D2.5 REPORT ON REGULATORY REQUIREMENTS

Spectrum Policies and Regulatory Analysis

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Abstract	This report provides an insight into the regulatory environment applicable to NTN and the current rules and regulations regarding use of spectrum that can be used to conceptualize NTN operations. The report also highlights system needs that may require either the introduction of new rules or the modification of existing ones, to facilitate the development of a harmonized NTN environment. The work conducted in this regard has focused on the frequency ranges below 7.125 GHz and above 10 GHz and has identified two paths for NTN development.

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EXECUTIVE SUMMARY

The development and operations of 6G Non–Terrestrial Networks (6G-NTN) requires careful consideration of regulatory matters, such as the allocations of frequency ranges to services, the protection of terrestrial and satellite services, and the appropriate use of the frequency bands to which NTN has access.

The objective of this report is to provide an insight into the regulatory environment that covers NTN and the current rules and regulations regarding the use of spectrum that can be used to conceptualize NTN operations, as well as to highlight the system needs that may require either the introduction of new rules or the modification of existing ones to facilitate the development of a harmonized NTN environment.

The work conducted in this regard has focused on the frequency ranges under 7.125 GHz and above 10 GHz, and has identified paths for NTN development that can be categorized in two groups:

- A path that minimizes the need to modify regulation (short – to mid-term deployment path).
- A path that requires proposing modifications to existing regulations, which also include modifications to the Radio Regulations which can only take place at a World Radio Conference (WRC) and by means of a suitable Agenda Item.

For frequency bands below 7.125 GHz, noting the work by 3GPP where:

- 3GPP has already adopted NTN band classes n256 (1980-2010 MHz / 2170-2200 MHz) and n255 (1525-1559 MHz / 1626.5-1660.5 MHz) from Release 17 onwards.
- 3GPP is expected to adopt in Release 18 a set of new band class n254 (1610-1626.5 MHz / 2483.5-2500 MHz).

These would continue to be considered as feasible frequency ranges for satellite-based NTN.

This report also delves into the frequency range 3.4-3.7 GHz that is particularly interesting as a possible candidate for NTN, including the analysis of a series of challenges to the construction of an Uplink/Downlink pair that benefits from this frequency range, such as:

- Challenges arising from hardware limitations and/or network synchronisation, should Up/Down operations within the same band be considered.
- Regulatory challenges arising from current frequency allocations, which allow only downlink transmission in this portion of the band. Any possible changes to this allocation would require a concerted effort through ITU Member States to bring the matter for discussion at a WRC.

For frequency bands above 10 GHz, and to streamline the start of system design based on the current regulatory framework contained in the ITU Radio Regulations, it would be appropriate for satellite-based NTN to consider operating in a frequency range that is already allocated to the mobile satellite service (MSS), and particularly in the 39.5-40.5 GHz (space-to-Earth), 45.5-47 GHz (both directions) and 50.4-51.4 GHz (Earth-to-space).

Although this report also studied the frequency pairing 17.7-20.2 GHz (space-to-Earth) and 27.5-30 GHz (Earth-to-space), the use of this portion for NTN purposes is subject to operational restrictions under the regulatory framework of earth stations in motion communicating with GSO networks or NGSO satellite systems.

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This report also elaborates on the regulatory risks associated with the use of the above-mentioned bands and, wherever possible, the suggested potential mitigation measures. Consequently, the results of this document will serve as a source of input to other work packages that require information regarding potential frequency bands for NTN and associated regulatory constraints for their respective analyses relevant to the development for the 6G-NTN project.

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ABBREVIATIONS

3GPP	Third Generation Partnership Project
AES	Aircraft earth stations
AMS(R)S	Aeronautical mobile satellite (on route) service
CGC	Complementary Ground Component (in accordance with ECC Decision 06(09))
EESS	Earth exploration satellite service (in accordance with Article 1 of ITU Radio Regulations)
EPFD	Equivalent power flux density
ESAA	Earth station aboard aircraft
ESIM	Earth station in-motion
ESV	Earth station on board vessels
FS	Fixed service (in accordance with Article 1 of ITU Radio Regulations)
FSS	Fixed-satellite service (in accordance with Article 1 of ITU Radio Regulations)
GMDSS	Global Maritime Distress and Safety System
GSO	Geostationary Orbit
HAPS	High altitude platform station (in accordance with Article 1 of ITU Radio Regulations)
HDFSS	High density fixed-satellite service
HIBS	HAPS as IMT base station operating between 18 km and 25 km above ground
ITU	International Telecommunication Union
ITU-R	International Telecommunications Union – Radiocommunication Sector
IMT	International Mobile Telecommunications
MNO	Mobile network operators
MS	Mobile service (in accordance with Article 1 of ITU Radio Regulations)
MSS	Mobile-satellite service (in accordance with Article 1 of ITU Radio Regulations)
NGSO	Non-geostationary orbit
NTN	Non-terrestrial network
PFD	Power flux density

RAS	Radioastronomy service (in accordance with Article 1 of ITU Radio Regulations)
RIT	Radio Interface Technology
RR	ITU Radio Regulations
SDO	Standards Developing Organizations
SNO	Satellite network operators
TN	Terrestrial network
VMES	Vehicle-Mounted Earth Station
WP	Work Package
WRC	World Radiocommunication Conference

1 INTRODUCTION

In this chapter, the deliverable's objectives, structure, and its relation to other Work Packages (WPs) are briefly presented and discussed.

1.1 OBJECTIVE OF THE DOCUMENT

The main objective of this deliverable is to analyse the applicable regulatory framework and the spectrum usage conditions in sub-6GHz and Q/V bands between the different network nodes of 6G Non-Terrestrial Networks (NTNs) component:

- Geosynchronous Orbit (GSO),
- Non-Geosynchronous Orbit (NGSO),
- High-Altitude Platform Station (HAPS),
- Aircraft, drones, mounted and terrestrial.

Regulatory-related requirements for the system will be derived from this analysis. Furthermore, the deliverable will analyse relevant International Telecommunications Union – Radiocommunication Sector (ITU-R) activities post-WRC-23 (World Radiocommunication Conference) and identify the potentially required changes to the regulatory framework.

1.2 STRUCTURE OF THE DOCUMENT

The deliverable follows the structure briefly described below:

Section 2 provides an overview of the international regulatory framework for radio services contained in the ITU-R Radio Regulations and highlight relevant aspects associated to NTN services as intended for supporting 6G services. Section 2 also highlights the role of 3GPP in the definition of capabilities related to 6G systems and services and the link between 3GPP and the ITU-R.

Section 3 of the report provides an overview, per frequency band of interest, of the existing frequency and service allocations present in the ITU-R Radio Regulations.

Section 4 builds on section 3 to describe how those frequency and service allocations could affect the deployment of future NTN 6G services.

Section 5 provides examples of national decisions related to the deployment of NTN services, and highlights cases in which national decisions have deviated from the international framework

Finally, section 6 provides conclusions of the regulatory analysis and identifies mechanisms to initiate 6G NTN deployment in the future

1.3 RELATION TO OTHER WORK PACKAGES IN 6G-NTN

The deliverable *D2.5 – Report on Regulatory Requirements* will be used as a basis in other deliverables and WPs of the 6G-NTN, such as

- *Task 3.1 – Multi-layered NTN system architecture*, for which the technical operational parameters identified in the international regulatory provisions could be analysed to

determine whether they are likely to become operational constraints to the deployment of NTN in specific frequency bands,

- *Task 4.3 – Spectrum coexistence aspects*, where some of the elements on frequency band usage scenarios defined in D2.5 can be used,
- *Task 6.3 – Standardization and pre-standardization*, for the planning and implementation of the 6G-NTN standardization actions, which aim to provide contributions to the relevant Standards Developing Organizations (SDOs) and pre-standardization interest groups.

2 OVERVIEW OF THE ITU REGULATORY FRAMEWORK

2.1 INTERNATIONAL TELECOMMUNICATIONS UNION

The International Telecommunication Union (ITU) is an intergovernmental organisation under the auspice of the United Nations. The rights and obligations of the 193 Member States, and the provisions for the functioning of the Union, are established by two treaties: the ITU Constitution and the ITU Convention, including the annexed ITU Radio Regulations (RR) that are subject to a rolling four-year review through the World Radiocommunication Conferences. Thus, the RR have a binding nature for ITU Member States.

The ITU Radio Regulations (RR) [1] contain a detailed technical and operational basis for utilisation of the radio spectrum up to 3000 GHz across the world. For the purposes of the RR, the world has been divided into three administrative ITU Regions as shown Figure 1, extracted from the RR.

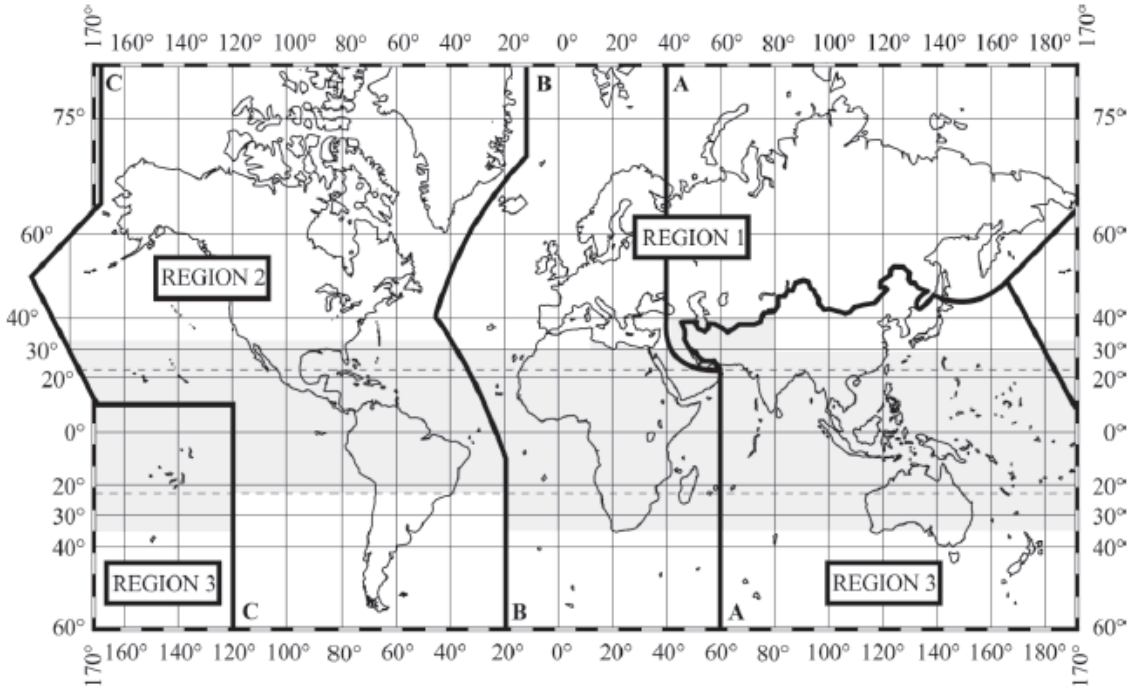

FIGURE 1. FOR THE ALLOCATION OF FREQUENCIES, THE WORLD HAS BEEN DIVIDED INTO THREE REGIONS.

The Table of Frequency Allocations, which maps the frequency bands to the different services allocated to the three ITU Regions, is contained in Article 5 of the RR.

An *allocation* is defined as an entry in this table for the purpose of its use by a specific radiocommunications service on a primary or a secondary basis. A given frequency band can be allocated to multiple services, resulting in the need to establish in some cases a hierarchy of services. Co-primary services can share a frequency band, and stations of these co-primary services have equal status to operate in said frequency band. In some instances, the RR may provide specific mechanisms for coordination between stations of these co-primary services or prescribe a set of technical and/or operational conditions for operation in this frequency band without coordination (including cross-border coordination cases) when such stations are complying with these conditions.

Stations belonging to a *secondary* service shall operate under non-interference/non-protection (NI/NP) vis-a-vis stations of the primary service, meaning that stations

a) shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date;

b) cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date;

c) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.

Each administration has its own sovereign rights to the use of the spectrum within its national territory. Although deviations from the RR are possible, given the binding nature of the RR, any deviations from its provisions at national level are rare. Individual countries or a collection of countries under a regional group with substantial market in the context of radio communications sector, such as Brazil, China, US and the European Union, have under exceptional circumstances chosen to deviate from the RR in order to serve the needs of their national or regional interests. See for example the European Commission's EC Decision 2019/784 [2] relative to the use of the 24.25-25.25 GHz range, which at the time was not allocated to Mobile services in Region 1. In other instances, national security needs may also dictate possible deviations from the RR.

2.1.1 The World Radiocommunications Conference

The role of the World Radiocommunications Conference (WRC) is

- to agree upon the conditions of operations of the various radiocommunications services, in order to ensure coexistence and spectrum sharing,
- to adjust, if necessary, the Table of Frequency allocations, apportioning existing bands or introducing new bands, allocating bands to services, and modifying the status of the allocated services.

The topics that will be addressed by a WRC are defined four years in advance and set in the conference's Agenda. The Agenda Items of the conference thus contain all topics relative to the operations of radiocommunications services and the use of spectrum upon which the Member States must decide, on the basis of the various technical studies executed by the ITU-R Study Groups during the four-year study cycle.

2.2 DEFINITION OF RADIO SERVICES RELEVANT TO NTN

The RR defines the following radiocommunication services, which are of interest to the discussions contained in this document.

2.2.1 Terrestrial Services

As defined in Article 1.7 of the RR, terrestrial radiocommunication means any radiocommunication other than space radiocommunication or radio astronomy.

Article 1.62 of the RR further indicates that a terrestrial station is a station effecting terrestrial radiocommunication. Unless otherwise stated in the RR, any station is a terrestrial station.

2.2.1.1 Fixed Service (FS)

As defined in Article 1.20 of the RR, Fixed service (FS) is a radiocommunication service between fixed points on the earth surface or within the major portion of the Earth's atmosphere.

FS applications include transport networks, backhaul connections for base stations of the mobile service, fixed wireless access (point-to-point and point-to-multipoint), Electronic News Gathering (ENG) and Broadcasting Auxiliary Services (BAS).

With regards to the stations communicating in the FS, it is important to distinguish terrestrial stations, or stations in general, from the more specific Land Stations, and from Earth Stations. Land stations are stations on land operating in the Mobile Service (MS), and Earth Stations are fixed stations on earth operating on the fixed satellite service (FSS). All three types of stations are on earth, and therefore could be confused as being “terrestrial”, especially when dealing with translated text.

2.2.1.2 High Altitude Platform Station (HAPS) as an application in the FS

As defined in Article 1.66A of the RR, a high-altitude platform station (HAPS) is a station located on an object at an altitude between 20 to 50 km from the ground, and at a specified, nominal, fixed point relative to the Earth.

HAPS have been proposed as a solution to provide broadband (Fixed Wireless Access and Broadband Wireless Access in the FS) and backhauling connectivity to stations of the mobile service, in areas where terrestrial infrastructure would be difficult to deploy. HAPS can provide services to wide areas and augment the capabilities of service providers [4].

In the context of the RR, it is understood that HAPS is an application of FS and that the transmissions to or from HAPS shall be limited to bands specifically identified in Article 5 of the RR, by means of footnotes in the Table of Frequency Allocations such as:

- No. 5.457: country-specific footnote for 6440-6520 MHz (HAPS-to-ground) and 6560-6640 MHz (ground-to-HAPS)
- No. 5.530E: Region 2 footnote for 21.4-22 GHz (HAPS-to-ground)
- No. 5.532AA: Region 2 footnote for 24.25-25.25 GHz (HAPS-to-ground)
- No. 5.534A: Region 2 footnote for 25.25-27 GHz (ground-to-HAPS) limited to gateway links and 27-27.5 GHz (HAPS-to-ground)
- No. 5.537A: country-specific footnote for 27.9-28.2 GHz (HAPS-to-ground)
- No. 5.543B: worldwide for 31-31.3 GHz (both directions)
- No. 5.550D: worldwide for 38-39.5 GHz (HAPS-to-ground)
- No. 5.552A: worldwide for 47.2-47.5 GHz and 47.9-48.2 GHz (both directions).

2.2.1.3 Mobile Service (MS) including Aeronautical, Maritime and Land Mobile Service

As defined in Article 1.24 of the RR, Mobile Service (MS) is the radiocommunications service between mobile and land stations or between mobile stations. Mobile and land mobile stations are those that communicate while in motion or during halts at unspecified points (i.e., user devices), while land stations are those not intended to be used while moving. Therefore, under this definition, base stations are land stations within the MS.

The MS is further subclassified, depending on the locations of the stations communicating, as

- land mobile service (Article 1.26 of the RR), where the stations communicating are land-based;

- maritime mobile service (Article 1.28 of the RR), where the stations communicating are located on the coast or on ships;
- aeronautical mobile service (Article 1.32 of the RR), where this is the communication between aeronautical stations (usually the land stations but can be located on a ship or on a platform at sea) and aircraft stations, or between aircraft stations.

2.2.1.4 International Mobile Telecommunication (IMT) system as an application in the MS

Certain portions of frequency bands allocated to MS are "identified" for developing a specific application of that service. Although the identification mechanism is not explicitly defined in the RR, it is understood to mean the intention or interest to develop that portion of the band for a specific application. For example, several frequency bands allocated to the MS have been identified for development of mobile systems known as International Mobile Telecommunications (IMT) since 1992. Such identification does not grant any additional priority to that application within the MS with respect to other applications of the MS and does not establish any priority with respect to other services in the RR.

TABLE 1. LIST OF FOOTNOTES IN THE RADIO REGULATIONS CONCERNING THE IDENTIFICATION OF FREQUENCY BANDS FOR IMT.

Footnote	Band/Portion	Region	Countries
5.286AA	450-470 MHz	Global	
5.295	470-608	R2 countries	Bahamas, Barbados, Canada, the United States and Mexico
5.296A	470-698 MHz (1), 610-698 MHz (2)	R3 countries	(1) In Micronesia, the Solomon Islands, Tuvalu and Vanuatu (2) Bangladesh, Lao, Maldives, New Zealand and Viet Nam
5.[15B]*	614-698 MHz	R1 countries	Saudi Arabia, Bahrain, Egypt, the United Arab Emirates, Iraq, Jordan, Kuwait, Oman, Palestine, Qatar and the Syrian Arab Republic
5.308A	614-698 MHz	R2 countries	Bahamas, Barbados, Belize, Canada, Colombia, El Salvador, the United States, Guatemala, Jamaica and Mexico
5.313A	698-790 MHz	R3 countries	Australia, Bangladesh, Brunei, Darussalam, Cambodia, China, Korea (Rep. of), Fiji, India, Indonesia, Japan, Kiribati, Lao P.D.R., Malaysia, Myanmar,(Union of), New Zealand, Pakistan, Papua New Guinea, the Philippines, the Dem. People's Rep. of Korea, Solomon,Islands, Samoa, Singapore, Thailand, Tonga, Tuvalu, Vanuatu and Viet Nam
5.317A	698-960 MHz (1), 694-790 MHz (2), 790-960 MHz (3)	(1) R2, (2) R1, (3) R1+R3	

Footnote	Band/Portion	Region	Countries
5.341A	1427-1452 MHz and 1492-1518 MHz	R1	
5.341B	1 427-1 518 MHz	R2	
5.341C	1 427-1 452 MHz and 1 492-1 518 MHz	R3	
5.346	1 452-1 492 MHz	R1 countries	Algeria, Angola, Saudi Arabia, Bahrain, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo (Rep. of the), Côte d'Ivoire, Djibouti, Egypt, United Arab Emirates, Eswatini, Gabon, Gambia, Ghana, Guinea, Iraq, Jordan, Kenya, Kuwait, Lesotho, Lebanon, Liberia, Madagascar, Malawi, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Oman, Uganda, Palestine, Qatar, Dem. Rep. of the Congo, Rwanda, Senegal, Seychelles, Somalia, Sudan, South Sudan, South Africa, Tanzania, Chad, Togo, Tunisia, Zambia, and Zimbabwe
5.346A	1452-1492 MHz	R3	
5.384A	1710-1885 MHz, 2300-2400 MHz and 2500-2690 MHz	Global	
5.388	1885-2025 MHz and 2110-2200 MHz	Global	
5.429B	3300-3 400 MHz	R1 countries	Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Comoros, Congo (Rep. of the), Côte d'Ivoire, Egypt, Eritrea, Eswatini, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Equatorial Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritius, Mauritania, Mongolia, Mozambique, Namibia, Niger, Nigeria, Uganda, the Dem. Rep. of the Congo, Rwanda, Sao Torre and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, South Sudan, South Africa, Tanzania, Chad, Togo, Zambia and Zimbabwe
5.429D	3300-3 400 MHz	R2	
5.429F	3300-3400 MHz	R3 countries	Cambodia, India, Indonesia, Lao P.D.R., Pakistan, the Philippines, Singapore, and Viet Nam,
5.430A	3400-3600 MHz	R1	
5.431B	3400-3600 MHz	R2	

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Footnote	Band/Portion	Region	Countries
5.432A	3400-3500 MHz	R3 countries	Korea (Rep. of), Japan, Pakistan and the Dem. People's Rep. of Korea
5.432B	3400-3500 MHz	R3 countries	Australia, Bangladesh, Brunei Darussalam, China, French overseas communities of Region 3, India, Indonesia, Iran (Islamic Republic of), Malaysia, New Zealand, the Philippines, Singapore and Thailand
5.433A	3500-3600 MHz	R3 countries	Australia, Bangladesh, Brunei Darussalam, China, French overseas communities of Region 3, Korea (Rep. of), India, Indonesia, Iran (Islamic Republic of), Japan, New Zealand, Pakistan, the Philippines, the Dem. People's Rep. of Korea and Singapore
5.[A13C]*	3600-3700 MHz	R1 countries	Angola, Botswana, Guinea, Lesotho, Malawi and South Sudan
5.[A13D]*	3600-3800 MHz	R1 countries	Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, Benin, Burkina Faso, Burundi, Cameroon, Central African Rep., Comoros, Congo (Rep. of the), Côte d'Ivoire, Djibouti, Egypt, United Arab Emirates, Eswatini, Gabon, Gambia, Ghana, Guinea, Iraq, Jordan, Kazakhstan, Kenya, Kuwait, Lebanon, Liberia, Libya, Madagascar, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Oman, Uganda, Uzbekistan, Palestine, Qatar, the Syrian Arab Republic, the Dem. Rep. of the Congo, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, Sudan, South Africa, Tanzania, Chad, Togo, Tunisia, Yemen, Zambia and Zimbabwe,
5.434	3600-3700 MHz	R2	
5.[36A12]*	3700-3800 MHz	R2 countries	Bahamas, Belize, Brazil, Canada, Colombia, Costa Rica, United States, Guatemala, the French overseas departments and communities in Region 2, Greenland, the overseas countries and territories within the Kingdom of the Netherlands in Region 2, Paraguay, Peru, Trinidad and Tobago and Uruguay
5.441A	4800-4900 MHz	R2 countries	Brazil, Paraguay, Uruguay
5.441B	4800-4990 MHz		Angola, Argentina, Armenia, Azerbaijan, Benin, Botswana, Brazil, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Chile, China, Colombia, Congo (Rep. of the), Côte d'Ivoire, Djibouti, Eswatini, Russian Federation, Gabon, Ghana, Guinea, Iran (Islamic Republic of), Iraq, Kazakhstan, Lao P.D.R., Lesotho, Liberia, Madagascar, Malawi, Mali, Mongolia, Nambia, Niger, Uganda, Uzbekistan, the Dem. Rep. of the Congo, Kyrgyzstan, the Dem. People's Rep. of Korea, South Sudan, South Africa, Chad, Togo, Viet Nam, Zambia and Zimbabwe
5.[6A12]*	6425-7125 MHz (1), 7025-7125 MHz (2)	(1) R1, (2) R3	

Footnote	Band/Portion	Region	Countries
5.[6B12]*	6425-7025 MHz	R3 countries	Cambodia, Lao P.D.R. and the Maldives
5.[6C12]*	6425-7125 MHz	R2 countries	Brazil and Mexico
5.[10B12]*	10-10.5 GHz	R2 countries	Brazil, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Paraguay, Peru and Uruguay
5.532AB	24.25-27.5 GHz	Global	
5.550B	37-43.5 GHz	Global	
5.553A	45.5-47 GHz		NOTE: Terrestrial component only. Algeria, Angola, Bahrain, Belarus, Benin, Botswana, Brazil, Burkina Faso, Cabo Verde, Korea (Rep. of), Côte d'Ivoire, Croatia, United Arab Emirates, Estonia, Eswatini, Gabon, Gambia, Ghana, Greece, Guinea, Guinea-Bissau, Hungary, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lesotho, Latvia, Liberia, Lithuania, Madagascar, Malawi, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Oman, Qatar, Senegal, Seychelles, Sierra Leone, Slovenia, Sudan, South Africa, Sweden, Tanzania, Togo, Tunisia, Zambia and Zimbabwe
5.553B	47.2-48.2 GHz	R2 and R1/R3 countries	Algeria, Angola, Saudi Arabia, Australia, Bahrain, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Rep., Comoros, Congo (Rep. of the), Korea (Rep. of), Côte d'Ivoire, Djibouti, Egypt, United Arab Emirates, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Equatorial Guinea, India, Iran (Islamic Republic of), Iraq, Japan, Jordan, Kenya, Kuwait, Lesotho, Liberia, Libya, Lithuania, Madagascar, Malaysia, Malawi, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Oman, Uganda, Qatar, the Syrian Arab Republic, the Dem. Rep. of the Congo, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Singapore, Slovenia, Somalia, Sudan, South Sudan, South Africa, Sweden, Tanzania, Chad, Togo, Tunisia, Zambia and Zimbabwe
5.559AA	66-71 GHz	Global	
** The exact numbering of footnotes 5.[xxx] as shown above for appearance in Article 5 of the RR was not known at the time of writing this Report.*			

2.2.1.5 High altitude platform as IMT Base Station (HIBS) as an application in MS

A special category of HAPS as base stations to provide IMT services has been included in the RR, to be considered as an application of the MS. This special category is known as High altitude platforms as IMT Base Stations (HIBS).

The first example of this provision can be found in No. 5.388A where the bands 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3 and the bands 1885-1980 MHz and 2110-2160 MHz in Region 2, may be used by HAPS acting as base stations.

Although the use of HAPS as IMT base stations was introduced in Resolution 221 of in WRC-00 [3], a revision to Resolution 221 was adopted at WRC-23 specifying that HIBS is also expected to operate between 18 km and 25 km from ground.

Based on the analysis of the spectrum needs for high altitude platforms supporting broadband links is provided in ITU-R Report F.2438 [4] and the decision at WRC-23, the following bands are specifically identified for HIBS in Article 5 of the RR:

- No. 5.[14A]: footnote applicable to the band 698-960 MHz for Region 2 and 694-960 MHz for Region 1, particularly the portions in 694-728 MHz, 830-835 MHz and 805.3-806.9 MHz are limited to reception by HIBS.
- No. 5.[14B]: country-footnote in Region 3 for portions of 698-960 MHz. The 698-728 MHz and 830-835 MHz portions are limited to reception by HIBS.
- No. 5.388A: 1710-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3 and the frequency bands 1710-1980 MHz and 2110-2160 MHz in Region 2. The portions 1710-1785 MHz in Regions 1 and 2, and 1710-1815 MHz in Region 3, are limited to reception by HIBS. The portion 2110-2170 MHz is limited to transmission from HIBS.
- No. 5.[14C]: 2500-2690 MHz in Regions 1 and 2, and 2500-2655 MHz in Region 3. The portions 2500-2510 MHz in Regions 1 and 2, and 2500-2535 MHz in Region 3, are limited to reception by HIBS.

