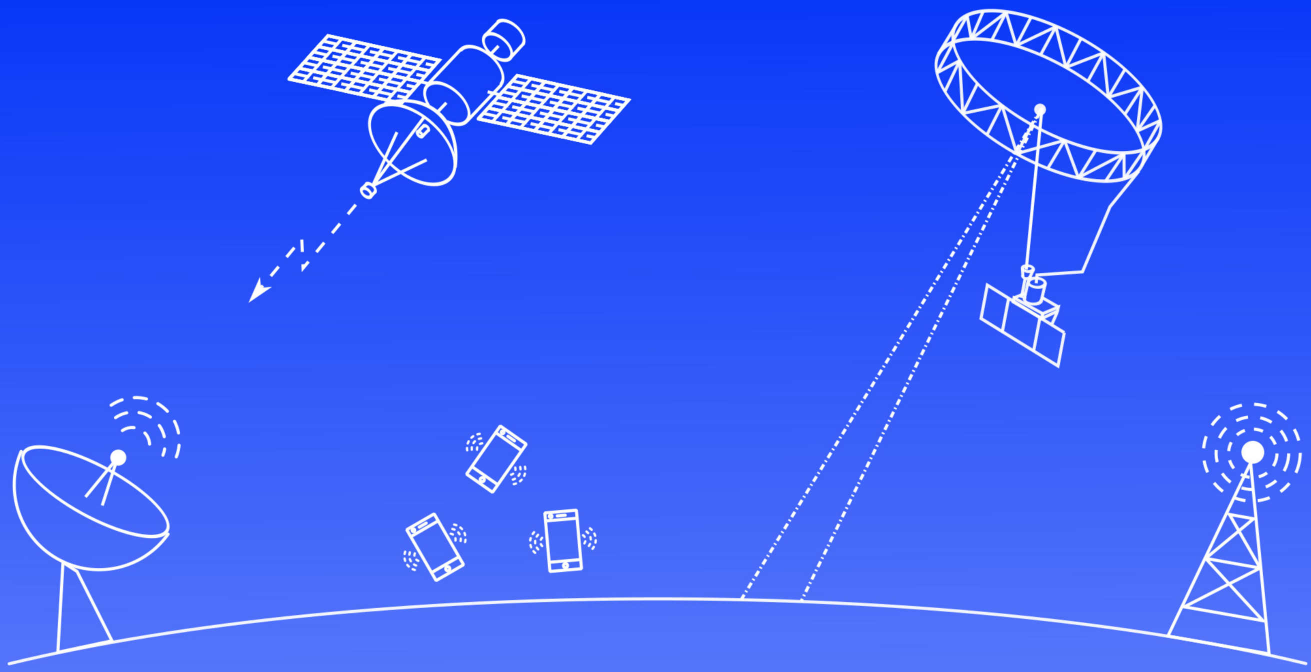

Potential Impact of Agenda Items of the World Radiocommunication Conference 2023 on Remote Sensing

Views of the
IEEE Geoscience and Remote Sensing Society

PUBLISHED BY THE IEEE GEOSCIENCE AND REMOTE SENSING SOCIETY

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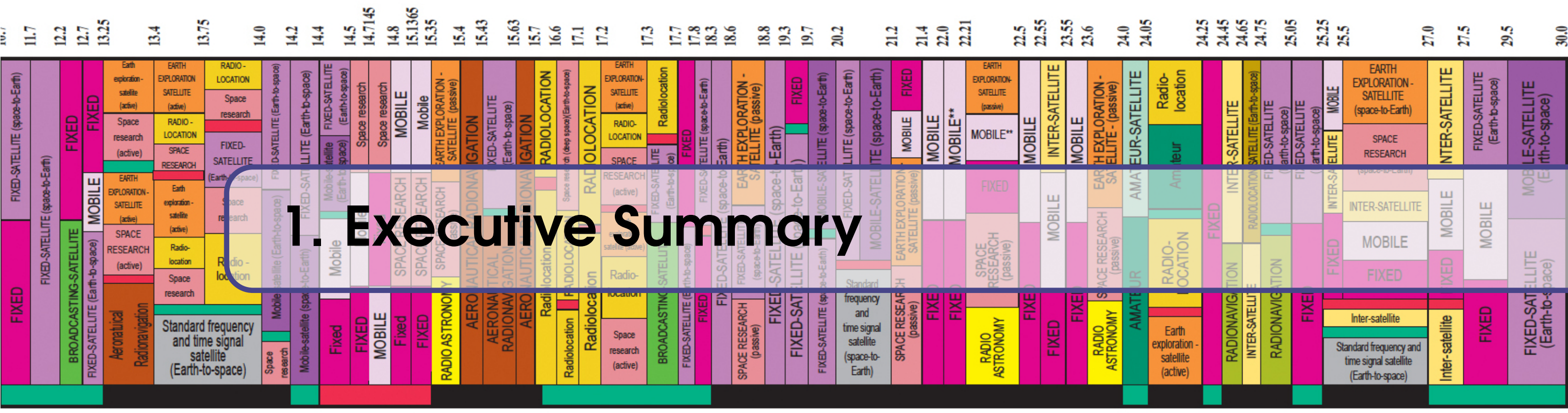

1. Executive Summary

The World Radiocommunication Conference 2023 (WRC-23) will be held from 20 November to 15 December 2023 in Dubai, United Arab Emirates. WRC-23 will consider several modifications to the International Telecommunications Union (ITU) Radio Regulations in its agenda. The following document presents and discusses the agenda items that could potentially affect microwave remote sensing and provide the position of the Geoscience and Remote Sensing Society (GRSS) of the Institute of Electrical and Electronics Engineers (IEEE) on them.

These agenda items affecting passive and active remote sensing instruments are summarized in Table 1.1 and Table 1.2 for passive and active instruments, respectively, with the frequency bands under consideration and the frequency bands relevant to remote sensing. EESS (passive) and EESS (active), introduced later, are the ITU terms for spaceborborne passive and active Earth microwave remote sensing.

Agenda Item	Proposed Use	Frequency Ranges under consideration	Relevant EESS (passive) Bands	Relevant Passive Instruments
1.2	International Mobile Telecommunication (IMT)	6425-7025 MHz (region 1)	C-band (non allocated)	Current: • WindSat • AMRS-2 • HY-2A MWI Future: • CIMR • AMRS-3 • HY-2B MWI • MTVZA-GY-MP
		7025-7125 MHz (globally)	C-band (non allocated)	Current: • AMRS-2 Future: • CIMR • AMRS-3 • MTVZA-GY-MP
		10.0-10.5 GHz (region 2)	10.6-10.7 GHz	Current: • WindSat • AMRS-2 • GPM GMI Future: • CIMR • AMRS-3 More in Table 4.4
1.4	High Altitude Platform Stations as International Mobile Telecommunication Base Stations (HIBS)	694-960 MHz 1710-1885 MHz 1885-1980 MHz 2010-2025 MHz 2110-2170 MHz 2500-2690 MHz	No allocations	Current: • none known Future: • UWB radiometer at 0.5-2.0 GHz

Agenda Item	Proposed Use	Frequency Ranges under consideration	Relevant EESS (passive) Bands	Relevant Passive Instruments
1.10	Non-safety aeronautical mobile	15.4-15.7 GHz 22-22.21 GHz	15.35-15.4 GHZ 22.21-22.5 GHz	None known SSMIS
1.14	EESS(passive)	231.5-252 GHz	235-238 GHz 250-252 GHz	Current: • Aura MLS Future: • Metop-SG-B1 ICI
1.16	Earth Stations in Motion (ESIM) (space-to-Earth) for NGSO Fixed-Satellite Service (FSS)	17.7-18.6 GHz 18.8-19.3 GHz 19.7-20.2 GHz	18.6-18.8 GHz	Current: • SSMIS • Windsat • AMSR-2 • GPM GMI • COWVR • SWOT • HY-2A MWI • Jason AMR Future: • CIMR • AMRS-3 More in Table 4.7
1.17	Satellite-to-satellite links	11.7-12.7 GHz 18.1-18.6 GHz 18.8-20.2 GHz	18.6-18.8 GHz	Same as for Agenda Item 1.16
1.18	Mobile-Satellite Service (MSS)	1695-1710 MHz 2010-2025 MH 3300-3315 MHz 3385-3400 MHz	No allocations	Current: • none known Future: • UWB radiometer at 0.5-2.0 GHz
9.1 (d)	NGSO FSS space stations in large constellations	37.5-38 GHz	36-37 GHz	Current: • SSMIS • AMSR-2 • GPM GMI • COWVR • MTVZA-GY • HY-2A MWI • FY-3C MWRI • MADRAS • Altika • Sentinel-3B MWR Future: • CIMR • AMRS-3 More in Table 4.9

Table 1.1: Agenda items affecting passive instruments.

Agenda Item	Proposed Use	Frequency Ranges under consideration	Relevant EESS (active) Bands	Relevant Active Instruments
1.2	International Mobile Telecommunication (IMT)	3300-3400 MHz (region 1) 3600-3800 MHz (region 2)	3100-3300 MHz	Current: • HJ-1C • NovaSAR-S Future: • NISAR
		10.0-10.5 GHz (region 2)	10.0-10.4 GHz	Current: • COSMO-SkyMed • TanDEM-X Future: • UMBRA • HRWS
1.12	EESS (active)	40-50 MHz	40-50 MHz	
1.15	Earth Station in Motion (ESIM) services	13.25-13.75 GHz 17.2-17.3 GHz	13.25-13.75 GHz	Current: • JASON-3 Poseidon • CryoSat-2 • CFOSAT • OceanSat-3 • GPM PR • FY-3G PMR Future: • CRISTAL
1.18	Mobile-Satellite Service (MSS)	1695-1710 MHz (region 2) 2010-2025 MHz (region 1) 3300-3315 MHz (region 2) 3385-3400 MHz (region 2)	3100-3300 MHz	Current: • HJ-1C • NovaSAR-S Future: • NISAR
1.19	Fixed Satellite Service (space-to-Earth)	17.3-17.7 GHz	17.2-17.3 GHz	None known
9.1 (b)	Amateur Service and the Amateur-Satellite Service	1240-1300 MHz	1215-1300 MHz	Current: • ALOS • SAOCOM • Lutan-1 Future: • NISAR • Tandem-L • Rose-L

Table 1.2: Agenda items affecting active instruments..

Issues related to specific agenda items are discussed individually in the main part of the document. However, some general considerations can be made here. The most serious threat to microwave remote sensing and scientific services comes again from mobile communications in the form of 5G (Agenda Item 1.2) or in combination with other systems (Agenda Items 1.4 and 1.18). Of equal concern are systems to provide global internet coverage using transmitters on satellites in Non-Geostationary Orbit (NGSO) deployed in large constellations, which are considered in Agenda Items 1.15, 1.18 and 9.1(d). These two topics are expected to continue to dominate future World Radiocommunication Conferences beyond WRC-23.

