receive at frequencies far above 960 MHz, then the interference from LTE/WIMAX base stations to these ground stations would be alleviated. CEPT Report 42 gives results on the compatibility between UMTS and DME/L-DACS-2. Those results have been extended to the compatibility between LTE/WiMAX and DME/L-DACS, based on the similarities between UMTS on one side and LTE/WiMAX on the other side. For additional information, see CEPT Report 42, especially with respect to mitigation techniques.

Table 76: Summary of compatibility studies of IMT versus other services (continued)

Band/scenario (interferer into victim)	Summary result
960 MHz – LTE/WiMAX BS to MIDS MS	To avoid any interference on each MIDS frequency the protection distance between LTE/WiMAX 900 base station and MIDS stations should be up to 2 km accordingly when the MIDS receiver is placed in the direction of the LTE/WiMAX base station antenna that corresponds to the worst-case situation. However, the protection should be reduced if the real unwanted emission level of the equipment is better than specified. For the worst-case situation (the MIDS receiver is placed in the direction where the LTE/WiMAX base station antenna gain is maximum), to fully protect MIDS without any protection distance, the unwanted emission level should be: • 21 dB better than specified in the 970-1 000 MHz band • 17 dB better than specified in the 1 000 – 1 206MHz MIDS band (corresponding to the 1-12.75GHz spurious band) • For other azimuths of antenna, the separation distance and the additional filtering requirements decrease However, a performance degradation of the MIDS can be tolerated: this corresponds to interference on the first 11 MIDS channels (ranging from 969 to 999 MHz). Consequently, if there is an additional isolation of 17 dB above 1 GHz no additional separation distance is required to protect the MIDS receiver for the worst-case situation (the MIDS receiver is placed in the direction where the LTE/WiMAX base station antenna gain is maximum). Information put forward by some manufacturers about the performance of a typical LTE/WiMAX900 base station shows that the practical level of unwanted emission provides isolation considerably higher than that required (17dB). Indeed, the interference criteria would be met already at 980 MHz or even lower. It should be noted that the study did not consider the regulatory status of the Joint Tactical Information Distribution System (JTIDS)/ Multifunctional Information Distribution System (MIDS), which operates in the band 960-1 215 MHz under the conditions of provision 4.4 of the Radio Regulations.
1 880 MHz. LTE/ WiMAX BS to DECT BS/MS	It can be concluded that the interference created by the LTE/ WiMAX1800 system would be similar to that created by GSM1800. No guardband is therefore required between LTE/WiMAX1800 and DECT allocations, provided that DECT is able to properly detect interference on closest DECT carriers F9-F7 and escape to more distant carriers F6-F0 within 1 880-1 900 MHz. LTE/WiMAX1800 macro-cells can be deployed in the same geographical area in coexistence with DECT which is deployed inside of the buildings, as the interference between DECT RFP and PP and macro-cellular LTE/WiMAX1800 BS and UE is not a problem. When pico-cellular LTE/WiMAX1800 BS is deployed inside a building in coexistence with DECT RFP and PP in the same area, some potential interference is likely to exist from indoor pico-cellular LTE/ WiMAX1800 BS to DECT if they are placed too close and they are operating in the adjacent channel at 1 880 MHz.

Table 76: Summary of compatibility studies of IMT versus other services (continued)

Band/scenario (interferer into victim)	Summary result
1 710 MHz. LTE/WiMAX MS to METSAT earth station receivers	The meteorological satellite (METSAT) earth stations have been adjacent to GSM1800 for many years and have not experienced interference from GSM MS transmissions. It is believed that the interference from LTE/WiMAX UE to METSAT earth stations operating in adjacent frequency band is unlikely to be a problem.
1 785 MHz. Radio microphone to LTE/WiMAX BS	It can be considered that the proposed guardband of 700 kHz in ERC Report 063 and ERC/REC 70-03 for the protection of GSM1800 is sufficient for protecting LTE/WiMAX 1800 BS receivers. This assumes that the radio microphone maximum transmitting power is limited to 13 dBm (20 mW) for handheld microphones and 17 dBm (50 mW) for body-worn microphones, as recommended in ERC Report 63 and ERC/REC 70-03.
1 710 MHz/1 785 MHz/1 805 MHz. LTE/WiMAX BS to fixed service	Compatibility between UMTS and fixed services operating in co-frequency and adjacent bands was studied in ERC Reports 064 and 065, which reported that the critical interference scenarios are between UMTS BS and fixed service stations. It is considered that these reports are also applicable to LTE/WiMAX.

Source: CEPT Report 041

10.6 Specific case of sharing of IMT and aeronautical services

In addition, further studies have been conducted by CEPT (reported in CEPT Report 042) regarding compatibility between UMTS and other aeronautical services in adjacent bands above 960MHz. Noting that compatibility with systems outside of the 900/1 800 MHz bands is studied for LTE (and any other identified technology at all band edges), CEPT has reviewed the risk of interference between UMTS and existing and planned aeronautical systems above 960 MHz, in order to enable the development of all systems below and above 960 MHz without taking a risk relating to aeronautical safety. It focuses on the compatibility between UMTS 900 and the aeronautical systems (existing: DME and future: L-DACS) in the band 960-1 215/1 164 MHz.

The results cover interference from L-DACS airborne and ground-station transmissions to the UMTS terminals as well as interference from UMTS base stations to DME/L-DACS airborne receivers and L-DACS ground-station receivers. Rural and mixed urban deployments of UMTS have been studied.

Currently DME systems are mostly deployed above 977 MHz. L-DACS was expected to be deployed in 2020 at the earliest.

The results of the studies are as follows:

1) L-DACS 2 airborne transmitters will not cause any interference to UMTS terminals, when the distance between the aircraft and an outdoor UMTS terminal is greater than 8.6 km, with an L-DACS 2 transmitting frequency of 960.1 MHz. For an L-DACS 2 transmitting frequency of 962.6 MHz, this distance becomes 6.5 km. The limiting factor is currently the selectivity of the UMTS UE;
2) L-DACS 2 ground stations could cause desensitization to UMTS terminals at a distance up to 17.5 km, depending on the propagation characteristics in the area considered and

L-DACS 2 ground-station antenna height, with an L-DACS 2 transmitting frequency of 960.1 MHz. For an L-DACS 2 transmitting frequency of 962.6 MHz, this distance becomes 14.7 km. The limiting factor is currently the selectivity of the UMTS UE.

3) No interference from UMTS base stations to DME airborne receivers is expected above 972 MHz. Below 972 MHz some interference, in the order of 3 to 4 dB, may occur at low altitudes for the mixed-urban case.
4) L-DACS airborne receivers are no more sensitive to interference than DME.
5) UMTS base-station transmissions may cause interference to L-DACS ground stations, if deployed in the lowest part of the band, and if the L-DACS TDD option is selected, in the order of 17-25 dB, depending on the distance from the ground station to the nearest base station. If the FDD (LDACS-1) option is chosen and the associated ground stations receive at frequencies far above 960 MHz, then the interference from UMTS base stations to these ground stations would be alleviated.

10.7 Specific case of sharing of IMT and other mobile (non-IMT) services

ECC Report 096 contains a series of studies with services in adjacent bands. Based on the interference analysis, the following conclusions can be made:

1) UMTS900 can be deployed in the same geographical area in coexistence with GSM-R as follows:

    a. There is a priori no need of an additional guardband between UMTS900 and GSM-R, a carrier separation of 2.8 MHz or more between the UMTS900 carrier and the nearest GSM-R carrier is sufficient without prejudice to provisions in point 2. This conclusion is based on Monte Carlo simulations assumed suitable for the typical case.
    b. However, for some critical cases (e.g. with high-located antenna, open and sparsely populated areas served by high power UMTS BS close to railway tracks, and blocking, which would lead to assumption of possible direct line of sight coupling) the MCL calculations demonstrate that coordination is needed for a certain range of distances (up to 4 km or more from railway tracks).
    c. It is beneficial to activate GSM-R uplink power control, especially for the train-mounted MS, otherwise the impact on UMTS UL capacity could be important when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band. However, it has to be recognized that this is only applicable in low-speed areas as elsewhere the use of uplink control in GSM-R will cause significantly increased call drop-out rates.
    d. In order to protect GSM-R operations, UMTS operators should take care when deploying UMTS in the 900 MHz band, where site-engineering measures and/or better[198] filtering capabilities (providing additional coupling loss in order to match the requirements defined for the critical/specific cases) may be needed in order to install UMTS sites close to railway tracks when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band.

2) When UMTS900 is deployed in the same geographical area in coexistence with PMR/PAMR (CDMA PAMR, TETRA, TAPS) operating at frequencies above 915 MHz, some potential interference from PAMR/PAMR BS to UMTS900 BS could be a problem. Protection of UMTS900 BS requires interference mitigation techniques such as:

    a. reduced PMR/PAMR BS Tx power;

198 The out-of-band interference level is given by 3GPP TS 25.104 V7.4.0

   b. spatial separation;
   c. external filters;
   d. guardband.