** The exact numbering of 5.[14A], 5.[14B], 5.[14C] for appearance in Article 5 of the RR was not known at the time of writing this Report.*

2.2.2 Space Services

As defined in Article 1.8 of the RR, space radiocommunication means any radiocommunication involving the use of one or more space stations or the use of one or more reflecting satellites or other objects in space.

Article 1.63 of the RR indicates that an earth station is a station located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for communication with one or more space stations; or with one or more stations of the same kind by means of one or more reflecting satellites or other objects in space.

Article 1.64 of the RR further indicates that a space station is a station located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the Earth's atmosphere.

2.2.2.1 Mobile Satellite Service (MSS)

As defined in Article 1.25 of the RR, Mobile Satellite Service (MSS) includes communications between mobile earth stations and one or more space stations. Mobile earth stations can be located on land (land mobile satellite service), on board ships (maritime mobile satellite service), or onboard aircraft (aeronautical mobile satellite service).

2.2.2.2 Fixed Satellite Service (FSS)

As defined in Article 1.21 of the RR, Fixed Satellite Service (FSS) is a radiocommunications service between earth stations at given positions (including positions that change within a specific area) using one or more satellites.

2.2.2.3 Earth Stations in Motion (ESIM) as an application in FSS

Earth Stations in Motion (ESIM) are stations recognised as part of the FSS, presently allowed to operate with

- GSO networks in 10.7-10.95 GHz, 11.2-11.45 GHz and 12.75-13.25 GHz (No.5.[A115] and Resolution [COM5/2]);
- GSO networks in 17.7-20.2 GHz and 27.5-30 GHz (Nos. 5.517A, 5.527A and their corresponding Resolutions 169 and 156, respectively);
- NGSO systems in 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz and 27.5-29.1 GHz and 29.5-30 GHz (No.5.[A116] and Resolution [COM5/3]).

There are currently three types: ESIM onboard aircraft (aeronautical ESIM), ESIM onboard ships (maritime ESIM) and ESIM onboard land vehicles (land ESIM).

2.3 INTERWORKING RELATIONSHIP WITH 3GPP

2.3.1 International Mobile Telecommunications (IMT) framework

As mentioned in section 2.2.1.4, International Mobile Telecommunications (IMT) is a term adopted by the ITU to designate broadband mobile systems. It encompasses, currently, IMT-2000 (3G), IMT-Advanced (4G) and IMT-2020 (5G) with planning on-going for IMT-2030 (6G).

The ITU began its work on the development of global future public land mobile telecommunication system (FPLMTS) in 1986, corresponding to the second generation (2G) mobile systems. FPLMTS was renamed to IMT-2000 in 1994, with the objective of developing a new generation about every 10 years.

The ITU develops and adopts standards describing the requirements for IMT systems, elements of the IMT core network (ITU-T) and its radio interfaces (ITU-R). ITU standards related to IMT do not specify technologies but define criteria to be met by candidate radio interface technologies.

It is also important to clarify that the ITU "*does not have a definition for 3G, 4G or 5G and ITU cannot hold a position on whether or not a given technology is labelled with that term for marketing purposes*" [5].

Recommendation ITU-R M.1224, "Vocabulary of terms for International Mobile Telecommunications" contains the formal definitions in use in ITU-R Reports and Recommendations related to IMT systems.

The ITU-R process with regards to the development of IMT could be summarised as follows [6]

- The definition of a framework (formerly known as vision), containing definitions, desired capabilities, use cases and system targets (described in ITU-R Recommendations).
- Definition of the minimum requirements, submission templates and evaluation guidelines (described in ITU-R Reports).
- Invitation for proposals and independent evaluation through an ITU circular letter.
- Specification, approval, and implementation (described in ITU-R Reports & Recommendation and other documents).

As the process involves bodies external to the ITU, e.g., standardisation bodies such as 3GPP[1] (The 3rd Generation Partnership Project) and evaluation groups, a structured interaction process has been put in place to facilitate cooperation. The process is defined in Resolution ITU-R 65 [7] and the flowchart in Figure 2 summarizes the various steps and related ITU deliverables of the process. Table 2 lists the main ITU deliverables for each generation, for both the terrestrial and satellite components.

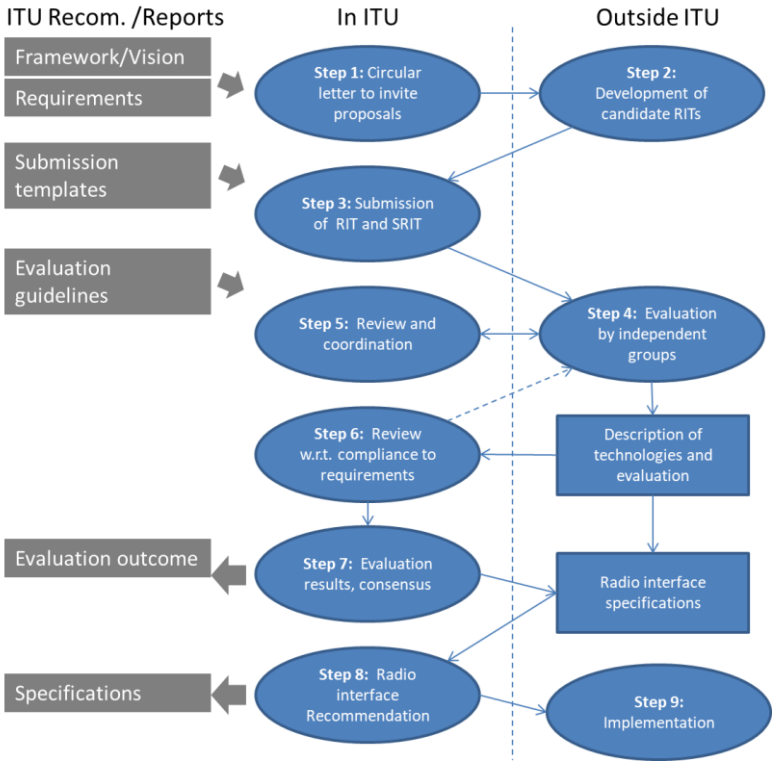

FIGURE 2. IMT DELIVERABLES AND THEIR INTERDEPENDENCY BETWEEN ACTIVITIES WITHIN ITU AND OUTSIDE ITU

[1] The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC). https://www.3gpp.org/about-us/introducing-3gpp

TABLE 2. ITU DELIVERABLES FOR EACH GENERATION OF IMT

	IMT-2000		IMT-Advanced		IMT-2020		IMT-2030	
	Terrestrial	Satellite	Terrestrial	Satellite	Terrestrial	Satellite	Terrestrial	Satellite
Vision / Framework	Rec M.687 &M.816 **1992**	Rec M.818 **1994**	Rec. M.1645 **2003**	Rep M.2176 **2010**	Rec M.2083 **2015**	Rep M.2514 **Oct 2022**	Rec M.2160 **Nov 2023**	
Minimum technical requirements	Rec M.1034 **1997**		Rep M.2134 **2008**		Rep M.2410 **2017**			
Submission templates	8/LCCE/47 **1998**		Rep M.2133 **2008**		Rep M.2411 **2017**			
Evaluation guidelines	Rec M.1225 **1997**		Rep M.2135 **2009**		Rep M.2412 **2017**			
Evaluation outcome			Rep M.2198 **2010**	Rep M.2279 **2013**	Rep M.2483 **July 2020**	**Expected end 2024**		
Specifications	Rec M.1457 **2000** **Last version 2017**	Rec M.1850 **2000** **Last version 2014**	Rec M.2012 **2012** **Last version 2018**	Rec. M.2047 **2013**	Rec. M.2150 **Feb 2021** **Last version Feb 2022**	**Expected 2025**		

3GPP is one of main standards bodies proposing radio interface technologies (RIT) to the ITU through the above-described process. The alignment between the IMT generations and 3GPP radio interfaces is illustrated below:

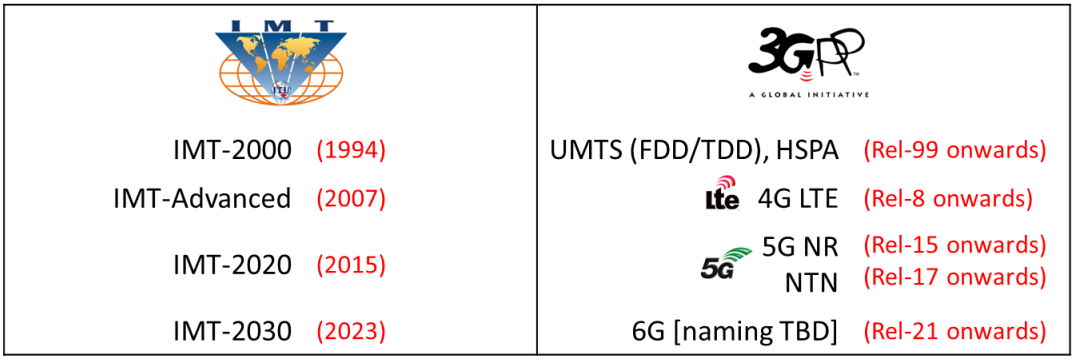

FIGURE 3. CURRENT ALIGNMENT BETWEEN ITU-R IMT GENERATIONS OF TECHNOLOGY AND 3GPP STANDARDS

2.3.2 IMT frequency bands identification

As noted in section 2.2.1.4, the table of frequency allocations of the RR contains several footnotes identifying the respective frequency band for use by IMT systems.

The IMT identification concept enables the ITU to provide to the ecosystem (administrations, standards organisations, vendors, and operators) common guidance and focus regarding the use of a portion of spectrum for the global development of an application or service.

This identification does not preclude the use of these frequency bands by any application of the services to which it is allocated and does not establish priority in the Radio Regulations. Thus, an IMT identification is to be interpreted as a strong but non-mandatory indication to the

administrations and the ecosystem that certain bands should be considered for IMT system development, licensing and implementation.

It should be noted that while most bands where IMT technologies are effectively implemented are identified for IMT in the ITU table of frequency allocations, there are some cases of IMT deployment -using equipment of specific 3GPP band classes- in bands allocated to the Mobile Service, but not identified for IMT.

The RR also identifies frequency bands for the satellite component of IMT. Initially implemented in the MSS allocations in the 2 GHz range as part of the IMT-2000 development, the IMT satellite frequencies were later extended to other MSS bands below 3 GHz, including the frequency bands 1518-1544 MHz, 1545-1559 MHz, 1610-1626.5 MHz, 1626.5-1645.5 MHz, 1646.5-1660.5 MHz, 1668-1675 MHz and 2483.5-2500 MHz (globally), as well as 2500-2520 MHz and 2670-2690 MHz (Region 3 only), as described in Resolution 225 (Rev. WRC-12) [8] .

IMT identifications are decided during World Radiocommunication Conferences (WRCs). Given the potential spectrum policy, industrial and technical implications, WRC agenda items dealing with IMT identifications attract considerable attention and generate debate.

In association with the identification of frequency band for IMT, the ITU-R also develops frequency arrangements within these bands whereby duplex modes (FDD, TDD) and direction of transmission are recommended. These frequency arrangements are described in Recommendation ITU-R M.1036 [9]. Such frequency arrangements are of particular importance for FDD, as the table of frequency allocation in Article 5 of the RR does not provide duplex direction indications.

Given that for the satellite component of IMT the direction of transmission (Earth-to-space, space-to-Earth) is specified in the table of frequency allocation, there is no satellite equivalent to the Recommendation ITU-R M.1036.

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3 FREQUENCY ALLOCATIONS RELEVANT TO FACILITATE NTN

3.1 BELOW 7.125 GHZ

3.1.1 Frequency bands allocated to relevant Terrestrial Services

As presented in the previous section, the ITU Radio Regulations defines radiocommunication services under which any application using radio waves may be classified. The “Mobile Service” is defined as “A radiocommunication service between mobile and land stations, or between mobile stations”. The Mobile Service being a terrestrial service includes communications between a mobile terminal and base stations, but also communications between ships or aircrafts, or between those and stations at fixed locations. When one endpoint of such communications is in outer space (i.e., a satellite), it is a space service and no longer a terrestrial service.

As explained in section 2.2.1.4, some of the bands allocated to the MS are identified for International Mobile Telecommunications (IMT). The following sections identify the frequency bands allocated to the Mobile Service with effective or planned deployment for IMT technologies.

3.1.1.1 Bands below 1 GHz

The relevant allocations in the range 400 MHz to 1 GHz are identified in Table 3. Only allocations with significant bandwidths and regional footprint are mentioned.

TABLE 3. SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS UNDER 1 GHZ

FS Allocation on a primary basis	**Globally:** 50 MHz (410-430 MHz+440-470 MHz) and 154 MHz (806-960 MHz) **In R1:** 16 MHz (790-806 MHz) **In R3:** 336 MHz (470-806 MHz)
FS Allocation on a secondary basis	**Globally:** 5 MHz (401-406 MHz) **In R2:** 234 MHz (470-512 MHz + 614-806 MHz)
Identifications for use with HAPS	N/A
MS Allocation on a primary basis	**Globally:** 50 MHz (410-430 MHz+440-470 MHz) and 262 MHz (698-960 MHz) except secondary portions in R2.
MS Allocation on a secondary basis	**Globally:** 5 MHz (401-406 MHz) **In R2:** 126 MHz (470-512 MHz + 614-698 MHz)
Identifications for IMT	No. 5.286AA: Global identification in 450-470 MHz Nos. 5.295, 5.296A, 5.308A, 5.313A, 5.317A: identified in portions of 470-960 MHz
Identifications for HIBS	Nos. 5.[14A] and 5.[14B]: identified portions of 694-960 MHz for HIBS differently across R1/R2/R3 and also specified restrictions in the transmission direction differently

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3.1.1.2 Bands between 1 GHz and 3 GHz

TABLE 4. SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS IN THE RANGE BETWEEN 1 AND 3 GHZ

FS Allocation on a primary basis	**Globally**: 98 MHz (1427-1525 MHz)[2], 21.6 MHz (1668.4-1690 MHz), 990 MHz (1700-2690 MHz) **In R1**: 50 MHz (1350-1400 MHz) **In R1+R3**: 5 MHz (1525-1530 MHz)
FS Allocation on a secondary basis	**Globally**: (1660.5-1668.4 MHz) **In R1**: 10 MHz (1690-1700 MHz) **In R2**: 10 MHz (1525-1535 MHz) **In R1+R3**: 5 MHz (1530-1535 MHz)
Identifications for use with HAPS	No. 5.388B[3]
MS Allocation on a primary basis	Allocations begin at 1.3 GHz. **Global**: 1109.6 MHz (several portions between 1427 MHz and 2690 MHz) **In R1**: 50 MHz (1350-1400 MHz), 89 MHz (1429-1518 MHz) with R1 exception for Aeronautical Mobile.
MS Allocation on a secondary basis	**Globally**: 35.8 MHz (in various portions of the band 1525 MHz to 1700 MHz) **In R1**: 10 MHz (1690-1700 MHz) with exception in No. 5.382
Identifications for IMT	**Mixture**: 91 MHz as split below No. 5.341A, R1 identification of range 1427-1452 MHz and 1492-1518 MHz. No. 5.341B, R2 identification of range 1427-1518 MHz No. 5.341C, R3 identification of range 1427-1452 MHz and 1492-1518 MHz. **Globally**: 695 MHz (1710-1885 MHz, 2300-2400 MHz and 2500-2690 MHz via No. 5.384A; and, 1885-2025 MHz and 2110-2200 MHz via No. 5.388)
Identifications for HIBS	No. 5.388A: R1+R3 identification of range 1710-1980 MHz, 2010-2025 MHz and 2110-2170 MHz; R2 identification of range 1710-1980 MHz and 2110-2160 MHz. No. 5.[14C]: R1+R2 identification of range 2500-2690 MHz; R3 identification of range 2500-2655 MHz.

3.1.1.3 Bands between 3 GHz and 5 GHz

TABLE 5 SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS IN THE MID-BAND RANGE (BETWEEN 3 AND 5 GHZ)

FS Allocation on a primary basis	**Globally**: 800 MHz (3.4-4.2 GHz) **Globally**: 600 MHz (4.4-5.0 GHz)
FS Allocation on a secondary basis	**In R2**: 100 MHz (3.3-3.4 GHz)
Identifications for use with HAPS	N/A
MS Allocation on a primary basis	**Globally**: 200 MHz (3.4-3.6 GHz), 600 MHz (4.4-5.0 GHz)

[2] 2 MHz (1.427-1.429 GHz), 23 MHz (1.429-1.452 GHz), 40 MHz (1.452-1.492 GHz), 23 MHz (1.492-1.525 GHz)

[3] In Regions 1 and 3, the bands 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz and, in Region 2, the bands 1885-1980 MHz and 2110-2160 MHz

	In R2+R3: 600 MHz (3.6-4.2 GHz)
MS Allocation on a secondary basis	**In R1**: 600 MHz (3.6-4.2 GHz) **In R2**: 100 MHz (3.3-3.4 GHz)
Identifications for IMT	**In R1 and R2**: 200 MHz (3.4-3.6 GHz) via No. 5.430A for R1, and No.5.431B for R2, **In R3**: 100 MHz (3.4-3.5 GHz), for some countries in No. 5.432A[4] **In R3**: 100 MHz (3.5-3.6 GHz), for some countries in No. 5.433A[5] **In R2**: 100 MHz (3.6-3.7 GHz) via No. 5.434

In the 3-5 GHz range, a significant amount of spectrum is allocated to the mobile service with a large portion identified for IMT use.

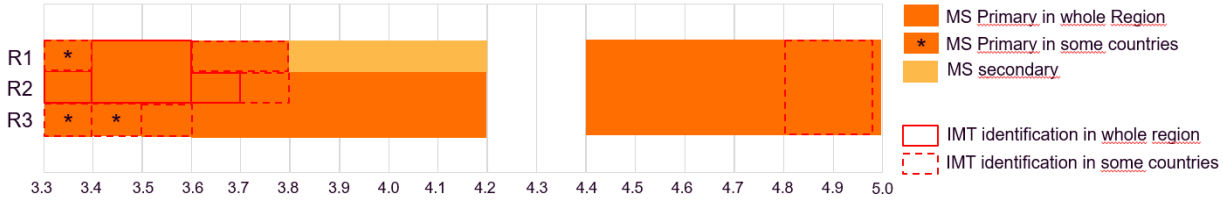

FIGURE 4. OVERVIEW OF FREQUENCY ALLOCATION AND IMT IDENTIFICATION IN 3-5 GHz

Figure 5 to Figure 10 illustrate the geographical spread of the current allocations to the Mobile service and IMT identifications in the range 3 to 5 GHz.

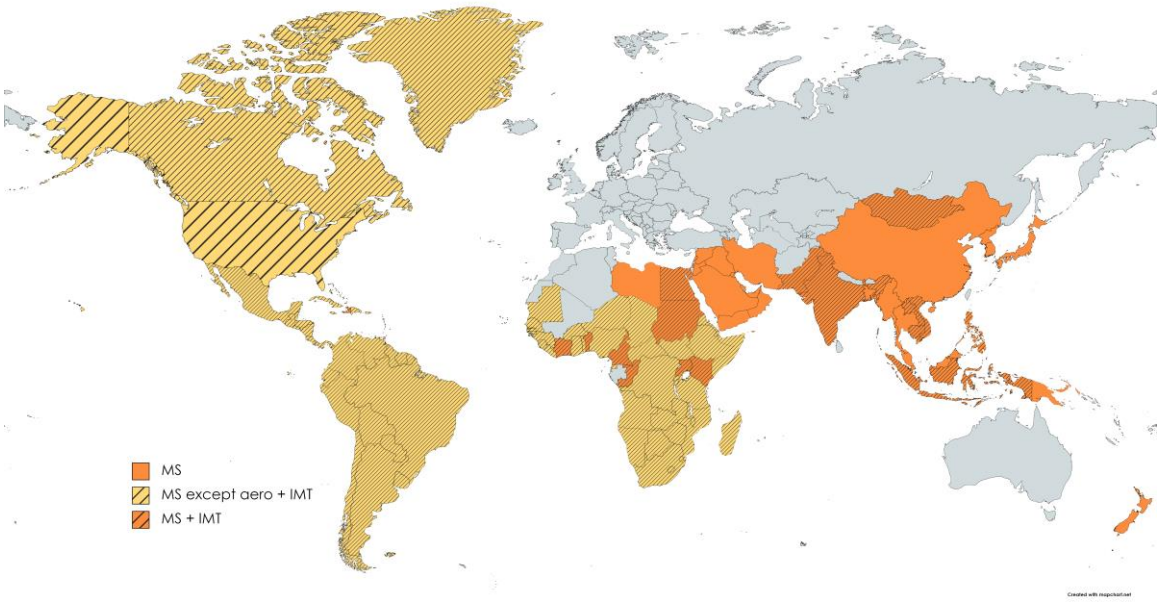

FIGURE 5. COUNTRIES WITH MS AND IMT IDENTIFICATION IN 3.3-3.4 GHz

[4] No.5.432: In Korea (Rep. of), Japan, Pakistan and the Dem. People's Rep. of Korea

[5] No.5.433A: Australia, Bangladesh, Brunei Darussalam, China, French overseas communities of Region 3, Korea (Rep. of), India, Indonesia, Iran (Islamic Republic of), Japan, New Zealand, Pakistan, the Philippines, the Dem. People's Rep. of Korea and Singapore

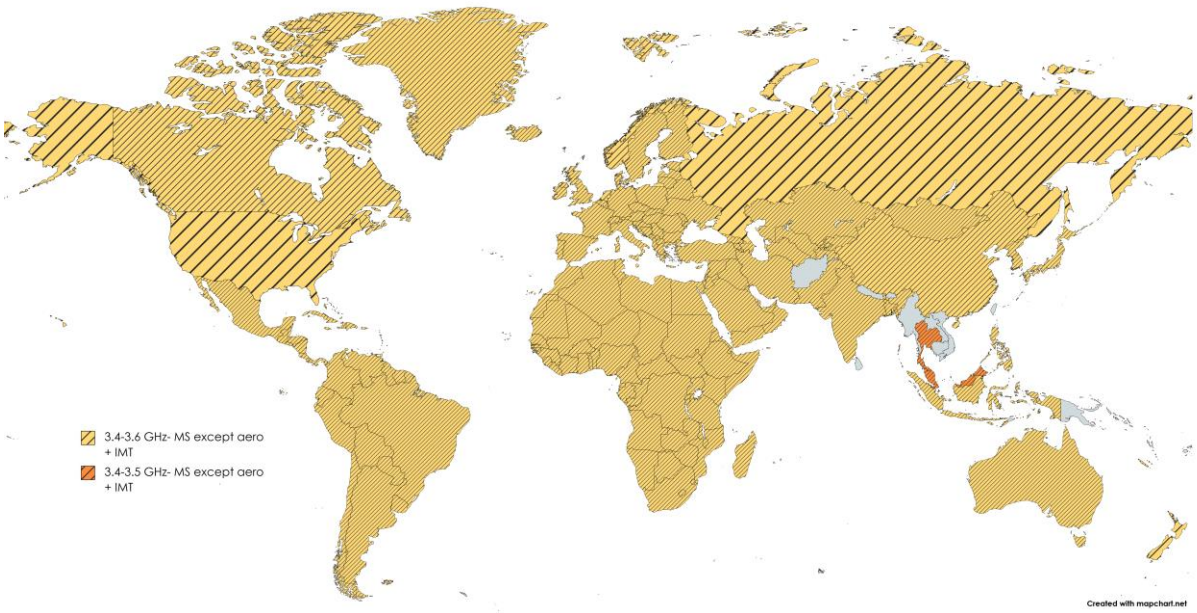

FIGURE 6. COUNTRIES WITH MS AND IMT IDENTIFICATION IN 3.4-3.6 GHz

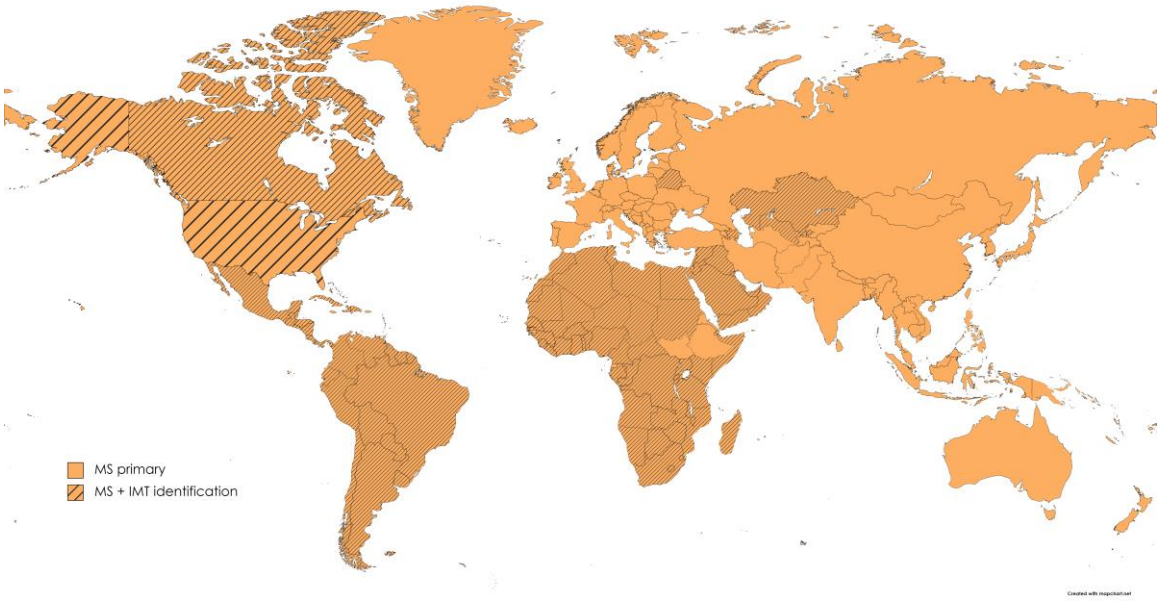

FIGURE 7. COUNTRIES WITH MS AND IMT IDENTIFICATION IN 3.6-3.7 GHz

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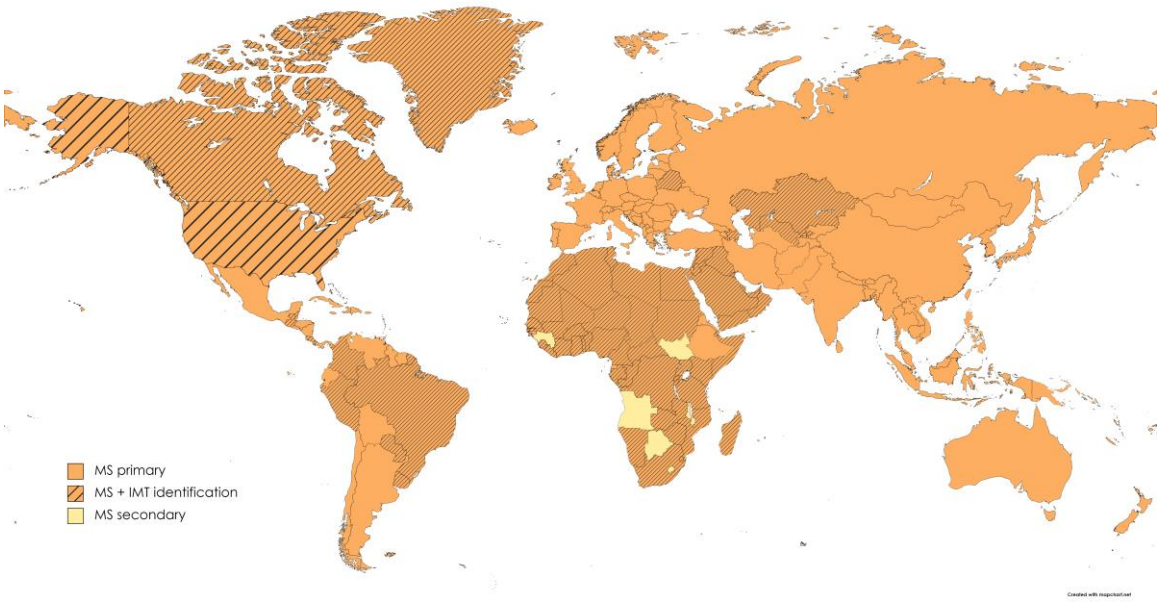