2. Acknowledgments

This document is the result of a collaboration between several members of the Frequency Allocations in Remote Sensing (FARS) Technical Committee of the IEEE Geoscience and Remote Sensing Society (GRSS).

This work was started by our beloved colleague Thomas von Deak, prematurely passed away in 2021, who laid down the structure of the document and wrote a very first draft of it. Many other FARS members have provided their assistance after that. In particular, completion of this work would have not been possible without the contribution of the following researchers:

- Beau Backus (National Oceanic and Atmospheric Administration, USA)
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- Joel T. Johnson (Ohio State University, USA)
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- David Lubar (Aerospace Corporation, USA)
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- Roger Oliva Balague (Zenithal Blue Technologies, Spain)
- Ming-Liang Tao (Northwestern Polytechnical University, China)
- Aravind Venkitasubramony (University of Colorado, USA)

The FARS Technical Committee is very grateful to all these people, who volunteered many hours to participate in online meetings and shared their knowledge during the development of this document. Last but not least, this endeavor would have not been possible without the encouragement and support of the GRSS Administrative Committee.

3. Introduction

This document is a compilation of the IEEE GRSS views on the WRC-23 agenda items and other related issues that may potentially impact space-based remote sensing operations. IEEE GRSS is vitally interested in having provisions in the ITU Radio Regulations enhance future system operations in the space science services which, in particular, includes space based remote sensing.

The International Telecommunication Union (ITU) is the United Nations specialized agency founded in 1865 to facilitate international connectivity in communications networks, develops the technical standards that ensure networks and technologies seamlessly interconnect and strives to improve access to for information and communication technologies to underserved communities worldwide. International usage of the radio frequency spectrum from 9 kHz to 3000 GHz is defined within the International Telecommunications Union – Radiocommunications Sector (ITU-R) Radio Regulations (RR) [1], which apply globally to some 40 different radiocommunication services. It is recognized that modifications to the International Radio Regulations can only be decided at a World Radiocommunication Conference (WRC), scheduled to occur at the end of an ITU-R study cycle with an approximate duration of four years during which the RR undergo a focused review and revision which is managed by members of the ITU-R (about 193 member states and 264 sector members). The cycle ends with a WRC where its members consider proposed revisions to the RR, which is an international treaty, and set the agenda for the next WRC. Most member states will subsequently adopt the approved RR revisions in their national radio regulations. The WRC agendas include focused topics whose scope is described by accompanying Resolutions.

Note that some of the WRC-23 agenda items seek to change existing regulations not globally, but only in some specific geographical areas. The ITU refers to them as ITU Regions. These regions are shown in Figure 3.1 (adapted from [1]) and will be used in the description of the agenda items in the next section.

Specific conditions for the use of a frequency band are usually described in footnotes of the RR. In this document, a footnote “xyz” will be indicated in the text as **RR No. xyx**.

The ITU-R Study Groups perform studies through their Working Parties, with each Working Party (WP) focusing on specific radiocommunication services and systems. Agenda Items may be assigned to one or more WP’s (referred to as “Responsible”) with information solicited from other interested WP’s (called “Contributing”). WP 7C, which falls under the Science Services Study Group (SG) 7 is responsible for remote sensing systems. In ITU terminology, the radiocommunication service associated with spaceborne remote sensing instruments is called Earth Exploration Satellite Service (EESS), and can be either active or passive. A complete list of radiocommunication services with the number of related RR articles defining them is fiven in Appendix. Figure 3.2 illustrates the structure of the ITU-R Study Groups and Working Parties.

The IEEE GRSS Frequency Allocations in Remote Sensing (FARS) Technical Committee (TC) has developed this document for the IEEE GRSS. The mission of the FARS-TC is to serve as an interface between GRSS and the radio-frequency regulatory world by:

- educating the remote sensing community on spectrum management processes and issues;

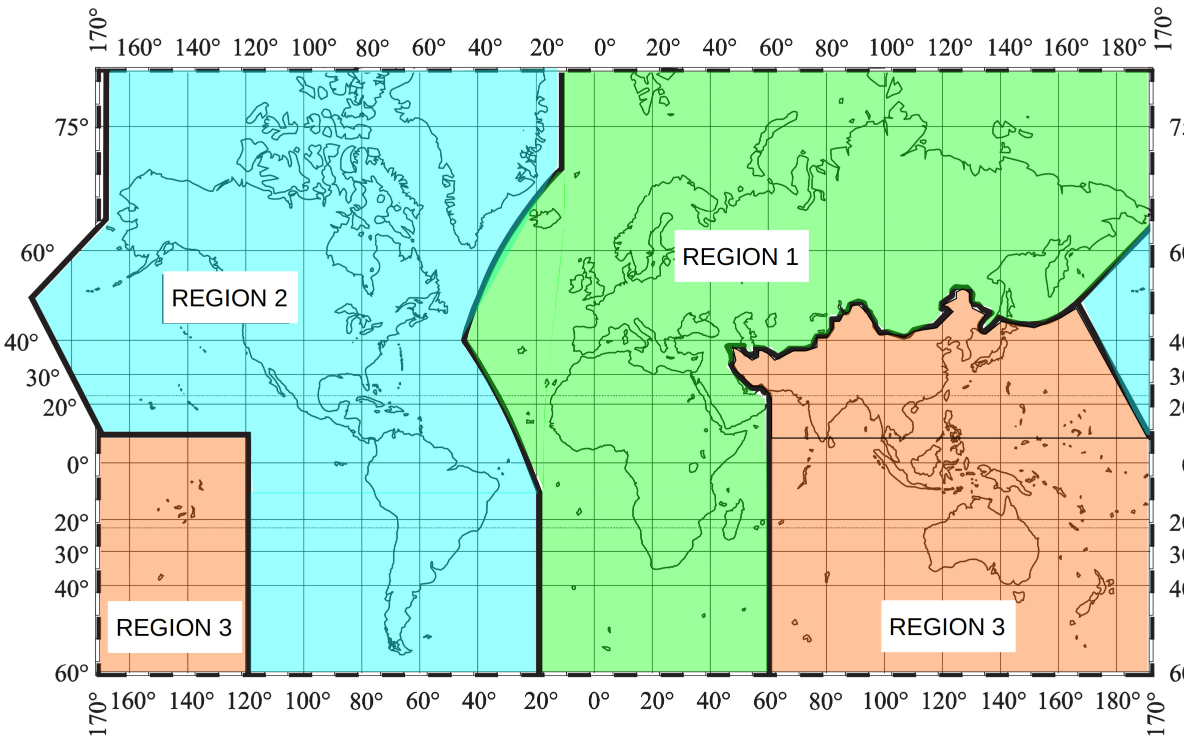

Figure 3.1: ITU Regions.

- promoting the development of radio frequency interference detection and mitigation technology;
- organizing technical sessions at conferences, workshops, etc. on the above processes, issues and technologies;
- providing spectrum managers and regulators with technical input and perspective from remote sensing scientists and engineers;
- fostering the exchange of information between researchers in different fields, such as remote sensing, radio astronomy, telecommunications, etc., with the common scope of minimizing harmful interference between systems.

The organization of this document on the IEEE GRSS views on WRC-23 agenda items aligns with the agenda for WRC-23 provided in ITU-R Resolution **811 (WRC-19)** and the preliminary agenda for WRC-27 in Resolution **812 (WRC-19)**. Not all the Agenda Items are of interest to the IEEE GRSS and therefore only those relating to IEEE GRSS issues, are discussed herein.

Radio frequency bands that are scientifically relevant for IEEE GRSS are those allocated by the Radio Regulations (RR) of the ITU to the Earth Exploration-Satellite Service (EESS), the Meteorological-Satellite Service (MSS), and the Space Research Service (SRS). Increased demand for spectrum by radiocommunication services other than space science remote sensing services has been reducing the effective bandwidth and quality of many frequency bands most relied upon by the remote sensing community. Protection of passive portions of the radio spectrum requires adequate out-of-band emission requirements to be levied on the adjacent services who may be transmitting in proximity to passive band segments. IEEE GRSS emphasises the fact that space-based remote sensors provide vital societal, ecological and environmental data. Earth observation data play a significant role in the United Nations 17 transformational Sustainable Development Goals (SDG), directly contributing to 40 of the 169 associated SDG Targets. Satellite-based observations directly support 30 of the 232 global SDG indicators used to track the progress of the 2030 Agenda for Sustainable Development. Availability and protection of the frequency bands necessary for spaceborne Earth observation applications are crucial to societal well being and scientific investigations. These applications include:

- meteorology and climatology (e.g., forecast, warning and prediction of weather phenomena and recording of climatological data);
- upper atmospheric and magnetospheric measurements;
- space weather observations;
- global warming and climate change monitoring;
- disaster prediction, detection and mitigation.

Successful remote sensor operations depend on the use of specific frequency bands that are defined by physical laws and by filtering of RFI originating from other radiocommunication sources to a degree where emissions from those sources will not impact sensor mission objectives. IEEE GRSS recognizes the societal value of sharing frequency bands between more than one radio service; however, this can only occur in cases where mutually agreed sharing and protection criteria have been established based upon the agreed results of ITU-R studies for the protection of such irreplaceable natural resources. The IEEE GRSS is of the opinion that sharing should not be implemented in frequency bands allocated to the space science remote sensing services or in adjacent bands where sharing has been shown to not be feasible. Furthermore, the IEEE GRSS supports any review by National Administrations that might lead to a reduction in the number of such infeasible sharing situations in the Table of Frequency Allocations contained in the ITU Radio Regulations. Taking into account ITU-R Resolution 804 **(rev. WRC-19)**, the IEEE GRSS is of the view that adherence to certain principles are mandatory conditions for the WRC to adopt any new WRC agenda item, under WRC agenda item 10, that is to be considered at a subsequent WRC. These principles included are:

- clear demonstration and quantification of the spectrum requirements;
- technical and operational parameters of the new systems for which modification of the RR is proposed;
- identification of the exact bands to be considered for regulatory changes;
- preliminary studies on the feasibility of sharing in these bands.