3) The potential interference from UMTS900 to aeronautical DME operating at frequencies above 972 MHz does not represent any difficulty. The frequency range between 960-972 MHz is not currently used by aeronautical DME although it is planned to be used in the near future. Some additional margins may be required for the protection of aeronautical DME operating at frequencies between 960 and 972 MHz, where the required additional margins are dependent on DME carriers and aircraft positions. The studies have shown that the only mitigation techniques, in order to ensure the compatibility between the DME system and UMTS900, that would bring sufficient isolation are additional filtering and a larger guardband. However, these two mitigation techniques are not judged applicable. It should be noted that the impact of the DME ground station (and FRS if necessary) on the UMTS 900 mobile stations has not been studied in this report and may need additional studies. Therefore, the report suggests that a regulatory solution should be examined. It is necessary that a common approach be used within Europe to ensure compatibility.
4) The compatibility study between UMTS900 and MIDS indicated that an additional margin of 17 dB of UMTS900 BS spurious emissions over the range 1 000-1 206 MHz in reference to 3GPP technical specifications is required for the protection of MIDS terminal receiver. If this additional margin is obtained by the UMTS BS real performance being better than 3GPP technical specifications, no other protection means (such as separation distance) are required for the protection of MIDS.
5) Potential interference between UMTS1800 and DECT does not appear to be a problem, as the DECT system has a dynamic channel allocation (DCA) mechanism which efficiently avoids an interfered channel except if both systems are deployed indoors. Indeed, although DECT uses DCA, interference analysis shows that in the case of UMTS1800 indoor pico-cellular deployment using the frequency channel adjacent to the DECT frequency band, the use of some mitigation techniques may be necessary to address potential interference to indoor DECT RFP or PP. However, in practice, GSM1800 deployment has demonstrated that no additional interference-mitigation techniques are really needed. This statement can be assumed to be extended to the compatibility between UMTS1800 and DECT systems.
6) The analysis indicates that the potential interference between UMTS1800 UE and METSAT earth stations should not be a problem.
7) The preliminary interference analysis leads to the conclusion that, with a guardband of 700 kHz, the potential interference from radio microphones to UMTS1800 BS should not be a problem if the radio microphone's maximum transmitted power is limited to 13 dBm (20 mW) for handheld microphones and 17 dBm (50 mW) for body-worn microphones as recommended in ERC Report 63 and ERC/REC 70-03E.

10.8 Guidelines and recommended actions for wireless broadband services in 900 MHz, 1 800 MHz and 2 GHz bands

Note should be taken that, within a country, the management of spectrum for compatibility among different IMT services or the technology to be used (or alternatively, the technology-neutral regulation) is closely related to the national criteria for planning and managing the spectrum.

Consequently, understanding that the technical compatibility and sharing studies between IMT and other services have been already conducted by ITU-R, the principles associated with the specific usage of IMT, including its efficient use for wireless broadband services, are relying on the follow-up studies and regulation developed by national administrations and regional organizations.

This is the main reason why most of the references provided in this chapter rely on studies, recommendations, reports or regulatory decisions adopted by regional organizations or the European Union. It is considered that such European references on the regulatory measures to stimulate the implementation of wireless broadband services in incumbent frequency ranges identified for IMT could be a valuable reference to guide further decisions by African spectrum-regulatory authorities.

Table 77 provides a comprehensive list of guidelines.

Table 77: Guidelines for technical conditions for IMT in incumbent mobile bands

No	Guideline	Applies to	Reference to Section(s)
10.1	As the 900 MHz, 1 800 MHz and 2 GHz bands are often already assigned to terrestrial operators, administrations may consider organizing or encouraging agreements among operators to plan the introduction of the latest wireless broadband technologies, when coordination issues would be raised or when cross-border coordination would be involved.	Planning of technical details for incorporation of latest technologies and adoption of technical parameters.	General
10.2	Administrations may consider the regulation implemented by other regions, for example Europe, through CEPT and the European Union, as mechanisms to foster harmonized deployment of wireless broadband technologies while maintaining compatibility with existing services in-band and in adjacent bands.		Referred to CEPT and EU reports, decisions and recommendations reported in this section
10.3	Consider adopting the general model of emissions limits defined by the BEM as a harmonized mechanism which allows prediction of interference emissions from other services and facilitates potential coordination among national operators or cross-border coordination. This concept of BEM considers the in-band and out-of-band emissions, as well as the impact upon adjacent services. The concept of BEM is adapted to the specific purpose of upgrading existing mobile technologies, because such power-emissions blocks are not related to any specific technology and consequently, it would allow introduction of new advanced broadband services while respecting the BEM emission limits.	Harmonized deployment of IMT services and foster technology upgrading.	Section 10.4 and Section 10.1

Table 77: Guidelines for technical conditions for IMT in incumbent mobile bands (continued)

No	Guideline	Applies to	Reference to Section(s)
10.4	Adoption of the concept of BEM and its associated emission limits would help administrations to ensure a compatible operation with respect to other services and would allow operators to introduce wireless broadband services without barriers due to regulation, if such regulation were to associate frequency assignments to specific mobile technologies.	Flexibility to deploy wireless broadband mobile services.	Section 10.4

11 Funding refarming efforts for IMT introduction

This section addresses the funding of the various refarming efforts. These efforts can vary significantly in scope and depth, as detailed in the previous sections on best practices and methods for refarming other services. They can range from re-engineering a limited number of P-P radio links, restacking nationally deployed networks (like DTTB networks) in combination with phasing out a legacy system (such as ATV or CDMA-850 networks).

In Section 11.1 the different refarming cost categories will be addressed. Subsequently, Section 11.2 will address how these different costs can be funded.

Recommendation ITU-R SM.1603-2 gives guidelines for issues around spectrum redeployment/refarming.

11.1 Refarming cost categories

Two refarming examples will be addressed to identify the various cost categories, which may also apply to refarming other services:

1) restacking or refarming DTTB services in the 700/800 MHz band;
2) DSO/ASO transition (see also Report ITU-R SM.2352-0 and Section 9).

11.1.1 Cost categories for restacking DTTB services

For restacking DTTB services a comprehensive list of cost categories is included in this section. The cost categories applicable in the specific local situation will depend on the activities included in the refarming project. The following cost categories are identified:

1) <u>(DTTB) network costs</u>. These costs are broken down into the following subcategories:

   a. *Network replanning costs*. For the incumbent DTTB networks, a different frequency plan will have to be developed, often in close collaboration with the other concerned DTTB network operators. Such a new frequency plan will show the sites where frequencies, powers and antennas need to be changed[199].
   b. *Implementation planning costs*. Given an agreed new and compatible frequency plan, it will still be necessary to implement the required changes in such a way to avoid frequency incompatibilities. In many cases the changes will be carried out in different retune phases or regions across the country. DTTB sites in one region, tuning to new frequencies, may become incompatible with sites in regions that are still operating according to the old frequency plan. This incompatibility (i.e. harmful interference) should be avoided with the implementation plan. Other operational aspects should

[199] Also, other network elements may have to be changed such as network topology, i.e. changes in the composition of Multi-Frequency Networks (MFN) and Single Frequency Networks (SFN). In addition, MFN sites may have to operate in SFN and this will have an impact on required equipment (such as GPS equipment). Finally, the applied artificial delays in SFNs may have to be changed.

also be considered such as weather conditions, access to sites and availability of personnel and equipment.

c. *Network retuning costs*. The new frequency plan will show what changes need to be implemented in the DTTB networks. The largest network-retuning cost would occur in the situation where additional sites would be needed. If possible, the network-planning should avoid such additional sites. Table 78 provides an example of the detailed network changes and cost elements for the network operator. It is noted that the effort to assess these network-retuning costs can be considerable, as it may involve tender procedures with equipment suppliers. Not only the purchasing costs need to be addressed with the equipment suppliers but also installation aid, schedule and supply conditions.

2) Viewer (network service user) support costs. Depending on the scope of the restacking project, these costs can be broken down as follows:

   a. *Communication costs.* Given the new frequency plan and implementation planning, concerned DTTB viewers should be informed on when they can expect the changes to happen and what they should do (for example, retune their DTTB receiver). This communication plan should be developed in close collaboration with the DTTB service providers (i.e. the broadcasters), the consumer retail industry, as well as companies providing installation aid to DTTB viewers.
   b. *UE installation costs.* Concerned DTTB viewers may need to reposition or redirect (to another site) their receiving antenna. Also, aid could be provided for assisting eligible households to retune their receivers
   c. *Receiver (UE) subsidy costs.* In the case the restacking project also includes the migration to new second-generation/HEVC receivers, the restacking project may organize and provide for subsidies for eligible households to acquire a new DTTB receiver.