FIGURE 8. COUNTRIES/REGIONS WITH MS IN 3.7-3.8 GHz

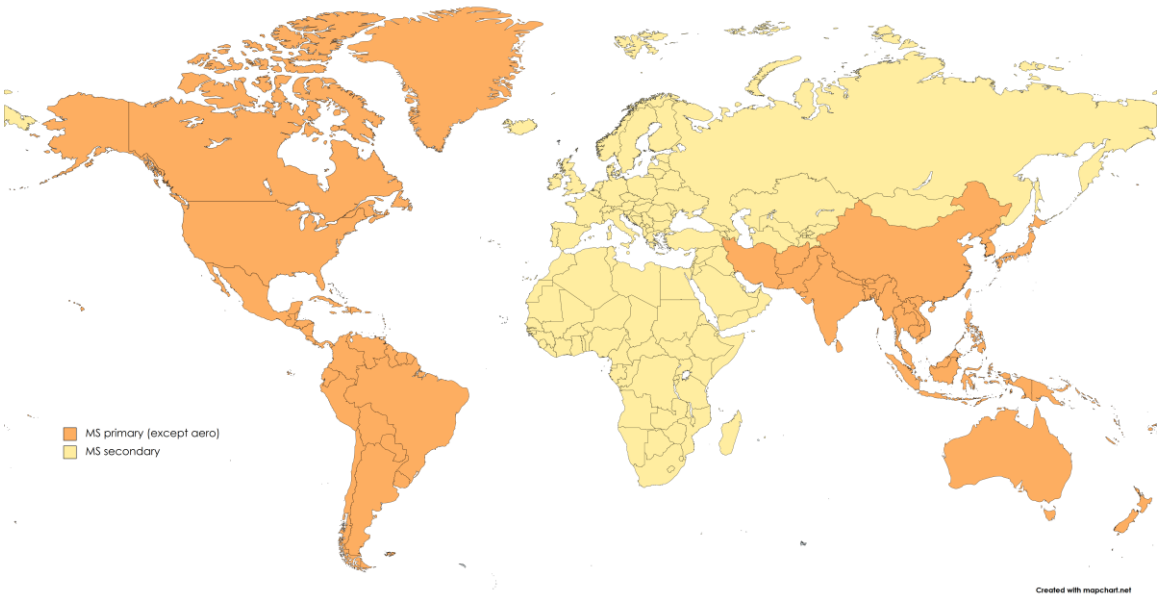

FIGURE 9. COUNTRIES/REGIONS WITH MS IN 3.8-4.2 GHz

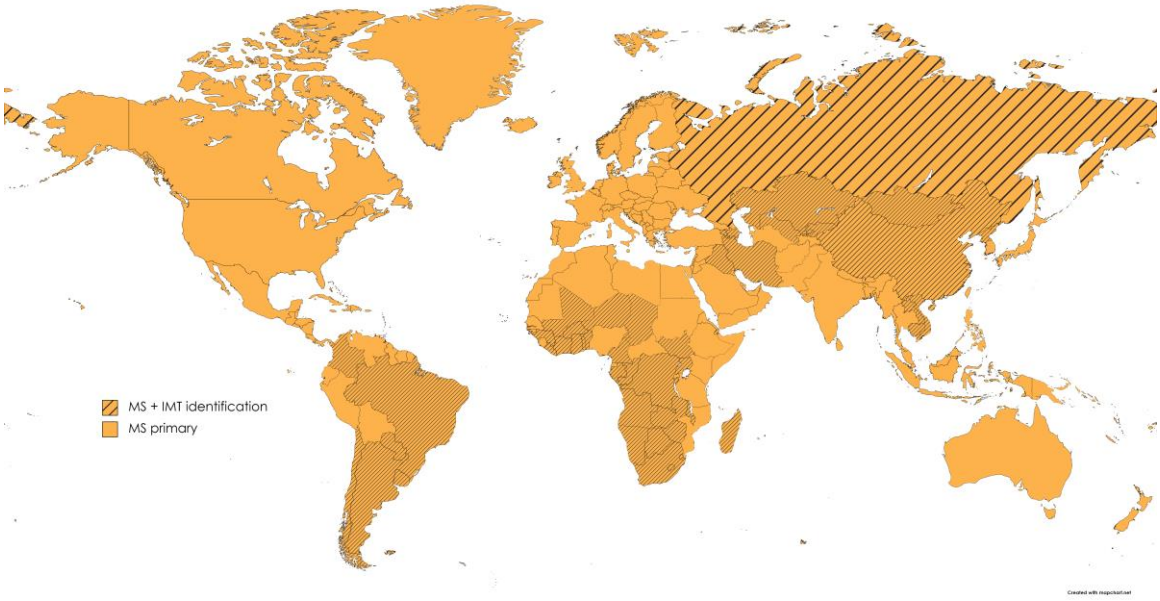

FIGURE 10. COUNTRIES WITH MS AND IMT IDENTIFICATION IN 4.8-4.99 GHz

The decisions made at WRC-23 have resulted in regional IMT identifications (R1 and R2) within the frequency ranges 3.3-3.4 and 3.6-3.8 GHz.

In the band 4.8-4.99 GHz, the IMT identification is present in about 40 countries. The worldwide Mobile Service application has been, so far, for aeronautical and maritime mobile service (i.e. non IMT applications). In order to protect non-IMT mobile stations, IMT stations shall not exceed a pfd level of -155 dBW/m²·MHz up to 19 km above sea level at 20 km from the coast. Significant coordination distances to protect aircraft stations from an IMT station apply (300 km on land path, 450km on sea path, 70km coordination distance for border coordination with respect to ground based fixed and non-IMT mobile services).

Recommendation ITU-R M.1036-6 [9] provides frequency arrangements for IMT systems. Figure 11 presents the recommended arrangement for the frequency range 3.3-3.7 GHz.

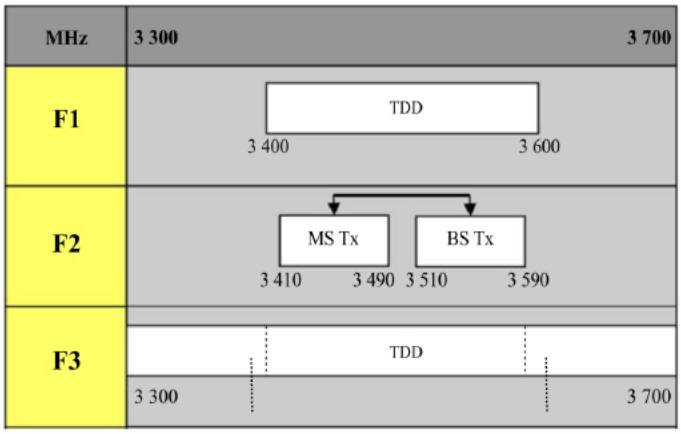

FIGURE 11. FREQUENCY ARRANGEMENT IN 3.3-3.7 GHZ WITHIN RECOMMENDATION ITU-R M.1036

In practice, only TDD arrangements F1 and F3 are implemented.

While the current IMT identifications within the 3.3-4.2 GHz range are limited to the band 3.3-3.7 GHz, a number of administrations have granted authorisations in other portions of the 3.7-4.2 GHz range on a national basis. For instance:

- Within CEPT, the band 3.4-3.8 GHz is harmonized for terrestrial IMT systems
- In US, the bands 3.55-3.98 GHz are available for broadband cellular networks
- In Brazil, the band 3.7-3.8 GHz has been earmarked for the development of private 5G networks in indoor and outdoor deployment cases. [6]

3.1.1.4 Bands between 5 GHz and 7.125 GHz

TABLE 6. SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS IN THE UPPER MID-BAND RANGE (BETWEEN 5 AND 7.125 GHZ)

FS Allocation on a primary basis	**Globally**: 1.4 GHz (4800-5000 MHz, 5850-7250 MHz)
FS Allocation on a secondary basis	N/A
Identifications for use with HAPS	No. 5.457: country identification 6440-6520 MHz (HAPS-to-ground direction) and 6560-6640 MHz (ground-to-HAPS direction)
MS Allocation on a primary basis	**Globally**: 1.855 GHz (5150-5350 MHz, 5470-5725 MHz, 5850-7250 MHz). No. 5.446A applies to the bands 5150-5350 MHz and 5470-5725 MHz are limited to radio local area network, aka Wi-Fi, in accordance with Resolution 229 (Rev.WRC-19).
MS Allocation on a secondary basis	N/A
Identifications for IMT	**In R1**: 700 MHz (6425-7125 MHz) **In R2**: 700 MHz (6425-7125 MHz) only in Brazil and Mexico **In R3**: 100 MHz (7025-7125 MHz), and 600 MHz (6425-7025 MHz) only in Cambodia, Lao P.D.R. and the Maldives

3.1.2 Frequency bands allocated to relevant Space Services

3.1.2.1 Bands below 1 GHz

The Mobile Satellite Service has narrow band allocations in the 400 MHz and 800/900 MHz range:

- 399.9-400.05 MHz (E-s)/400.015-401 MHz (s-E) on a worldwide basis
- 454-455 MHz/455-456 MHz/459-460 MHz (E-s) in a very limited number of countries.
- 806-840 MHz (E-s)/ 856-890 MHz (s-E) in Belarus, Russia, Ukraine
- 806-890 MHz in Region 2, except Brazil, USA, and Mexico. Operations are limited to national boundaries and subject to RR Article 9.21 in obtaining explicit agreement from affected countries
- 806-960 MHz in Region 3. Operations are limited to national boundaries and subject to RR Article 9.21 in obtaining explicit agreement from affected countries

The reduced bandwidth constrained geographical extension and restrictive regulatory status of these allocations limit their practical interest.

[6] See Anatel, Ato nº 8.991/2022

3.1.2.2 Bands between 1 GHz and 3 GHz

TABLE 7. SUMMARY OF SPACE SERVICE FREQUENCY ALLOCATIONS IN THE RANGE BETWEEN 1 AND 3 GHZ

FSS Allocation		
	On primary basis, s-E	**In R2**: 150 MHz (2520-2670 MHz) **In R3**: 15 MHz (2520-2535 MHz) **In R2 & R3**: 20 MHz (2500-2520 MHz) No. 5.415 applies[7]
	On primary basis, E-s	R2: 35 MHz (2655-2690 MHz) R3: 35 MHz (2655-2690 MHz)
	On secondary basis, s-E	N/A
	On secondary basis, E-s	N/A
MSS Allocations		
	On primary basis, s-E	**Globally**: 87.5 MHz[8] **In R1**: N/A **In R2**: 10 MHz (2160-2170 MHz) **In R3**: 20 MHz (2500-2520 MHz) + 15 MHz (2520-2535 MHz, No. 5.403 applies[9])
	On primary basis, E-s	**Globally**: 87.5 MHz[10] **In R1**: N/A **In R2**: 25 MHz (2010-2025, 2160-2170 MHz) **In R3**: 20 MHz (2670-2690 MHz) + 15 MHz (2655-2670 MHz, No. 5.420 applies[11])
	On secondary basis, s-E	**Globally**: 12.7 MHz (1613.8-1626.5 MHz)[12] **In R2**: 40 MHz (2120-2160 MHz)
	On secondary basis, E-s	**In R2**: 40 MHz (1930-1970 MHz)
Identifications for satellite component of IMT. See Resolution 225 (Rev.WRC-12) [8].		**Globally**: 113 MHz (1518-1544 MHz, 1545-1559 MHz, 1610-1626.5 MHz, 1626.5-1645.5 MHz, 1646.5-1660.5 MHz, 1668-1675 MHz, 2483.5-2500 MHz) **In R3**: 40 MHz (2500-2520 MHz, 2670-2690 MHz)

[7] The use of the bands 2 500-2 690 MHz in Region 2 and 2 500-2 535 MHz and 2 655-2 690 MHz in Region 3 by the fixed-satellite service is limited to national and regional systems, subject to agreement obtained under No. 9.21, giving particular attention to the broadcasting-satellite service in Region 1.

[8] 1518-1525 MHz, 1525-1559 MHz, 2170-2200 MHz, 2483.5-2500 MHz.

[9] Subject to agreement obtained under No. 9.21, the band 2 520-2 535 MHz may also be used for the mobile-satellite (space-to-Earth), except aeronautical mobile-satellite, service for operation limited to within national boundaries. The provisions of No. 9.11A apply.

[10] 1610-1660 MHz, 1660-1660.5 MHz, 1668-1675 MHz, 1980-2010 MHz.

[11] The band 2 655-2 670 MHz may also be used for MSS (Earth-to-space), except aeronautical mobile-satellite, service for operation limited to within national boundaries, subject to agreement obtained under No. 9.21. The coordination under No. 9.11A applies.

[12] The portion 1613.8-1626.5 MHz overlaps with the Earth-to-space direction of the MSS

3.1.2.3 Bands between 3 GHz and 5 GHz

TABLE 8. SUMMARY OF SPACE SERVICE FREQUENCY ALLOCATIONS IN THE MID-BAND/ C-BAND RANGE (BETWEEN 3 AND 5 GHZ)

FSS Allocation on a primary basis, in the s-E direction	**Globally**: 800 MHz (3.4-4.2 GHz) 300 MHz (4.5-4.8 GHz). This band is used according to the provisions of RR Appendix 30B and No. 5.441.
FSS Allocation on a primary basis, in the E-s direction	N/A
FSS Allocation on a secondary basis	N/A
MSS Allocation on a primary basis	N/A

3.1.2.4 Bands between 5 GHz and 7.125 GHz

TABLE 9. SUMMARY OF SPACE SERVICE FREQUENCY ALLOCATIONS IN THE UPPER MID-BAND/ C-BAND RANGE (BETWEEN 5 AND 7.125 GHZ)

FSS Allocation		
	On primary basis, s-E	Global: 375 MHz (6700-7075 MHz). No. 5.458B applies that this band is limited to feeder links for NGSO MSS networks
	On primary basis, E-s	Global: 1.384 GHz. (5091-5250 MHz, 5850-7075 MHz) No. 5.444A[13] and 5.447A[14] apply, limiting the allocation in 5091-5150 MHz and 5150-5250 MHz to feeder links of NGSO systems part of the MSS, respectively, and particularly imposing coordination requirements to protect the aeronautical radionavigation service in 5091-5150 MHz. These limitations reduce the practical uses of this band for NTN purposes. R1: 125 MHz. 5725-5850 MHz
	On secondary basis	N/A
MSS Allocations	On primary or secondary basis	N/A

3.1.3 Frequency bands that could support NTN

This section highlights the portions of spectrum which could become available to support NTN, given the current overlaps in the frequency allocations between services in the Table of Frequency Allocations, as well as the existence of a 3GPP operating band class in current 3GPP specifications [10][10]. Despite this overlap, the use of some portions of spectrum for NTN would still require regulatory waiver for deployment in certain jurisdictions.

[13] **5.444A** The use of the allocation to the fixed-satellite service (Earth-to-space) in the frequency band 5 091-5 150 MHz is limited to feeder links of non-geostationary satellite systems in the mobile-satellite service and is subject to coordination under No. **9.11A**. The use of the frequency band 5 091-5 150 MHz by feeder links of non-geostationary satellite systems in the mobile-satellite service shall be subject to application of Resolution **114(Rev.WRC-15)**. Moreover, to ensure that the aeronautical radionavigation service is protected from harmful interference, coordination is required for feeder-link earth stations of the non-geostationary satellite systems in the mobile-satellite service which are separated by less than 450 km from the territory of an administration operating ground stations in the aeronautical radionavigation service. (WRC-15)

[14] **5.447A** The allocation to the fixed-satellite service (Earth-to-space) in the band 5 150-5 250 MHz is limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service and is subject to coordination under No. 9.11A.

- With regards to the Table of Frequency Allocations, an overlap between the FS and MS, could be considered for NTN use by means of HAPS/HIBS with appropriate existing identifications,
- An overlap between the MSS and MS, could be considered for NTN use when the frequency bands are identified for the satellite component of IMT system.

3.1.3.1 Bands below 1 GHz

NTN under terrestrial service

For bands allocated to the Mobile Service below 1 GHz, note that most allocations in Region 1 are only to the Mobile Service, except aeronautical mobile, implying that NTN under drone applications would not be permitted. The same constraint also applies to Region 2 within the portions of 890-942 MHz. There is no such restriction for Region 3.

There is a HIBS identification in the frequencies below 1 GHz. However, the regional footnotes in the relevant portions of the band 694-960 MHz provide conditions and directionality restrictions that are not aligned between regions.

NTN under space service

The bands 806-890 MHz and 806-960 MHz are allocated to MSS in Region 2 (except Brazil, USA, Mexico) and Region 3, respectively, limited to national boundaries.

The 3GPP operating bands where at least the above-mentioned MSS bands are in full or partial overlap are identified below:

TABLE 10. SUMMARY OF 3GPP OPERATING BANDS UNDER 1 GHZ. SOURCE: 3GPP. TS 38.104 V18.4.0

NR *operating band*	Uplink (UL) *operating band* BS receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$	Downlink (DL) *operating band* BS transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n26	814 MHz – 849 MHz	859 MHz – 894 MHz	FDD
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n89	824 MHz – 849 MHz	N/A	SUL
n91	832 MHz – 862 MHz	1427 MHz – 1432 MHz	FDD
n92	832 MHz – 862 MHz	1432 MHz – 1517 MHz	FDD
n93	880 MHz – 915 MHz	1427 MHz – 1432 MHz	FDD
n94	880 MHz – 915 MHz	1432 MHz – 1517 MHz	FDD
n100	874.4 MHz – 880 MHz	919.4 MHz – 925 MHz	FDD

Note that many countries have adopted different variations of legacy AMPS/GSM-850 and GSM-900 band plans (or a mixture of both) in the 2G era as evidenced by the vast number of overlapping frequencies across these 3GPP operating band classes. Even with technology upgrades of the terrestrial network from older generation (2G/3G) to newer generation (4G/5G), the spectrum assignments may not change drastically for many countries due to the complexity in spectrum refarming, apart from neighbouring spectrum swap between adjacent mobile operators to consolidate slightly larger contiguous bandwidths. Although there is overlap between portions of MSS band (in Regions 2 and 3) with some of these 3GPP bands, it is expected that large portions of these bands may not be suitable for wide-scale NTN deployment.

3.1.3.2 Bands between 1 and 3 GHz

NTN under terrestrial service

The frequency bands 1710-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3, the frequency bands 1710-1980 MHz and 2110-2160 MHz in Region 2, the band 2500-2690 MHz in Regions 1 and 2, and the band 2500-2655 MHz in Region 3, are identified for HIBS and parts of these bands could support NTN deployment.

NTN under space service

Within this frequency range the MS and MSS overlap in the following portions:

space-to-Earth direction

- Globally: 63.5 MHz (1518-1535 MHz, 2170-2200 MHz, 2483.5-2500 MHz). The portion 1525-1535 MHz overlaps with a secondary allocation of the mobile service
- R2: 50 MHz (2120-2170 MHz)
- R3: 20 MHz (2500-2520 MHz)

Earth-to-space direction

- Globally: 35 MHz (1668-1675 MHz, 1980-2010 MHz)
- R2: 15 MHz (2010-2025 MHz)
- R3: 20 MHz (2670-2690 MHz)

With respect to the MS/MSS overlap in both directions, the following UL/DL band pairs in the 3GPP FR1 range can be noted.

TABLE 11 SUMMARY OF 3GPP OPERATING BANDS IN THE RANGE 2 - 3GHZ. SOURCE: 3GPP. TS 38.104 V18.4.0

MSS Range	ITU-R Region	NR *operating band*	Uplink (UL) *operating band* BS receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$	Downlink (DL) *operating band* BS transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
2120-2170	R2	n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2500-2520, 2670-2690	R3	n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
1518-1535	Global	n24 (NOTE 7)	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
2010-2025	R2	n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
2483.5-2500	Global	n53	2483.5 MHz – 2495 MHz	2483.5 MHz – 2495 MHz	TDD
1980-2010, 2170-2200	Global	n65	1920 MHz – 2010 MHz	2110 MHz – 2200 MHz	FDD
2120-2170	R2	n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
2483.5-2500	Global	n90	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
2500-2520, 2670-2690	R3				
NOTE 7: DL operation is restricted to 1526-1536 MHz frequency range. UL operation is restricted to 1627.5 – 1637.5 MHz and 1646.5 – 1656.5 MHz per FCC Order 20-51					

Although there is overlap between the Region 3 MSS band pairing in 2500-2520 (s-E) and 2670-2690 (E-s) with 3GPP's UL/DL allocations for band n7, the reverse direction of operations of this pairing compared to the frequency allocations makes the bands potentially incompatible. Therefore, they may not be considered as usable for NTN in the short and mid-term.

As for the use of other portions of overlap spectrum for NTN, this may require regulatory intervention for deployment within certain jurisdictions when sharing or reusing the same spectrum with terrestrial network.

Since Resolution 225 (Rev. WRC-12) identified the frequency bands 1518-1544 MHz, 1545-1559 MHz, 1610-1626.5 MHz, 1626.5-1645.5 MHz, 1646.5-1660.5 MHz, 1668-1675 MHz and

2483.5-2500 MHz (globally), as well as 2500-2520 MHz and 2670-2690 MHz (Region 3 only), for the satellite component of IMT, some of these bands have become the initial candidates for NTN satellite operating bands in 3GPP. See Table 12.

TABLE 12. SUMMARY OF 3GPP OPERATING BANDS NEAR 2 GHZ. SOURCE: 3GPP. TS 38.101-5 V18.4.0

NTN satellite operating band	Uplink (UL) operating band Satellite Access Node receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$	Downlink (DL) operating band Satellite Access Node transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
n256	1980 MHz – 2010 MHz	2170 MHz – 2200 MHz	FDD
n255	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
n254	1610 MHz – 1626.5 MHz	2483.5 MHz -2500 MHz	FDD

3.1.3.3 Bands between 3 GHz and 5 GHz

NTN under terrestrial service

There are no HAPS identifications in this frequency range.

NTN under space service

There are no MSS allocation in this frequency range, but overlaps are observed between the following FSS space-to-Earth and MS:

- Globally, 1.1 GHz (3400-4200 MHz, 4500-4800 MHz)

The spectrum portion overlaps with the following 3GPP operating bands:

TABLE 13. SUMMARY OF 3GPP OPERATING BANDS IN THE MID-BAND RANGE (3 – 5 GHZ). SOURCE: 3GPP. TS 38.104 V18.4.0

FSS s-E Range	ITU-R Region	NR *operating band*	Uplink (UL) *operating band* BS receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$	Downlink (DL) *operating band* BS transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
3400-4200	Global	n48	3550 MHz – 3700 MHz	3550 MHz – 3700 MHz	TDD
3400-4200	Global	n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
3400-4200	Global	n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
4500-4800	Global	n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD

This band, or parts thereof, is an attractive option for future NTN due to a number of factors:

- A historic use of this band for FSS downlinks could favour a positive perception by administrations of an evolutionary use of the band for innovating satellite service.
- The whole range is part of 3GPP specifications for 5G (3GPP band n48/n77/n78/n79), hence terminal equipment with Tx and Rx functions are already available.
- Terrestrial deployments in this band are expected in relatively densely populated areas, hence giving scope for satellite systems to exploit the band efficiently in less populated areas.

Further analysis on the feasibility of the 3400-4200 MHz band for NTN can be found in section 4.1.3.

3.1.3.4 Bands between 5 GHz and 7.125 GHz

NTN under terrestrial service

As No. 5.457[15] is only a country-specific footnote expressing the intention to operate gateway links for HAPS in the bands 6440-6520 MHz (HAPS-to-ground) and 6560-6640 MHz (ground-to-HAPS) within the territory of these countries, these bands do not yet provide clear path to support widespread deployment.

NTN under space service

Within this frequency range, the following overlaps are currently present in the table of frequency allocations of the RR between the FSS and MS services:

- Globally, 1.325 GHz: 5150-5250 MHz, 5850-6700 MHz, 6700-7075 MHz

The overlap of this spectrum portion with 3GPP operating bands is shown in Table 14.

TABLE 14. SUMMARY OF 3GPP OPERATING BANDS IN THE 5-7GHZ RANGE. SOURCE: 3GPP. TS 38.104 V18.4.0

FSS E-s Range	ITU-R Region	NR *operating band*	Uplink (UL) *operating band* BS receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$	Downlink (DL) *operating band* BS transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
5150-5250	Global	n46	5150 MHz – 5925 MHz	5150 MHz – 5925 MHz	TDD (NOTE 3)
5850-6700, 6700-7075	Global	n96 (NOTE 4)	5925 MHz – 7125 MHz	5925 MHz – 7125 MHz	TDD (NOTE 3)
5850-6700	Global	n102 (NOTE 4)	5925 MHz – 6425 MHz	5925 MHz – 6425 MHz	TDD (NOTE 3)
6700-7075	Global	n104 (NOTE 8)	6425 MHz – 7125 MHz	6425 MHz – 7125 MHz	TDD
NOTE 3: This band is restricted to operation with shared spectrum channel access as defined in TS 37.213. NOTE 4: This band is applicable only in countries/regions designating this band for shared-spectrum access use subject to country-specific conditions. NOTE 8: [This band is applicable only in countries/regions designating this band for IMT licensed operation in accordance with RCC Recommendation 1/21.]					

Since these few 3GPP operating band classes are associated with special notes implying that their inclusion is restricted for operation under shared-spectrum access (with Wi-Fi) or with specific geographical limitation in its usage, further analysis would be required to assess the feasibility of the band, or parts thereof, 5925-7125 MHz for NTN in the uplink (Earth-to-space) direction.