For passive sensors in particular, it is the view of the IEEE GRSS that valid technical studies examining compatibility between EESS (passive) and other ITU-R defined services should adhere to the following points in applying ITU-R Recommendation RS.2017 [2] protection criteria for passive remote sensing:

1. Both the percentage of time or measurement area criteria must be met in order for compatibility to be declared. Failure to meet one of the criteria fails to meet compatibility.
2. The criteria must be met for all, and any, of the areas where measurements can be taken. Therefore, the specified performance and interference criteria must be met using the worst-case time period and worst-case area.
3. The compatibility analysis must employ a measurement area, as specified in Rec. ITU-R RS.2017, over which the criteria are applied. Determining compatibility on the basis of applying the criteria globally is not valid as it introduces a bias which underestimates RFI impact in comparison to its application in a specified measurement area. It is the view of IEEE GRSS that the global percentage of time analyses should not be used for purposes other than to internally guide further technical studies. Submission to the ITU-R, or other venues, of percentage of time analyses without the prescribed area, can cause confusion within the ITU-R and causes difficulty during agenda item discussions to produce a consensus summary of the results text.
4. The total significant RFI from all existing and potential sources should be considered in evaluating the impact of an additional RFI source proposed through a WRC agenda item. Evaluating each new potential source of RFI in isolation from the other sources of RFI leads to the situation where the cumulative RFI of all sources exceeds the permissible levels of interference for EESS (passive), the data availability requirement is not met, and EESS (passive) service operations are degraded.

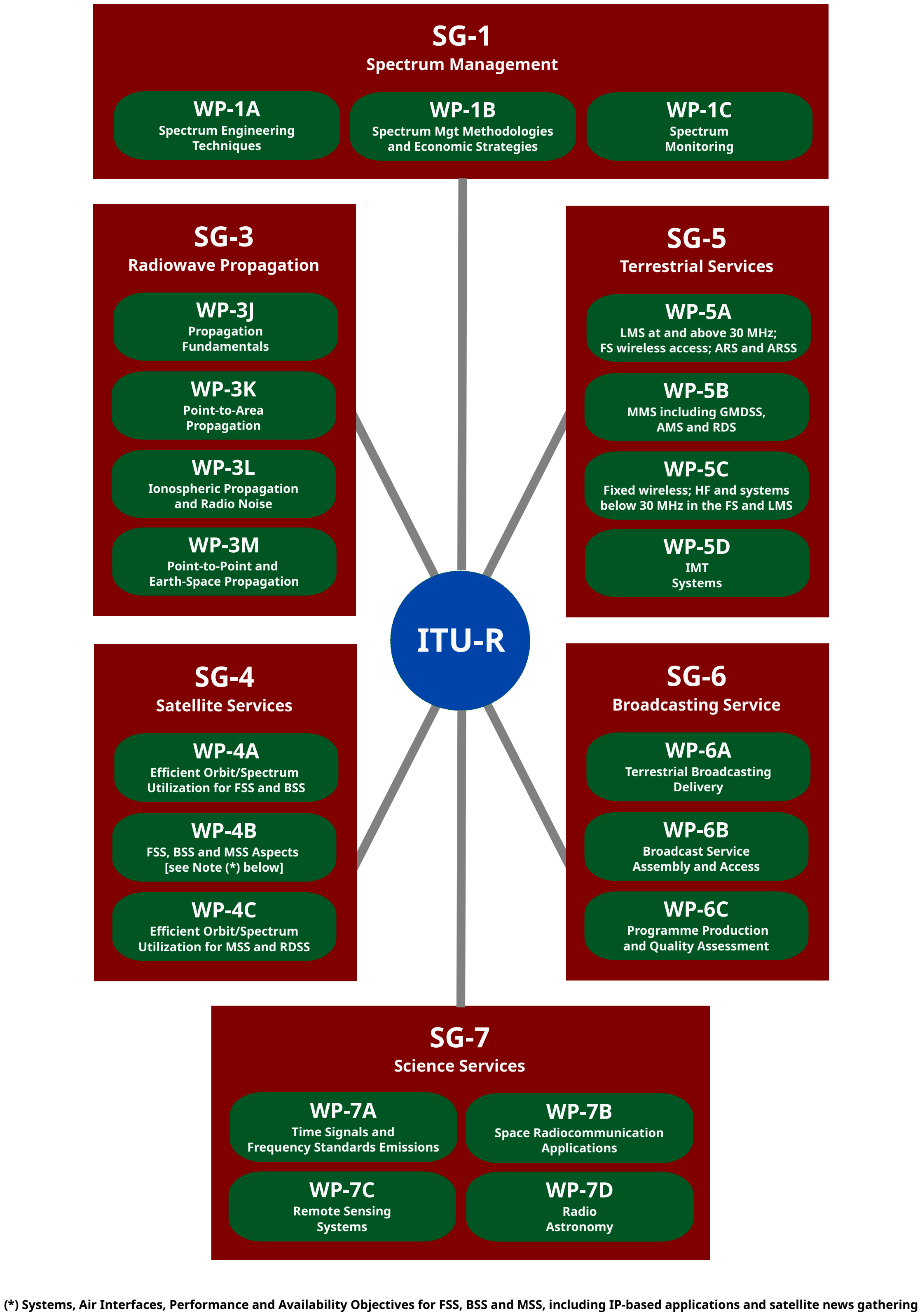

Figure 3.2: ITU-R Study Groups and Working Parties; radio services are indicated by their acronyms (see Appendix).

4. Agenda Items Relevant for Remote Sensing

4.1 Agenda Item 1.2

> **Agenda Item 1.2** will consider identification of the frequency bands 3300-3400 MHz, 3600-3800 MHz, 6425-7025 MHz, 7025-7125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution **245 (WRC-19)**.

Resolution **245 (WRC-19)** resolves that the appropriate sharing and compatibility studies should be conducted with a view to ensure the protection of services to which the frequency band is allocated on a primary basis, without imposing additional regulatory or technical constraints on those services, and also, as appropriate, on services in adjacent bands, for the frequency bands:

- 3600-3800 MHz and 3300-3400 MHz (Region 2);
- 3300-3400 MHz (amend footnote in Region 1);
- 7025-7125 MHz (globally);
- 6425-7025 MHz (Region 1);
- 10000-10500 MHz (Region 2).

The appropriate sharing and compatibility studies are to include studies with respect to services in adjacent bands, as appropriate.

International mobile telecommunications (IMT) is the generic term used by the ITU community to designate broadband mobile systems. It encompasses International Mobile Telecommunication (IMT)-2000, IMT- Advanced and IMT-2020 collectively. IMT encompasses three key sets of mobile standards defined and developed by ITU, namely: IMT-2000, specifying third-generation, or “3G” mobile telecom standards; IMT-Advanced, providing for the all-Internet based mobile broadband protocols known as “4G”; and IMT-2020, which broadly encompasses today’s “5G” mobile networks and services. IMT-2030 (also known as “6G”) networks are currently being defined, with respect to usage scenarios and requirements.

Most frequency bands considered in this agenda item are in the upper part of the so-called “mid-band spectrum”. Mid-band spectrum is defined as the range of frequencies between 1 and 6 GHz. The mid-band spectrum is considered ideal for 5G as it can allow transmission of larger data volume than lower bands across significant distances without suffering the signal attenuation that limits coverage area in the millimeter wave (mmWave) spectrum, for example by also being able to penetrate walls.

This agenda item is the responsibility of ITU-R WP 5D. WP 5D oversees the overall radio system aspects of International Mobile Telecommunications (IMT) systems, comprising IMT-2000, IMT-Advanced, IMT-2020 and IMT for 2030 and beyond. WP 7C is identified as Contributing.

EESS (active) has a primary allocation in the 3100-3300 MHz frequency band and the 10-10.4 GHz frequency band.

EESS (passive) and SRS (passive) have a primary allocation in the 10.6-10.7 GHz frequency band, while several passive remote sensing instruments operate in the C-band frequencies considered by this agenda item. Footnote **RR No. 5.458** indicates that Administrations should bear in mind the needs of the Earth exploration-satellite (passive) and space research (passive) services in their future planning of the bands 6425-7075 MHz and 7075-7250 MHz as passive microwave sensor measurements are carried out in these frequency bands. However, EESS (passive) does not have allocations in these bands. Studies in ITU-R have indicated a high potential for strong interference from widely used mobile systems such as IMT or WiFi, which would make the bands 6425-7075 MHz and 7075-7250 MHz unusable for EESS (passive) operations and their application for severe weather prediction and climate models. The result of one of these studies within WP 7C [3], also reported in [4], is shown in Figure 4.1.

The performance and interference criteria for passive remote sensing in ITU-R Recommendation RS.2017 [2] prescribe that the maximum interfering power should be below 20% of the radiometric resolution, which is given as 0.05 K for C-band. This results into a value of -166 dBW/(200 MHz) for the power received by the EESS (passive) sensor, corresponding to an antenna temperature equal to 0.01 K. This value is not to be exceeded over more than 0.1% of an area of 10000000 km^2. Figure 4.1 shows the amount of interfering power that exceeds the -166 dBW/(200 MHz) value based on a study that consider an instrument with the technical characteristics of AMSR-2. Unacceptable interference levels would occur everywhere on land and for several thousands of km from the coastline.

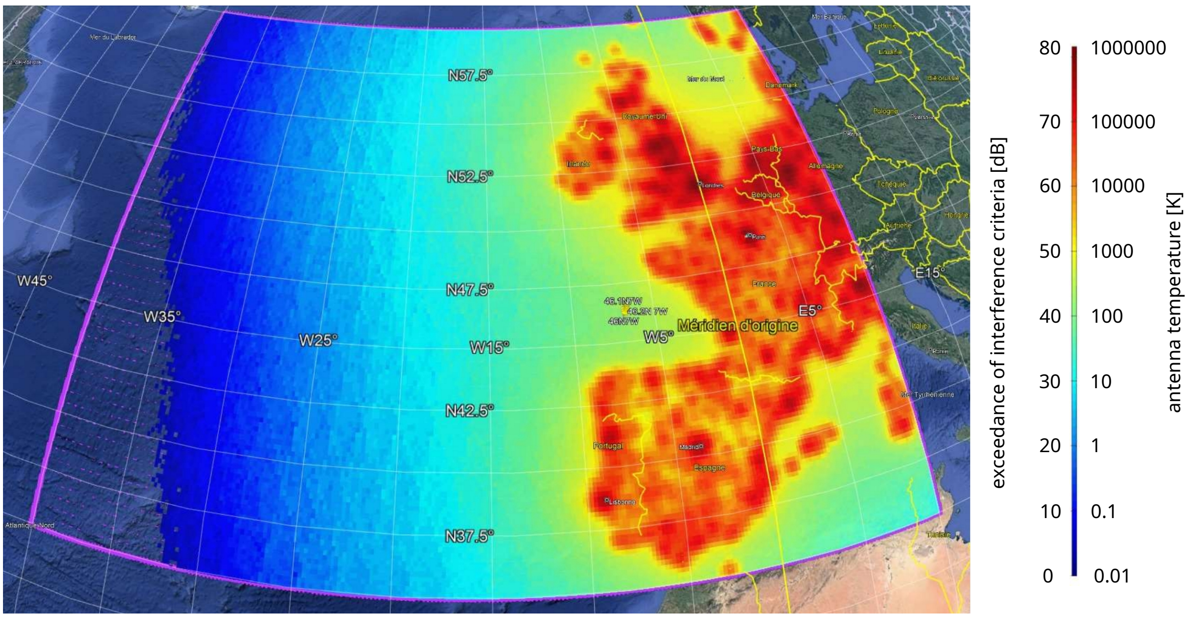

Figure 4.1: Average aggregated interference exceedance in the AMSR-2 satellite receiver and corresponding antenna temperature.