3) Spectrum-clearing costs. The assigned spectrum rights or licences may be perpetual or semi-perpetual, because the licence-renewal terms force the regulator to renew the licence if the licensee passes some minimum requirements (e.g. paying their licence fees on time and not causing harmful interference). Under such conditions, the regulator may opt to pay the incumbent licensees compensation costs for relinquishing their spectrum rights. Several instruments are available for determining these compensation costs, including the relatively new instrument of the incentive auction (see Section 11.2.3).
4) Licence assignment costs. As the spectrum is cleared for IMT services, the licence-assignment costs are those costs involved in assigning (spectrum) licences to IMT network operators. Licence-assignment costs can be substantial in the case of auction or public tender.

Table 78: Example of detailed network changes and cost elements (excluding additional sites)

#	Change	#	Operational change	#	Where	Cost element
1	Frequency change	1.1	New filter section	1.1.1	Site	Purchase cost/filter section
				1.1.2	Site	Installation charge supplier/combiner
				1.1.3	Site	Man-hour charge/filter section
				1.1.4	Site	Transport costs/filter section
				1.1.5	Site	Insurance costs/filter section value/for a year
		1.2	Retune TX antenna (or replacing the TX antenna)	1.2.1	Site	Retuning charge supplier/antenna system
				1.2.2	Site	Man-hour charge/antenna system
				1.2.3	Site	Materials/antenna system
				1.2.4	Site	Insurance costs/antenna system value/for a year
		1.3	Re-configure exciter	1.3.1	Site	Man-hour charge/TX configuration
		1.4	New Power Amplifier (PA) module	1.4.1	Site	Purchase cost/PA module
				1.4.2	Site	Installation charge supplier/PA module
				1.4.3	Site	Man-hour charge/PA module
				1.4.4	Site	Transport costs/PA module
				1.4.5	Site	Insurance costs/PA module value/for a year
2	NMS changes	2.1	Frequency change	2.1.1	Head-end	Man-hour charge/frequency change
			MFN to SFN change	2.1.2	Head-end	Man-hour charge/MFN>SFN change
			SFN to MFN change	2.1.3	Head-end	Man-hour charge/SFN>MFN change
			Network ID change	2.1.4	Head-end	Man-hour charge/NW ID change
			Artificial delay changes	2.1.5	Head-end	Man-hour charge/artificial delay change

Table 78: Example of detailed network changes and cost elements (excluding additional sites) (continued)

#	Change	#	Operational change	#	Where	Cost element
3	GPS connects	3.1	Connect GPS to transmitter	3.1.1	Site	Man-hour charge/GPS connect
				3.1.2	Site	Materials/GPS connect
4	Art. delay change	4.1	Re-configure exciter	4.1.1	Site	Man-hour charge/TX configuration

11.1.2 Cost categories for DSO/ASO transition

DSO/ASO transition costs can be split in two parts:

1) DTTB network-deployment costs. These costs are different from the costs addressed in Section 11.1.1, as the DTTB network-deployment costs are the costs for deploying the initial network (and are considerably higher). Such cost would be relevant for those African countries still having to start the DSO/ASO transition (see group 1 in Figure 16, Section 9.2). For the different cost categories and cost estimates, the reader is referred to the ITU Guidelines on the transition from analogue to digital broadcasting, Section 3.4.3.
2) Analogue Switch-Off (ASO) costs. These costs can be broken down as follows (it is noted that some of the subcategories listed overlap or can be combined with the categories provided in Section 11.1.1):

   a. *Viewer-migration costs.* ATV viewers need to migrate to DTTB. These viewer-migration costs can include compensation of the ATV viewer for the DTTB receiver purchasing costs (i.e. subsidies) and costs for helping to install new receiver equipment. Possibly these migration costs might be limited to only eligible households such as people with special needs, elderly or disabled people.
   b. *Temporary network-migration costs.* These migration costs are typically incurred by the broadcast-network operator and include costs such as design and engineering costs for temporary facilities and sites.
   c. *Spectrum-clearing costs.* As addressed in Section 11.1.1, the ATV-assigned spectrum rights or licences may be perpetual or semi-perpetual, because the licence-renewal terms force the regulator to renew the licence if the licensee passes some minimum requirements (e.g. paying their licence fees on time and not causing harmful interference). Under such conditions, the regulator may opt for paying the incumbent licensees compensation costs for relinquishing their spectrum rights.
   d. *Broadcaster simulcasting costs.* During the simulcast period (dual illumination) the public and commercial ATV services are distributed over two networks in parallel. This will inflict extra costs on the broadcaster, simulcasting its television service(s).
   e. *Project-management costs.* Costs for managing the ASO process involving the coordination of the effort of all involved parties, such as consumers/viewers, regional/local governments/councils, equipment manufacturers and retailers, and property managers (of multi dwelling units and shared aerials).

f. *Certification costs.* Setting of mandatory receiver-certification and labelling, safeguarding that the right equipment is available in the market and to aid viewers in selecting this equipment.

g. *Interference-mitigation costs.* Interference may occur between mobile applications (i.e. LTE/IMT) and DTTB services (see Sections 1.3.2 and 2.3.2). Also, the introduction of DTTB services may cause interference to cable networks, especially when the DTTB frequencies are also in use by cable companies. Cable viewers may need help resolving these problems, such as by providing affected viewers with better shielded connectors and cables.

11.2 Funding methods

This section addresses the different ways of funding the identified and included costs categories, as listed in the previous section. These funding methods can be broken down in three basic categories, which may be combined to finance specific cost categories:

1) public funding methods;
2) direct industry funding;
3) traditional auction and incentive auction.

11.2.1 Public funding methods

Public funding is arranged for by national legislation, which can be sector-specific (such as for the broadcasting and telecommunication sectors). The specific national legislation will dictate the available options. In particular, legislation around State aid should be considered. State aid can come in different forms and may lead to conflicts with the competition regulations.[200] The following are some of the public funding methods:

1) General taxes. Financial resources are made available as a certain proportion of the national budget. Such funding may take a long time to obtain as it will require parliamentary approval. However, it is not uncommon for this method to be applied. Typically, DSO/ASO transitions are large national programmes, requiring approval from parliament and the earmarking of a portion of the national budget for the transition.[201] This funding instrument seems less appropriate for restacking or refarming incumbent services.
2) TV licence fees. This type of funding is only relevant as a method for funding the DSO/ASO transition. This funding is typically used for financing the activities of the public broadcaster, which may also include the network provisioning (next to the service provisioning). TV licence fees are a form of collecting taxes. Taxes are collected on the basis of ownership of a television set/device. Every citizen in possession/or owning a television set will have to pay a TV licence fee. In countries with nearly 100 per cent of the population watching television, it is commonly assumed that everybody watches the public services and hence every citizen has to pay TV licence fees.
3) Redeployment funds. These funds are often established by the regulator for the specific purpose of financing refarming projects. The costs that can be covered with these funds are generally limited to spectrum-clearing costs (i.e. compensation of spectrum users for relinquishing their spectrum rights) and network costs (i.e. the costs for restacking the

[200] For more information on state aid limitations and rulings, see ITU Guidelines on the transition from analogue to digital broadcasting, Section 2.11.2.

[201] For example, in the United States, Congress set aside an initial (open-ended) budget of USD 890 million for the DSO/ASO transitions (under the 2005 Digital Transition and Public Safety Act). After exhausting the available budget of USD 1.34 billion, an additional USD 650 million was added for DTV transition assistance (under the American Recovery and Reinvestment Act of February 2009).

networks). Regulator-managed redeployment funds are often sourced from licence fees collected from the licence holders and/or proceeds from spectrum auctions. For the latter, special legislation is often required for the regulator to retain these proceeds, default situation being that these proceeds would be added to the national budget.

4) Industry funds. These funds are established for the purpose of promoting the development of the broadcasting and telecommunications sector. These funds may also include financial resources to assist the provision of universal services.[202] Like with the redeployment funds, regulator-managed industry funds are often sourced from spectrum-licence fees and auction proceeds.

11.2.2 Direct industry funding

Direct funding refers to the situation that the new entrant (in this report the IMT licensee) is directly financing (a part of) the costs of a related refarming or restacking project (such as the refarming of the incumbent spectrum users, e.g. CDMA-850 or DTTB). This is different from the funds listed in the previous section, where all licence holders contribute to a general fund, which is available for a number of projects (still to be decided). The following are examples of direct funding methods:

1) Licence assignment fees. The IMT licence can be assigned by means of a public tender (as opposed to assignment through auction). The public tender conditions may stipulate that the licensees will be obliged to contribute to some the cost categories listed in the previous section. These contributions may have to be paid after the assignment of the licence or in instalments during the licence period.