3.2 ABOVE 10 GHZ

3.2.1 Frequency bands allocated to relevant Terrestrial Services

3.2.1.1 Bands between 10 GHz and 15 GHz

TABLE 15. SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS 10-15GHZ RANGE. SOURCE: ITU-R RADIO REGULATIONS

FS Allocation on a primary basis	**Globally**: 3.83 GHz (10-10.45 GHz, 10.5-10.68 GHz, 10.7-12.1 GHz, 12.2-12.5 GHz, 12.7-13.25 GHz, 14.4-15.35 GHz)
	In R1: 1.35 GHz (10-10.45 GHz, 11.7-12.5 GHz, 14.3-14.4 GHz)
	In R2: 0.95 GHz (11.7-12.1 GHz, 12.2-12.75 GHz)
	In R3: 1.6 GHz (10-10.45 GHz, 11.7-12.75 GHz, 14.3-14.4 GHz)
FS Allocation on a secondary basis	N/A

[15] No.5.457: In Australia, Burkina Faso, Cote d'Ivoire, Mali and Nigeria

Identifications for use with HAPS	N/A
MS Allocation on a primary basis	**Globally**: 2.93 GHz (10.5-10.68 GHz, 10.7-11.7 GHz, 12.2-12.5 GHz, 12.75-13.25 GHz, 14.4-15.35 GHz)
	In R1: 1.35 GHz (10-10.45 GHz, 11.7-12.5 GHz, 14.3-14.4 GHz)
	In R2: 250 MHz (12.5-12.75 GHz)
	In R3: 1.6 GHz (10-10.45 GHz, 11.7-12.75 GHz, 14.3-14.4 GHz)
MS Allocation on a secondary basis	**In R2**: 400 MHz (11.7-12.1GHz)
IMT identifications	**In R2**: 500 MHz (10-10.5 GHz), for some countries in No. 5.[10B12][16]

3.2.1.2 Bands between 15 GHz and 31 GHz

TABLE 16 SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS 15-31GHZ RANGE. SOURCE: ITU-R RADIO REGULATIONS

FS Allocation on a primary basis	**Globally**: 9.65 GHz (17.7-19.7 GHz, 21.2-23.6 GHz, 24.25-29.5 GHz)
FS Allocation on a secondary basis	N/A
Identifications for use with HAPS	**In R2**: 3.35 GHz (21.4-22 GHz, 24.25-25.25 GHz for HAPS-to-ground, 25.25-27 GHz for ground-to-HAPS limited to gateway links and 27-27.5 GHz for HAPS-to-ground) via Nos. 5.530E, 5.532AA and 5.534A, respectively 300 MHz (27.9-28.2 GHz HAPS-to-ground) via No. 5.537A[17] (in certain countries)
MS Allocation on a primary basis	**Globally**: 9.55 GHz (17.8-19.7 GHz, 21.2-23.6 GHz, 24.25-29.5 GHz)
	In R1+R3: 100 MHz (17.7-17.8 GHz)
MS Allocation on a secondary basis	**In R2**: 100 MHz (17.7-17.8 GHz)
IMT identifications	**Globally**: 3.25 GHz (24.25-27.5 GHz) via No. 5.532AB

3.2.1.3 Bands between 31 GHz and 37 GHz

TABLE 17 SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS 31-37GHZ RANGE. SOURCE: ITU-R RADIO REGULATIONS

FS Allocation on a primary basis	**Global**ly: 2.9 GHz (31-31.3 GHz, 31.8-33.4 GHz, 36-37 GHz)
	In R1+R3: In certain countries[18], the portion 33.4-36 GHz is allocated to the FS on a primary basis via No. 5.549.
FS Allocation on a secondary basis	N/A
Identifications for use with HAPS	**Globally**: 300 MHz (31-31.3 GHz) via No. 5.543B
MS Allocation on a primary basis	**Globally**: 1.3 GHz (31-31.3 GHz, 36-37 GHz)
MS Allocation on a secondary basis	N/A
IMT identifications:	N/A

[16] No.5.[10B12]: Brazil, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Paraguay, Peru and Uruguay

[17] No. **5.537A** In Bhutan, Cameroon, China, Korea (Rep. of), the Russian Federation, India, Indonesia, Iran (Islamic Republic of), Iraq, Japan, Kazakhstan, Malaysia, Maldives, Mongolia, Myanmar, Uzbekistan, Pakistan, the Philippines, Kyrgyzstan, the Dem. People's Rep. of Korea, Sudan, Sri Lanka, Thailand and Viet Nam, the allocation to the fixed service in the frequency band 27.9-28.2 GHz may also be used by high altitude platform stations (HAPS) within the territory of these countries. Such use of 300 MHz of the fixed-service allocation by HAPS in the above countries is further limited to operation in the HAPS-to-ground direction and shall not cause harmful interference to, nor claim protection from, other types of fixed-service systems or other co-primary services. Furthermore, the development of these other services shall not be constrained by HAPS. See Resolution 145 (Rev.WRC-19).

[18] **No. 5.549** Saudi Arabia, Bahrain, Bangladesh, Egypt, the United Arab Emirates, Gabon, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malaysia, Mali, Morocco, Mauritania, Nepal, Nigeria, Oman, Pakistan, the Philippines, Qatar, the Syrian Arab Republic, the Dem. Rep. of the Congo, Singapore, Somalia, Sudan, South Sudan, Sri Lanka, Togo, Tunisia and Yemen

3.2.1.4 Bands between 37 GHz and 52.6 GHz

TABLE 18. SUMMARY OF TERRESTRIAL SERVICE FREQUENCY ALLOCATIONS 37-52.6GHZ RANGE. SOURCE: ITU-R RADIO REGULATIONS

FS Allocation on a primary basis	**Globally**: 11.7 GHz (37-43.5 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz)
FS Allocation on a secondary basis	N/A
Identifications for use with HAPS	**Globally**: 2.1 GHz (38-39.5 GHz HAPS-to-ground, 47.2-47.5 GHz and 47.9-48.2 GHz for both directions) via Nos. 5.550D/5.552A
MS Allocation on a primary basis	**Globally**: 15.2 GHz for all MS types: Mobile: 11.2 GHz (38-40.5 GHz, 43.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz) Mobile except aeronautical mobile: 2 GHz (37-38 GHz, 42.5-43.5 GHz) Land Mobile: 2 GHz (40.5-42.5 GHz)
MS Allocation on a secondary basis	Aeronautical & maritime mobile: 2 GHz (40.5-42.5 GHz, noting that Land Mobile is already primary)
Identifications for IMT	**Globally**: 6.5 GHz (37-43.5 GHz) via No. 5.550B 2.5 GHz (45.5-47 GHz, 47.2-48.2 GHz) via Nos. 5.553A/5.553B in certain countries[19,20]

3.2.2 Frequency bands allocated to relevant Space Services

3.2.2.1 Bands between 10 GHz and 15 GHz

TABLE 19. SUMMARY OF SPACE SERVICE FREQUENCY ALLOCATIONS IN THE 10-15 GHZ RANGE. SOURCE: ITU-R RADIO REGULATIONS

FSS Allocation		
	On primary basis, s-E	**Globally**: 1 GHz (10.7-11.7 GHz) **R1**: 250 MHz (13.4-13.65 GHz) **R2**: 500 MHz (11.7-12.2 GHz) **R3**: 550 MHz (12.2-12.75 GHz)
	On primary basis, E-s	**Globally**: 1.55 GHz (12.75-13.25 GHz, 13.75-14.8 GHz) **R1**: 1.25 GHz (10.7-11.7 GHz, 12.5-12.75 GHz) **R2**: 50 MHz (12.7-12.75 GHz)
	On secondary basis, s-E	N/A
	On secondary basis, E-s	N/A
MSS Allocations		
	On primary basis, s-E	N/A
	On primary basis, E-s	N/A
	On secondary basis, s-E	N/A

[19] **No.5.553A** Algeria, Angola, Bahrain, Belarus, Benin, Botswana, Brazil, Burkina Faso, Cabo Verde, Korea (Rep. of), Côte d'Ivoire, Croatia, United Arab Emirates, Estonia, Eswatini, Gabon, Gambia, Ghana, Greece, Guinea, Guinea-Bissau, Hungary, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lesotho, Latvia, Liberia, Lithuania, Madagascar, Malawi, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Oman, Qatar, Senegal, Seychelles, Sierra Leone, Slovenia, Sudan, South Africa, Sweden, Tanzania, Togo, Tunisia, Zambia and Zimbabwe, the frequency band 45.5-47 GHz is identified for use by administrations wishing to implement the terrestrial component of International Mobile Telecommunications (IMT),

[20] **No.5.553B** In Region 2 and Algeria, Angola, Saudi Arabia, Australia, Bahrain, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Rep., Comoros, Congo (Rep. of the), Korea (Rep. of), Côte d'Ivoire, Djibouti, Egypt, United Arab Emirates, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Equatorial Guinea, India, Iran (Islamic Republic of), Iraq, Japan, Jordan, Kenya, Kuwait, Lesotho, Liberia, Libya, Lithuania, Madagascar, Malaysia, Malawi, Mali, Morocco, Mauritius, Mauritania, Mozambique, Namibia, Niger, Nigeria, Oman, Uganda, Qatar, the Syrian Arab Republic, the Dem. Rep. of the Congo, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Singapore, Slovenia, Somalia, Sudan, South Sudan, South Africa, Sweden, Tanzania, Chad, Togo, Tunisia, Zambia and Zimbabwe, the frequency band 47.2-48.2 GHz is identified for use by administrations wishing to implement International Mobile Telecommunications (IMT).

	On secondary basis, E-s	**Globally**: 200 MHz (14.3-14.5 GHz)

Operation of ESIMs with GSO networks in the 12.75-13.25 GHz (Earth-to-space) are allowed by No. 5.[A115], under the provisions set in Resolution [COM5/2] (WRC-23).

3.2.2.2 Bands between 15 GHz and 31 GHz

TABLE 20. SUMMARY OF SPACE SERVICE FREQUENCY ALLOCATIONS IN THE 15-31 GHZ RANGE. SOURCE: ITU-R RADIO REGULATIONS.

FSS Allocation		
	On primary basis, s-E	**Globally**: 3.5 GHz (17.7-21.2 GHz) **In R1**: 400 MHz (17.3-17.7 GHz)
	On primary basis, E-s	**Globally**: 5.7 GHz (15.43-15.63 GHz, 17.3-18.4 GHz, 19.3-19.7 GHz, 24.75-25.25 GHz, 27.5-31 GHz) **In R1**: 100 MHz (24.65-24.75 GHz) **In R2**: 500 MHz (27-27.5 GHz) **In R3**: 600 MHz (24.65-24.75 GHz, 27-27.5 GHz)
	On secondary basis, s-E	N/A
	On secondary basis, E-s	N/A
MSS Allocations		
	On primary basis, s-E	**Globally**: 1.1 GHz (20.1-21.2 GHz) **In R2**: 400 MHz (19.7-20.1 GHz)
	On primary basis, E-s	**Globally**: 1.1 GHz (29.9-31 GHz) **In R2**: 400 MHz (29.5-29.9 GHz)
	On secondary basis, s-E	**In R1+R3**: 400 MHz (19.7-20.1 GHz)
	On secondary basis, E-s	**In R1+R3**: 400 MHz (29.5-29.9 GHz)

In the frequency bands 19.7-20.2 GHz and 29.5-30 GHz in Region 2, and in the bands 20.1-20.2 GHz and 29.9-30 GHz in Regions 1 and 3, where the FSS and MSS overlap, the provisions set in Resolution 156 (WRC-15) for footnote No. 5.526, , indicate that networks which are both in the fixed-satellite service and in the mobile-satellite service may include links between earth stations at specified (fixed) or unspecified points or while in motion (e.g., from planes or ships), through one or more satellites for point-to-point and point-to-multipoint communications.

Operations of earth stations in motion (including satellite user terminals) with GSO networks in the bands 17.7-19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) are allowed by No. 5.517A under the provisions set in Resolution 169 (Rev. WRC-19).

Furthermore, similar ESIM operation with NGSO systems in the bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) are also allowed by No. 5.[A116] under the provisions set in Resolution [CPM5/3] (WRC-23).

3.2.2.3 Bands between 31 GHz and 37 GHz

None

3.2.2.4 Bands between 37 GHz and 52.6 GHz

TABLE 21. SUMMARY OF SPACE SERVICE FREQUENCY ALLOCATIONS IN THE 37-52.6GHZ RANGE (Q/V BANDS). SOURCE: ITU-R RADIO REGULATIONS

FSS Allocation		
	On primary basis, s-E	**Globally**: 5 GHz (37.5-42.5 GHz), with portions identified for High Density Fixed Satellite Service (HDFSS) applications (No. 5.516B) **In R1**: 1.5 GHz (47.5-47.9 GHz, 48.2-48.54 GHz, 49.44-50.2 GHz)
	On primary basis, E-s	**Globally**: 6 GHz (42.5-43.5 GHz, 47.2-50.2 GHz, 50.4-52.4 GHz), with portions identified for HDFSS applications (No. 5.516B) No. 5.555C limits the use of 51.4-52.4 GHz for GSO gateway links only
	On secondary basis, s-E	N/A
	On secondary basis, E-s	N/A
MSS Allocations		
	On primary basis, s-E	**Globally**: 4.5 GHz (39.5-40.5 GHz, 43.5-47 GHz)
	On primary basis, E-s	**Globally**: 3.5 GHz (43.5-47 GHz)
	On secondary basis, s-E	**In R2**: 500 MHz (40.5-41 GHz)
	On secondary basis, E-s	**Globally**: 1 GHz (50.4-51.4 GHz)

3.2.3 Frequency bands that could support NTN

This section highlights the portions of spectrum presently available to support NTN in which there are overlaps in the allocations between

- FS and MS, which can be considered for NTN use by means of HAPS/HIBS with appropriate existing identifications,
- MSS and MS, which can be considered for NTN use, not necessarily needing future identification for satellite component for IMT if the intended application is for earth-station terminals,
- FSS and MS, which can be considered for NTN use by means of earth-station in motions (ESIM) with appropriate regulatory provisions clarifying such use.

And in addition, there is a corresponding 3GPP operating band class within 3GPP specifications for these overlaps. Notwithstanding the overlap, the use of some portions of spectrum for NTN would still require regulatory waiver for deployment in certain jurisdictions.

3.2.3.1 Bands between 10 GHz and 15 GHz

NTN under terrestrial service

There are no HAPS identifications in this frequency range.

NTN under space service

The FS and FSS overlap in various portions of the band:

- In the Earth-to-space direction, globally, 12.7-13.25 GHz and 14.4–14.8 GHz
- In the space-to-Earth direction, globally, 10.7–11.7 GHz.

Based on the provisions set in Resolution [COM5/2] (WRC-23), NTN via GSO networks could consider the uplink band 12.75-13.25 GHz (Earth-to-space) in association with the downlink bands 10.7-10.95 GHz, 11.2-11.45 GHz (space-to-Earth), but the restriction of ESIM to GSO only in this uplink band may limit the scale of NTN deployment.

Within this 10-15 GHz frequency band, the MSS and MS overlap only in 100 MHz in the 14.4–14.5 GHz portion, where MSS has a secondary basis allocation. This quantum may limit its interest in NTN.

3.2.3.2 Bands between 15 GHz and 31 GHz

NTN under terrestrial service

As the portions 21.4-22 GHz and 24.25-25.25 GHz in the direction HAPS-to-ground, and 25.25-27 GHz in ground-to-HAPS direction, are limited to gateway links, it limits their usability for widespread NTN deployments.

Similarly, given that the band 27-27.5 GHz in HAPS-to-ground direction is allocated only in Region 2, and the band 27.9-28.2 GHz in HAPS-to-ground direction is identified only in certain countries, this limits its interest for NTN.

NTN under space service

The MSS and MS do not overlap in this frequency range.

The FSS and MS overlap as follows

- In the Earth-to-space direction, globally, within the ranges 17.8-19.7 GHz, 24.75-25.25 GHz and 27.5-29.5 GHz
- In the space-to-Earth direction, globally, within the ranges 17.8-19.7 GHz.

The overlaps between the noted frequency allocations and current 3GPP operating bands is shown in Table 22.

TABLE 22. SUMMARY OF 3GPP OPERATING BANDS IN THE 26-28 GHZ RANGE. SOURCE: 3GPP. TS 38.104 V18.4.0

NR *operating band*	**Uplink (UL) and Downlink (DL) *operating band* BS transmit/receive UE transmit/receive $F_{UL,low}$ – $F_{UL,high}$ $F_{DL,low}$ – $F_{DL,high}$**	**Duplex mode**
n257	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	TDD
n261	27500 MHz – 28350 MHz	TDD

Due to the lack of overlap between MSS and MS, and since it is likely that NTN deployment in these bands would aim to serve satellite user terminals (i.e. not mobile terminal), treating NTN within an ESIM framework would be a suitable possibility in the bands between 15 GHz and 31 GHz.

Based on the current provisions set in Resolution 156 (WRC-15) [11] and Resolution 169 (Rev. WRC-23) [12][12], NTN through GSO networks could consider the bands 17.7-20.2 GHz (space-to-Earth) and 27.5-30 GHz (Earth-to-space).

Furthermore, the bands 17.7-18.6 GHz, 18.8-19.3 GHz, 19.7-20.2 GHz (space-to-Earth), and 27.5-29.1 GHz, 29.5-30 GHz (Earth-to-space) are also candidate bands for NTN use via NGSO systems, based on the provisions set in Resolution [COM5/3] (WRC-23).

Further analysis would be required to assess the feasibility of the bands 17.7-20.2 GHz (space-to-Earth) and 27.5-30 GHz (Earth-to-space) for NTN.

3.2.3.3 Bands between 31 GHz and 37 GHz

NTN under terrestrial service

Within this frequency range the MS and FS overlap, globally, in the bands 31–31.3 GHz and 36–37 GHz. Furthermore, given the identification in the band 31–31.3 GHz for worldwide use of HAPS without directionality restriction (No. 5.543B and Resolution 167 (WRC-19)), the band 31–31.3 GHz could be a possible candidate for NTN.

NTN under space service

Within this frequency range there are no allocations to the FSS or MSS in the Radio Regulations.

3.2.3.4 Bands between 37 GHz and 52.6 GHz

NTN under terrestrial service

The MS and FS overlap, globally, in the bands 37–43.5 GHz, 47.2–50.2 GHz, 50.4–52.6 GHz. Furthermore, given the identification of the 38–39.5 GHz[21], 47.2–47.5 GHz and 47.9–48.2 GHz[22] for worldwide use of HAPS without directionality restriction, these could be a possible candidate for NTN.

NTN under space service

Within this frequency range the MS and the MSS overlap in 39.5–40.5 GHz (space-to-Earth) and 43.5-47 GHz (no directionality).

The FSS and MS overlap as follows

- In the Earth-to-space direction, globally, within the ranges 42.5-43.5 GHz, 47.2-50.2 GHz and 50.4-52.4 GHz

- In the space-to-Earth direction, globally, within the ranges 37.5-42.5 GHz.

The overlap in spectrum between the frequency allocations noted and existing 3GPP operating bands is shown in Table 23.

[21] No. 5.550D and Resolution 168 (WRC-19)
[22] No. 5.552A and Resolution 122 (Rev.WRC-19)

TABLE 23. SUMMARY OF 3GPP OPERATING BANDS IN THE 39-48 GHZ RANGE. SOURCE: 3GPP. TS 38.104 V18.4.0

NR *operating band*	**Uplink (UL) and Downlink (DL) *operating band* BS transmit/receive UE transmit/receive $F_{UL,low}$ – $F_{UL,high}$ $F_{DL,low}$ – $F_{DL,high}$**	**Duplex mode**
n259	39500 MHz – 43500 MHz	TDD
n260	37000 MHz – 40000 MHz	TDD
n262	47200 MHz – 48200 MHz	TDD

Since it is likely that NTN deployment in these bands would aim to serve satellite user terminals (i.e. not mobile terminals), it would be appropriate for NTN to consider operating in the existing MSS band, particularly in the portion where MS and MSS overlap (39.5–40.5 GHz in s-E direction and, 43.5-47 GHz in both directions) and potentially in the 50.4-51.4 GHz (Earth-to-space direction) noting however that MSS has a secondary allocation in this portion.

In addition, even though there is currently no 3GPP operating band in the 45.5-47 GHz range, this portion is already identified for IMT in over 50 countries in accordance with No. 5.553A.

Further analysis would be required to assess the feasibility of using these bands for NTN.

4 REGULATORY ANALYSIS FOR NTN DEPLOYMENT

4.1 BELOW 7.125 GHZ

4.1.1 Technical conditions for NTN operation under relevant Terrestrial Services

4.1.1.1 HIBS operation in 1710-1980 MHz, 2010-2025 MHz, 2110-2170 MHz and 2500-2690 MHz

WRC-2000 identified through RR No. 5.388A the frequency bands 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3, and the frequency bands 1885-1980 MHz and 2110-2160 MHz in Region 2 for use by high-altitude platform stations as base stations to provide IMT. Furthermore, Resolution 221 (Rev.WRC-07) [3] provides the technical conditions that need to be met by HIBS to ensure that emissions to neighbouring countries do not cause harmful co-channel interference to the other services and applications allocated in these frequency bands, including terrestrial IMT stations.

Studies conducted between proposed HIBS and terrestrial IMT networks operating within the frequency ranges 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz show that co-frequency compatibility between HIBS and other IMT networks in the same geographical area is only feasible if either a range of separation distances at the border or pfd limits are introduced to ensure the protection of those terrestrial IMT networks, particularly in cases of non-synchronized cross-border terrestrial IMT networks in neighbouring countries.

WRC-23 agreed to expand the HIBS allocation to 1710-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3, and 1710-1980 MHz and 2110-2160 MHz in Region 2 by amending No. 5.388A and Resolution 221, as well as to 694-960 MHz and 2500-2690 MHz.

Detailed provisions governing the technical condition for operation of HIBS in 1710-1980 MHz, 2010-2025 MHz and 2110-2170 MHz are outlined in Resolution 221 (Rev. WRC-23):

- For the purpose of protecting terrestrial IMT mobile stations in neighbouring countries from co-channel interference, HIBS shall not exceed a co-channel pfd of -111 dB (W/(m^2 · MHz)) at the Earth's surface outside a country's borders unless explicit agreement from the affected administration is provided at the time of the notification of HIBS.
- For the purpose of protecting terrestrial IMT base stations in neighbouring countries from co-channel interference, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a country's borders unless explicit agreement from the affected administration is provided at the time of the notification of HIBS:

−144.55	dB(W/(m² · MHz))	for 0° ≤ θ < 11°
−144.55 + 0.45 (θ − 11)	dB(W/(m² · MHz))	for 11° ≤ θ < 80°
−113.55	dB(W/(m² · MHz))	for 80° ≤ θ < 90°

  where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees
- For the protection of Fixed Service, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a county's borders unless explicit agreement of the affected administration is provided at the time of the notification of HIBS.

−150	dB(W/(m² · MHz))	for 0° ≤ θ < 2°
−150 + 1.78 (θ − 2)	dB(W/(m² · MHz))	for 2° ≤ θ < 20°
−118 + 0.215 (θ − 20)	dB(W/(m² · MHz))	for 20° ≤ θ < 48°
−112	dB(W/(m² · MHz))	for 48° ≤ θ < 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

- For the protection of satellite component of IMT operating in mobile-satellite service (space-to-Earth) in the adjacent frequency band 2170-2200 MHz, HIBS operating in the frequency range 2110-2170 MHz shall not exceed an out-of-band pfd of -165 dB (W/(m^2 · 4 kHz)) at the Earth's surface in the adjacent frequency band 2160-2200 MHz in Region 2 and 2170-2200 MHz in Regions 1 and 3.
- For the purpose of protecting specific fixed service operating in Armenia, Azerbaijan, Belarus, the Russian Federation, Kazakhstan, Mongolia, Uzbekistan, Kyrgyzstan, the Democratic People's Republic of Korea, Tajikistan and Turkmenistan, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a county's borders unless explicit agreement of the affected administration is provided at the time of the notification of HIBS:

−165	dB(W/(m² · MHz))	for 0° ≤ θ < 5°
−165 + 1.75 (θ − 5)	dB(W/(m² · MHz))	for 5° ≤ θ < 25°
−130	dB(W/(m² · MHz))	for 25° ≤ θ < 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees

Detailed provisions governing the technical conditions for operation of HIBS in 694-960 MHz, or portions thereof, are outlined in Resolution [COM4/3] (WRC-23):

- For the purpose of protecting terrestrial IMT mobile stations in neighbouring countries from co-channel interference, HIBS shall not exceed a co-channel pfd of -114 dB (W/(m^2 · MHz)) at the Earth's surface outside a country's borders unless explicit agreement from the affected administration is provided at the time of the notification of HIBS.
- For the purpose of protecting terrestrial IMT base stations in neighbouring countries from co-channel interference, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a country's borders unless explicit agreement from the affected administration is provided at the time of the notification of HIBS:

−136 + 0.21 (θ)^2	dB(W/(m² · MHz))	for 0° ≤ θ < 8.3°
−121.8 + 0.08 (θ)	dB(W/(m² · MHz))	for 8.3° ≤ θ < 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees

- For the purpose of protecting specific fixed service operating in Armenia, Azerbaijan, Belarus, the Russian Federation, Kazakhstan, Mongolia, Uzbekistan, Kyrgyzstan, the Democratic People's Republic of Korea, Tajikistan and Turkmenistan, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a county's borders unless explicit agreement of the affected administration is provided at the time of the notification of HIBS:

−150	dB(W/(m² · MHz))	for 0° ≤ θ < 11°
−150 + 0.3912 (θ − 11)	dB(W/(m² · MHz))	for 11° ≤ θ < 80°

−123	dB(W/(m² · MHz))	for 80° ≤ θ < 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees

Detailed provisions governing the technical condition for operation of HIBS in 2500-2690 MHz, or portions thereof, are outlined in Resolution [COM4/4] (WRC-23):

- For the purpose of protecting terrestrial IMT mobile stations in neighbouring countries from co-channel interference, HIBS shall not exceed a co-channel pfd of -109 dB (W/(m^2 · MHz)) at the Earth's surface outside a country's borders unless explicit agreement from the affected administration is provided at the time of the notification of HIBS.
- For the purpose of protecting terrestrial IMT base stations in neighbouring countries from co-channel interference, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a country's borders unless explicit agreement from the affected administration is provided at the time of the notification of HIBS:

−144.55	dB(W/(m² · MHz))	for 0° ≤ θ < 11°
−144.55 + 0.45 (θ − 11)	dB(W/(m² · MHz))	for 11° ≤ θ < 80°
−113.55	dB(W/(m² · MHz))	for 80° ≤ θ < 90°

  where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees
- For the protection of fixed service, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a county's borders unless explicit agreement of the affected administration is provided at the time of the notification of HIBS:

−148	dB(W/(m² · MHz))	for 0° ≤ θ < 2°
−148 + 0.71 (θ − 2)	dB(W/(m² · MHz))	for 2° ≤ θ < 47°
−116	dB(W/(m² · MHz))	for 47° ≤ θ < 90°

  where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees
- For the protection of broadcasting-satellite service in the territory of other administrations in the frequency range 2520-2630 MHz, HIBS shall not exceed the following co-channel pfd at the Earth's surface outside a county's borders unless explicit agreement of the affected administration is provided at the time of the notification of HIBS:

−130	dB(W/(m² · MHz))	for 0° ≤ θ < 20°
−139.8	dB(W/(m² · MHz))	for 20° ≤ θ < 90°

  where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.
- For the protection of aeronautical-radionavigation service systems in the territory of other administrations in the frequency range 2700-2900 MHz, the pfd level of HIBS operating in 2500-2690 MHz produced at the Earth's surface in the territory of other administrations shall not exceed the following unwanted emissions limit, unless explicit agreement of the affected administration is provided at the time of the notification of HIBS:

−156.2	dB(W/(m² · MHz))	for θ ≤ 7°
−163 + 15 $\log_{10}$ (θ − 4)	dB(W/(m² · MHz))	for 7° < θ ≤ 30.5°
−141 + 2.7 $\log_{10}$ (θ − 4)	dB(W/(m² · MHz))	for θ = 30.5°
−157 + 14 $\log_{10}$ (θ − 4)	dB(W/(m² · MHz))	for 30.5° < θ ≤ 40.5°

−101.5	dB(W/(m² · MHz))	for θ > 40.5°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

- For the protection of radiolocation service systems in the territory of other administrations in the frequency range 2700-2900 MHz, the pfd level of HIBS operating in 2500-2690 MHz produced at the Earth's surface in the territory of other administrations shall not exceed the following unwanted emissions limit, unless explicit agreement of the affected administration is provided at the time of the notification of HIBS:

−165.6	dB(W/(m² · MHz))	for θ ≤ 37°
−165.6 + 5.5 (θ − 37)	dB(W/(m² · MHz))	for 37° < θ ≤ 45°
−121.6 + (θ – 45) / 3	dB(W/(m² · MHz))	for 45° < θ ≤ 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

- For the purpose of protecting radioastronomy service stations in the frequency band 2690-2700 MHz, the pfd level of HIBS operating in 2500-2690 MHz produced at any radio astronomy observatory site shall not exceed an unwanted emission limit of -177 dB (W/(m^2 · 10 MHz)), unless explicit agreement from the affected administration is provided at the time of the notification of HIBS.
- For the purpose of protecting the mobile-satellite service (space-to-Earth) and radiodetermination-satellite service (space-to-Earth) in the frequency band 2483.5-2 500 MHz, the use of HIBS in the frequency band 2500-2690 MHz shall comply with an unwanted emission limit of −30 dBm/MHz in the frequency band 2483.5-2500 MHz.