Use and importance of the potentially affected bands

Remote sensing measurements that could be impacted by the deployment of IMT systems proposed under this agenda item are essential for scientific applications.

Frequencies in the bands at 6.425-7.250 GHz and 10.6-10.7 GHz are critical to the measurement of Sea Surface Temperature (SST) and wind speed over the ocean, respectively. Global maps of SST are important for weather prediction, for understanding climate and climate change and for commercial applications such as assessing fisheries. Winds at the ocean surface are important for monitoring severe storms, for developing boundary conditions in weather forecast models and for operational applications such as routing ocean traffic. SST is important for modeling the coupling between ocean and atmosphere and for understanding the heat exchange across the boundary. Temperature together

Satellite Name	Instrument Type	Agency	Launch	End of life	Center Frequency	Bandwidth
NI-SAR	SAR	NASA/ ISRO	2024	⩾2026	3.2 GHz	75 MHz
NovaSAR-S	SAR	UKSA	2018-09-16	⩾2025	3.2 GHz	100 MHz
HJ-1C	SAR	CAST	2012-11-19	⩾2023	3.2 GHz	30 MHz
HJ-2E	SAR	CRESDA/ CAST	2022-10-13	⩾2030	3.2 GHz	30 MHz
HJ-2F	SAR	CRESDA/ CAST	2022-08-10	⩾2031	3.2 GHz	30 MHz

Table 4.1: Some relevant existing and planned EESS (active) sensors using the 3100-3300 MHz band.

with salinity determines water density, and the density-driven circulation (thermohaline circulation) moves large amounts of water and heat around the globe. Prior to the launch of microwave sensors to image SST (the sensitivity to SST peaks near 6.5 GHz), SST was measured in the infrared but the passive microwave instruments are not as limited by cloud cover and have proven particularly important for helping to forecast storms and for monitoring areas of persistent cloud cover. Winds at the ocean surface can be monitored with passive microwave instruments because the waves generated by the winds alter the emissivity of the surface. Hence, the microwave instruments are not only providing information about winds but also about the conditions at the surface. This is information necessary for understanding the development of storms and understanding energy exchange at the surface. In the microwave spectrum the sensitivity to surface roughness increases with frequency until about 10 GHz, after which it is roughly constant.

Frequencies in the 3100-3300 MHz and 10-10.4 GHz bands are typical for operations of active remote sensing systems like the Synthetic Aperture Radar (SAR). SAR is an imaging radar that exploits the relative movement of the sensor over the observed scene to achieve high spatial resolution. S-band is less affected by ionospheric effects than L-band and achieves a balance between surface penetration capability and imaging resolution. Its shorter wavelength makes it well-suited for detecting small targets, such as ships and oil spills in the ocean, in good details. It can also be used for disaster monitoring, including detection and survey of floods, landslides, and urban damage after earthquakes or other natural disasters. Additionally, S-band SAR can provide high-resolution imagery for urban mapping and for applications such as building identification and land-use classification. X-band is excellent to achieve sub-meter level image resolution with instruments using a maximum bandwidth of 1.2 GHz within the 9.2-10.4 GHz band. These frequencies exhibit very small penetration into the vegetation cover and fast coherence decay in vegetated areas, and thus are suitable for urban monitoring, ice, and snow applications.

EESS (active) Sensors

3100-3300 MHz: EESS (active) has a secondary allocation in the S-band between 3100 and 3300 MHz. The S-band has many of the advantages of the longer-wavelength L-band, such as good penetration of low vegetation, low temporal decorrelation and low tropospheric propagation losses, as well as some of those of higher frequencies, such as smaller antenna requirements, lower degree of ionospheric effects and the ability to measure rain when operating at high power in ground-based applications. Although it has secondary status, it is only shared with radio positioning operations and space research operations, and reported RFI cases are rare. The most important current and planned sensors are listed in Table 4.1 below. Even though it is not a spaceborne sensor, the Passive Active L- and S-band Sensor (PALS) that is part of the Airborne Science Program of NASA also includes a radar

Satellite Name	Instrument Type	Agency	Launch	End of life	Center Frequency	Bandwidth
Umbra	SAR	Umbra	2021-06-30	⩾2035	9.8 GHz	1200 MHz
COSMO-SkyMed	SAR	ASI	2019-12-18	⩾2026	9.8 GHz	1200 MHz
HRWS	SAR	ISRO	⩾2029	⩾2036	9.8 GHz	1200 MHz

Table 4.2: Some relevant existing and planned EESS (active) sensors using the 10-10.4 GHz band.

scatterometer operating with a center frequency of 3.15 GHz.

10-10.4 GHz: The X-band is another important band for scientific radar imaging. Like the L-band and the C-band, the X-band is also extensively used for applications such as seismic hazard analysis, environmental disaster monitoring, and infrastructure assessment. Examples of satellite SAR systems operating at the X-band include the German two-satellite TerraSAR on Tandem-X, the Italian five-satellite constellation COSMO-SkyMed, and the Spanish PAZ SAR-X. Next-generation SAR systems also take advantage of the use of allocated 1200 MHz bandwidth in X-band including the German TSX-NG mission. Since X-band could achieve high-resolution imaging with larger bandwidth and small antennas, commercial SAR companies are emerging and have launched satellite constellations in recent years, such as the ICEYE, Capella, Umbra, and StriX. Impacts from the IMT services should be carefully considered. Active sensors operating or planning to operate in this band are listed in Table 4.2.

EESS (passive) Sensors

6425-7250 MHz: Observations at C-band are essential for estimating global sea surface temperature and used in combination with other frequencies for other applications such as measuring soil moisture, temperature of the ocean surface and sea surface wind through clouds. 6425-7250 MHz is a unique frequency range for EESS (passive) sensors, since it corresponds to the peak sensitivity to sea surface temperature [5]. For applications over land, it is a compromise with lower frequencies, which only allow measurements with poor spatial resolution, and higher frequencies, where attenuation by vegetation and the atmosphere is a major obstacle. Since atmospheric effects are relatively small in these frequencies, sensors operating in the 6-7 GHz frequency band are particularly important to monitor areas with persistent cloud cover.

Sea water temperature, together with salinity, determines the thermohaline circulation of the global ocean and knowledge of these is critical for any global meteorological or climatological model. Since atmospheric effects are relatively small in this frequency range, sensors operating in the 6-7 GHz frequency band have proven particularly useful to forecast storms and to monitor areas with persistent cloud cover. Global maps of sea surface temperature are also important for commercial applications such as fishery assessment. Because of its importance, several missions operate or plan to operate in this band, as listed in Table 4.3.

10.6-10.7 GHz: The frequency band 10.6-10.7 GHz is essential for observing global sea surface winds. This frequency range offers the largest sensitivity when sensing surface roughness because the roughness is comparable to the electromagnetic wavelength. This is the case for short sea surface waves, e.g, capillary waves, which are the ones appearing at low wind speeds. Wind measurements are important for monitoring and predicting behavior of severe storms and understanding ocean dynamics. Wind over the sea surface is also an indicator of waves, and measurements at this frequency are used to correct for effects of roughness on surface emissivity in other applications such monitoring rain, sea ice and sea surface temperature. It is also a good frequency for sea-surface temperature, as the

Satellite Name	Instrument Name	Agency	Launch	End of life	Frequency	Bandwidth
Coriolis	WindSat	US DoD	2003-01-06	⩾2023	6800 MHz	125 MHz
GCOM-W	AMSR-2	JAXA	2012-05-17	⩾2023	6925 MHz 7300 MHz	350 MHz 350 MHz
HY-2B	MWI	NSOAS	2018-10-24	⩾2023	6600 MHz	350 MHz
CIMR	CIMR	ESA	⩾2028	⩾2033	6925 MHz	400 MHz
Meteor-MP N1	MTVZA-GY	RosHydroMet	⩾2025	⩾2032	6900 MHz	400 MHz
Meteor-MP N2	MTVZA-GY	RosHydroMet	⩾2026	⩾2033	6900 MHz	400 MHz

Table 4.3: Existing and planned EESS (passive) sensors using the 6425-7250 GHz band.

highest sensitivity to this parameter is between 5 and 10 GHz. The 10.7 GHz frequency band, together with the 18 GHz and the 37 GHz bands, also allows us to estimate the amount of cloud liquid water in non-precipitating clouds. This information is crucial for weather forecasts, particularly during severe events and in climate models. Several missions operate or plan to operate in this band. Table 4.4 contains a list of some relevant existing and planned sensors that include measurements in the 10.6-10.7 GHz frequency range as a primary measurement for winds over the ocean or in combination with measurements at other frequencies for additional remote sensing applications.

Satellite Name	Instrument Name	Agency	Launch	End of life	Frequency	Bandwidth
CIMR	CIMR	ESA	⩾2028	⩾2033	10.65 GHz	100 MHz
Coriolis	WindSat	US DoD	2003-01-06	⩾2023	10.7 GHz	300 MHz
FY-3C	MWRI-1	CMA	2013-09-23	⩾2023	10.65 GHz	180 MHz
FY-3D	MWRI-1	CMA	2017-11-14	⩾2024	10.65 GHz	180 MHz
FY-3F	MWRI-1	CMA	2023-08-03	⩾2029	10.65 GHz	180 MHz
GCOM-W	AMSR-2	JAXA	2012-05-17	⩾2023	10.65 GHz	100 MHz
GOSAT-GW	AMSR-3	JAXA	⩾2024	⩾2031	10.65 GHz	100 MHz
GPM	GMI	NASA	2014-02-27	⩾2027	10.65 GHz	100 MHz
HY-2A	MWI	NSOAS	2011-08-16	⩾2023	10.7 GHz	250 MHz
HY-2B	MWI	NSOAS	2018-10-25	⩾2023	10.7 GHz	250 MHz
Meteor-M N2	MTVZA-GY	RosHydroMet	2014-07-08	⩾2023	10.6 GHz	100 MHz
Meteor-M N2-2	MTVZA-GY	RosHydroMet	2019-07-05	⩾2024	10.6 GHz	100 MHz
Meteor-M N2-3	MTVZA-GY	RosHydroMet	2023-06-27	⩾2027	10.6 GHz	100 MHz
WSF-M1	WSF-M	US DoD	⩾2024	⩾2030	10.85 GHz	500 MHz

Table 4.4: Examples of existing and planned EESS (passive) sensors using the 10.6 -10.7 GHz band.