2) Licence fee mark-ups. If the new entrant's existing mobile licence is adjusted (and renewed) and no assignment procedure takes place (this may be the case for public entities), the regulator may arrange for a licence fee mark-up to cover the costs of the involved refarming project. It is noted that a general mark-up for all or a group of unrelated licence holders is considered here a public (indirect) method of financing (see Section 11.2.1).

11.2.3 Traditional auction and incentive auction

In this report, traditional auction refers to a single process to assign a predefined number of available lots (i.e. spectrum rights) to a number of qualified bidders. This is opposed to the incentive auction, which is a combination of two interrelated auctions in which an equilibrium is found between supply and demand of spectrum (in the reverse and forward auction, respectively).

For the traditional auction, various well-tested auction formats are available.[203] Two main formats are typically used:

1) open multi-round ascending auction format where the price increases over a number of bidding rounds until there is no more bidding; and;

2) sealed-bid auction formats.

Regulators opting for auction to (partly) fund refarming efforts should first assess the associated costs of the refarming project (by selecting the applicable cost categories as listed in Section 11.1) and determine which costs should be covered by the new entrant(s). Subsequently, the regulator

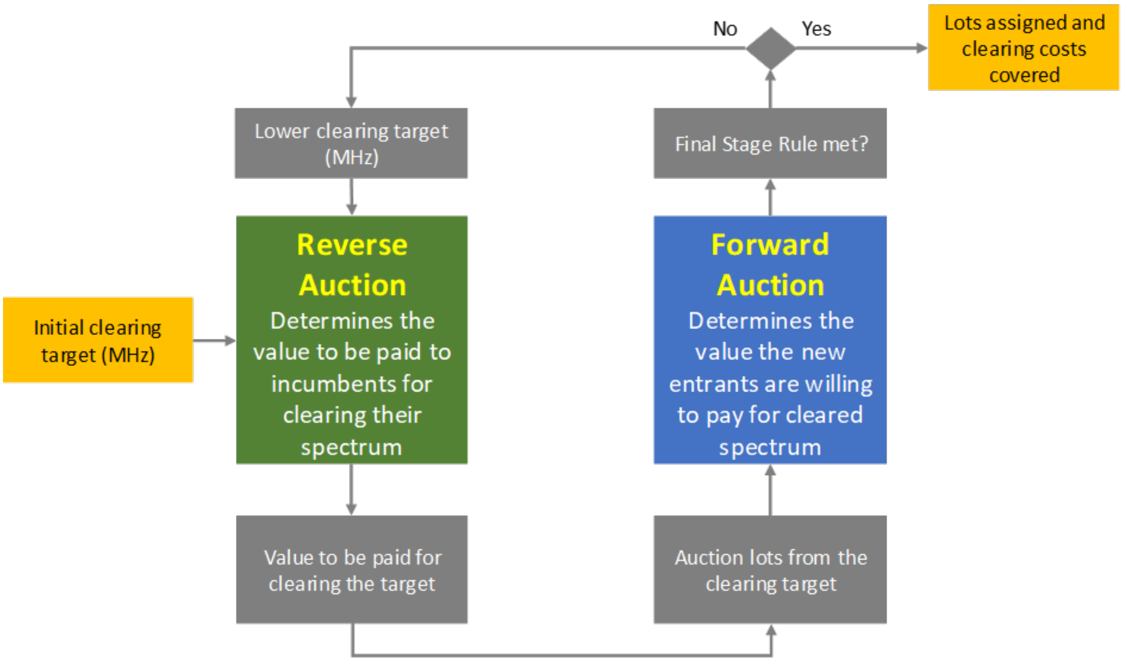
202 Universal services are those deemed to be essential for every user to access basic communications services at a reasonable quality and an affordable price.

203 For an overview of spectrum-auction formats and the pros and cons of each format, see ITU Guidelines for the transition from analogue to digital broadcasting, Annex B, Section 4.

sets a reserve price for each lot (e.g. 2 x 10 MHz) in the auction. The reserve price is the minimum at which the regulator is willing to sell the different lots. The reserve prices should then be high enough to cover at least the refarming costs the regulator wishes to collect from the new entrants (i.e. the qualified bidders).

The incentive auction was first applied in the United States to clear the 600 MHz band of television broadcasting services for the introduction of IMT services. It is a novel design that was specifically developed for the FCC.[204] The principle of the spectrum incentive auction is depicted in Figure 18.

Figure 18: Principle of the spectrum incentive auction



From Figure 18 the following can be observed:[205]

1) The incentive auction starts with setting an initial clearing target. In the case of the 600 MHz incentive auction in the United States of America, this initial target was set at 126 MHz. For the purpose of setting a number of descending clearing targets, spectrum-planning scenarios were developed in which a descending amount of spectrum was cleared (i.e. the clearing target). For each clearing target, the spectrum-planning would tell in what way this spectrum could be cleared (i.e. how many and which television stations should be cleared). It is noted that for the larger clearing targets, channel 37 (which sits in the middle of the 600 MHz band) was not available for IMT. Also, this channel 37 had two guardbands (of 3 MHz) around it to be respected by IMT. Consequently, the clearing targets were not symmetrical in terms of available IMT blocks, as the larger clearing targets had relatively less usable IMT spectrum.
2) Before the reverse auction would commence, the broadcasting licensees had provided the regulator an initial price for which they were willing to let go of their spectrum rights. The reverse auction would start with a price based on these initial indications. The reserve

[204] See "Incentive Auction Rules Option and Discussion", Appendix C to Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Notice of Proposed Rulemaking, Docket No. 12-268, 27 FCC Record 12357 (2012).

[205] The explanation of the incentive auction in this report is simplified as in practice the auction not only required the licensees to relinquish their spectrum rights but also to move their services to another part of the spectrum band, outside the clearing target.

auction was a clock auction with descending prices (i.e. Dutch auction). Bidders indicating that a certain price at the clock would be too low for them to let go of their spectrum would exit the auction. The descending clock would stop (and hence the auction) if the number of remaining bidders would be enough to satisfy the clearing target.

3) The forward auction would start with the spectrum blocks that are available in the clearing target. For example, the 126 MHz clearing target included 100 MHz usable IMT spectrum. The forward auction is a clock multi-round ascending auction[206] in which the bidders would bid for the available lots. This forward auction would stop if there was no more bidding. Then the final-stage rule would be checked if that was satisfied. This rule determines the minimum price at which the FCC was willing to sell the IMT lots. The rule comprised two parts; (a) a minimum value reflecting the economic value of the IMT lots (e.g. expressed as USD 1.25/MHz/pop) and (b) a minimum value for covering a number of costs:

    a. network costs for reallocating the broadcasting services (i.e. migrating the services that would continue, although on other frequencies);
    b. spectrum-clearing costs, payments for the broadcasting licensees to relinquish their spectrum rights;
    c. auction preparation and running costs.

4) If both parts of the final-stage rule were not satisfied, the clearing target would be lowered. Apparently, the available IMT lots in the forward auction were not scarce enough to generate enough value to satisfy the final-stage rule. By lowering the clearing target, the available IMT lots would be lowered. Consequently, the number of broadcasting licensees to be cleared in the reverse auction would be lower too, as would the total value to be paid to these broadcasters, as well as the minimum values in the final-stage rule. By carrying out multiple rounds of the reverse and forward auction in which the clearing target is subsequently lowered, an equilibrium would be found. Ultimately, 84 MHz was cleared in four stages (i.e. the clearing targets were 114 MHz stage 2, 108 MHz stage 3 and 84 MHz in stage 4).[207] The 84 MHz fitted seven paired blocks of 2 x 5 MHz (i.e. 70 MHz usable IMT spectrum).[208]

Finally, various observations can be made on the applicability of incentive auctions for clearing spectrum:

1) As demonstrated above, the outcome of the incentive auction is not certain. The amount of spectrum that ultimately will be cleared depends on the bidding in the two interrelated auctions. It is not certain that an equilibrium will be found. The design of the various clearing targets will greatly determine whether or not an equilibrium can be found.[209]
2) The reasons for the FCC to resort to this novel instrument were twofold:

    a. The hold-out problem with the incumbent broadcasters.[210] The incumbent broadcasters had semi-perpetual spectrum licences which the FCC deemed insurmountable without financial compensation for them to relinquish their spectrum rights.
    b. Very scarce spectrum. Apparently, the demand for IMT spectrum was assessed to be so large that the required spectrum far outstripped the available spectrum. For example, restacking the existing broadcasting services (with the same coverage and

[206] Open multi-round ascending auctions traditionally do not use a clock format, i.e. with bidding rounds with a fixed duration. The clock was used to speed up the bidding process.
[207] It is noted that the bidding in the 600 MHz incentive auction commenced in March 2016 and concluded in March 2017! A total of 372 bidding rounds were conducted.
[208] It is noted that all these IMT spectrum blocks sit below channel 37 (which was not available for IMT).
[209] Some auction analyst claim that it was a close call for the US incentive auction to have found this equilibrium.
[210] The hold-out problem is also known in real estate or road development projects, requiring private landowners to relinquish their land in return for payment of fair market value. However, one or more remaining landowners can push-up the value beyond fair market value.

quality of service) in a smaller band was deemed not possible, as it would not leave enough spectrum for IMT. It is noted that in many countries, such planned restacking solutions are (still) deemed possible and also deemed to satisfy IMT demand.