4.1.2 Technical conditions for NTN operation under relevant Space Services

4.1.2.1 NTN operation in L band – 1518-1559 MHz, 1626.5-1660.5 MHz and 1668-1675 MHz

The MSS allocation in L band and extended L band is summarised in Figure 12. Portions of the L band, namely 1525-1559 MHz and 1626-1660.5 MHz, have been adopted in 3GPP officially as an NTN band n256.

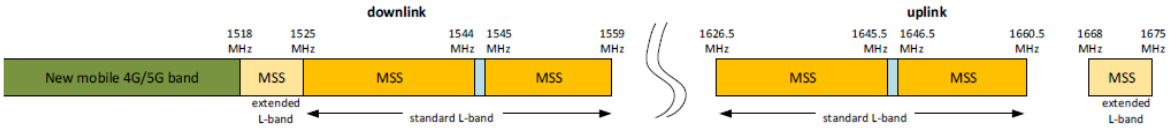

FIGURE 12. SUMMARY OF FREQUENCY ALLOCATION IN L-BAND AND EXTENDED L-BAND

The MSS L band uplink (Earth-to-space direction) refers to the bands 1626.5-1660.5 MHz. This part is allocated to MSS use with the following exceptions:

- the Radio Astronomy service operates in the upper 500 kHz (1660-1660.5 MHz)
- the fixed service may operate in the band 1626.5-1645.5 in a set of countries for legacy systems
- the portion 1645.5-1646.5 MHz is reserved for distress and safety communications.

In addition, portions of the following band are also used for safety services with higher priorities:

- the portion 1626.5-1645.5 MHz is also used for GMDSS (Global Maritime Distress and Safety System). As per No. 5.353A, the communications for distress, urgency and safety of the GMDSS are afforded priority,
- the portion 1646.5-1656.5 MHz is also used for AMS(R)S (Aeronautical Mobile Satellite (Route) Service, i.e., In-flight communications) with higher priority. Specifically, within the US, the AMS(R)S is afforded priority in the 1656.5-1660.5 MHz portion, as per No. 5.362A.

The MSS L band downlink (space-to-Earth direction) refers to the bands 1525-1559 MHz. The MSS operates with primary status with the following exceptions:

- In the portion 1525-1535 MHz: Space operations, downlink in all Regions. PFD limits apply to this allocation but not to the MSS downlinks. There is no identified filing using this allocation.
- In the portion 1525-1530 MHz: The Mobile Service operates in a limited number of countries in Europe, Middle East, Africa and central Asia (see No. 5.349). There is no pfd limit imposed upon the MSS to protect those services. The only constraint that may arise from this MS terrestrial allocation is local interference to the MSS / UE terminals. The extent of deployment of MS in the applicable countries is unknown. Similar limitations exist with respect to legacy Fixed service stations in certain countries (see No. 5.352A) .
- In the portion 1550-1559 MHz: The Fixed Service operates in a limited number of countries for legacy systems. Administrations are urged to avoid deploying new FS links, as per No. 5.359.
- In the portion 1544-1545 MHz: This part is exclusively reserved for distress and safety communications.

Similar to the uplink, portions of the band are also used for safety services with higher priorities, summarized below

- 1530-1544 MHz: This part is also used for GMDSS (Global Maritime Distress and Safety System). As per No. 5.353A, the communications for distress, urgency and safety of the GMDSS are afforded priority
- 1545-1555 MHz: This part is also used for AMS(R)S (Aeronautical Mobile Satellite (Route) Service, i.e., In-flight communications) with higher priority. Specifically in the US, the AMS(R)S priority is afforded in 1555-1559MHz as per No. 5.362A.

To operate different services in this band, the rule is ‘first come, first served’. Historically, the band has been used predominantly by GSO systems. However, NGSO systems may use it subject to coordination with earlier systems. The coordination of MSS services in this band is governed by an MoU among the notifying administrations of the existing GSO systems operating in the band. An MoU is dedicated to Regions 1 and 3 while a specific framework rules the Region 2.

Under the MoU, the operators negotiate on a yearly basis their prospective needs, taking into account preceding spectrum sharing. The sharing is made upon specific system characteristics by implementing geographical/frequency domain allocation.

The Extended L band is composed of 1518-1525 MHz (space-to-Earth) and 1668-1675 MHz (Earth-to-space). This Extended L band is not subject to the multilateral MoU, and the coordination is made under the ‘first come, first served’ principle.

The downlink band 1518-1525 MHz is adjacent to the 4G/5G band within 1427-1517 MHz. This band 1427-1517 MHz is marked as SDL (supplementary downlink band). The CEPT has studied

the adjacent band compatibility between MSS downlinks and SDL, and the studies have shown that MSS terminals could suffer receiver blocking and overloading from such interference. This topic has been extensively studied at the ITU-R and led to the completion of Report ITU-R M.2529[23] and Recommendation ITU-R M.2519[24].

The MSS allocation in Extended L band is worldwide but has extremely stringent pfd limitations over US in 1518-1525 MHz, which may make its use difficult over North America.

4.1.2.2 NTN operation in L/S paired band – 1610-1626.5 MHz and 2483.5-2500 MHz

The MSS allocation in 1.6/2.4 GHz band are summarised in Figure 13, note that the portions in 1610-1626.5 MHz and 2483.5-2500 MHz have been adopted by 3GPP officially as NTN band n254.

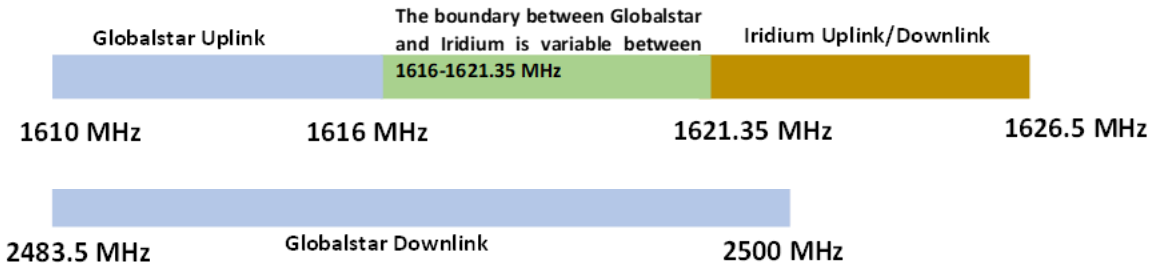

FIGURE 13. SUMMARY OF FREQUENCY ALLOCATION IN 1.6/2.4 GHZ BAND

The frequency band within 1610-1626.5 MHz is split between Iridium's Time Division Multiple Access (TDMA) MSS system and Globalstar's CDMA MSS system. This band is allocated to the MSS in uplink direction in the band 1610-1613.8 MHz, and in both directions in the band 1613.8-1626.5 MHz (with primary allocation to uplink direction, and lower priority for downlink direction). The uplink allocation band is in use by Globalstar for the user terminal uplinks up to 1621.35 MHz (from 1616 to 1621.35 MHz). Above this frequency, Iridium is licensed to operate in both uplink and downlink in TDD mode. The boundary between Globalstar and Iridium uplink frequency ranges is variable depending on the licensing administration.

Besides MSS, the main services to be protected in this band 1610-1626.5 MHz are:

- Radioastronomy service: this service is operated within 1610.6-1613.8 MHz and is extremely sensitive to interference. Technical conditions applicable to space services to protect the radioastronomy are provided in No. 5.372.
- Radiodetermination Satellite Service (Uplink): a series of filings form the Administration of China. Chinese filings are to be noted, in use for uplinks for the domestic Radionavigation satellite system.
- Aeronautical Mobile Satellite (Route) Service: This service has worldwide primary allocation in both uplink and downlink. Iridium has gained ICAO recognition of flight use of its capacity, which requires other operators to coordinate with Iridium for using the relevant portions of this band.

[23] Report ITU-R M.2529 – Adjacent band compatibility studies of IMT systems in the mobile service in the band 1492-1518 MHz with respect to systems in the mobile-satellite service in the frequency band 1518-1525 MHz

[24] Recommendation ITU-R M.2519 - Technical and regulatory measures to provide compatibility between IMT and MSS, with respect to MSS operations in the frequency band 1518-1525 MHz for administrations wishing to implement IMT in the frequency band 1492-1518 MHz

- Maritime Mobile Satellite Service: This service is allocated in the band 1621.35-1626.5 MHz. The allocation has been made at WRC-19 to permit Iridium provision of GMDSS (safety of life at sea).
- Aeronautical Radionavigation: Although this service has a worldwide allocation, the only known assignment corresponds to the Swedish Administration. The terminals (UEs) operating within the 1610-1626.5 MHz uplink allocation shall not exceed an EIRP density of -3 dBW/4kHz, and -15 dBW/4kHz in countries implementing aeronautical radionavigation, as per No. 5.366.
- Fixed Service: ITU recommends phasing out the Fixed Service in this frequency band. The FS allocation covers the bands 1550-1559 MHz, 1610-1645.5, 1646.5-1660 MHz used by Inmarsat, Globalstar and Iridium. To the writer's knowledge, there have been no reports of compatibility issues with the FS in this band. There are no pfd limits in the regulations and no recommended channel arrangements similar to those present in the neighbouring FS bands. The FS deployments should therefore be very limited, if any.

The frequency band within 2483.5-2500 MHz comprises an MSS downlink allocation, used by Globalstar CDMA systems.

The 2483.5-2500 MHz band is also allocated to terrestrial services such as Radiolocation, Fixed and Mobile services. In addition, the band is also allocated to the Radiodetermination satellite service (RDSS). Such RDSS service is operated in particular by China and India for national uses.

4.1.2.3 NTN operation in S band – 1980-2010 MHz and 2170-2200 MHz

The frequency bands 1980-2010 MHz and 2170-2200 MHz are allocated to the MSS on a primary basis in all three Regions, plus 2010-2025 MHz and 2160-2170 MHz in Region 2, with these allocations being co-primary with FS and MS. The allocations are illustrated in Figure 14. Note that S band (namely, 1980-2010 MHz and 2170-2200 MHz) has been adopted by 3GPP officially as NTN band n256.

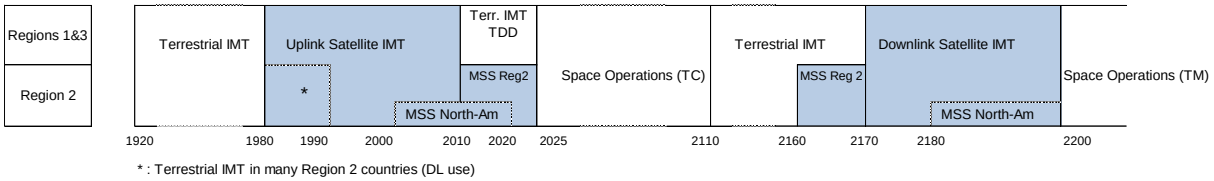

FIGURE 14. SUMMARY OF FREQUENCY ALLOCATION IN S-BAND

Table 24 presents coordination thresholds (in dB(W/m^2) over a reference bandwidth) applicable to NGSO space stations with respect to terrestrial services as contained in Annex 1 to Appendix 5 of the Radio Regulations:

TABLE 24. PFD COORDINATION TRIGGER APPLICABLE TO NGSO SPACE STATIONS IN THE S-BAND FOR THE PROTECTION OF TERRESTRIAL SERVICES

Band	0-5°	5-25°	25-90°	Ref. bandwidth
2160-2200 MHz	-141	-141+0.5(δ-5)	-131	4 kHz (1)
	-123	-123+0.5(δ-5)	-113	1 MHz (2)

(1) This limit per 4 kHz bandwidth applies only with respect to analogue Fixed Service telephony
(2) This limit applies to all terrestrial services allocated in the band

Whenever the coordination threshold is exceeded over the territory of an administration, the incoming service is required to coordinate with the affected administration's registered assignments.

It should be noted that the bands 1930-1970 MHz and 2120-2160 MHz are allocated respectively for uplink and downlink to the MSS on a secondary basis in Region 2 only. This allocation overlaps 3GPP bands n1 and n2, massively used for terrestrial mobile.

WRC-19 Agenda Item 9.1 issue 9.1.1 called for ITU-R studies "*to study possible technical and operational measures to ensure coexistence and compatibility between the terrestrial component of IMT (in the mobile service) and the satellite component of IMT (in the mobile service and the mobile-satellite service) in the frequency bands 1980-2010 MHz and 2170-2200 MHz where those frequency bands are shared by the mobile service and the mobile-satellite service in different countries, in particular for the deployment of independent satellite and terrestrial components of IMT and to facilitate development of both the satellite and terrestrial components of IMT*". As a result, Resolution 212 (Rev.WRC-19) was modified to provide guidance on the implementation of technical and operational measures to facilitate coexistence between the satellite and terrestrial components of IMT. Some of the main suggested conditions include,

For the terrestrial component of IMT:

- Terrestrial systems are invited, in both bands, to use base station antennas with improved sidelobe performance,
- Consider reducing the equivalent isotopically radiated power in the frequency band 1980-2010 MHz to a level sufficient for coexistence, for example, nominally to -10 dB (W/5 MHz)

For the satellite component of IMT:

- Use narrower spot beams and steeper roll-off from the boresight of the satellite antenna (i.e., not only reducing the interference level from the antenna sidelobe but also increasing frequency reuse and resilience to interference).
- Antenna steering, where such capability exists in the satellite design.
- Consider reducing the power flux-density to a level sufficient for coexistence, for example to nominally -122 dBW/m^2 for 1 MHz for the protection of some base stations or nominally -108.8 dBW/m^2 for 1 MHz for the protection of some user equipment on the Earth's surface on the territories of other administrations using this frequency band for the terrestrial IMT component.

Although Resolution 212 (Rev.WRC-19) [13] called for further studies on the matter, to date ITU-R Working Party 4C has made no significant advances. It is important to note that co-coverage, co-frequency deployment of independent satellite and terrestrial IMT components is not feasible unless techniques such as the use of an appropriate guard-band, or other mitigation techniques, are applied to ensure coexistence and compatibility between the terrestrial and satellite components of IMT, but that co-coverage, co-frequency deployment of terrestrial and satellite components of IMT could be feasible if deployed as integrated networks supported by a system providing the management of frequency utilization by both components.

Figure 15 and Figure 16 illustrate the adjacent and co-channel terrestrial bands of the S band, for both uplink and downlink direction. The critical interference paths are identified.

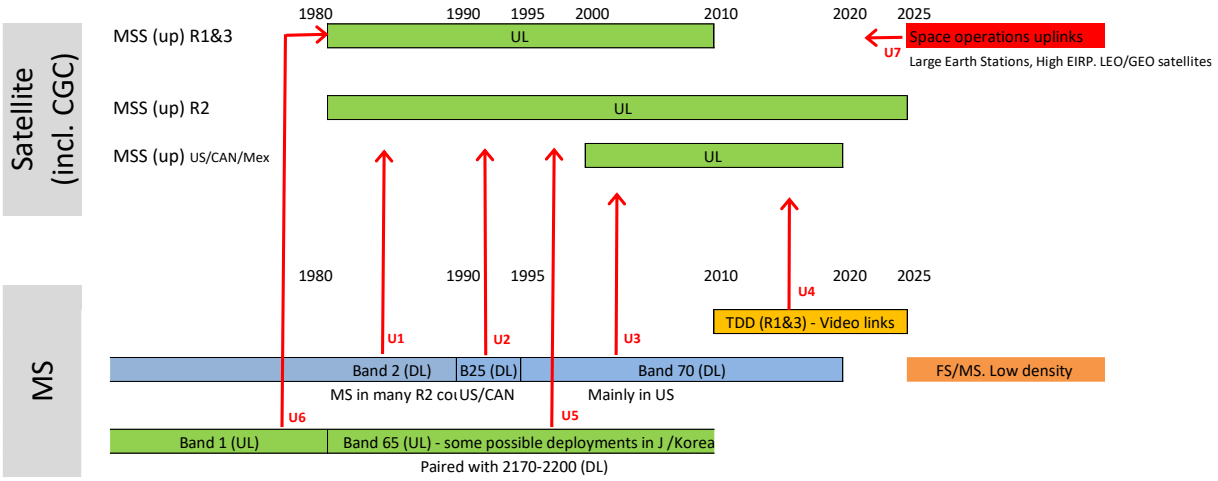

FIGURE 15. INTERFERENCE PATH BETWEEN MS AND MSS IN 1980-2010 MHZ

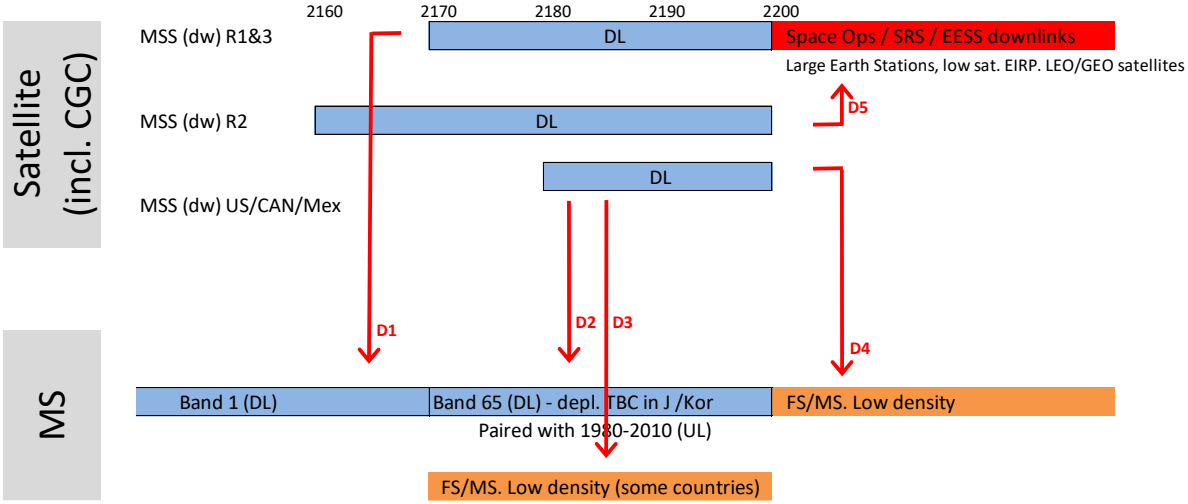

FIGURE 16. INTERFERENCE PATH BETWEEN MS AND MSS IN 2170-2200 MHZ

Table 25 presents a high-level summary of each potential interference case, together with the potential mitigation techniques.

TABLE 25. AN OVERVIEW OF POTENTIAL INTERFERENCE SOURCES AND SUGGESTED MITIOGATION TECHNIQUES APPLICABLE TO THE S-BAND

	Identifier	Source of interference	Victim	Comments	Mitigation
UL	U1 U2 U3	Terrestrial BS	Satellite Rx	Co-frequency/adjacent coverage & adjacent band/co-coverage Mainly interfering BSs in Region 2 (Americas): - U1: massive deployment in all Americas - U2: US and Canada only - U3: US terrestrial AWS-4	Satellite antenna isolation & sateliite payload filtering wrt aggregate BS emissions
	U4	Terrestrial BS and UE	Satellite Rx	Limited TDD service in Regions 1 and 3	
	U5	TerrestrialUE (within an MS or CGC network)	Satellite Rx	Co-frequency/adjacent coverage. CGCs of another MSS systems, and/or local MS uplink deployments	Satellite antenna isolation wrt aggregate UE emissions
	U6	Terrestrial UE	Satellite Rx	adjacent band – massive band 1 uplink deployment worldwide	Satellite payload filtering
	U7	Space Operations Earth Station	Satellite Rx	Adjacent band – significant guard band, but high power directional emissions from Space Operations emissions	Satellite payload filtering
DL	D1	Satellite Tx	Terrestrial UE (within an MS or CGC network)	Co-frequency/adjacent coverage. CGCs of another MSS systems, and local MS downlink deployments	Pfd limitation for UE protection
	D2	Satellite Tx	Terrestrial UE	Adjacent band/co-coverage – massive band 1 downlink deployment worldwide	Filtering to meet adjacent band pfd for UE protection
	D3	Satellite Tx	Other Fix satellite service	Co-frequency/adjacent coverage	Meet pfd value on countries requiring protection
	D4	Satellite Tx	Other Fix satellite service	Adjacent band/co-coverage	Filtering to meet adjacent band pfd limit
	D5	Satellite Tx	Space operation systems	Adjacent band. Large and sensitive Earth stations to be protected	Sharp filtering to reach adjacent band pfd below Space Ops levels

Noting the adoption by 3GPP of the S-band as NTN band n256, the S band spectrum has the potential to become a key asset for satellite operators. As it would be an exclusive portion of spectrum, it may help in overcoming regulatory issues arising from terminal authorisation and market access.

4.1.2.4 NTN downlink operations in C band – 3.4-4.2 GHz and 4.5-4.8 GHz

This section is predicated on an assumption that the NTN operations in C band are for standard smartphone access from the LEO orbit.

The bands 3.4-4.2 GHz and 4.5-4.8 GHz are currently allocated to the Fixed-Satellite Service (space-to-Earth) on a worldwide basis. A long-standing usage of this band by geostationary satellite systems is observed.

The band 4.5-4.8 GHz is subject to the provisions of the Space Plan contained in Appendix 30B of the Radio Regulations. The Space Plans have been established for certain space services and frequency bands in order to facilitate equitable access to a certain part of the frequency/orbit resource. To guarantee equitable access, it is based on a reservation of capacity and orbital location for future use by the ITU Member States.

This planned resource (orbital slot and frequency band) is called an “allotment”. Other systems on the GSO orbit can use the bands part of the Plan, provided they protect the national allotments.

NGSO FSS systems are also permitted provided they protect allotments or achieve coordination with additional systems. Such protection is ensured by compliance with the limits in RR Article 22.2 in the range 3.4-4.2 GHz and 4.5-4.8 GHz. For the sub-band 3.7-4.2 GHz, the protection of GSO is considered achieved if the limits in the form of downlink equivalent power flux density (epfd↓) are met. The corresponding limits contained in Article 22, Table 22-1E, are reproduced in Table 26:

TABLE 26. EPFD↓ LIMITS CONTAINED IN THE RADIO REGULATIONS, ARTICLE 22

Frequency band (MHz)	**epfd↓ (dB(W/m^2))**	**Percentage of time during which epfd↓ may not be exceeded**	**Reference bandwidth (kHz)**	**Reference antenna diameter and reference radiation pattern (m)**
3 700-4 200	−195.4	100	4	1.8
	−197.9	100	4	2.4
	−201.6	100	4	3.7
	−203.3	100	4	4.5
	−204.5	100	4	5.5
	−207.5	100	4	8
	−208.5	100	4	10
	−212.0	100	4	15

It should be noted that the above epfd↓ values apply for 100% of the time. That is, shall never be exceeded. This may put a high constraint to the deployment of NGSO services during in-line events (when the NGSO satellite crosses the main beam of the GSO stations pointing to the GSO satellites). This point is further explored in section 4.1.3.

Although in the bands 3.4-3.7 GHz and 4.5-4.8 GHz the GSO systems shall also be protected, unlike the band 3.7-4.2 GHz, there is no epfd↓ limit to quantify acceptable NGSO emission levels.

To protect terrestrial services, the emissions from FSS space stations are subject to power flux density limitations on the ground contained in Article 21 – Table 21-4. The limits are reproduced in Table 27.

TABLE 27. PFD LIMITS FOR THE PROTECTION OF TERRESTRIAL SERVICES

Frequency band	Service	Limit in dB(W/m^2) for angles of arrival (δ) above the horizontal plane			Reference bandwidth
		0°-5°	5°-25°	25°-90°	
3 400-4 200 MHz	Fixed-satellite (space-to-Earth) (geostationary-satellite orbit)	−152	−152 + 0.5(δ − 5)	−142	4 kHz
3 400-4 200 MHz	Fixed-satellite (space-to-Earth) (non-geostationary-satellite orbit)	−138 − *Y* [22, 23]	−138 − *Y* + (12 + *Y*)(δ − 5)/20 [22, 23]	−126 [23]	1 MHz
4 500-4 800 MHz	Fixed-satellite (space-to-Earth)	−152	−152 + 0.5(δ − 5)	−142	4 kHz

[22] **21.16.15** The value of *Y* is defined as *Y* = 0 for max(N_N, N_S) ≤ 2; *Y* = 5 log(max(N_N, N_S)) for max(N_N, N_S) > 2, where N_N is the maximum number of space stations in a system simultaneously transmitting on a co-frequency basis in the fixed-satellite service in the Northern Hemisphere, and N_S is the maximum number of space stations in the same system simultaneously transmitting on a co-frequency basis in the fixed-satellite service in the Southern Hemisphere. In determining N_N and N_S, two space stations simultaneously transmitting during periods of short-duration handover shall be considered as one satellite. (WRC-03)

[23] **21.16.16** The applicability of these limits may need to be reviewed by a future competent conference if the number of co-frequency non-geostationary systems brought into use and simultaneously operating in the same hemisphere is greater than five. (WRC-03)

Figure 17 summarizes the various service allocations and applicable regulatory constraints in the frequency range 3.4 – 5 GHz.