IEEE GRSS View

The IEEE GRSS supports solutions that ensure

- compatibility between EESS (active) in 3100-3300 MHz and potential IMT deployments in 3300-3400 MHz;
- no impact on EESS (passive) in 6425-7250 MHz from potential IMT operations in 6425-7125 MHz;
- protection of EESS (active) at 10-10.4 GHz from potential interference associated with a new utilisation of the band 10-10.5 GHz by IMT in Region 2;
- protection of EESS (passive) at 10.6-10.7 GHz from unwanted out-of-band emissions potentially due to a new utilisation of the band 10-10.5 GHz by IMT in Region 2.

As shown in Figure 4.1, aggregate interference from IMT systems at 6425-7125 MHz would render most C-band radiometer measurements unusable, leading to a loss of important monitoring of SST, that is vital for weather forecast and climate studies, extending thousands of km from the coast. The predicted level of RFI would not allow to perform any interference mitigation technique and the high level of power could potentially also harm the EESS receiver. ITU-R is studying alternative frequency ranges at C-band for the estimation of sea surface temperature by microwave radiometers. IEEE GRSS does not oppose identifying alternative frequency bands for passive remote sensing, however it opposes establishing the proposed C-bands allocations for IMT use and strongly support no change in the Radio Regulations in regard to the 6425-7125 MHz band under Agenda Item 1.2.
All studies undertaken within ITU-R have shown that sharing between IMT and EESS (active) is not feasible. For this reason, and due to potential risk of interference for EESS (passive) at 10.68-10.7 GHz, IEEE GRSS opposes any regulatory actions on the identification of 10.0-10.5 GHz for IMT use under this agenda item.
IEEE GRSS does not oppose additional allocations to the mobile service on a primary basis in IMT services in 3300-3400 MHz. However, further consideration should be given to limiting power emitted in the adjacent 3100-3300 MHz band in order to protect EESS (active) sensors, such as the Chinese HJ-1C SAR mission, the HJ-2-05 SAR mission, the UK NovaSAR mission, and the joint NASA-ISRO Synthetic Aperture Radar (NISAR). IEEE GRSS is of the view that compatibility studies should also provide an understanding of the potential negative impact of making regulatory changes in the band 3300-3400 MHz.

4.2 Agenda Item 1.4

Agenda Item 1.4 will consider, in accordance with Resolution **247 (WRC-19)**, the use of High Altitude Platform Stations as IMT Base Stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level;

This agenda item seeks to extend the opportunities for the use of high-altitude platform stations as IMT base stations (HIBS) in certain frequency bands below 2.7 GHz, or portions thereof, already identified for IMT. Studies within ITU-R address the following:

- sharing and compatibility studies to ensure protection of services to which the frequency band is allocated on a primary basis and adjacent services, as appropriate, in the bands
  - 1710-1885 MHz (1710-1815 MHz to be used for uplink only in Region 3);
  - 2500-2690 MHz (2500-2535 MHz to be used for uplink only in Region 3, except 2655-2690 MHz in Region 3);
- review of the conditions set up for HIBS in **RR No. 5.388A**, **RR No. 5.388B**, that establisehes some power emission limits, and in Resolution **221 (WRC-07)** in the bands 1885-1980 MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3 and in the bands 1885-1980 MHz and 2110-2160 MHz in Region 2.

A High Altitude Platform Station (HAPS) is a wireless system operating in the stratosphere at an altitude around 20 km and to provide communication services. This operational altitude is chosen mainly because of the favourable atmospheric conditions in this part of the atmosphere. Almost all weather phenomena occur below this altitude and wind speeds are very low. In addition, the airspace above approximately 20 km height is usually not regulated by air traffic control. The use of HAPS as IMT Base Station is referred to as HIBS. HIBS systems fall under the Mobile Service (MS), while traditional HAPS are regulated under the Fixed Service (FS). HIBS systems offer:

- a very large footprint (∼200 km in diameter) that can extend the coverage provided by mobile network operators;
- much lower latency than higher-orbit satellite systems, including NGSO solutions;
- support for existing IMT-compatible mobile devices;
- minimal ground infrastructure and maintenance requirements.

This agenda item is the responsibility of ITU-R WP 5D, while WP 7C is a contributing group.

The frequency band 2690-2700 MHz allocated to EESS (passive) could potentially be affected. This band is protected under footnote **RR No. 5.340** that states that all emissions are prohibited in this band. There are currently no known spaceborne missions that have used or are using the 2690-2700 MHz EESS (passive) allocation, and Recommendation ITU-R RS.1861 contains no representative system characteristics for instruments operating in this band. However, the airborne PALS platform includes a microwave radiometer operating in this frequency band.

The operation of ultra-wideband (UWB) microwave radiometers could be affected by HIBS operations in the 694-960 MHz, 1710-1815 MHz (to be used for uplink only in Region 3) and 1885-1980 MHz. Ultra-wideband Microwave radiometers performing observations of the natural thermal noise in these bands (and more broadly from 500-2000 MHz) are an emerging technology for the sensing of Earth's surface and in particular ice sheets, sea ice, and oceans. Because the EESS-passive service does not have a primary allocation at these frequencies, observations of the naturally generated thermal noise are performed opportunistically (when possible) in portions of the spectrum's time and/or frequency space that is locally unoccupied. Increased occupancy in these bands will negatively impact the potential coverage that could be achieved in ultra-wideband microwave remote sensing for these applications.

In addition, many passive remote sensing instruments use heterodyne design, where the primary radio frequency range is downconverted to an Intermediate Frequency (IF) for amplification and channelization. The bands affected by this agenda item are used as IF by numerous radiometers. Given the proposed use for uplink signals and the associated risk of high levels of aggregated transmitted power, uncontrolled expansion of the HAPS could result in additional, stricter mandates on RFI and Electromagnetic Interference (EMI) susceptibility tests, raising the cost of implementation and testing for these instruments.

IEEE GRSS View

Concerning the potential new bands for HIBS, IEEE GRSS is interested in the protection of the EESS (passive) in the band 2690-2700 MHz (subject to the provisions of No. 5.340) from HIBS operated in the adjacent 2500-2690 MHz band.
Concerning the review of the conditions of the existing bands for HIBS, IEEE GRSS is of the view that any review of the conditions for HIBS set out in **RR Nos. 5.388A, 5.388B** and in Resolution **221 (WRC-07)** should produce results that will not adversely impact remote sensing operations.
IEEE GRSS supports the protection of the EESS (passive) in the band 2690 - 2700 MHz from HIBS operated in the 2500 - 2690 MHz band. IEEE GRSS also supports studies to assess the impact that HIBS operations in the 2500 - 2690 MHz band may have on space research (SRS) (passive) and Earth exploration-satellite (EESS) (passive) services in the 2640 - 2655 MHz band in which the SRS (passive) and EESS (passive) have allocations on a secondary basis (**RR No. 5.339**).

4.3 Agenda Item 1.10

Agenda Item 1.10 will consider, based on Resolution **430 (WRC-19)**, studies of the ITU Radiocommunication Sector on:

1. spectrum needs for new non-safety aeronautical mobile applications for air-air, ground-air and air-ground communications of aircraft systems;
2. sharing and compatibility in the frequency band 22-22.21 GHz, already allocated on a primary basis to the mobile, except aeronautical mobile service, in order to evaluate the possible revision or deletion of the “except aeronautical mobile” restriction while ensuring the protection of primary services in the considered frequency bands and, as appropriate, in adjacent frequency bands;
3. sharing and compatibility on possible new primary allocations to the aeronautical mobile service for non-safety aeronautical applications in the frequency band 15.4-15.7 GHz, while ensuring the protection of primary services in the considered frequency bands and, as appropriate, adjacent frequency bands;
4. definition of appropriate protection for passive services and radio astronomy allocated in adjacent bands from unwanted emission of the aeronautical mobile service.

The Aeronautical Mobile Service (AMS) is a radiocommunication service between mobile stations on the ground and stations on aircrafts. It is used for communications, including flight coordination or emergency purposes, and can be classified as operation within or outside civil air routes.

The 15.35-15.4 GHz and 22.21-22.5 GHz frequency bands are allocated to the Earth Exploration-Satellite Service (passive) as primary and are adjacent to the frequency bands under agenda item 1.10. The 15.35-15.4 GHz band is listed under **RR No. 5.340** and therefore all emissions are prohibited there. The frequency band 22.21-22.5 GHz is also allocated on a primary basis to Fixed and Mobile (excluding aeronautical) and is used by the Special Sensor Microwave Image/Sounder (SSMIS), a conical scan instrument on the Defense Meteorological Satellite Program (DMSP), that obtains water vapor measurements in the spectrum from 22.0345 to 22.4355 GHz.

It should be noted that there are currently no known Earth Observation missions that have operated or are operating at 15.35-15.4 GHz, and Recommendation ITU-R RS.1861 contains no representative system characteristics for instruments operating in these bands. Currently, the main scientific use of the 15.35-15.4 GHz frequency band is in the field of Radio-Astronomy for the study of the Milky Way and other galaxies, active galaxies , and cosmology and the structure of the universe.

However, radiometers at 183 GHz and above employ an IF at 15 GHz, raising the risk of potential EMI from the use of the 15.4-15.7 GHz frequency band by AMS. Future Earth Observation missions could also exploit this band to monitor aspects such as atmospheric water vapour, precipitation, clouds or snow.

IEEE GRSS View

IEEE GRSS supports regulatory solutions for items 1, 3 and 4 of this agenda item. However it is concerned that allowing aeronautical mobile at 22-22.21 GHz may negatively impact and degrade EESS (passive) measurements in this band.

4.4 Agenda Item 1.12

> **Agenda Item 1.12** will consider a possible new secondary allocation to the Earth exploration-satellite (active) service for spaceborne radar sounders within the range of frequencies around 45 MHz, taking into account the protection of incumbent services, including those in adjacent bands, in accordance with Resolution **656 (WRC-19)**.

The frequency range under consideration is 40-50 MHz and has a number of incumbents, including fixed, mobile, and broadcasting services on a primary basis, as well as space research service as a secondary service. Country-specific footnotes for this frequency range provide primary allocations for the aeronautical radionavigation and radiolocation services in certain parts of the world. For example, oceanographic radars also operate, under the radiolocation service, in portions of this frequency range with a secondary allocation in some regions of the world and a primary allocation in other regions of the world. The amateur service operates in the adjacent band 50-54 MHz. This agenda item is the responsibility of WP 7C.

ITU-R has developed a recommendation and a report on this topic:

- Report ITU-R RS. 2455 *Results of sharing studies between a 45 MHz radar sounder and in-band and selected out-of-band incumbent services over the 40-50 MHz frequency range*.
- Recommendation ITU-R RS.2042 *Typical technical and operating characteristics for spaceborne radar sounder systems using the 40-50 MHz band*, which provide the technical and operating characteristics of spaceborne radar sounders that would operate in the 45 MHz region.