3) Incentive auctions are complex, lengthy and expensive. It should be assessed whether or not the market parties have the auction experience and resources to deal with such complexity, and whether or not the market is profitable enough to bear such costs.

11.3 Guidelines and recommended actions for funding refarming efforts

Table 79 provides a comprehensive list of the guidelines as included in this Section 11.

Table 79: Guidelines for funding refarming efforts for IMT introduction

No	Guideline	Applies to	Reference to Section(s)
12.1	Administrations are advised to consider the following refarming cost categories: • Network costs, which can be broken down in: o Network-replanning costs; o Implementation-planning costs; o Network-retuning costs; • Network-service user (or viewer) support costs, which can be broken down in: o User-communication costs; o User-equipment installation costs; o User-equipment subsidy costs; • Spectrum-clearing costs; • Licence-assignment costs.	Network operators and network service users.	Section 11.1.1
12.2	Administrations are advised to consider the following cost categories for DSO/ASO transition: • DTTB network-deployment costs; • Analogue switch-off (ASO) costs, which can be broken down in: o Viewer-migration costs; o Temporary network-migration costs; o Spectrum-clearing costs; o Broadcaster simulcasting costs; o Project-management costs; o Certification costs; o Interference-mitigation costs.	Broadcasting network operators, broadcasters (or other service providers), affected viewers, regulators and other spectrum users.	Section 11.1.2

Table 79: Guidelines for funding refarming efforts for IMT introduction (continued)

No	Guideline	Applies to	Reference to Section(s)
12.3	After assessing the costs in each of the relevant cost categories, administrations may have different options for funding these costs. These funding options can be broken down in three basic categories, which may be combined to finance specific cost categories: • Public funding methods; • Direct industry funding; • Traditional auction and incentive auction.	Administrations or regulators having to finance refarming projects.	Sections 11.2.1, 11.2.2 and 11.2.3
1.2.4	Administrations are advised to first consider alternatives to incentive auctions, which are deemed applicable in specific situations whereby: • A hold-out problem exists with incumbent spectrum users that need to be reallocated quickly • The necessary spectrum for IMT is by far outstripping available spectrum (i.e. extreme spectrum scarcity) • A planned restacking project is deemed not adequate for clearing enough spectrum.	Administrations or regulators having to clear spectrum.	Section 11.2.3

12 General guidelines and recommended actions

Table 80 includes a compendium of general guidelines relevant for most of the bands. Specific detailed recommendations and guidelines are included in the corresponding sections for each band. The guidelines in Table 80 are not presented in any order of priority.

Table 80: General guidelines for the introduction of IMT

No.	General guideline
1	Consider developing a regional roadmap (or several subregional roadmaps) for the further introduction of IMT in Africa. The African roadmap would guide the main elements for the orderly introduction of IMT in all applicable bands and would likely require further customization to specific situations in particular African countries. The subregional roadmaps would apply for African countries with similar IMT plans and deployments of other services/applications in the identified IMT bands and those adjacent. A regional roadmap would act as reference for a group of administrations in their planning for future IMT deployments and would facilitate the adoption of harmonized IMT band plans, as well as promoting cross-border coordination between the involved administrations. To make these subregional roadmaps fully efficient and reliable, an inventory of current spectrum usage in the IMT and adjacent bands would be required for identifying these similar country profiles. The regional and subregional IMT roadmaps would cover key spectrum management decisions, including: • Mechanisms for incorporation of the IMT spectrum bands in the national regulations; • Order of making such bands available for deployment; • Harmonized technical and regulatory conditions; • Parts of the spectrum to be refarmed; • In what way this refarming can be carried out, and; • Recommendations for international cross-border coordination on bilateral or multilateral basis. The applicable guidelines and information as provided in this report can provide guidance in developing this regional IMT roadmap.

Table 80: General guidelines for the introduction of IMT (continued)

No.	General guideline
2	Ultimately, in addition to having and following a regional or subregional roadmap, administration should prepare a specific national roadmap for the introduction of IMT. Such a roadmap would be focused on the long-term demand for IMT services and the availability of spectrum over a number of years. A national IMT roadmap would cover a number of key spectrum-management decisions, including: • Matching of forecasted IMT demand and available spectrum; • Mechanisms for incorporation of the IMT spectrum bands in the national regulations; • Defining the order of making such bands available for deployment; • Defining the technical and regulatory conditions to be applied; • Identifying the parts of the spectrum to be refarmed and in what way; • Determining the required resources for implementing the roadmap; • Recommendations for international cross-border coordination on bilateral or multilateral basis, and; • Scheduling the (parliamentary) approval procedures and key publication dates of the necessary regulatory measures. For drafting and executing this roadmap a national task force or committee could be established with representatives of all involved stakeholders, ensuring the early involvement of these stakeholders and inclusion of the specifics of the national situation. The applicable guidelines and information as provided in this report can be a valuable resource for aiding the key spectrum-management decisions such a task force or committee would have to make.
3	Adopt the harmonized frequency bands for the implementation of IMT at national level and ensure the NTFA do include the relevant IMT identifications. Administrations should maintain their NFTAs and frequency registers (including the actual assignments and changes thereof) updated. The national frequency allocations related to IMT should also refer to or adopt the applicable ITU-R frequency arrangements.
4	For the cross-border coordination of IMT versus other IMT services, promote the bi-or multilateral coordination processes by sharing the essential spectrum-planning parameters affecting the operation of services at border areas. The HCM4A Agreement provides the mechanisms for sharing such spectrum-planning parameters and processes for cross-border coordination.
5	For the cross-border coordination of IMT versus other IMT services, when possible and efficient in the light of implementation timing, organize for having bilateral or multilateral frequency-coordination meetings among neighbours to coordinate the frequency assignments to IMT base stations in the border areas.
6	For those cases where frequencies have been assigned, foster the involvement of the concerned operators to speed up the coordination process and get agreement on the frequency assignments. This would be particularly relevant for the situation of upgrading the applied technologies in the 900 MHz, 1 800 MHz and 1 900 MHz bands, for the purpose of providing wireless broadband services.
7	Consider the adoption of the concept of BEM, which would provide the least restrictive technical conditions (LRTC), while facilitating compatibility with other services (including between IMT services). The BEM characteristics would serve administrations to agree a common point to trigger discussions and modify technical parameters as necessary. Either to more stringent or more relaxed parameters, depending on the specific interference environment.

Table 80: General guidelines for the introduction of IMT (continued)

No.	General guideline
8	Potential adopters of the BEM concept should consider that a number of organizational conditions should be in place, including: • Regular publication of the NTFA, preferably regionally harmonized and supported with an up-to-date frequency register (including assignments and licensees); • Adoption and publication of a coherent licensing framework, including individual licensing for IMT (and other) services, which facilitates for a comprehensive set of LRTC; • Adequate reporting system for operators (and other spectrum users) to report on their network deployment and actual spectrum use, and; • Spectrum-monitoring capabilities for aiding the enforcement of any additional technical measures and any dispute resolution.
9	Planning of the IMT networks should be undertaken at early stages for the whole country, even if no deployment is foreseen in the short term. This would facilitate sufficient time to conduct any necessary national coordination or cross-border checks with respect to other services, for example, to identify the required separation distances to other interfered with or interfering stations. The earlier the mitigation techniques or specific adaptations are identified to solve potential interference problems, the easier and cheaper the solutions will be.
10	The technical conditions necessary for obtaining successful coordination between different systems, both at national and international level, depend on the specific situation. The typical values or scenarios used in the sharing and compatibility studies should be considered as a reference. The solutions as provided in these studies cannot be automatically applied to all particular and singular scenarios. Therefore, it is highly recommended that once the spectrum-planning stage for IMT deployment is conducted, by using the recommended parameters (for powers of transmitting and receiving stations, interference protection criteria, etc.), a check is performed to compare the actual parameters versus the typical/standard ones. This check is for early identification of any potential risks of interference or potential cases where additional studies or mitigation techniques would be required.
11	A number of countries around the world have experience of refarming processes for incumbent services. Different approaches or options have been adopted by administrations. Guidelines on the best refarming practices having been provided in this report for a range of refarming scenarios and for different services (broadcasting, fixed satellite, etc.). Administrations are encouraged to launch the processes of refarming as early as possible as early planning will help minimize the cost and the time required for the refarming process.
12	Consider implementing regulations associated with the requirements for equipment operating in IMT bands similar to the European RTTE Directive. This Directive defines the essential requirements for market introduction of radio equipment and taking this radio equipment into service. Article 3.2 of the Directive states that: "…radio equipment shall be so constructed that it effectively uses the spectrum allocated to terrestrial/space radio communication and orbital resources so as to avoid harmful interference." It also contains provisions addressing the obligations of administrations and operators for taking radio equipment into service and allowing it to connect to compatible networks.