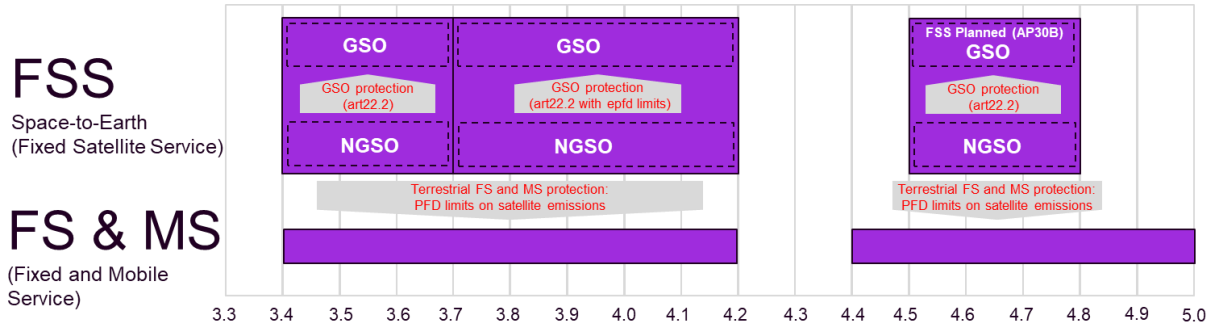

FIGURE 17. REGULATORY CONSTRAINT WITHIN FREQUENCY ALLOCATION IN 3-5 GHz

As the band 4.5-4.8 GHz is not identified for IMT in the RR, it is not considered as a suitable band for NTN at this stage.

4.1.2.5 NTN uplink operations in C band in the range 3.4-4.2 GHz

The Table of Frequency Allocations in the Radio Regulations contains no allocation for services in the earth to space direction in the frequency band 3.4-4.2 GHz. Therefore, under present regulations, NTN operations might be envisaged under RR Article 4.4 which frames non-conforming operations:

> ***Article 4.4*** *Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.*

It is further explained in the ITU Rules of Procedure when applying Article 4.4 that "*determination of whether or not a frequency assignment to a transmitting station is capable of causing harmful interference to the stations of another administration operating in accordance with the Radio Regulations does not lie only on the side of the administration operating the transmitting station that may be producing the interference and other administrations should have information about a use under Article 4.4 to assess its interference potential or identify the source of harmful interference. For this reason, an administration intending to use a frequency assignment to a transmitting station under Article 4.4 has to notify to the Bureau this frequency assignment, pursuant to Article 11, if possible, prior to bringing it into use. For space services, this includes the prior application of the relevant provisions of Article 9.*"

Even though such regulatory regime offers no international regulatory recognition, satellite NTN uplinks may be envisaged subject to the following:

- No regulatory protection could be ensured for the NTN satellite reception from interference coming from allocated services. Such interference may be particularly severe from Mobile networks using IMT technologies operating in parts of the 3.4-4.2 GHz band. Those networks generally operate in lower part of the 3.4-4.2 GHz band.

- NTN terminals may be authorised to transmit to the NTN satellites under a national authorisation, conditioned not to create harmful interference to services deployed by other administrations in the same band, typically at country borders. (See for example section 5.1)

Since NTN terminals are materially similar as TN terminals, the Mobile allocation may provide some regulatory justification for such terminal to transmit in parts of the 3.4-4.2 GHz band under a similar national authorisation for TN, or through a waiver such as the 'supplemental-coverage-from-space' approach proposed by the FCC in the US (refer to section 5.1.1). Given that the Mobile allocation in 3.4-4.2 GHz does not include uses for aeronautical mobile applications, transmissions from NTN terminals towards space stations authorised by regulators under national provisions are likely to include the same restriction.

4.1.2.6 NTN uplink operations in C band – 5.925-7.125 GHz

This section is predicated on an assumption that the NTN operations in C band are for standard smartphone access from the LEO orbit.

The band 5.925-7.075 GHz is allocated to the Fixed-Satellite Service (Earth-to-space) in RR Article 5. This allocation may render NTN uplink operations simpler, although the mobile terminal uplink does not strictly conform to the FSS since mobile terminals would have seemingly different characteristics to an FSS earth station.

Per Article 22.2, NGSO systems (including prospective NTN) shall protect GSO FSS uplinks. In the band 5.925-6.725 GHz, an uplink equivalent power flux density (epfd↑) limit of -183 dBW/m²/4 kHz must be respected at all times.

The band 7.075-7.125 GHz is allocated to Fixed and Mobile services, but not allocated to any space services.

The whole range 5.925-7.125 GHz is also allocated to the Fixed and Mobile Services. Several applications are either deployed, in development or contemplated in this band. These include,

- Fixed point to point links
- Wireless Local Area Networks, which are developing in several portions of the 6GHz band (e.g., in the US the whole range has been identified for such use, while in Europe the band 5.925-6.425 GHz has been harmonized)

4.1.3 Regulatory challenges that could hinder NTN deployment

4.1.3.1 NTN downlink operations in C band – 3.4-4.2 GHz

For downlink transmissions towards UEs, the FSS downlink allocation may provide spectrum resources. However, the compliance to RR Article 21 pfd limits and RR Article 22 epfd↓ limits could prove challenging as described below.

Compliance with Article 21 pfd limits (for protection of other terrestrial services):

The pfd limits in RR Article 21 apply in the entire band 3.4-4.2 GHz.

It is assumed that the provision of NTN services on smartphones will require relatively high signal strength, due to the limited antenna directivity and receiver performance of the terminal.

The pfd limit to protect terrestrial services at elevations above 25° is -126 dBW/m²·MHz, and even more stringent at lower elevations depending on the number of satellites (through the application of a scaling factor). NTN operations may generate in its service area of operations significantly higher pfd. According to preliminary system dimensioning, and subject to further analysis, a possible pfd value for NTN service provision could be estimated to -92 dBW/m²·MHz as determined in Table 28. This is 34 dB higher than the pfd limits prescribed in Article 21.

The NTN satellite antenna will therefore have to ensure a high discrimination towards areas in the territory of administrations where terrestrial services are entitled to protection.

For jurisdictions in which a Satellite Network Operator (SNO) and a Mobile Network Operator (MNO) are operating under a joint agreement, i.e., where the MNO terrestrial coverage is complemented by an NTN network, the pfd level to protect the TN network may be part of the agreement and potentially relaxed compared to the Article 21 limits.

TABLE 28. COMPUTATION OF TARGET POWER FLUX DENSITY ON EARTH SURFACE FROM NTN SATELLITE

Parameter	Value	Unit	Source
C/N target at UE	3.5	dB	Assumption
Boltzmann constant	-228.6	dB(W/K.Hz)	Constant
Temperature	300	K	Assumption
Noise figure	9	dB	Rec ITU-R M.2292
Reference bandwidth	1	MHz	Assumption
Frequency	3500	MHz	Assumption
Noise power	-134.8	dBW/RefBW	Calculation
Carrier power	-131.3	dBW/RefBW	Calculation
UE gain	-3	dBi	Rec ITU-R M.2292
Wavelength	0.0857	m	Calculation
Effective Area	-35.331034	dB(m²)	Calculation
Flux (w/o body loss margin)	-96.0	dBW/m²/RefBW	Calculation
Body Loss	4	dB	Rec ITU-R M.2292
Flux accounting for body loss	**-92.0**	dBW/m²/RefBW	Calculation

Compliance with Article 22 epfd limits (for protection of GSO):

The epfd limits in RR Article 22 apply in the band 3.7-4.2 GHz, whereas no epfd limit is enforced in the portions 3.4-3.7 GHz. Nevertheless, the provision in RR Article 22.2 that NGSO system shall not cause unacceptable interference and shall not claim protection from GSO networks will still apply within 3.4-3.7 GHz.

For the protection of the GSO earth station reception, two typical situations may be examined:

Case 1: The GSO earth station is in the service area of the NTN satellite. The NTN satellite only transmits when located at a topocentric angle θ from the GSO arc direction (GSO arc exclusion mechanism) as seen from the victim ground station. By comparing the expected operational pfd level of an NTN system with the epfd$\downarrow$ limits of RR Article 22 (scaled with the GSO reference earth station receive gain at angle θ), it is possible to evaluate the minimum value of θ and assess if this constraint is acceptable for NGSO NTN operations.

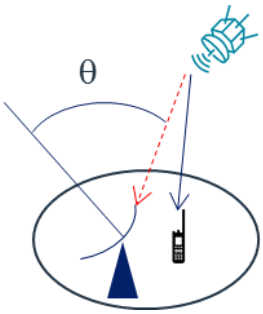

FIGURE 18. GSO RECEIVE STATION IN SERVICE AREA (CASE 1)

Case 2: The NGSO satellite is in the main beam of the victim GSO earth station and is servicing a distant area. The comparison between the acceptable epfd$\downarrow$ value and the pfd produced on ground in the NTN service area would allow to estimate the required minimum discrimination to be provided by the NTN satellite antenna.

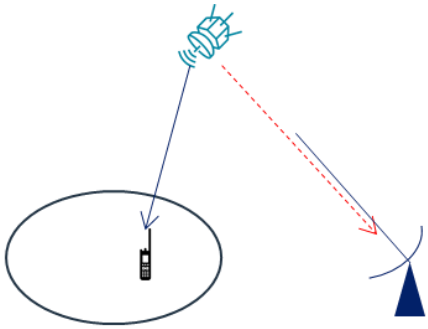

FIGURE 19. GSO RECEIVE STATION OUTSIDE SERVICE AREA (CASE 2)

To further elaborate the two specific cases above, a precise epfd↓ evaluation based on constellation aggregate effects may be conducted to assess the GSO protection constraints.

Based on the above, it follows that the NTN downlink operations to address smartphone-type terminals may be incompatible with GSO earth stations operations when such stations are visible from the NTN satellite.

4.1.3.2 NTN uplink operations in C band – 3.4-4.2 GHz

The following issues may constrain NTN uplink operations in the 3.4-4.2 GHz band:

Current lack of relevant space service allocation in Earth-to-space direction

Operations under RR Article 4.4 would be required under the current framework, leaving the evaluation of the possibility for the provision of a viable service to each national regulator. In the uplink context, Article 4.4 implies:

- Acceptance of interference into satellite reception, RR Article 4.4 being applied to the assignments of the satellite network by the notifying administration
- No interference from the NTN UEs authorized by an administration on which territory the service is provided, with respect to assignments registered by other administrations (typically at borders).

This status is not favourable to the widespread adoption and international roaming, but may be acceptable as a temporary situation pending a more stable regulatory framework.

Interference from Mobile/IMT public networks in NTN satellite reception

Public mobile networks (TN) employing IMT / 3GPP technologies operate using a TDD scheme. In situations where the NTN uplinks are operating co-frequency with those networks, the satellite receiver will experience aggregate interference alternatively from TN User Equipment and TN Base Stations located in its footprint. The BSs are expected to create a very high level of interference, and there is no expectation that the NTN satellite network could synchronize its operations with TN to avoid this adverse interference scenario. The uplink operation of NTN uplinks in portions of the band 3.4-4.2 GHz where TN public mobile networks are deployed should therefore be avoided. This generally concerns the lower part of the 3.4-4.2 GHz range and may vary according to the countries or regions concerned.

Interference from Mobile/IMT private networks in NTN satellite reception

Although these networks employ similar TDD technologies as public cellular networks, their deployment is expected to be limited to specific areas, and the EIRP of the base stations is also

expected to be significantly lower than those of the public networks. These networks may be deployed in portions of the 3.4-4.2 GHz not used by the public TN networks.

The operation of these networks is not expected to constitute an obstacle to the operation of co-frequency NTN uplinks, provided that the NTN network avoids beam pointing towards the concerned area.

Interference from NTN terminals to FSS Earth stations

In the 3.4-4.2 GHz band, there is a long-standing use of GSO FSS downlinks which must be protected. NTN UE operations in portions of the 3.4-4.2 GHz band will comply with 3GPP standards, hence with a limited EIRP level (23 dBm maximum power). This limited power level combined to the large discrimination of FSS Earth Station could make both applications compatible at reasonable separation distances (in the order of tens of kilometres, to be handled at national level). Location-aware mechanisms may allow to implement protection zones around FSS receiving earth stations to be protected.

Given potential line-of-sight visibility with FSS earth stations, restrictions or specific conditions on aeronautical usage of NTN UEs may be required, noting that such limitations currently already apply since the existing allocation in the band 3.4-4.2 GHz is for Mobile except aeronautical mobile service. Particularly, this restriction is critical to ensure protection of aeronautical radionavigation service in the upper adjacent band 4.2-4.4 GHz which is reserved exclusively for radio altimeters installed onboard aircraft.

Interference from NTN terminals to Fixed Service

Protection of Fixed Service stations would have to be ensured: NTN transmissions may need to be controlled through location-aware mechanisms so that UEs in the vicinity of Fixed Service receive stations do not create harmful interference.

It is noted that there is a tendency in some areas, for example Europe, towards a decrease in the use of the Fixed Service within this frequency range (see ECC Report 173 [15]).

4.1.3.3 NTN uplink operations in C band – 5.925-7.125 GHz

Considering the applications currently deployed, or planning to be deployed in this frequency range, the following constraints may apply:

Compatibility with GSO FSS uplinks - Interference to GSO FSS satellites from NTN UEs

The two estimates in the following show that a satisfactory I/N value in a GSO victim satellite could be met while supporting a significant number of NTN UE, however, it will be challenging to meet the Article 22 uplink limits:

- Compatibility with the epfd↑ limit of Article 22.5D in 5.925-6.725 GHz

  A calculation shows that a single smartphone with 23 dBm power, -3 dBi antenna gain, and a 180 kHz emission bandwidth, produces a line-of-sight pfd of -188.65 dBW/m²·4kHz at 36000 km altitude. In these conditions, the limit of -183 dBW/m²·4kHz would be exceeded with 4 simultaneous co-frequency UE transmissions. Given the anticipated inability of NTN UEs to implement GSO arc avoidance, the compliance with epfd↑ limits will be extremely challenging.

- Estimate based on I/N

  ECC Report 302 estimates the aggregate interference of RLANs to a set of typical GSO FSS system. Following a similar approach, and using a simplified set of parameters, the following estimate can be prepared. Assume the G/T of the GSO satellite as 3 dB/K, the NTN UE power of 23dBm power and a UE terminal antenna gain of -3 dBi. The GSO interference criterion is I/N = -10 dB (derived from ECC Report 302). With these assumptions, the interference threshold is reached with about 115 simultaneous transmissions in any given 180 kHz bandwidth, or about 23,000 UE simultaneous transmissions spread over a 36 MHz GSO transponder.

Compatibility with GSO FSS uplinks - Interference from GSO FSS Earth Stations to NTN satellite on-board receiver

Earth Stations transmitting to the GSO orbit have relatively high EIRP levels to cover the path loss and ensure a sufficient signal level at the GSO receiver with sometimes relatively low G/T for wide regional beams. Such signals could reach the LEO orbit of NTN systems at very high levels in comparison to the signal received from an NTN UE. Significant impairments are expected in the two following situations:

- The NTN satellite points at an area where a GSO FSS Earth station is transmitting. Harmful interference could occur even at very large angular separation from the GSO Earth station main beam
- The NTN satellite flies close to the main beam of the GSO Earth Station. Harmful interference could occur even if the NTN satellite points far from the Earth station location

The above suggests that NTN uplinks and GSO FSS uplinks are mutually exclusive.

Compatibility with the Fixed Service

For point-to-point links under Fixed Service applications, NTN transmissions may need to be controlled through location-aware mechanisms so that UEs in vicinity of Fixed Service receive stations do not create harmful interference.

In the US, the Wi-Fi may develop co-frequency with point-to-point links in this band, by employing an “Automated Frequency Coordination” (AFC) mechanism. Such mechanisms, although complex, may be a possible example for managing compatibility between NTN uplinks and fixed point-to-point links.

Compatibility with RLANs/Wi-Fi applications - NTN UE impact on the RLANs/Wi-Fi

Such interference situation with unlicensed devices is of local nature and is not expected to raise significant issues due to the built-in radio resource management of WiFi networks, the large bandwidth available (500 MHz or more, compared to an NTN UE emission of a few 100 kHz) and the nature of the deployments (indoor).

Compatibility with RLANs/Wi-Fi applications - RLANs/Wi-Fi impact on NTN reception

The aggregated interference of Wi-Fi networks into NTN satellite receivers is not expected to raise major issues given the low power nature of the Wi-Fi operations, located in the vast majority of cases indoors. However, if co-frequency usage of NTN UL was contemplated, a more accurate interference estimate needs to be made, based on Wi-Fi deployment scenarios on the long term and particularly within the US where ‘standard power’ outdoor Wi-Fi operations are allowed in the sub-bands 5.925-6.425 GHz and 6.525-6.875 GHz.

Impact of potential identification for IMT

If IMT networks are deployed in the 6.425-7.025 GHz and 7.025-7.125 GHz bands in TDD mode it would be extremely challenging for NTN uplink emissions to operate co-frequency with IMT networks due to the aggregate interference into the NTN satellite receiver coming from TN Base Stations. A widespread IMT network deployment will be detrimental to the NTN quality of service.

In light of all the above, the band 5.925-7.125 GHz is not considered as suitable for NTN uplink operation.

4.2 ABOVE 10 GHZ

4.2.1 Technical conditions for NTN operation under relevant Terrestrial Services

4.2.1.1 HAPS in 21.4-22 GHz, 24.25-27.5 GHz and 27.9-28.2 GHz

Given that the geographic availability of HAPS, based on provisions as outlined below, is limited to either Region 2 or to specific countries, and that there are additional power level constraints, this band is of limited usability for NTN deployment. The regulatory conditions that limit the areas of deployment in the band are contained in

- No. 5.530E: Region 2 footnote for 21.4-22 GHz (HAPS-to-ground) in accordance with Resolution 165 (WRC-19)
- No. 5.532AA: Region 2 footnote for 24.25-25.25 GHz (HAPS-to-ground) in accordance with Resolution 166 (WRC-19)
- No. 5.534A: Region 2 footnote for 25.25-27.5 GHz (ground-to-HAPS) limited to gateway links in accordance with Resolution 166 (WRC-19)
- No. 5.537A: country-specific footnote for 27.9-28.2 GHz (HAPS-to-ground) in accordance with Resolution 145 (Rev. WRC-19)

Prior to 2019, Resolution 145 (Rev. WRC-12) used to address the pairing of 27.9-28.2 GHz (HAPS-to-ground) and 31-31.3 GHz (ground-to-HAPS) for operation within 23 countries in Regions 1 and 3. However, the decisions made at WRC-19 have decoupled the band 31-31.3 GHz from Resolution 145 and subsequently identified 31-31.3 GHz as a global, bidirectional HAPS band in accordance with a set of provisions contained in Resolution 167 (WRC-19). The details of the conditions in the band 31-31.3 GHz are further elaborated in section 4.2.1.2.

4.2.1.2 HAPS in 31-31.3 GHz

The band 31-31.3 GHz was previously identified for use in 23 countries by HAPS in the ground-to-HAPS direction, but decisions made at WRC-19 have upgraded this identification to worldwide use by HAPS in both directions in accordance with No. 5.543B and Resolution 167 (WRC-19).

When adopting its decision, the relevant provisions -contained in Resolution 167 (WRC-19)- were developed based on Report ITU-R F.2473[25] for the purpose of protecting incumbent services, such as FS, EESS and RAS, in co- and adjacent frequency bands.

To achieve protection of the FS in the territory of other administrations in the frequency band 31–31.3 GHz, the pfd level per HAPS produced at the surface of the Earth in the territory of other administrations shall not exceed the following values, developed for clear sky conditions:

0.875 θ – 143	dB(W/(m² · MHz))	for 0° ≤ θ < 8°
2.58 θ – 156.6	dB(W/(m² · MHz))	for 8° ≤ θ < 20°
0.375 θ – 112.5	dB(W/(m² · MHz))	for 20° ≤ θ < 60°
–90	dB(W/(m² · MHz))	for 60° ≤ θ ≤ 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

In order to ensure the protection of the EESS (passive), the level of unwanted EIRP density per HAPS transmitter operating in the frequency band 31–31.3 GHz into the adjacent frequency band 31.3–31.8 GHz shall be limited to

− θ – 13.1	dB(W/200 MHz)	for −4.53° ≤ θ < 22°
−35.1	dB(W/200 MHz)	for 22° ≤ θ < 90°

where θ is the elevation angle in degrees at the platform height.

For the protection of RAS when HAPS is operating in the ground-to-HAPS direction, the pfd level produced by any HAPS ground station operating in the frequency band 31-31.3 GHz at RAS station locations at a height of 50 m shall not exceed a value of -141 dB(W/(m^2 · 500 MHz)) in the frequency band 31.3-31.8 GHz.

For the protection of RAS when HAPS is operating in the HAPS-to-ground direction, the pfd level produced by any HAPS transmitter operating in the frequency band 31-31.3 GHz shall not exceed −171 dB(W/(m^2 · 500 MHz)) for continuum observation in the frequency band 31.3-31.8 GHz at RAS station locations at a height of 50 m.

4.2.1.3 HAPS in 38-39.5 GHz

The band 38-39.5 GHz is identified for worldwide use by HAPS in both directions in accordance with No. 5.550D and Resolution 168 [14] (WRC-19).

For the purpose of protecting FS in the territory of other administrations in the frequency band 38-39.5 GHz, the pfd level per HAPS produced at the surface of the Earth in the territory of other administrations shall not exceed the following limits developed for clear-sky conditions:

−137	dB(W/(m² · MHz))	for 0° ≤ θ ≤ 13°

[25] Report ITU-R F.2473 - 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

−137 + 3.125 (θ – 13)	dB(W/(m² · MHz))	for 13° < θ ≤ 25°
−99.5 + 0.5 (θ – 25)	dB(W/(m² · MHz))	for 25° < θ ≤ 50°
−87	dB(W/(m² · MHz))	for 50° < θ ≤ 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

For the purpose of protecting MS in the territory of other administrations when HAPS is operating in the ground-to-HAPS direction in the frequency band 38-39.5 GHz, coordination of a transmitting HAPS ground station is required when the pfd in dB(W/(m² · MHz)) at the border of a neighbouring administration exceeds a pfd limit of −110.8 dB(W/(m² · MHz)) assuming mobile-station antenna height of 20 m. When HAPS is operating in the HAPS-to-ground direction in the frequency band 38-39.5 GHz, the pfd level per HAPS produced at the surface of the Earth in the territory of other administrations shall not exceed the following limits developed for clear-sky conditions:

−107.8	dB(W/(m² · MHz))	for 0° ≤ θ ≤ 4°
−107.8 + 1.5 (θ – 4)	dB(W/(m² · MHz))	for 4° < θ ≤ 10°
−98.8	dB(W/(m² · MHz))	for 10° < θ ≤ 90°

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

For the purpose of protecting earth stations in GSO FSS (space-to-Earth) in the territory of other administrations when HAPS is operating in the HAPS-to-ground direction in the frequency band 38-39.5 GHz, the pfd in the territory of other neighbouring administrations shall not exceed the following values

−169.9 + 1954 α²	dB(W/(m² · MHz))	for 0° ≤ α < 0.136°
−133.9	dB(W/(m² · MHz))	for 0.136° ≤ α < 1°
−133.9 + 25 log α	dB(W/(m² · MHz))	for 1° ≤ α < 47.9°
−91.9	dB(W/(m² · MHz))	for 47.9° ≤ α ≤ 180°

where α is the minimum angle between the line to the HAPS (taking into account the HAPS location tolerance) and the lines to the GSO arc, in degrees, at any point on the territory of other administrations.

For the purpose of protecting earth stations in the GSO and NGSO FSS (space-to-Earth) in the territory of neighbouring administrations when HAPS is operating in the ground-to-HAPS direction in the frequency band 38-39.5 GHz, coordination of a transmitting HAPS ground station is required when the pfd in dB(W/(m² · MHz)) at the border of a neighbouring administration exceeds a pfd limit of -111.3 dB(W/(m² · MHz)) for NGSO operations and -108.9 dB(W/(m² · MHz)) for GSO operations.

4.2.1.4 HAPS in 47.2-47.5 GHz and 47.9-48.2 GHz

The bands 47.2-47.5 GHz and 47.9-48.2 GHz were initially identified at WRC-97 for worldwide use by HAPS in both directions in accordance with No. 5.552A and Resolution 122 (WRC-97). Over several WRC cycles, this Resolution has been updated several times to include provisions for the purpose of protecting other incumbent services, including the latest revision at WRC-19.

For the protection of RAS stations in the frequency band 48.94–49.04 GHz from unwanted emissions of HAPS operating in the frequency bands 47.2–47.5 and 47.9–48.2 GHz, the separation distance between an RAS antenna and the nadir of an HAPS transmitter shall exceed 50 km.

To facilitate sharing with the FSS (Earth-to-space), the maximum transmit EIRP density of a HAPS ground station shall not exceed the following levels under clear-sky conditions:

6.4	dB(W/MHz)	for $30° \le \theta \le 90°$
22.57	dB(W/MHz)	for $15° < \theta \le 30°$
28	dB(W/MHz)	for $5° < \theta \le 15°$

where θ is the HAPS ground station elevation angle in degrees (angle of arrival above the horizontal plane).

For the purpose of protecting FS systems in the territory of other administrations in the frequency bands 47.2-47.5 GHz and 47.9-48.2 GHz, the pfd level per HAPS produced at the surface of the Earth in the territory of other administrations shall not exceed the following limits developed for clear-sky conditions:

−141	dB(W/(m² · MHz))	for $0° \le \theta \le 3°$
$-141 + 2 (\theta - 3)$	dB(W/(m² · MHz))	for $3° < \theta \le 13°$
−121	dB(W/(m² · MHz))	for $13° < \theta \le 90°$

where θ is the angle of the arrival of the incident wave above the horizontal plane, in degrees.

For the purpose of protecting MS systems in the territory of other administrations in the frequency bands 47.2-47.5 GHz and 47.9-48.2 GHz, the pfd level per HAPS produced at the surface of the Earth in the territory of other administrations shall not exceed the following limits developed for clear-sky conditions:

−106	dB(W/(m² · MHz))	for $0° \le \theta \le 4°$
$-106 + 1.2 (\theta - 4)$	dB(W/(m² · MHz))	for $4° < \theta \le 11.5°$
−97	dB(W/(m² · MHz))	for $11.5° < \theta \le 90°$

where θ is the angle of the arrival of the incident wave above the horizontal plane, in degrees.

4.2.2 Technical conditions for NTN operation under relevant Space Services

4.2.2.1 FSS/MSS in 10.7-12.75 GHz, 12.75-13.25 GHz, 13.75-14.5 GHz

The bands 10.7-12.75 GHz (space-to-Earth), 12.75-13.25 GHz (Earth-to-space) and 13.75-14.8 GHz (Earth-to-space) are allocated to the Fixed Satellite Service.

The use by the FSS of the band 14.5-14.8 GHz (Earth-to-space) is subject to Resolutions 163 and 164 (WRC-15) which limit its use to some countries. In addition, in those countries and in the band 14.5-14.75 GHz, the antenna diameter of the Earth stations shall be greater than 6m. Hence this band portion is not suitable for NTN applications.