Use and importance of the 40-50 MHz frequency range

There is a growing interest for remote measurements of the Earth's subsurface providing radar maps of subsurface scattering layers with the intent of locating deposits of water or ice and examining sub-ice glacial bed surfaces. Some of the main scientific applications are 1) to understand the global thickness, inner structure and the thermal stability of the Earth's ice sheets in Greenland and Antarctica as an observable parameter of Earth climate evolution, and 2) to understand the occurrence, distribution and dynamics of the Earth fossil aquifers in desert environments such as northern Africa and the Arabian peninsula as key elements in understanding recent paleoclimatic changes. Spaceborne radar sounders can provide information about the unique physical properties of Earth and other planets. Their relatively low frequency allows the penetration of the transmitted signals into a given subsurface to infer its geoelectrical properties and composition by analyzing the radar echoes. Stacking together subsequent echo traces, a bidimensional image (i.e., a radargram) is generated, with two axes representing depth and the position of the sensor along its ground track (see Figure 4.2).

The main factor driving the radar sounder subsurface penetration is the total two-way attenuation of the transmitted signal in the probed subsurface that is function of the selected probing frequency. The reason for an allocation between 40 and 50 MHz (VHF band) for a spaceborne sounding radar is based upon a trade-off between achievable subsurface penetration, vertical and horizontal resolution of observations, and mitigation of ionospheric distortion effects on the radar signal. As an example, the penetration of an incident radar wave is normally many tens of wavelengths and at 40-50 MHz is deeper than at 500 MHz by a factor of 20 to 30, and is thus more favourable for Earth penetration studies. Moreover, experimental evidence based on ground and airborne campaigns clearly show that in the VHF band, this type of sensor is able to reach depths of several kilometers in ice and about one hundred meters in sand sheets. The large penetration in icy regions is due to the fact that fresh-water ice at VHF frequencies is one of the most radar transparent materials.

Planned radar sounder systems operating in the 40-50 MHz band are NASA OASIS, NASA DEBRIS and a potential mission called STRATUS. These systems share rather similar technical and operational characteristics. In detail, they

- are nadir-looking instruments planned to be flown on a Sun-Synchronous, near-polar orbit at about 400-500 km;
- transmit a 10 MHz linear frequency modulated signal centered at 45 MHz;
- would have operations restricted to night-time (i.e., around 4 am ∓ 2 hours).

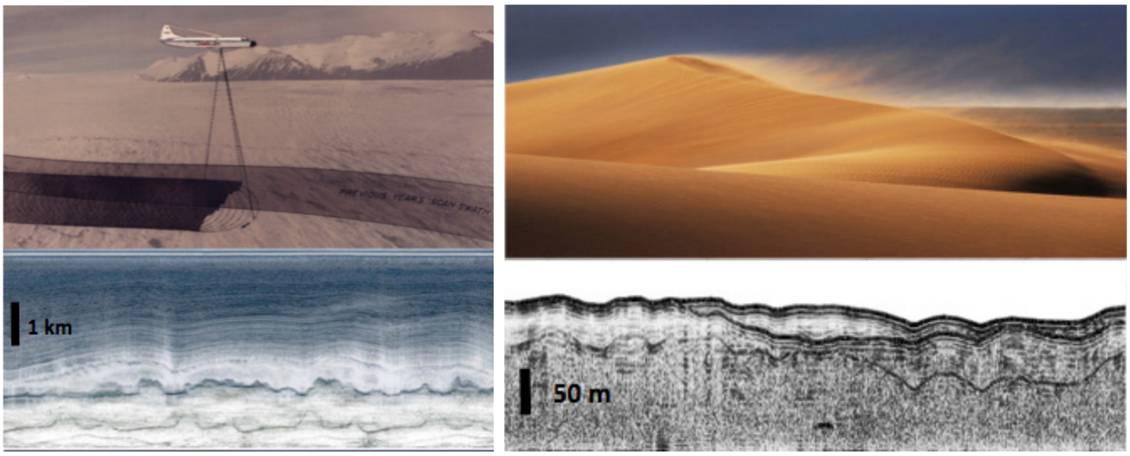

Figure 4.2: Low-frequency airborne radar subsurface mapping of (left) bed topography of the Antarctic ice sheets to a depth of 2.5 km and of water table to a depth of 55 m in (right) desert in Kuwait [6].

IEEE GRSS View

IEEE GRSS supports the creation of a secondary allocation to the EESS (active) at WRC-23 while ensuring the compatibility between spaceborne radar sounders and incumbent services around 45 MHz, but opposes regulatory solutions that would impose additional constraints to limit the operation of the proposed EESS active radar sounder beyond those necessary to provide protection of the affected incumbent service operations, also considering that radar sounder system are planned to be operated only in uninhabited or sparsely populated regions of the globe. IEEE GRSS is of the view that additional flexibility in the radar allocation parameters (e.g., transmitted power, time of acquisitions) is needed to ensure the operability and maximize the science return of the different proposed spaceborne radar sounding systems operating in the 40-50 MHz range. Aspects that IEEE GRSS believes to require consideration are:

- the radar sounder transmitter will be on for a single maximum continuous duration of 10 minutes in a 92.7 minutes orbit, and clarifications on the distribution of the transmission scheme within an orbit are important;
- the instrument will only perform measurements in a few hours window centered approximately at 4 a.m. local time;
- the identification of a relevant set of locations for the potential victim receivers at different latitudes, taking also into account the planned areas of radar sounder observations and including all relevant losses, such as those due to Earth's atmosphere and ionosphere.

The overall objective should be the determination of an appropriate generic limit for the sounder transmitted Power Flux Density (PDF) at the Earth surface that addresses the protection of incumbent services and allows the operation of spaceborne radar sounders.

4.5 Agenda Item 1.14

Agenda Item 1.14 will review and consider possible adjustments of the existing or possible new primary frequency allocations to EESS (passive) in the frequency range 231.5-252 GHz, to ensure alignment with more up-to-date remote-sensing observation requirements, in accordance with Resolution **662 (WRC-19)**;

Resolution 662 (WRC-19) invites the ITU-R to:

- review the existing primary allocations to the EESS (passive) in the frequency range 231.5-252 GHz in order to analyse if these allocations are aligned with observation requirements of passive microwave sensors;
- study the impact that any change to the EESS (passive) allocations in the frequency range 231.5-252 GHz might have on the other primary services in these frequency bands;
- study, as appropriate, possible adjustments to the EESS (passive) allocations in the frequency range 231.5-252 GHz.

The main purpose of the agenda item is to better align the EESS (passive) allocations with passive sensor design requirements or adding possible new allocations to the EESS (passive) in the 231.5-252 GHz frequency range. The allocations to the EESS (passive) were created 20 years ago at a time when operational requirements were unclear.

The existing primary EESS (passive) allocations in the frequency range considered by this agenda item are 235-238 GHz and 250-252 GHz. Also note that the band 237.9-238 GHz is allocated to the EESS (active) and the SRS (active) for spaceborne cloud radars only.

Use and importance of the 231.5-252 GHz frequency range

This frequency range is important for ice cloud and atmospheric gases measurements. Measuring ice cloud properties such as ice particle size and distribution is critical to understanding the climate and hydrological cycle because they influence precipitation, atmospheric structure, and cloud processes. The interaction of microwave radiation with cloud ice particles is not very strong below 200 GHz, but increases significantly above that. Measurements by microwave sensors operating in the frequency band 231.5-252 GHz are significantly more sensitive to ice clouds parameters. The frequency band 231.5-252 GHz provides the optimal sensitivity to ice particles, which can be used to measure the hydrometeor properties of cirrus clouds, higher altitude convective, and anvil clouds. Sub-bands inside 231.5-252 GHz are adept at detecting ice particles around 700 μm in size.

In addition, important measurements of chemical processes and compounds in the Earth atmosphere are possible in this frequency range, thanks to the presence of spectral lines for nitric acid (HNO_3), ozone (O_3), sulphur dioxide (SO_2) and isotopic oxygen (^8OO). Nitric acid is a primary reservoir for reactive nitrogen, playing a role in upper tropospheric processes that maintain ozone abundances and clouds. Tracking the stability of ozone in the atmospheric layer between 15 and 50 km above the Earth surface is crucial. Sulphur dioxide is emitted into the atmosphere by volcanic eruptions and ultimately results in sulphate aerosols, which are observable in this frequency range and are important from the perspective of understanding climatological impact. Lastly, isotopic oxygen concentrations may be used to derive temperature/pressure information for the troposphere, which is fundamental for science due to its impact on many atmospheric processes.

NASA Aura mission, launched in 2004, carries a Microwave Limb Sounder (MLS) that observes thermal microwave emission from the Earth limb. This radiometer has several channels around 240 GHz, which are listed in Table 4.5, all of them operating at H-polarization. The channels used for ozone consist of two frequency bands because observations from the two bands need to be combined for ozone concentration retrieval.

Channel	Center Frequency	Bandwidth	Primary Utilisation
MLS-33/4	231.86 GHz 247.46 GHz	500 MHz	O_3 wing
MLS-33/3	232.46 GHz 246.86 GHz	500 MHz	O_3 wing
MLS-8	233.9515 GHz	1250 MHz	^{8}OO
MLS-33/2	234.86 GHz 244.46 GHz	500 MHz	O_3 wing
MLS-7 MLS-24	235.7151 GHz	1250 MHz 10 MHz	O_3
MLS-33/1	236.66 GHz 242.66 GHz	500 MHz	O_3 wing

Table 4.5: MLS spectral bands with information on their utilization (from https://spec.jpl.nasa.gov/).

Future instruments include the Ice Cloud Imager (ICI) being developed by ESA and EUMETSAT for a Meteorological Operational Satellite Second Generation (MetOp-SG) mission. The ICI instrument is a conically scanning millimetre/sub-millimetre wave radiometer serving climate monitoring and operational meteorology by providing information to the weather and climate models on ice clouds, especially cirrus clouds, cloud ice water path, cloud ice effective radius and cloud altitude. It will also provide vertical humidity profile and vertical profiles of hydrometeors (cloud ice, graupel and snowfall distribution), as well as water vapour, all in support of Numerical Weather Prediction (NWP) and nowcasting. ICI data will enhance the ability of NWP centres to initialise global and regional models with information on ice clouds, which is today not well represented in these weather and climate models. Also, observations of this type are not currently available to improve the initialisation of three-dimensional cloud fields.