Glossary of terms

3GPP	3rd Generation Partnership Project
AAS	active antenna system
ALD	assistive listening devices
AMS	aeronautical mobile service
ANFR	French Agency for Frequencies
APCO	The Association of Public-Safety Communications Officials
APT	Asia-Pacific Telecommunity
ARCEP	French Regulatory Authority
ARNS	aeronautical radionavigation service
ASO	analogue switch-off
ATS	aeronautical telemetry services
ATU	African Telecommunications Union
ATV	analogue television
AUC	African Union Commission
BEM	block edge mask
BFWA	broadband fixed wireless access
BS	base station
BSS	broadcast-satellite service
BTS	base transceiver station
BWA	broadband wireless access
CA	carrier aggregation
CBA	C-Band Alliance
CDMA	code division multiple access
CEPT	European Conference of Postal and Telecommunications Administrations
CPM	Conference Preparatory Meeting
DCA	dynamic channel allocation
DECT	digital enhanced cordless telecommunications
DME	distance measuring equipment (aeronautical system)
DL	downlink
DTTB	digital terrestrial television broadcasting

(continued)

DVB-T2	digital video broadcasting – terrestrial (2nd generation)
EC	European Commission
ECC	European Communications Committee
EESS	earth exploration-satellite service
eMBMS	evolved multimedia broadcast multicast service
EMC	electromagnetic compatibility
ENG/OB	electronic news-gathering/outside broadcasting
e.i.r.p.	equivalent isotropically radiated power
EN	European norm
ERP	effective radiated power
ERC	European Radiocommunications Committee
EU	European Union
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FCFS	first come, first served
FDD	frequency division duplex
FeMBMS	further-evolved multimedia broadcast multicast service
FBWA	fixed broadband wireless access
FWA	fixed wireless access
FS	fixed service
FSS	fixed-satellite service
GE-06	Geneva Agreement of 2016
GSM	global system for mobile communications
GSM-R	global system for mobile communications –railways
GSO	geostationary orbit
HAPS	high-altitude platform system
HCM	European harmonized calculation method
HD FS	high-density fixed service
HDFSS	high-density fixed-satellite service
HDTV	high-definition television
HSPA	high-speed packet access
HIPSSA	The Support for the Harmonisation of the ICT Policies in sub-Saharan Africa project
IDTV	integrated digital television set
IEEE	Institute of Electrical and Electronics Engineers

(continued)

IMT	International Mobile Telecommunications
I/N	interference-to-noise ratio
IoT	Internet of Things
ISDB-T	Integrated services digital broadcasting – terrestrial
ISM	industrial, scientific and medical
ITFA	International Table of Frequency Allocations
L-DACS	L-band digital aeronautical communication system
LMDS	local multipoint distribution service
LRTC	least-restrictive technical conditions
LSA	licensed shared access
LTE	Long-Term Evolution
M2M	machine-to-machine
MCL	minimum coupling loss
METSAT	meteorological satellite
MFN	multifrequency network
MFCN	mobile fixed communications network
MIDS	multifunctional information distribution system
MMDS	microwave multimedia distribution system
MMS	maritime mobile service
MS	mobile service
MSS	mobile-satellite service
MTV	mobile television
MWS	mobile wireless system
NB	narrow band
NTFA	national table of frequency allocations
NGSO	non-geostationary orbit
Non-AAS	non-active antenna system
OOB	out-of-band
OOBE	out-of-band emissions
NR	new radio
PAMR	public access mobile radio
PCI	physical cell identity
pfd	power flux-density
PMR	private mobile radio
PMSE	programme-making and special events
PPDR	public protection and disaster relief

(continued)

RAS	radio astronomy service
RLAN	radio local area network
RR	Radio Regulations
RX	receiver
SAB/SAP	services auxiliary to broadcasting/programme-making
SADC	Southern African Development Community
SFN	single frequency network
SLD	supplemental downlink
SRD	short-range device
SRS	space research service
SSNIP	small but significant non-transitory increase in price
STB	set-top box
TAPS	TETRA advanced packet service
TDD	time division duplex
TETRA	terrestrial trunked radio
TLM	telemetry
TRP	total radiated power
TX	transmitter
UE	user equipment
UHD	ultra-high-definition
UHDTV	ultra-high-definition television
UL	uplink
UMTS	Universal Mobile Telecommunications System
VSAT	very small aperture terminal
WAPECS	wireless access policy for electronic communications services
WAS	wireless access system
WB	wide band
WiMAX	worldwide interoperability for microwave access
WLAN	wireless local area network
WRC	World Radiocommunication Conference

Appendix A: Cross-border frequency coordination

This appendix provides an overview of the two types of frequency coordination between countries: case-based and agreement-based frequency coordination.

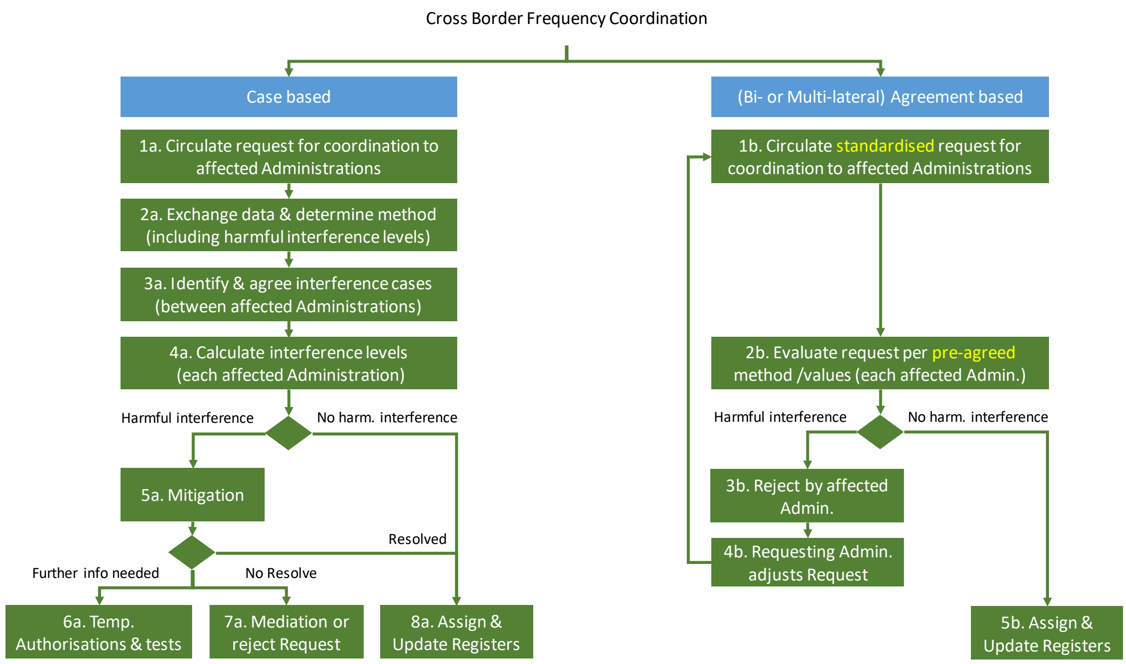
It is noted that more information on cross-border frequency coordination can be found in Recommendation ITU-R SM.1049 (including how to establish a coordination zone, procedures for exchange of information, as well as how to establish maximum permissible interference-field strength values).

Case-based frequency coordination is in principle applied in the absence of bi- or multi-lateral agreements. Case-based refers to the situation of one country needing to coordinate a frequency (or a set of frequencies) it would like to protect from harmful interference or which it expects could cause such interference. Case-based coordination would ultimately result in an agreement on the frequency usage of the frequencies involved in the case.

Bilateral or multilateral agreements are agreed well in advance of the actual (detailed) planning and assignment of frequencies. These agreements include, in varying degrees, the process or method of frequency coordination (such as procedures, datasets, registers, propagation models and planning software) and the key applied parameters (such as specified levels of harmful interference, coordination zones and distances). These agreements can cover large parts of the spectrum and may include a range of telecommunication services.

Figure 19 shows the process of case-based and agreement-based coordination.