In the band 14-14.5 GHz, provisions have been adopted either globally (and contained in the Radio Regulations), by regional organisations or by administrations to allow for operations of Earth stations operating while in motion. In particular:

- Use of FSS terminals transmitting in the band 14-14.5 GHz on board ships is permitted as ESVs (Earth Stations onboard Vessels) as per Resolution 902 (WRC-03). This resolution includes off-axis radiation patterns for terminals, a minimum antenna size of 1.2m and EIRP density limits towards the horizon. Coordination is required with the coastal state for operations at less than 125 km.

- The secondary Aeronautical MSS (AMSS) allocation in 14-14.5 GHz may be used for Aeronautical Earth Stations (AES) subject to technical limitations contained in Recommendation ITU-R M.1643 to protect the Fixed Service and the Radioastronomy.

- CEPT has a framework applicable in the band 10.7-12.75 GHz and 14-14.5 GHz for the harmonised use of:

    - Fixed terminals operating with GSO FSS satellites (ECC/DEC(17)04)
    - Land based ESIM operating with GSO FSS satellites (ECC/DEC(18)04)
    - ESIM operating with NGSO FSS systems (ECC/DEC(18)05)
    - Aircraft Earth Stations (AES) (ECC/DEC(05)11)
    - Earth Stations on board Vessels (ESV) (ECC/DEC(05)10)

- In the United States, the Federal communications commission (FCC) has developed domestic regulations applying in the Ku band for the following categories of terminals:

    - ESAA : Earth Station Aboard Aircraft
    - VMES : Vehicle-Mounted Earth Station (land use)
    - ESV : Earth Station on board Vessels
    - ESIM : Earth Station In Motion. Collective designation for ESAA, VMES, ESV

This comprehensive framework is expected to be applicable to NTN applications for terminals installed on diverse moving platforms. The following operational constraints are identified in particular:

- For terminals on board aircraft:

    - certain pfd density levels on the ground must be respected to protect terrestrial services in those countries where these are implemented. See Figure 20.

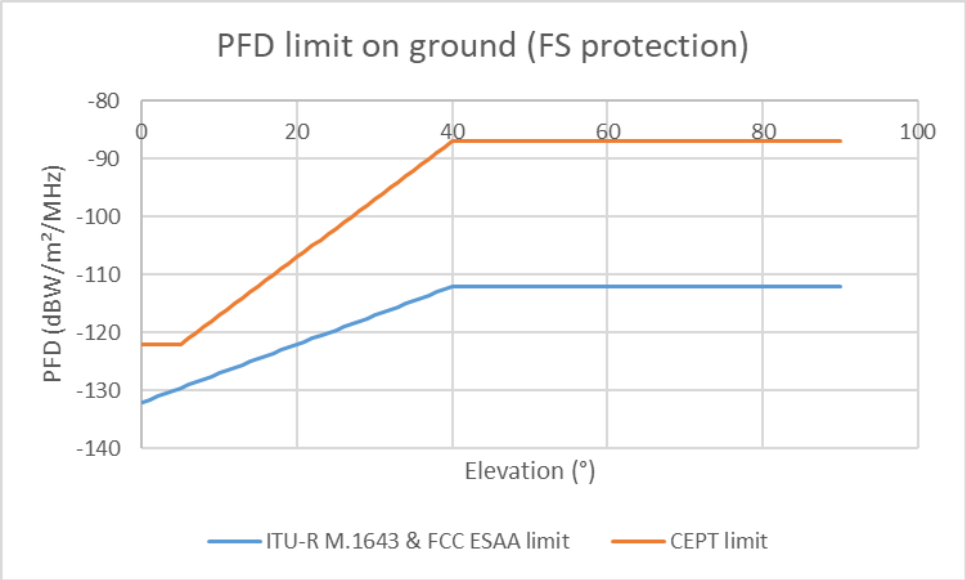

FIGURE 20 PFD LIMITS FOR THE PROTECTION OF FS CONTAINED IN THE FCC REGULATORY FRAMEWORK FOR EARTH STATIONS

  - RAS in the band 14.47-14.5 GHz must be protected from any co-frequency emission within visibility of the RAS sites, and from unwanted emissions arising from AES terminals operating in 14-14.47 GHz.
- For terminals on board ships or on land vehicles, pfd density levels at the coast, or respectively the borders, must be respected for countries where protection is required for terrestrial services (e.g., -116 dBW/m² · MHz with respect to concerned CEPT countries).

The NTN system downlink transmissions will be subject to the pfd limits defined in RR Article 21, particularly, Table 21-4. In addition, NTN NGSO systems will have to protect GSO networks in accordance with RR Article 22.2 and associated epfd limits.

Within 3GPP, ongoing discussions related to Ku-band as part of Rel-19 consider the following potential configurations:

- Region 3 and 1: DL 10.7–12.75 GHz, UL 12.75–13.25 GHz & 13.75–14.5 GHz;
- Region 2: DL 10.7–12.7 GHz, UL 12.75–13.25 GHz & 13.75–14.5 GHz.

4.2.2.2 FSS/MSS in 17.7-20.2 GHz and 27.5-30 GHz

The bands 17.7-20.2 GHz (space-to-Earth) and 27.5-30 GHz (Earth-to-space) are allocated to the FSS. In addition, the bands 19.7-20.2 GHz and 29.5-30 GHz are allocated to the MSS, on primary basis in Region 2, and in Regions 1 and 3 on a secondary basis for the lower 400 MHz and on a primary basis for the upper 100 MHz.

The ITU and individual administrations (collectively in CEPT) have defined operating conditions for ESIMs which would apply to NTN. Such regulations include:

- Resolution 169 (Rev. WRC-23) and Resolution [COM5/3] (WRC-23) applying to GSO and NGSO ESIMs in Ka band, respectively.
- Within CEPT, ECC/DEC(13)01 and ECC/DEC(15)04 applying respectively to GSO and NGSO ESOMPs (a precursor name for ESIMs)

For Maritime ESIMs:

- Resolution 169 (Rev. WRC-23) applying to GSO ESIMs while Resolution [COM5/3] (WRC-23) applying to NGSO ESIMs that provide EIRP limits towards the horizon, and coordination is required with the coastal state at distances lower than 70 km.

  CEPT has defined a pfd limit at the coast of -109 dBW/m² · 14 MHz for GSO and NGSO ESIMs

For Aeronautical ESIMs:

- Resolution 169 (Rev. WRC-23) and Resolution [COM5/3] (WRC-23) define pfd on ground to protect terrestrial services from ESIMs emissions in the relevant parts of the band 27.5-29.5 GHz for GSO ESIMs and NGSO ESIMs, respectively.
- CEPT has also developed pfd requirements to protect the Fixed Service. Those requirements are illustrated in Figure 21.

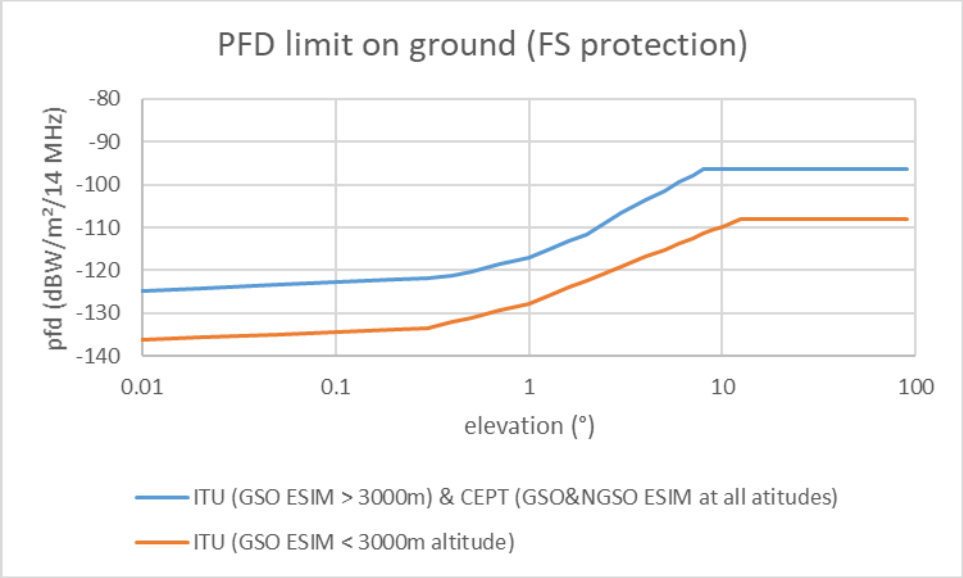

FIGURE 21 PFD LIMITS APPLICABLE TO AERONAUTICAL ESIMS, FOR THE PROTECTION OF FIXED SERVICE, DEFINED BY CEPT.

The bands 20.2-21.2 GHz and 30-31 GHz are allocated to the FSS and the MSS in the space-to-Earth and Earth-to-space direction respectively. These bands are identified for government use in many countries and may represent an opportunity for governmental NTN applications. However, coexistence and coordination with existing military satellites in 20.2-21.2 GHz and 30-31 GHz, which could support different use cases, could be challenging.

The NTN system downlink transmissions will be subject to the pfd limits defined RR Article 21, particularly, Table 21-4. In addition, NTN NGSO systems will have to protect GSO networks in accordance with RR Article 22.2 and associated epfd limits.

Currently, 3GPP specified in TS 38.108 Rel-18 the NTN Ka bands as follows:

TABLE 29. NTN OPERATING BANDS IN ABOVE 10 GHZ FOR SATELLITE NETWORKS (FR2-NTN)

NR operating band	Uplink (UL): $F_{UL,low}$ – $F_{UL,high}$	Downlink (DL): $F_{DL,low}$ – $F_{DL,high}$	Duplex mode
n512[1]	27.5 – 30.0 GHz	17.3 – 20.2 GHz	FDD

n511[2]	28.35 – 30.0 GHz	17.3 – 20.2 GHz	FDD
n510[3]	27.5 – 28.35 GHz	17.3 – 20.2 GHz	FDD
NOTE 1: This band is applicable in the countries subject to CEPT ECC Decision (05)01 and ECC Decision (13)01.			
NOTE 2: This band is applicable in the USA subject to FCC 47 CFR part 25.			
NOTE 3: This band is applicable for Earth Station operations in the USA subject to FCC 47 CFR part 25. FCC rules currently do not include ESIM operations in this band (47 CFR 25.202).			

4.2.2.3 FSS/MSS in 37.5-42.5 GHz, 43.5-47 GHz, 47.2-50.2 GHz, 50.4-52.4 GHz

Amongst the bands allocated to FSS between 37 GHz and 52.6 GHz, the Radio Regulations through No. 5.516B identified 39.5-40 GHz (space-to-Earth in Region 1), 40-40.5 GHz (space-to-Earth globally), 40.5-42 GHz (space-to-Earth in Region 2) and 48.2-50.2 GHz (Earth-to-space in Region 2) for HDFSS applications. Although such identification for HDFSS would present some level of harmonisation at a regional or global level for ubiquitous applications, the lack of a provision to allow the use of FSS for communications between satellite and earth stations on moving platforms or ESIM in these ranges may not make them suitable by means of treating NTN as an application of FSS.

The only exception amongst the above-mentioned bands is 40-40.5 GHz, which encompasses an existing, global, primary MSS allocation that could be used for NGSO deployment in the downlink direction, including NTN. It is expected that this downlink direction could be paired with another existing MSS allocation for uplink direction either those allocated as primary in the 43.5-47 GHz range, or the secondary allocation in the 50.4-51.4 GHz range.

To protect existing fixed or mobile services sharing the frequency band 40-40.5 GHz with equal rights with the satellite service, the maximum pfd produced at the surface of the Earth by emissions from satellites transmitting in the frequency band 40-40.5 GHz shall not exceed:

$$pfd(\theta) = -115 \ \ (dB(W/(m^2 \cdot 1\ MHz))) \qquad \text{for } 0° \le \theta \le 5°$$

$$pfd(\theta) = -115 + 0.5(\theta - 5) \ (dB(W/(m^2 \cdot 1\ MHz))) \qquad \text{for } 5° < \theta \le 25°$$

$$pfd(\theta) = -105 \ \ (dB(W/(m^2 \cdot 1\ MHz))) \qquad \text{for } 25° < \theta \le 90°$$

where θ is the angle of arrival of the radio-frequency wave (degrees above the horizon).

To protect radio astronomy service in 42.5-43.5 GHz, it is further noted that satellites in NGSO systems and GSO networks operating in the frequency band 42-42.5 GHz in the downlink direction shall not exceed the following values at the site of any radio astronomy station, respectively:

1) epfd produced in 42.5-43.5 GHz by NGSO operating in 42-42.5 GHz (No. 5.551H)

   - -230 dB(W/m^2) in 1 GHz and −246 dB(W/m^2) in any 500 kHz of the frequency band 42.5-43.5 GHz at the site of any radio astronomy station registered as a single-dish telescope; and
   - -209 dB(W/m^2) in any 500 kHz of the frequency band 42.5-43.5 GHz at the site of any radio astronomy station registered as a very long baseline interferometry station.

2) pfd produced in 42.5-43.5 GHz by GSO operating in 42-42.5 GHz (No. 5.551I)

- -137 dB(W/m^2) in 1 GHz and –153 dB(W/m^2) in any 500 kHz of the 42.5-43.5 GHz band at the site of any radio astronomy station registered as a single-dish telescope; and
- -116 dB(W/m^2) in any 500 kHz of the 42.5-43.5 GHz band at the site of any radio astronomy station registered as a very long baseline interferometry station.

In the bands 47.2-50.2 GHz and 50.4-52.4 GHz that are allocated to FSS (Earth-to-space), it is noted that the specific unwanted emission limits outlined in Table 1 of Resolution 750 (Rev. WRC-19)[26] would apply to GSO and NGSO earth stations operating in different portions of these bands when adjacent to the EESS (passive) frequency band. In addition, the portion of 51.4-52.4 GHz is limited to GSO networks only and the earth stations shall be limited to gateway earth stations with a minimum antenna diameter of 2.4m.

4.2.3 Regulatory challenges that could hinder NTN deployment

4.2.3.1 NTN using ESIM regime in 12.75-13.25 GHz

Considering the lack of an MSS allocation in the portions of the Ku band currently allocated to FSS, one mechanism that could enable the deployment of NTN, particularly in the portion 12.75-13.25 GHz, is via the ESIM regime. There are provisions that allow ESIM installed on aircrafts and vessels to communicate with GSO networks in the band 12.75-13.25 GHz (Earth-to-space) in association with 10.7-10.95 GHz, 11.2-11.45 GHz (space-to-Earth) and that may offer additional opportunities to deploy NTN via GSO networks. That said, the decision at WRC-23 only provided a framework for ESIMs to communicate with GSO networks in 12.75-13.25 GHz . Operations in this band with a GSO only option would be of limited interest. Therefore, until seamless interworking between GSO and NGSO constellations is a reality, the use of this portion of the Ku band would remain a secondary priority.

4.2.3.2 NTN using ESIM regime in 17.7-20.2 GHz and 27.5-30 GHz

As was the case with the Ku band case discussed in the previous section, considering the lack of an MSS allocation in the FSS Ka band (except for 19.7-20.2 GHz and 29.5-30 GHz), one approach to enable the remaining portions of the FSS Ka band to become a candidate NTN band is via an ESIM regime. Since it is already possible for ESIMs to communicate with GSO networks and NGSO systems in the FSS Ka band allocation, this band can be seen as viable for NTN deployment that would aim to serve satellite user terminals (i.e. not the form factor of a mobile terminal).

4.2.3.3 NTN using ESIM regime in 37.5-42.5 GHz, 47.2-50.2 GHz, 50.4-51.4 GHz

Since it is likely that NTN deployment in these bands would aim to serve satellite user terminals (i.e. not terminals with the form factor of a mobile terminal), it would be appropriate for NTN to consider operating in the existing MSS band, particularly the portion where MS and MSS overlap, such as 39.5–40.5 GHz (space-to-Earth), 43.5-47 GHz (both directions) and potentially 50.4-51.4 GHz (Earth-to-space) even though MSS is only secondary.

For the band 43.5-47 GHz, it is recognised that the portions within 43.5-45.5 GHz have been identified as a NATO band for military satellite usages. Though it may represent an opportunity for governmental NTN applications, the complexity in coexistence and coordination with military satellites supporting different use cases (e.g., high downlink EIRP density) could be challenging.

[26] Resolution 750 (Rev. WRC-19) Compatibility between the Earth exploration-satellite service (passive) and relevant active services

Instead, the focus of NTN could be shifted to 45.5-47 GHz, especially since this portion is already identified for IMT for over 50 countries in accordance with No. 5.553A.

However, it is noted that only the range 39.5-40.5 GHz is included in the existing 3GPP band n259, whereas the two other frequency ranges are not part of any existing 3GPP band classes. To benefit from the economies of scale that a harmonised standard would bring, particularly in the cost of the satellite user terminal ecosystem, there may be a need to work towards a new band class covering the relevant uplink portion in this Q/V band.

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5 NATIONAL/REGIONAL SPECTRUM POLICIES FOR NTN DEPLOYMENT

5.1 NATIONAL DECISIONS IN FREQUENCY ALLOCATION

Each administration has sovereign rights to the use of the spectrum within its national territory. Although deviations from the ITU Radio Regulations are possible, administrations would treat any deviation from its provisions at national level with careful consideration particularly when said deviation to the RR could pose risks of interference beyond its national territory to other services allocated in neighbouring countries or regions in accordance with the RR.

When considering NTN deployment, and particularly in cases of space stations of the NTN interworking with unmodified terrestrial mobile terminals, there is natural preference towards the reuse of portions of spectrum with overlapping allocations for mobile and space services. There are also instances where such overlap does not exist. In this scenario, before an administration could license such NTN deployments, changes to its national spectrum planning framework, including deviation with respect to RR, may be required. One relevant case study is the proposed approach being considered in the United States, presented in section 5.1.1.

It is noted that for successful country-wide NTN deployment exclusive access to spectrum would be beneficial, and particularly dedicated MSS spectrum. Another avenue for administrations is then to allocate dedicated spectrum for exclusive access: it would provide the NTN operator with a dedicated frequency band that is not shared with other users, would give the NTN operator more control over the network and would help to ensure that it is reliable and efficient. One relevant case study is the Saudi Arabia's auction of MSS spectrum in S-band to facilitate the deployment of NTN technologies including mobile-satellite services (MSS), internet on airplane via Air-to-Ground (A2G) provided by a terrestrial network, and internet of things via satellite (MSS-IoT). This case is discussed in section 5.1.2.

Within CEPT, studies have been initiated in June 2023 on "Satellite based Direct-to-Cell (D2C) for smartphones communications". This activity is expected to result in an ECC Report by end 2024/early 2025. Refer to section 5.1.3.

5.1.1 NTN for supplementary coverage: a case study from the United States

An example of a sovereign approach towards deployment of NTN under the national table of frequency allocations is the case of the United States to allow the use of various frequency bands for NTN networks, with the objective of providing supplementary coverage from space, augmenting the coverage provided by a terrestrial operator within one of six designated geographical areas[27]. The details can be found in the Notice of Proposed Rulemaking (NPRM) contained in GN Docket No. 23-65[28] dated 23 February 2023. The proposal would allow satellite operators – already holding authorisations to provide services from the FCC – to work with terrestrial license holders to provide the service.

[27] The proposed GIAs are: (1) CONUS; (2) Alaska; (3) Hawaii; (4) American Samoa; (5) Puerto Rico/U.S. Virgin Islands; and (6) Guam/Northern Mariana Islands

[28] Federal Communications Commission FCC-CIRC2303-01 https://docs.fcc.gov/public/attachments/DOC-391236A1.pdf and https://www.fcc.gov/document/gn-docket-no-23-65-opening-pn

5.1.1.1 Portions of the band under consideration

Through the proposed approach, the FCC would authorize satellite operators -working in close collaboration with terrestrial service providers- to provide services that expand the coverage of the terrestrial licensee, with especial emphasis in remote and underserved areas. Under the proposal, the FCC would add a co-primary Mobile Satellite Service (MSS) allocation as a non-federal footnote[29] in the following bands currently allocated to terrestrial services, to support supplemental coverage from space:

- 600 MHz band (663-698 MHz, 617-652 MHz),
- 700 MHz band (698-746 MHz, 746-758 MHz, 775-788 MHz and 805-806 MHz)
- 800 MHz band (824-849 MHz and 869-894 MHz),
- portions of the PCS band (1850-1915 MHz and 1930-1995 MHz),
- portions of the WCS band (2305-2320 MHz and 2345-2360 MHz).

Although the FCC's proposal is limited to "spectrum and locations where (1) there is only a single terrestrial entity that holds, either directly or indirectly, all co-channel licenses for the relevant frequencies in a given geographically independent area (GIA), such as CONUS; and (2) there are no primary, non-flexible-use legacy incumbent operations (whether federal or non-federal) in the band", the agency is open for comments on alternative scenarios including instances where multiple co-channel terrestrial licensees are authorized in a given geographical area.

The regulatory elements part of the Notice stipulates that handsets communicating with space stations would be considered Earth Stations and would be authorized as part of the Commission's current Part 25 rules.

The Commission further clarifies that any proposed allocation would remain subject to the United States' international obligations under treaties, bilateral or multilateral agreements, Article 5 of the ITU Radio Regulations, and other instruments of the ITU. Where there is no international MSS allocation in a band, proposed operations would be on a co-primary basis domestically, but assignment of such authorizations will be expressly conditioned not to cause harmful interference to, or claim protection from harmful interference caused by, a station operating in accordance with the provisions of the ITU Radio Regulations internationally.

5.1.1.2 Direction of communications, type of terminals and type of service

The link direction (up / down) will be inherited from the use of the terrestrial band (uplink or downlink) and such use would be included in the footnote text. Part of the Commissions' request for comments include whether the footnote should be more restrictive in directionality or not. See §31 of the NRPM.

Additionally, the Commission seeks comments on whether communications should be extended to fixed terminals to be used within the MSS allocation, in line with previous authorisations to terrestrial service providers to enable communications with both fixed and mobile terminals[30].

Furthermore, noting that the goal of the proposed rule is to seamlessly complement terrestrial operations in the band, the Commission is requesting comments on whether the allocation should be specific to the MSS or would be extended to allow FSS operators to provide the

[29] See https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-2, § 2.105 United States Table of Frequency Allocations.
[30] See §29 of the NRPM.

service, further noting that a single constellation can be licensed to provide both FSS and MSS services and that in certain cases FSS operators are authorized to communicate with ESIMs.

The NPRM explicitly excludes HAPS. Footnote 257 of the NPRM reads:

> "*We recognize that one application of NTN as defined in 3GPP is the use of High Altitudes Platforms (HAPS) to provide access to a user terminal. As noted, however, this proceeding does not propose, or seek comment on, the inclusion of HAPS within the SCS framework*".

5.1.1.3 Limits to the provision of the service across areas and to a single provider

In §41 of the NRPM the Commission highlights the complexities associated to the sharing and coordination of operations between operators of terrestrial networks in adjacent areas and the operations from the space stations, which arise from the time-varying nature of the coverage delivered by NGSO networks as well as the wide area coverage provided by the satellite antennas. It cites these complexities as the reason behind the proposed limitations to single terrestrial license holders in a geographical area:

> "*to minimize the possibility for interference between geographically adjacent markets, we propose, as an initial step in this proceeding, to limit the provision of supplemental coverage from space to instances where a single terrestrial licensee holds all co-channel licenses in the relevant band throughout one of six GIAs.*"

5.1.1.4 Limits to service providers with commercial arrangements

The NPRM includes elements that indicate that the provision of supplementary coverage from space would be connected to an existing commercial agreement between a satellite operator and the terrestrial license holder.

5.1.1.5 3GPP Efforts

Included in the Commissions' requests for comments are any efforts by 3GPP that should be taken into account by the Commission in this initiative to supplement terrestrial coverage using NTNs:

> *"we seek comment and stakeholder input on the status of any work being done by 3GPP or other standards organizations to address interference and other concerns associated with satellite-based operations in flexible-use spectrum currently designated for terrestrial networks, and whether any such work should be incorporated by the Commission through this proceeding".*

5.1.2 Auction of MSS spectrum for NTN: a case study from the Saudi Arabia

The Communications, Space and Technology Commission (CST) in Saudi Arabia (formerly known as Communications and Information Technology Commission (CITC)) conducted a public consultation on "Spectrum Auction of 2100 MHz for Non-Terrestrial Networks (NTN) Information Memorandum" in late 2021 with an intent to hold the auction in 2022. It pointed out that this auction would be a part of its strategic role as a digital regulator, in empowering the role of frequency spectrum in the national digital transformation, adopting the latest generation of satellite technologies, and facilitating a hosting environment for NTN technologies including mobile-satellite services (MSS), internet on airplane via Air-to-Ground (A2G) provided by a terrestrial network, and internet of things via satellite (MSS-IoT).

Upon reviewing 13 submissions from stakeholders, including operators, vendors, and industry associations, a number of changes to the auction's terms and conditions were made and the final Information Memorandum[31] for the auction was published in August 2022. The auction planned to release a total of 2x30 MHz of paired spectrum in the frequency bands 1980-2010 MHz (uplink) and 2170-2200 MHz (downlink) into two 2x15 MHz blocks as shown in Figure 22.

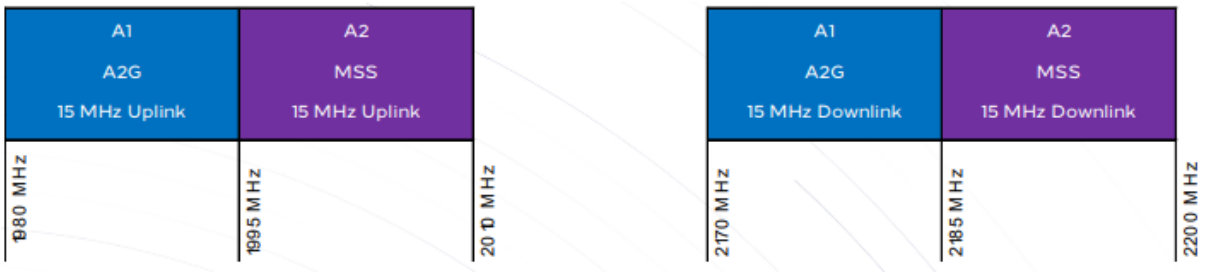

FIGURE 22. SPECTRUM BLOCKS AVAILABLE FOR AUCTION IN SAUDI ARABIA

Block A1 is limited initially to the provision of Air-to-Ground (A2G) services. Block A2 is limited initially to the provision of MSS (including in its most innovative forms such as satellite-based 5G NTN). The successful bidder of either block could also opt to apply for an upgrade of the licence for deploying terrestrial network, including a complementary ground component (CGC), once commercial MSS products are provided to Saudi consumers with the MSS licence.

The auction conducted in November 2022 where the 4 qualified bidders competed for the two available spectrum blocks over the course of 32 bidding rounds. The auction ended with Saudi Telecom Company (STC) winning both spectrum blocks for a licence tenure of 15-year. Those blocks will require the license holder to build an A2G network covering the national air routes with internet services, as well as to provide MSS across the country.