The ICI instrument will perform measurements in 11 channels. The frequency coverage is from 183 GHz up to 664 GHz. Each channel consists of two symmetric spectral bands around a central frequency, both needed to retrieve the physical parameters of interest. Measurements from multiple channels may be needed to estimate some of the parameters. For example, ice retrieval algorithms require the use of all ICI channels. Channel 4 is within the 231.5-252 GHz frequency range that is under consideration of WRC-23 agenda item 1.14. Its two symmetric spectral bands of ICI-4 occur at 239.2-242.2 GHz and 244.2-247.2 GHz, which is used for measuring cloud ice water paths and cirrus clouds. This channel at 243 GHz is key to estimate the cloud ice content, centrally placed between 183 and 325 GHz water vapour transitions and providing an optimal range of sensitivity to the ice phase in this frequency domain. This channel allows measuring radiances at both horizontal and vertical polarisations through the atmosphere due to minimum atmospheric absorption compared to the neighbouring channels.

IEEE GRSS View

IEEE GRSS supports aligning the allocations to the EESS (passive) in the frequency range 231.5-252 GHz with current operational requirements, either through an adjustment of the existing allocations or the addition of new allocations to EESS (passive) covering frequency being or planned to be used by microwave radiometers. In particular, the band 235-238 GHz is used for limb sounding only, and the EESS (passive) allocation in this band should be maintained. GRSS also agrees with a proposed approach to allocate the bands 239.2-242.2 GHz and 244.2-247.2 GHz to EESS (passive) along with moving the existing FS/MS allocation in the band 239.2-241 GHz to the band 235-238 GHz in order to avoid frequency overlap between microwave sensors and FS/MS.

4.6 Agenda Item 1.15

Agenda Item 1.15 will consider, in accordance with Resolution **172 (WRC-19)**), harmonizing the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by Earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service globally.

ITU-R WP 4A is the responsible group for this agenda item and WP 7C was added as a Contributing group in 2021.

Resolution **172 (WRC-19)** focusses mainly on the use of the band 12.75-13.25 GHz for uplink transmissions by Earth Stations In Motion (ESIM) systems on aircraft (A-ESIM) and vessels (M-ESIM) communicating with GSO space stations in the fixed-satellite service (FSS), as pictured in Figure 4.3.

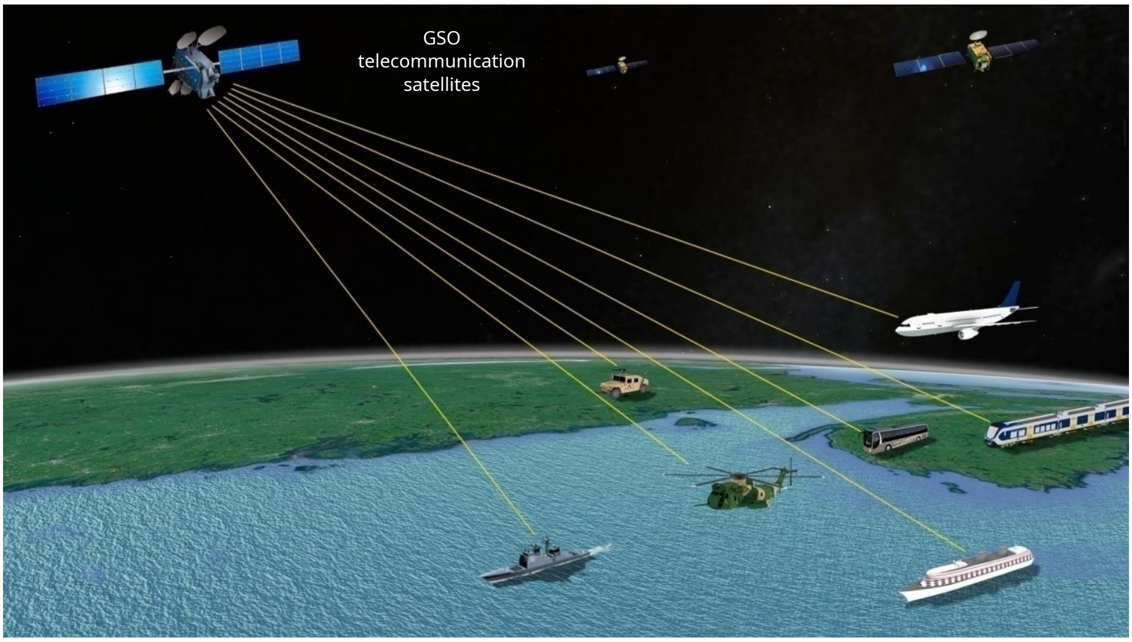

Figure 4.3: ESIM on different moving platforms like aircraft and vessels.

Initial considerations on whether Resolution **172 (WRC-19)** could also lead to a review of ESIM operations as FSS (space-to-Earth) in the 10.7-10.95 GHz frequency band, with potential out of band emissions into the adjacent EESS (passive) 10.6-10.7 GHz frequency band were subsequently dismissed.

The frequency range used by remote sensing that could potentially be affected is the EESS (active) band at 13.25-13.75 MHz.

Use and importance of the 13.25-13.75 GHz frequency range

The 13.25-13.75 GHz band is allocated to EESS (active) on a primary basis. The Ku-band is an important frequency band for spaceborne altimeters, scatterometers, and precipitation radars, as well as many airborne systems making similar measurements on a more regional basis. ITU Report ITU-R RS.2068-2 , addresses the long-term need for access to the 13.25-13.75 GHz band from the viewpoint of the following major active sensor types currently operating in this band.

Several types of active sensors operate in this band: scatterometers, radar altimeters, SAR and

Satellite Name	Instrument Name	Agency	Launch	End of life	Center Frequency	Bandwidth
CFOSAT	CSCAT	NSOAS/ CNES	2018-10-29	⩾2023	13.256 GHz	0.5 MHz
OceanSat-3	OSCAT-3	ISRO	2022-11-27	⩾2023	13.515 GHz	1 MHz
JASON-3	Poseidon-3B Altimeter	NASA/ CNES/ EUMETSAT	2016-01-17	⩾2024	13.575 GHz	320 MHz
CryoSat-2	SIRAL	ESA	2010-04-08	⩾2028	13.575 GHz	320 MHz
GPM	DPR	NASA/ JAXA	2014-02-17	⩾2027	13.6 GHz	unknown
FY-3G	PMR (FY-3)	CMA	2023-04-16	⩾2029	13.35 GHz	20 MHz
CRISTAL	IRIS	ESA	⩾2027	⩾2034	13.5 GHz	500 MHz
Qilu-1	SAR	CAST	2023-04-20	⩾2031	unknown	300 MHz

Table 4.6: Some relevant existing and planned EESS (active) sensors using the 13.25-13.75 GHz band.

precipitation radars. A scatterometer is a type of radar systyem that measures the near surface wind vector over the oceans. Wind data are critical to the determination of regional weather patterns and global climate. Altimeters are downward-looking pulsed-radar system to measure ocean, land and ice surfaces. Precipitation radars are designed to provide measurements on the intensity and distribution of the rain, on the rain type, on the storm depth and on the height at which the snow melts into rain. The first SAR system mission operating in Ku-band, the Qilu-1 Satellite, was launched by China in 2021. Table 4.6 contains a list of some of the active sensors that operate or plan to operate in this frequency range.

IEEE GRSS View

IEEE GRSS is of the view that the potential impact from A-ESIM and M-ESIM EESS (active) sensors, in the adjacent band 13.25-13.75 GHz, should be considered in decisions resulting from this agenda item.

Regarding the potential impact from the FSS (space-to-Earth) allocation in 10.7-10.95 GHz on EESS (passive) operations in the adjacent 10.6-10.7 GHz, IEEE GRSS is of the view that Resolution **172 (WRC-19)** does not call for studies on this matter or contemplate any changes to the space-to-Earth direction in the band 10.7-10.95 GHz under WRC-23 agenda item 1.15. The IEEE GRSS is of the strong opinion that protection of EESS (passive) in the 10.68-10.7 GHz band from FSS downlinks in the adjacent 10.7-10.95 GHz frequency band are included under this agenda item insofar as the results of this agenda item may cause increased occurrence of FSS downlinks over areas where they do not currently occur, particularly ocean or polar areas. The IEEE notes that the FSS downlinks in the 10.7-12.75 GHz frequency band operate on a non-interfering, non-protected basis so that, theoretically, if it was found that FSS emissions in the adjacent band reflected off the surface of the Earth presented harmful interference to EESS (passive) operations in the 10.68-10.7 GHz band then EESS (passive) operators could order that the FSS operators using the 10.7-12.75 GHz and causing interference to EESS (passive) cease operations.

4.7 Agenda Item 1.16

Agenda Item 1.16 will consider technical, operational and regulatory measures, as appropriate, to facilitate the use of the frequency bands 17.7-18.6 GHz and 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) by NGSO FSS Earth stations in motion, while ensuring due protection of existing services in those frequency bands, on the basis of the ITU-R studies performed in accordance with Resolution **173 (WRC-19)**.

Resolution 173 (WRC-19) resolves to invite ITU-R to study:

- "the technical and operational characteristics and user requirements of the different types of Earth stations in motion that plan to operate within NGSO FSS systems in the frequency bands 17.7-18.6 GHz and 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), or parts thereof";
- "sharing and compatibility between Earth stations in motion operating with NGSO FSS systems and current and planned stations of primary services allocated in the frequency bands 17.7-18.6 GHz and 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), or parts thereof, to ensure protection of, and not impose additional constraints on, Geo-Stationary Orbit (GSO) systems and other services, including terrestrial services, in those frequency bands and in adjacent bands, including passive services".

The ESIM operations that would be facilitated under this agenda item are intended to provide data services to aeronautical (commercial and business aviation) and maritime routes (passenger cruise ship, merchant ship, fishing vessel, etc.) on a global basis. While not explicitly excluded, land based ESIM operations will not be addressed under this agenda item. Within the frequency bands under consideration, 17.7-18.6 GHz and 18.8-19.3 GHz are adjacent to the band 18.6-18.8 GHz, which is allocated to the Earth exploration-satellite service (passive) on a primary basis in all three Regions. Since the NGSO FSS necessary emissions occur outside of the 18.6-18.8 GHz band, it is the out-of-band emissions of the FSS that are to be studied in regards to its compatibility with recommended RFI protection limits of the EESS (passive) operating in the 18.6-18.8 GHz frequency band.

Two interference paths between the FSS downlink operations and the EESS (passive) sensor exist, as shown in Figure 4.4. The first is coupling between the main lobe of the FSS satellite antenna and the back lobes of the EESS (passive) sensor antenna. The second path is the reflection of the FSS antenna main lobe emissions off of the surface of the Earth into the main lobe of the EESS (passive) sensor antenna. The corresponding signal path between the FSS satellite and the ESIM is identified with a dashed line in the figure.