Figure 19: Case-based and agreement-based frequency coordination between countries



For case-based coordination the steps (1a to 8a) as included in Figure 19 can be described as follows:

1) Circulate request for coordination to affected administrations. This request is often initiated by an administration planning to introduce or change a station (for example, for IMT or DTTB). The request letter and accompanying data, although not pre-defined, often include the station coordinates, affected services, system parameters and frequency characteristics and planned introduction date. The request is sent to all affected administrations. For determining which administrations could be affected, the requesting administration should first make an assessment of the interference cases for the coordination zone (i.e. the area in which harmful interference is expected).
2) Exchange data and determine calculation method. Following the request letter, the affected administrations exchange data needed for determining the interference levels between the affected services. The calculation method should also be determined and agreed between the administrations, for carrying out the interference calculations.
3) Identify and agree interference cases. In this process, the different interference cases are identified and agreed between the affected administrations. For example, the unwanted signals from an IMT base station in country A may cause harmful interference to the rooftop reception of DTTB signals in country B.
4) Calculate interference levels. In this step the interference-field strength levels are calculated based on the exchanged data, the agreed calculation method and for the identified and agreed interference cases.
5) Mitigation. When finding interference cases with field strength levels above the permissible levels, mitigation should be pursued. Several mitigation options are generally available, ranging from power reductions (ERP), antenna diagram changes (e.g. more directed antenna diagrams away from the border), antenna-tilting and possibly frequency changes.
6) Temporary authorizations and tests. After mitigation, it may be that the affected administrations cannot agree on a shared solution, due to missing information on specific interference cases. The administrations may then agree to issue a temporary authorization, allowing the requesting administration to temporarily assign the frequency to the station (or set of stations). In this grace period, further field tests or calculations can be carried out to gather more information on the specific interference cases.
7) Mediation or reject coordination request. After mitigation, the affected administrations may not commonly agree a solution, due to disagreement on the calculation results and their impact on the involved services. Mediation could resolve matters. As described in the ITU-RR (Article 6), ITU may be invited to send representatives to participate in an advisory capacity for resolving interference cases. Ultimately, if no resolution can be agreed, the coordination request may be rejected and the requesting administration should make alternative plans.
8) Assign and update registers. After calculating the interference-field strength levels, it may be that no harmful interference can be found for the defined interference cases. The administrations may then agree that the requesting administration can assign the frequency to the station. Following the agreement or assignment, the affected administrations should update their registers containing their assignments and/or frequencies under coordination. Following the update of the NTFA the administration should also record the assignment (i.e. station) in the Master International Frequency Register (MIFR) of ITU.

It is noted that administrations in Africa (as part of the GE-06 area) for the coordination of DTTB-DTTB or IMT- DTTB, should follow the procedures included in the GE-06 Agreement (see Section 1.3.4). For other agreement-based coordination, the steps (1b to 5b) included in Figure 19 can be described as follows:

1) Circulate standardized request for coordination to affected administrations. The standardized request is often initiated by an administration planning to introduce or change a station. The request form is accompanied with a standardized data set and sent

to all affected administrations. For determining which administrations are affected, the requesting administration calculates based on a pre-determined method, and using the data in the agreed frequency register. The requesting administration will include those stations located in the applicable coordination zone. This calculation will show which stations in the coordination zone will suffer from harmful interference (i.e. where the interference-field strength is above maximum permissible levels). By applying the pre-agreed coordination zone, calculation method and maximum permissible interference-field strengths (also referred to as trigger values), the interference cases are defined.

2) Evaluate request per pre-agreed method and values. In this step the interference-field strength levels for the identified cases are calculated based on the pre-defined data/frequency register, the agreed calculation method. These calculations are carried out independently by each affected administration. Different calculation results between the affected administrations may need to be resolved before it can be determined whether the (agreed) calculated field strengths are above the permissible interference-field strength levels. In this evaluation process, the affected administration may have to consider preferential rights of certain frequencies or shared frequencies that may have been established, based on previous bilateral or multilateral coordination agreements.

3) Rejection by affected administration. Following the commonly agreed calculation results, the affected administration can reject the request if the calculations show that the interference-field strength is above the maximum permissible level. Mitigation between the affected administrations for resolving the harmful interference may follow, but is often not part of the formal procedure of the agreement.

4) Requesting administration adjusts request. Following mitigation between administrations or the requesting administration adjusting its request, the requesting administration may circulate a renewed or adjusted coordination request.

5) Assign and update registers. Following the commonly agreed calculation results, the affected administration can accept the request if the calculations show that the interference-field strength is below the maximum permissible level. Following this acceptance, the requesting administration is then permitted to assign the frequencies to the station. Following the agreement or assignment, the affected administrations should update their registers (NTFA and register). Again, the administrations should also have the assignments recorded in the MIFR of ITU.

Appendix B: ITU Recommendations and Reports

This appendix provides a comprehensive list of ITU Recommendations and Reports, relevant to the spectrum issues as addressed in this report.

Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	BS.2340-0	2014	Sharing between the mobile service and the broadcasting service in the 1 452-1 492 MHz frequency band
Rec	ITU-R	BT.1206-3	2016	Spectrum limit masks for digital terrestrial television broadcasting
Rec	ITU-R	BT.1895-1	2011	Protection criteria for terrestrial broadcasting systems
Rec	ITU-R	BT.2033-1	2015	Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands
Rep	ITU-R	BT.2215-7	2018	Measurements of protection ratios and overload thresholds for broadcast TV receivers
Rep	ITU-R	BT.2265-1	2014	Guidelines for the assessment of interference into the broadcasting service
Rep	ITU-R	BT.2296-0	2013	Example of application of Recommendation ITU-R BT.1895 and Report ITU-R BT.2265 to assess interference to the broadcasting service caused by the impact of IMT systems on existing head amplifiers of collective television distribution systems
Rep	ITU-R	BT.2301-1	2016	National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services
Rep	ITU-R	BT.2301-2	2016	National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services
Rep	ITU-R	BT.2337-1	2017	Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz
Rep	ITU-R	BT.2338-0	2014	Services ancillary to broadcasting/services ancillary to programme-making spectrum use in Region 1 and the implication of a co-primary allocation for the mobile service in the frequency band 694-790 MHz

(continued)

Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	BT.2339-0	2014	Co-channel sharing and compatibility studies between digital terrestrial television broadcasting and international mobile telecommunication in the frequency band 694-790 MHz in the GE-06 planning area
Rec	ITU-R	F.2119	2019	Guidance on technical parameters and methodologies for sharing and compatibility studies related to fixed and land mobile services in the frequency range 1.5-30 MHz
Rep	ITU-R	F.2326-0	2014	Sharing and compatibility study between indoor International Mobile Telecommunication small cells and fixed service stations in the 5 925-6 425 MHz frequency band
Rep	ITU-R	F.2327-0	2014	Sharing and compatibility study between International Mobile Telecommunication systems and point-to-point fixed wireless systems in the frequency band 4 400-4 990 MHz
Rep	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
Rep	ITU-R	F.2331-0	2014	Sharing and compatibility between International Mobile Telecommunication systems and fixed service systems in the 470-694/698 MHz frequency range
Rep	ITU-R	F.2331-0	2014	Sharing and compatibility between International Mobile Telecommunication systems and fixed service systems in the 470-694/698 MHz frequency range
Rep	ITU-R	F.2333-0	2014	Sharing and compatibility study between International Mobile Telecommunication and the fixed service in the frequency band 1 350-1 527 MHz
Rep	ITU-R	F.2333-0	2014	Sharing and compatibility study between International Mobile Telecommunication and the fixed service in the frequency band 1 350-1 527 MHz
Rep	ITU-R	F.2474	2019	Sharing and compatibility studies of HAPS systems in the fixed service in the 27.9-28.2 GHz and 31.0-31.3 GHz frequency ranges
Rep	ITU-R	F.2475	2019	Sharing and compatibility studies of HAPS systems in the fixed service in the 38-39.5 GHz frequency range

(continued)

Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	F.2476	2019	Sharing and compatibility studies of HAPS systems in the fixed service in the 47.2-47.5 GHz and 47.9-48.2 GHz frequency ranges
Rep	ITU-R	M.1023-1	1990	Frequency-sharing between the land mobile service and the broadcasting service (television) below 1 GHz
Rec	ITU-R	M.1034-1	1997	Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
Rec	ITU-R	M.1035-0	1994	Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)
Rec	ITU-R	M.1036-6	2019	Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications in the bands identified for IMT in the Radio Regulations
Rec	ITU-R	M.1072-0	1994	Interference due to intermodulation products in the land mobile service between 25 and 3 000 MHz
Rec	ITU-R	M.1073-3	2012	Digital cellular land mobile telecommunication systems
Rec	ITU-R	M.1167-0	1995	Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)
Rec	ITU-R	M.1224-1	2012	Vocabulary of terms for International Mobile Telecommunications (IMT)
Rec	ITU-R	M.1388-0	1999	Threshold levels to determine the need to coordinate between space stations in the broadcasting-satellite service (sound) and particular systems in the land mobile service in the band 1 452-1 492 MHz
Rec	ITU-R	M.1450-5	2014	Characteristics of broadband radio local area networks
Rec	ITU-R	M.1457-14	2019	Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
Rec	ITU-R	M.1464-2	2015	Characteristics of radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and meteorological radars in the radiodetermination service operating in the frequency band 2 700-2 900 MHz
Rec	ITU-R	M.1580-5	2014	Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000