While having access to MSS spectrum is important, governments should ensure that the relevant licensing rules for NTN are in place, in a transparent and streamlined manner. The use of classic spectrum auctions, given the global nature of satellite networks, would prevent affordable services, render the space network infrastructure costs unsustainable, and could potentially cause fragmentation in the type of technologies that could be used. This is evident in the mentioned Saudi Arabia case, where despite the original good intention to facilitate access to exclusive MSS spectrum for NTN, the outcome indicated otherwise.

5.1.3 Satellite based Direct-to-Cell: an European initiative

Within CEPT, studies have been initiated in June 2023 under a work item on “Satellite based Direct-to-Cell (D2C) for smartphones communications”.

The CEPT administrations that initiated the study highlighted that

> “*the current mobile phone market is characterised by the start of using constellations of non-geostationary satellites for complementarily extending the coverage of terrestrial mobile communications services to and from unmodified market available smartphones. In order to avoid individual and non-harmonised country-by-country solutions including the risk of insufficient cross-border coordination solutions there is a need for a European wide harmonised approach in the long-term including regulatory and technical boundary*

[31] https://regulations.citc.gov.sa/en/Pages/PublishedPublicConsultations.aspx#/PublishedPublicConsulationDetails/18

conditions for supporting such a satellite based D2C solution. For that, it is to ensure that interoperability, European wide roaming, seamless handover between networks and non-discriminatory access remain possible."

The scope of the studies is to develop an understanding of direct-to-cell satellite connectivity (technical description of the satellite component and how it works) and to explore relevant regulatory and national licensing issues. These cellular devices are unmodified smartphones, including 3GPP NTN in MSS bands and/or with connectivity in Mobile/Fixed Communications Network (MFCN) bands. There is an intended focus on satellite-to-cellular device systems operating in frequency bands without satellite allocations (i.e., the MFCN bands). No specific bands are targeted at this stage, but it is understood by the authors of this report that the focus is on bands below 6 GHz.

Issues identified for studies are related to frequency sharing and compatibility, but also of regulatory nature, as detailed below:

- Frequency sharing and compatibility issues:
    - use under ITU RR Article 4.4 and/or ITU coordination for frequency filings
    - power flux density limits /coordination triggers, including in-band and out-of-band interference issues, in particular to protect neighbour countries that did not authorize the service
    - cross-border interference management
    - radioastronomy protection
- Regulatory issues:
    - agreements among SNO-MNOs including:
        - MSS classical service available on mass market smartphones
        - Use of the MNO licensed terrestrial band to complement terrestrial coverage
    - Mobility/roaming, network identity
    - standardization, interoperability
    - emergency services support
    - lawful intercept
    - integration of the satellite networks in overall integrated radio access electronic communication services.

This CEPT activity is expected to result in an ECC Report by end 2024/early 2025.

5.2 REGULATORY CLARITY FOR THE DEPLOYMENT OF NTN

NTN, being an emerging technology, faces a lack of regulatory clarity in many countries. This can make obtaining necessarily licenses for NTN operations and terminal deployment in the appropriate frequency bands difficult.

Some of the key regulatory challenges that NTN deployment could face include:

- Spectrum allocation: NTNs require spectrum for their operations, and in many countries, there is a limited amount of spectrum available. This can make it difficult for NTN operators to obtain the spectrum they need, either in a dedicated frequency band or in reusing TN frequency band.

- Interference management: NTNs can interfere with other wireless networks, such as terrestrial mobile networks and satellite networks that could be using the same (or adjacent) frequency bands. This means that NTN deployment needs to carefully manage interference to avoid disrupting other services.

There are two main ways to implement NTNs: as a standalone network or as a complementary network to TN.

5.2.1 NTN as a standalone network

This approach implies that NTN is an overlay on top of the existing TNs within any country. Standalone deployments ensure the overlay of NTN and TN without any issue even within overlapping geographical coverage areas, since the NTN and TN operate in different frequency bands.

In a standalone network deployment, NTN would require access to dedicated frequency bands, ideally in bands already allocated to MSS that are not available for TN (e.g. 3GPP band n255), in selected portions of FSS associated with special regulatory framework (e.g. ESIM in Ka band), or in TN bands that have been carved out from existing assignments within a country.

TABLE 30. SUMMARY OF PROS/CONS ASSOCIATED WITH STANDALONE NTN DEPLOYMENTS

Pros	Cons
Greater flexibility: Standalone NTNs are not limited by the availability of terrestrial infrastructure, so they can be deployed anywhere.	**Higher deployment cost**: Standalone NTNs are more expensive to deploy because they require their own spectrum and core network.
Better coverage: Standalone NTNs can provide better coverage in areas where there is no existing mobile coverage and rural fringe TN coverage area without having to worry about coordination.	**Regulatory challenges**: Uncertainty in gaining access to dedicated spectrum with sufficient bandwidth in a ubiquitous and cost-effective manner within a country.
Less interference: Standalone NTNs do not interfere with TN due to the access to dedicated spectrum.	**Seen as TN competitor**: Standalone NTNs could be misconstrued as a direct competitor to TN.

5.2.2 NTN as a complementary network to TN

This approach requires a partnership between the NTN and TN operators, to deliver complementary coverage while reusing spectrum and terrestrial infrastructure from the respective TN partner. Complementary deployments ensure the least intervention from the end-user perspective to benefit from the interworking between TN and NTN when the end-user is outside of the TN footprint but within the NTN footprint. The only concern would be the need for NTN to cease transmission when entering into the TN footprint, resulting in a potential coverage blackspot in some geographical areas due to the need to avoid geographical overlap between NTN and TN that operate in the same frequency band.

TABLE 31. SUMMARY OF PROS/CONS ASSOCIATED WITH NTN DEPLOYMENTS AS COMPLEMENTARY COVERAGE

Pros	Cons
Lower deployment cost: Complementary NTNs are less expensive to deploy because they do not require their own spectrum and core network.	**Limited coverage**: Complementary NTNs can only provide coverage in areas where there is no existing mobile coverage but would need to avoid any fringe TN coverage area due to interference concern.
Partnering with TN: Complementary NTNs working in partnership with TN would gain access to spectrum and reuse existing terrestrial infrastructure.	**Precise emission control:** To enable usage and minimize interference into TN, an automated system to regulate emissions from NTN space stations, with detailed knowledge of the radiation characteristics and instantaneous frequency usage of terrestrial networks would be required.
	Regulatory challenges: Reusing TN spectrum for NTN deployment may need regulatory intervention especially when the selected portions of TN spectrum do not contain appropriate frequency allocation for space service (e.g. MSS).

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6 POSSIBLE OPPORTUNITIES ARISING FROM WRC-27 AGENDA ITEMS

6.1 WRC-27 AGENDA ITEMS RELEVANT TO NTN FOR BANDS BELOW 7.125 GHZ

6.1.1 Additional MSS allocation for NTN deployment in bands identified for IMT

WRC-23 decided to establish a WRC-27 Agenda item, AI 1.13, to consider studies towards a possible new MSS allocation in the frequency range between 694/698 MHz and 2700 MHz for satellite-based NTN, to complement terrestrial IMT network coverage, in accordance with Resolution [COM6/9] (WRC-23)[32].

As there was concern raised by some administration about the consideration of TDD band, it is noted that C-band in 3.4-3.7/3.8 GHz was excluded from the scope of this agenda item. It is further emphasised that studies should take into account the IMT frequency arrangements addressed in the most recent version of Recommendation ITU-R M.1036.

This agenda item opens the opportunity to add MSS allocation within some frequency band choices for NTN that may be otherwise operated under RR Article 4.4 to date based on a favourable outcome at WRC-27.

6.1.2 Additional MSS allocation for generic application

WRC-23 decided to establish a WRC-27 Agenda item, AI 1.14, to consider possible additional MSS allocations in 2010-2025 MHz (Earth-to-space) and 2160-2170 MHz (space-to-Earth) in Regions 1 and 3, and 2120-2160 MHz (space-to-Earth) in all Regions, in accordance with Resolution [COM6/10] (WRC-23)[33].

Noting that the portion 2010-2025 MHz is already allocated to MSS (Earth-to-space) in Region 2, this agenda item could potentially result in harmonisation across Regions 1 and 3 to enable better use of the 2010-2025 MHz portion globally, and also potentially making it a possibility for satellite-based NTN uplink.

Given that the 2120-2160 MHz and 2160-2170 MHz MSS allocations (space-to-Earth), are covered by an existing and worldwide IMT identification (Footnote No. 5.388) and are already part of 3GPP band 1 which would also be subject to study under WRC-27 Agenda item 1.13, the ITU may need to address the overlapping responsibility between the two Agenda Items.

6.1.3 Additional MSS allocation for low data rate applications

WRC-23 decided to establish WRC-27 Agenda item 1.12 to consider, based on the results of studies, possible MSS allocations and regulatory actions in the frequency bands 1427-1432 MHz (space-to-Earth), 1645.5-1646.5 MHz (space-to-Earth) (Earth-to-space), 1880-1920 MHz (space-to-Earth) (Earth-to-space) and 2010-2025 MHz (space-to-Earth) (Earth-to-space)

[32] Resolution [COM6/9] (WRC-23) - Studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage

[33] Resolution [COM6/10] (WRC-23) - Studies on possible new frequency allocations to the mobile-satellite service in the frequency bands 2010-2025 MHz (Earth-to-space) and 2160-2170 MHz (space-to-Earth) in Regions 1 and 3, and 2120-2160 MHz (space-to-Earth) in all Regions

required for the future development of low-data-rate NGSO systems, in accordance with Resolution [COM6/8] (WRC-23)[34].

It is noted that 2010-2025 MHz is also appeared in this agenda item, but in addition of Earth-to-space direction as per the other two agenda items, the scope of this agenda item also considers space-to-Earth direction.

Although this agenda item provides an avenue to seek additional MSS allocations in specific bands, the notion of limiting the MSS allocation only for low-data rate application may not be in line with the objective of the 6G-NTN project.

6.2 WRC-27 AGENDA ITEMS RELEVANT TO NTN FOR BANDS ABOVE 10 GHZ

6.2.1 ESIM in Q/V band for GSO and NGSO

At WRC-23, it was decided to establish WRC-27 Agenda item 1.1 to consider the technical and operational conditions for the use of the frequency bands 47.2-50.2 GHz and 50.4-51.4 GHz (Earth-to-space), or parts thereof, by aeronautical and maritime earth stations in motion communicating with space stations in the fixed-satellite service and develop regulatory measures, as appropriate, to facilitate the use of the frequency bands 47.2-50.2 GHz and 50.4-51.4 GHz (Earth-to-space), or parts thereof, by aeronautical and maritime earth stations in motion communicating with geostationary space stations and non-geostationary space stations in the fixed-satellite service, in accordance with Resolution 176 (Rev.WRC-23)[35].

This AI is similar to those of past WRCs (e.g. WRC-23 AI 1.15, 1.16), where regulatory framework for ESIM operations have been developed for Ku and Ka bands for operations with GSO and NGSO systems. The frameworks include technical provisions governing the use of the bands by aeronautical and maritime ESIMs, noting that the operation of land-based ESIM is subject to the authorisation of an administration for deployment within the national territory of that administration.

With this in mind, this agenda item intends to extend the ESIM framework to Q/V band and would make the broader Q/V band, , a potential candidate band to support satellite-based NTN.

[34] Resolution [COM6/8] (WRC-23) - Studies on potential new allocations to, and regulatory actions for, the mobile-satellite service in the frequency bands 1427-1432 MHz (space-to-Earth), 1645.5-1646.5 MHz (space-to-Earth) (Earth-to-space), 1880-1920 MHz (space-to-Earth) (Earth-to-space) and 2010-2025 MHz (space-to-Earth) (Earth-to-space) required for the future development of low-data-rate non-geostationary mobile-satellite systems

[35] Resolution 176 (Rev.WRC-23) - Studies on the use of the frequency bands 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space), or parts thereof, by aeronautical and maritime earth stations in motion in the fixed-satellite service

7 CONCLUSIONS

7.1 RECOMMENDATION ON PREFERRED FREQUENCY BAND FOR NTN

7.1.1 Bands below 7.125 GHz

For bands below 7.125 GHz, as identified in section 3.1.3, the following bands are possible candidates for NTN, particularly for satellite-based NTN: 1518-1525 MHz, 1525-1559 MHz, 1610-1626.5 MHz, 1626.5-1660.5 MHz, 1668-1675 MHz, 1980-2010 MHz, 2170-2200 MHz, 2483.5-2500 MHz, 3.4-4.2 GHz and 5.925-7.125 GHz.

Since 3GPP has already adopted NTN band classes n256 (1980-2010 MHz / 2170-2200 MHz) and n255 (1525-1559 MHz / 1626.5-1660.5 MHz) from Release 17 onwards, with an expectation that new band class n254 (1610-1626.5 MHz / 2483.5-2500 MHz) to be adopted into Release 18 onwards for 5G-NTN, all of these bands would continue to be considered as feasible for satellite-based 6G-NTN.

With regard to the possible opportunity arising from WRC-27 Agenda item 1.13 for the likelihood of seeking a new MSS allocation in any IMT identified band between 694/698 MHz and 2.7 GHz, the outcome of this agenda item may lead to the creation of new 5G-NTN band class(es) from existing 3GPP TN band class(es). It is expected that such bands would also continue to be considered as feasible for satellite-based 6G-NTN.

Considering the regulatory analysis in section 4.1.3, it is recognised that the frequency band 3.4-4.2 GHz would be feasible for satellite-based 6G-NTN downlink. Particularly the portions within 3.4-3.7 GHz where epfd$_{\downarrow}$ limit does not apply appear as the ideal option for a new candidate NTN band. With regards to the uplink, and given the challenges identified in section 4.1.3.3, relative to the use of 5.925-7.125 GHz for NTN uplink, the use of this band for 6G-NTN uplink would be challenging. There is then a need to explore other alternative uplink band to be paired with a 3.4-3.7 GHz downlink.

In light of the above, there are four possible options, listed in Table 32.

TABLE 32. SUMMARY OF ALTERNATIVE NTN BAND PAIRINGS IN BAND BELOW 7.125 GHZ

#	Downlink	Uplink	Remarks
1	3.4-3.7 GHz	Existing NTN band classes in L or S band	• Combination of C-band for downlink (advantage in throughput) and lower L-/S-band for uplink (advantage in RF power budget). • Given the available bandwidth in uplink portion of the existing NTN band classes in L-/S-band, the uplink traffic would be restricted with such uplink pairing. • Availability of uplink band may vary locally depending on individual jurisdictions • The opportunity to consider 2010-2025 MHz as the uplink choice may be enhanced with three

#	Downlink	Uplink	Remarks
			WRC-27 Agenda items seeking to harmonise this band for MSS globally
2	3.4-3.7 GHz	3.7-4.2 GHz	• 3.7-4.2 GHz only has FSS allocation in space-to-Earth direction and may require significant regulatory effort to introduce Earth-to-space direction (either FSS or MSS) to enable such uplink pairing. • The implementation of FDD duplex within 3.4-4.2 GHz would require duplexer in the user terminal (not the case currently in 3GPP n77/n78). Alternatively, a half-duplex scheme may avoid the need for a duplexer in the user terminal, at the cost of a reduced throughput
3	3.4-3.7 GHz	3.4-3.7 GHz (as half duplex FDD or full duplex FDD with a duplex gap)	• 3.4-3.7 GHz only has FSS allocation in space-to-Earth direction and may require significant regulatory effort to introduce Earth-to-space direction (either FSS or MSS) to enable such uplink pairing. • A half-duplex FDD in 3.4-3.7 GHz (without duplexer in the user terminal since it is reusing the existing 3GPP n77/n78 under TDD) would require portions of 3400-3700 MHz to be fixed for downlink and the remaining portion fixed for uplink, where downlink and uplink are also operating at different time slots, thereby sacrificing the total throughput. This may require some form of network synchronisation. • Alternatively, a full duplex FDD within 3.4-3.7 GHz would require a portion of the band to be dedicated to downlink and a portion of the band for uplink with a duplex gap. This approach also require duplexer in the user terminal (not the case currently in 3GPP n77/n78).
4	3.4-3.7 GHz (possibly up to 4.2 GHz)	5.925-7.025 GHz	• 5.925-7.025 GHz only has an FSS allocation in Earth-to-space direction and may require significant regulatory effort to introduce MSS to enable the uplink transmission originating from a mobile terminal for such NTN uplink pairing. • With the IMT identification in the portions of 6.425-7.025 GHz operating in TDD mode, it would be challenging for NTN uplink emissions to operate co-frequency with IMT networks due to the aggregate interference into the NTN satellite receiver coming from TN base stations when this band is adopted for wider TN deployment.

It is noted that the operation of satellite-based NTN under Option #1 is the only option in line with current regulatory framework in the ITU Radio Regulations. However, as highlighted in section 4.1.3.1, the pfd limit in the downlink of 3.4.3-7 GHz in RR Article 21 may be challenging for direct-to-device NTN service provision unless a possible relaxation to the pfd limit is sought, or the possibility is provided to waive the application of such limits when an agreement is in place between the concerned TN and NTN operators. High satellite antenna isolation could be required to minimize radiation towards the territory of administrations where the NTN service is not authorized and where Article 21 pfd limits apply. This could generate areas underserved by NTN close to the borders of those administrations.

The other three options would either require a change to the RR or some form of regulatory waiver -including deviation from the RR- to be considered on a case-by-case basis within individual jurisdictions. With respect to Options #3 and #4, the frequency ranges could potentially be expanded to the 3.4-4.2 GHz if there is an avenue to seek the appropriate regulatory changes at a future WRC (e.g. WRC-31). In addition, for Options #3 and #4, as highlighted in sections 4.1.3.2 and 4.1.3.3, the interference from TN deployments (aggregate emissions from Base Stations) in the NTN uplinks is expected to be very significant depending on the density of the TN networks, potentially making the service unavailable if a large number of TN Base Stations is visible from the satellite.

7.1.2 Bands above 10 GHz

For bands above 10 GHz, and as identified in section 3.2.3, the following bands are possible candidate for NTN, particularly for satellite-based NTN: 17.7-20.2 GHz (space-to-Earth), 27.5-30 GHz (Earth-to-space), 39.5–40.5 GHz (space-to-Earth), 43.5-47 GHz (both directions) and 50.4-51.4 GHz (Earth-to-space).

Based on the current regulatory framework in the ITU Radio Regulations (post WRC-23), the 17.7-20.2 GHz (space-to-Earth) and 27.5-30 GHz (Earth-to-space) band pair is one of the candidate bands for satellite-based NTN. In addition, it would also be appropriate for satellite-based NTN to consider operating in an existing MSS allocation within Q/V band, particularly the portions where MS and MSS overlap in the bands 39.5-40.5 GHz (space-to-Earth), 45.5-47 GHz (both directions), 50.4-51.4 GHz (Earth-to-space).

Furthermore, and noting that WRC-27 Agenda item 1.1[36] concerning the 47.2–51.4 GHz spectrum, a favourable outcome may offer future opportunities for NTN application in the broader Q/V band with an existing FSS allocation (37.5-42.5 GHz, 47.2-50.2 GHz, 50.4-51.4 GHz) for ESIM installed on aircrafts and vessels communicating with both GSO network and NGSO systems.

On a local/regional basis, additional flexibility on the available frequency plan may be provided. For instance, the CEPT has developed

- ECC Decision (23)01 designating the band 40.5-42.5 GHz for the use of uncoordinated earth stations in the FSS (space-to-Earth) on a non-exclusive and unprotected basis.

[36] WRC-27 Agenda item 1.1 - to consider the technical and operational conditions for the use of the frequency bands 47.2-50.2 GHz and 50.4-51.4 GHz (Earth-to-space), or parts thereof, by aeronautical and maritime earth stations in motion communicating with space stations in the fixed-satellite service and develop regulatory measures, as appropriate, to facilitate the use of the frequency bands 47.2-50.2 GHz and 50.4-51.4 GHz (Earth-to-space), or parts thereof, by aeronautical and maritime earth stations in motion communicating with geostationary space stations and non-geostationary space stations in the fixed-satellite service, in accordance with Resolution 176 (Rev.WRC-23);

Note that this band is also harmonized for MFCN (Mobile/Fixed Communications Networks) operations in CEPT, according the ECC Decision (22)06.

- ERC Decision (00)02 designating
    - the band 39.5-40.5 GHz for uncoordinated FSS and MSS Earth stations (space-to-Earth)
    - the band 37.5-39.5 GHz for uncoordinated FSS Earth stations (space-to-Earth) on an unprotected basis from the FS.
- ECC Decision (21)01 designating the band 48.2-50.2 GHz for uncoordinated FSS Earth stations (Earth-to-space)

Depending on the flexibility provided for future ESIMs operating in those frequency ranges, bands designated for uncoordinated Earth Stations in CEPT countries may become suitable for NTN use.

7.2 POSSIBLE REGULATORY CHANGES AND POTENTIAL RISKS FOR NTN DEPLOYMENT

For 6G-NTN, novel services or novel use of certain frequency bands may raise regulatory challenges. In this section, the major regulatory risks envisaged are identified, and possible mitigations are proposed.

7.2.1 Bands below 7.125 GHz

In the bands below 7.125 GHz, user equipment with small form factor, typically smartphones, are addressed.

For the development of the 6G-NTN, it is necessary that a sufficient amount of spectrum is made available beyond the currently allocated MSS bands in L and S bands, such as those standardized for 5G-NTN as n255 and n256.

The spectrum options identified in section 7.1.1 rely in part on frequency bands already allocated to MSS, including the L and S bands, and also on bands with terrestrial allocations to mobile services.

TABLE 33. SUMMARY OF REGULATORY RISKS TO THE DEPLOYMENT OF NTN SERVICES IDENTIFIED FOR BANDS BELOW 7.125 GHZ

#	Risk description	Concerned options	Possible mitigation measures
1	Restricted access to existing MSS L and S bands for uplink	1	• Pursue additional MSS allocations, particularly in 2010-2025 MHz • Advocate for a possible future WRC-31 agenda item for additional MSS in bands below 7.125 GHz that could enable other option(s) for NTN uplink
2	Lack of availability of 2010-2025 MHz for uplink	1	• Advocate for worldwide allocation.

			• Advocate for generic MSS allocation as the decision for WRC-27 Agenda items 1.13[37] and/or 1.14[38], but not limited to low data rate MSS applications in this band under WRC-27 Agenda item 1.12[39]
3	Mobile systems protection hinders 3.4-3.7 GHz use for 6G-NTN downlink	1,2,3,4	<u>Regulatory</u> • Advocate for regulatory clarity concerning the possibility of using existing FSS allocations in the space-to-Earth direction, noting that the current framework already allows for satellite downlink in 3.4-3.7 GHz, or even 3.4-4.2 GHz, for the same downlink signal to be picked up directly by mobile terminals. • Clearly define protection requirements for terrestrial mobile systems (e.g., pfd) • Advocate for a possible future WRC-31 agenda item in the removal/relaxation of current pfd hard limits similar to those in RR Article 21, while in the interim convince for opt-in regulation allowing administrations to lift pfd restrictions (currently, a satellite filing found to contain emissions at levels above the limits set in RR Article 21 is rejected by the ITU Radiocommunications Bureau) • Operation under RR Article 4.4 may provide medium term mitigation of this risk to open service in lead markets <u>Technical</u> • 6G-NTN satellite antenna needs to provide sufficient isolation to provide service to an area while protecting neighbouring countries, • Flexible frequency planning capabilities to adapt to contractual/spectrum lease agreements with local MNOs

[37] WRC-27 Agenda item 1.13 - to consider studies on possible new allocations in the frequency range between 694/698 MHz and 2.7 GHz to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution [COM6/9] (WRC-23);

[38] WRC-27 Agenda item 1.14 - to consider possible additional allocations to the mobile-satellite service in 2010-2025 MHz (Earth-to-space) and 2160-2170 MHz (space-to-Earth) in Regions 1 and 3, and 2120-2160 MHz (space-to-Earth) in all Regions, in accordance with Resolution [COM6/10] (WRC-23);

[39] WRC-27 Agenda item 1.12 – to consider, based on the results of studies, possible allocations to the mobile-satellite service and possible regulatory actions in the frequency bands 1427-1432 MHz (space-to-Earth), 1645.5-1646.5 MHz (space-to-Earth) (Earth-to-space), 1880-1920 MHz (space-to-Earth) (Earth-to-space) and 2010-2025 MHz (space-to-Earth) (Earth-to-space) required for the future development of low-data-rate non-geostationary mobile-satellite systems, in accordance with Resolution [COM6/8] (WRC-23);

4	Incumbent FSS GSO systems protection hinders 3.4-3.7 GHz use for 6G-NTN downlink	1,2,3,4	• Implement operational measures based on specific GSO systems and geographical areas to be protected
5	Lack of authorization to operate 6G-NTN uplink in 3.7-4.2 GHz	2	• Ensure long term protection of GSO FSS DL: 6G-NTN UEs to operate on non-interference basis w.r.t GSO Earth Station reception • Mainly a national issue (low power UE emissions): advocate for "light" secondary-like recognition at international level to facilitate national authorizations
6	Excess interference from terrestrial mobile networks into 6G-NTN uplink (either in 3.4-3.7 GHz or in 5.925-7.025 GHz)	3,4	Regulatory • No regulatory-based mitigation Technical • Very high satellite antenna isolation towards non-partner MNOs service areas, • TN/NTN resource allocation • Protection zones: Coordinate NTN operations to areas at large distance from zones of high TN deployment densities
7	Exclusion of aeronautical 6G-NTN UEs in 3.4-4.2 GHz	1,2,3,4	• Develop technical and regulatory conditions permitting the use of aerial UEs, on the basis of specific characteristics of NTN

It is noted that risk #3 and #4 concerning the downlink in the 3.4-3.7 GHz band are particularly critical since they apply to all the four spectrum options below 7.125 GHz envisaged for 6G-NTN and identified in section 7.1.1.

Risk #6 applies to NTN uplink in the band 3.4-3.7 GHz and relates mainly to the aggregate interference from TN Base Stations in visibility of the satellite. This risk is particularly critical for high density TN deployment regions and may severely affect the NTN service unless large separation distances from such regions are observed.

7.2.2 Bands above 10 GHz

This frequency range is expected to support the more directional terminals, typically mounted on moving platforms. Given that 3GPP is working towards developing specifications for 5G-NTN using Ka band and noting that it is already possible to deploy ESIMs communicating with NGSO systems in the band, it can be considered as feasible for satellite-based 6G-NTN. From this perspective, the focus for new spectrum bands for 6G-NTN should be on the Q/V band.

The table below identifies the main regulatory risk areas affecting the use of Q/V band for satellite-based 6G-NTN applications.

TABLE 34. SUMMARY OF REGULATORY RISKS TO THE DEPLOYMENT OF NTN SERVICES FOR BANDS ABOVE 10 GHZ

#	Risk description	Possible mitigation measures
8	Absence of a favourable outcome for WRC-27 Agenda Item 1.1 on the use of ESIMs with NGSO systems in the Q/V band	• Develop national/regional regulations providing flexibility for Q/V band ESIMs irrespective of GSO or NGSO • Use Ka band as a fall-back option
9	Lack of worldwide harmonization of portions of Q/V band usable for terminals	• **This is a very likely risk** • System design shall provide the flexibility to use any portion of the Q/V band range for UEs on a national basis
10	Protection of RAS in 42.5-43.5 GHz	• System design shall take into account RAS protection from design stages based on the protection levels described in section 4.2.2.3

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