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Rec/ Rep	ITU	Number	Year	Title
Rec	ITU-R	M.1581-5	2014	Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000
Rec	ITU-R	M.1635-0	2005	General methodology for assessing the potential for interference between IMT-2000 or systems beyond IMT-2000 and other services
Rec	ITU-R	M.1641-2	2015	A methodology for co-channel interference evaluation to determine separation distance from a system using high-altitude platform stations to a cellular system to provide IMT-2000 service
Rec	ITU-R	M.1645-0	2003	Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000
Rec	ITU-R	M.1646-0	2003	Parameters to be used in co-frequency sharing and pfd threshold studies between terrestrial IMT-2000 and BSS (sound) in the 2 630-2 655 MHz band
Rec	ITU-R	M.1767-0	2006	Protection of land mobile systems from terrestrial digital video and audio broadcasting systems in the VHF and UHF shared bands allocated on a primary basis
Rec	ITU-R	M.1801-2	2013	Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz
Rec	ITU-R	M.1822-0	2007	Framework for services supported by IMT
Rec	ITU-R	M.1823-0	2007	Technical and operational characteristics of digital cellular land mobile systems for use in sharing studies
Rec	ITU-R	M.1825-0	2007	Guidance on technical parameters and methodologies for sharing studies related to systems in the land mobile service
Rec	ITU-R	M.2009-2	2019	Radio interface standards for use by public protection and disaster relief operations in some parts of the UHF band in accordance with Resolution 646 (Rev.WRC-12)
Rec	ITU-R	M.2012-4	2019	Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)
Rec	ITU-R	M.2015-2	2018	Frequency arrangements for public protection and disaster relief radiocommunication systems in accordance with Resolution 646 (Rev.WRC-15)

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Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	M.2030-0	2003	Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2 600 MHz operating in adjacent bands and in the same geo-graphical area
Rep	ITU-R	M.2031-0	2003	Compatibility between WCDMA 1800 downlink and GSM 1900 uplink
Rep	ITU-R	M.2039-3	2014	Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses
Rep	ITU-R	M.2041-0	2003	Sharing and adjacent band compatibility in the 2.5 GHz band between the terrestrial and satellite com-ponents of IMT-2000
Rep	ITU-R	M.2045-0	2004	Mitigating techniques to address coexistence between IMT-2000 time division duplex and frequency division duplex radio interface technol-ogies within the frequency range 2 500-2 690 MHz operating in adjacent bands and in the same geo-graphical area
Rec	ITU-R	M.2070-1	2017	Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-Advanced
Rep	ITU-R	M.2074-0	2006	Radio aspects for the terrestrial component of IMT-2000 and systems beyond IMT-2000
Rec	ITU-R	M.2083-0	2015	IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond
Rec	ITU-R	M.2090-0	2015	Specific unwanted emission limit of IMT mobile sta-tions operating in the frequency band 694-790 MHz to facilitate protection of existing services in Region 1 in the frequency band 470-694 MHz
Rec	ITU-R	M.2101-0	2017	Modelling and simulation of IMT networks and sys-tems for use in sharing and compatibility studies
Rep	ITU-R	M.2109-0	2007	Sharing studies between IMT-Advanced sys-tems and geostationary-satellite networks in the fixed-satellite service in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands
Rep	ITU-R	M.2111		Sharing studies between IMT-Advanced and the radiolocation service in the 3 400-3 700 MHz bands
Rep	ITU-R	M.2111-0	2007	Sharing studies between IMT-Advanced and the radiolocation service in the 3 400-3 700 MHz bands
Rep	ITU-R	M.2112-0	2007	Compatibility/sharing of airport surveillance radars and meteorological radar with IMT systems within the 2 700-2 900 MHz band

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Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	M.2113-1	2008	Report on sharing studies in the 2 500-2 690 MHz band between IMT-2000 and fixed broadband wireless access systems including nomadic applications in the same geographical area
Rep	ITU-R	M.2116-2	2013	Characteristics of broadband wireless access systems operating in the land mobile service for use in sharing studies
Rep	ITU-R	M.2146-0	2009	Coexistence between IMT-2000 CDMA-DS and IMT-2000 OFDMA TDD WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area
Rep	ITU-R	M.2241-0	2011	Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz
Rep	ITU-R	M.2291-1	2016	The use of International Mobile Telecommunications (IMT) for broadband public protection and disaster relief (PPDR) applications
Rep	ITU-R	M.2292-0	2014	Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses
Rep	ITU-R	M.2316-0	2014	Assessment of interference to radars operating within the 2 700-2 900 MHz band from broadband wireless systems operating in adjacent frequency bands
Rep	ITU-R	M.2324-0	2014	Sharing studies between potential International Mobile Telecommunication systems and aeronautical mobile telemetry systems in the frequency band 1 429-1 535 MHz
Rep	ITU-R	M.2360-0	2015	Sharing between GSO MSS and other services in the allocations in the 22-26 GHz range
Rep	ITU-R	M.2374-0	2015	Coexistence of two TDD networks in the 2 300-2 400 MHz band
Rep	ITU-R	M.2376-0	2015	Technical feasibility of IMT in bands above 6 GHz
Rep	ITU-R	M.2378-0	2015	Operational guidelines for the deployment of broadband wireless access systems for local coverage operating below 6 GHz
Rep	ITU-R	M.2410-0	2017	Minimum requirements related to technical performance for IMT-2020 radio interface(s)
Rep	ITU-R	M.2440-0	2018	The use of the terrestrial component of International Mobile Telecommunications (IMT) for narrowband and broadband machine-type communications
Rep	ITU-R	M.2441-0	2018	Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)

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Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	M.2480-0	2019	National approaches of some countries on the implementation of terrestrial IMT systems in bands identified for IMT
Rep	ITU-R	M.2481-0	2019	In-band and adjacent band coexistence and compatibility studies between IMT systems in 3 300-3 400 MHz and radiolocation systems in 3 100-3 400 MHz
Rec	ITU-R	M.687-2	1997	International Mobile Telecommunications-2000 (IMT-2000)
Rec	ITU-R	M.816-1	1997	Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
Rec	ITU-R	M.818-2	2003	Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
Rep	ITU-R	RA.2332-0	2014	Compatibility and sharing studies between the radio astronomy service and IMT systems in the frequency bands 608-614 MHz, 1 330-1 400 MHz, 1 400-1 427 MHz, 1 610.6-1 613.8 MHz, 1 660-1 670 MHz, 2 690-2 700 MHz, 4 800-4 990 MHz and 4 990-5 000 MHz
Rep	ITU-R	RS.2336-0	2014	Consideration of the frequency bands 1 375-1400 MHz and 1 427-1 452 MHz for the mobile service – Compatibility with systems of the Earth exploration-satellite service within the 1 400-1 427 MHz frequency band
Rec	ITU-R	S.1856-0	2010	Methodologies for determining whether an IMT station at a given location operating in the band 3 400-3 600 MHz would transmit without exceeding the power flux-density limits in the Radio Regulations Nos. 5.430A, 5.432A, 5.432B and 5.433A
Rep	ITU-R	S.2368-0	2015	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
Rep	ITU-R	SA.2325-0	2014	Sharing between space-to-space links in space research, space operation and Earth exploration-satellite services and IMT systems in the frequency bands 2 025-2 110 MHz and 2 200-2 290 MHz
Rep	ITU-R	SA.2325-0	2014	Sharing between space-to-space links in space research, space operation and Earth exploration-satellite services and IMT systems in the frequency bands 2 025-2 110 MHz and 2 200-2 290 MHz

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Rec/ Rep	ITU	Number	Year	Title
Rep	ITU-R	SA.2329-0	2014	Sharing assessment between meteorological-satellite systems and IMT stations in the 1 695-1 710 MHz frequency band
Rec	ITU-R	SM.1049-1	1995	A method of spectrum management to be used for aiding frequency assignment for terrestrial services in border areas
Rec	ITU-R	SM.1541-6	2015	Unwanted emissions in the out-of-band domain
Rec	ITU-R	SM.1603-2	2014	Spectrum redeployment as a method of national spectrum management
Rep	ITU-R	SM.2353-0	2015	The challenges and opportunities for spectrum management resulting from the transition to digital terrestrial television in the UHF bands
Rec	ITU-R	SM.851-1	1993	Sharing between the broadcasting service and the fixed and/or mobile services in the VHF and UHF bands

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