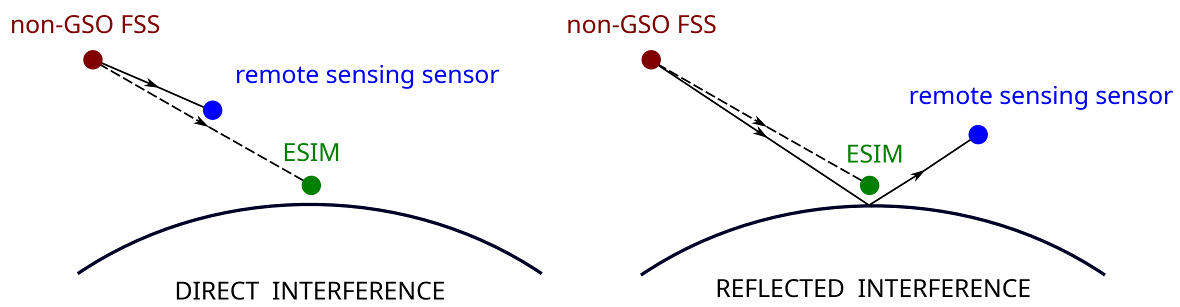

Figure 4.4: Interference paths from FSS (space-to-Earth) and EESS (passive).

Due to the narrow beams of passive remote sensing sensors, the direct interference scenario is relevant only during Cold Sky Calibration, when the EESS (passive) antenna looks upwards. IEEE GRSS recommends that this case be taken into consideration, perhaps by establishing coordination rules between FSS and EESS (passive) operations.

The most critical scenario of RFI to remote sensing systems is the reflected interference. Existing FSS GSO space-to-Earth links in the 18.6-18.8 GHz frequency band may already be causing interference to EESS (passive) in exceedance of the Recommendation ITU-R RS.2017 protection criteria. This type of interference has been documented since 2010 [7] and Figure 4.5 shows an example of it affecting the GPM Microwave Imager (GMI) sensor [8].

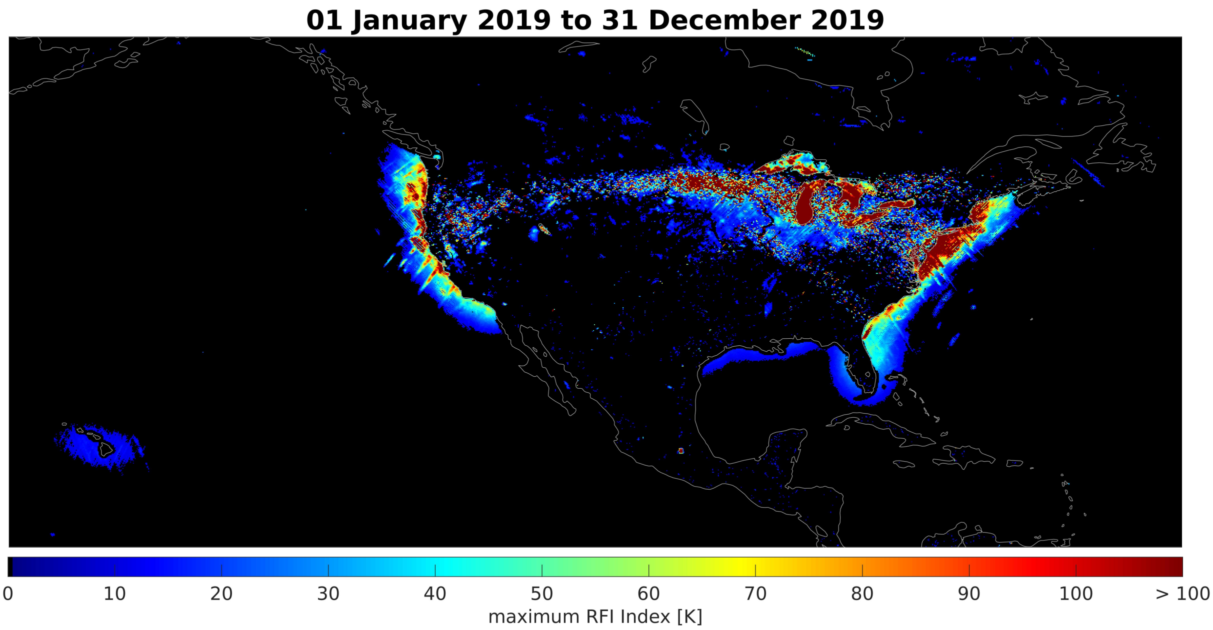

Figure 4.5: Interference affecting the GMI sensor.

Use and importance of the 18.6-18.7 GHz frequency range

The 18.6-18.8 GHz frequency band channel is one of the more used in passive remote sensing for the variety of processes that can be monitored through this band. The band is used for observing atmospheric water vapor, precipitation, clouds, freeze and thaw processes, sea ice, snow, sea surface temperature, sea surface winds and ocean topography. In general these measurements are accompanied by measurements at other frequencies (such as 10.6, 24, 37 or 89 GHz) in order to make relative retrievals about the abundance of these geophysical quantities.

The 18.7 GHz band is of particular importance for the measurement of sea-ice extent, which is a key variable in climate monitoring. The use of passive frequencies for retrieving this information is important due to the high cloud cover and the long polar night that prevent retrieving this information using optical instruments. These microwave measurements also allow us to estimate the multi-year structures of sea-ice. Finally, the 18.7 GHz channel is also used in active altimeter missions for ocean topography to help correct for the path delays, and to correct for the atmospheric attenuation in retrievals of sea-surface winds.

Because of its importance, several missions operate or plan to operate in this band. Table 4.7 contains a list of some missions that operate or plan to operate in the 18.6-18.7 GHz frequency range.

Satellite Name	Instrument Name	Agency	Launch	End of life	Frequency	Bandwidth
Aqua	AMSR-E	NASA	2002-05-04	⩾2025	18.7 GHz	100 MHz
CIMR	CIMR	ESA	⩾2028	⩾2033	18.7 GHz	200 MHz
Coriolis	WindSat	US DoD	2003-01-06	⩾2023	10.7 GHz	750 MHz
CRISTAL	AMR-CR	ESA	⩾2027	⩾2034	10.7 GHz	200 MHz
FY-3C	MWRI-1	CMA	2013-09-23	⩾2023	18.7 GHz	200 MHz
FY-3D	MWRI-1	CMA	2017-11-14	⩾2023	18.7 GHz	200 MHz
FY-3F	MWRI-1	CMA	⩾2023	⩾2029	18.7 GHz	200 MHz
GCOM-W	AMSR-2	JAXA	2012-05-17	⩾2023	18.7 GHz	200 MHz
GOSAT-GW	AMSR-3	JAXA	⩾2024	⩾2031	18.7 GHz	200 MHz
GPM	GMI	NASA	2014-02-27	⩾2027	18.7 GHz	200 MHz
HY-2A	MWI	NSOAS	2011-08-16	⩾2023	18.7 GHz	250 MHz
HY-2B	MWI	NSOAS	2018-10-24	⩾2023	18.7 GHz	250 MHz
ISS COWVR	COWVR	NASA	2021-12-21	⩾2024	18.7 GHz	780 MHz
JASON-3	AMR	NASA	2016-01-17	⩾2023	18.7 GHz	200 MHz
Meteor-M N2	MTVZA-GY	RosHydroMet	2014-07-08	⩾2023	18.7 GHz	200 MHz
Meteor-M N2-2	MTVZA-GY	RosHydroMet	2019-07-05	⩾2024	18.7 GHz	200 MHz
Meteor-M N2-3	MTVZA-GY	RosHydroMet	⩾2023	⩾2027	18.7 GHz	200 MHz
Metop-SG-B1	MWI	EUMETSAT	⩾2025	⩾2032	18.7 GHz	200 MHz
Sentinel-6A	AMR-C	EUMETSAT	2020-11-21	⩾2027	18.7 GHz	200 MHz
Sentinel-6B	AMR-C	EUMETSAT	⩾2025	⩾2032	18.7 GHz	200 MHz
SWOT	MWR	NASA	2022-12-16	⩾2026	18.7 GHz	200 MHz
WSF-M1	WSF-M	US DoD	⩾2024	⩾2030	181.85 GHz	500 MHz

Table 4.7: Examples of existing and planned EESS (passive) sensors using the 18.6-18.7 GHz band.

IEEE GRSS View

IEEE GRSS does not oppose NGSO FSS ESIM deployment in the bands 17.7-18.6 GHz and 18.8-19.3 GHz (space-to-Earth) provided that their operation will not result in increased interference to EESS (passive) sensors in the adjacent 18.6-18.8 GHz band.

The current interference to EESS (passive) operations from all other services acting in accordance with the RRS are to be added to the potential new interference to determine the total amount of RFI to EESS (passive) operations that may result from actions taken by the WRC in response to this agenda item. IEEE GRSS is of the view that interference to EESS (passive) caused by surface water reflections from satellite downlinks needs to be taken into account in sharing and compatibility considerations, particularly by setting appropriate emission power limits and out-of-band masks for the transmitting FSS NGSO station. In addition, due to the very large number of NGSO satellites expected to have transmitters in the frequency bands considered under this agenda item, particular attention should be paid to correctly estimate potential aggregate interference.

4.8 Agenda Item 1.17

Agenda Item 1.17 will consider, on the basis of the ITU-R studies performed in accordance with Resolution **773 (WRC-19)**, regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an Inter-Satellite Service (ISS) allocation where appropriate.

The primary goal of this agenda item is to develop, based on the results of relevant sharing and compatibility studies, the technical conditions and regulatory provisions for satellite-to-satellite operations in the frequency bands 27.5-30 GHz (Earth-to-space) and 11.7-12.7 GHz, 18.1-18.6 GHz and 18.8-20.2 GHz (space-to-Earth) allocated to the FSS. As satellites with scientific missions generate increasing volumes of data and requirements for reduced data latency become more restrictive, the space science community would benefit if their future missions could make use of available commercial satellite communications service providers to operate as data relays. The frequency bands 18.4-18.6, 18.8-19.3 GHz could be used for forward links to low-Earth-orbit science satellites through commercial fixed satellite service providers in the same manner as they would through a current data relay satellite network such as NASA's Tracking and Data Relay Satellite System (TDRSS). They could be used for forward links to Low Earth Orbit (LEO) science satellites through commercial FSS service providers in the same manner as they would through a data relay satellite network.

This agenda item is the responsibility of ITU-R WP 4A with WP 7C as a contributing group.

The bands 18.4-18.6 GHz and 18.8-19.3 GHz are adjacent to the band 18.6-18.8 GHz, which is allocated to EESS (passive) on a primary basis. The 18.6-18.8 GHz frequency band channel is used for observing the atmospheric water vapor, precipitation, clouds, freeze and thaw processes, sea ice, snow, sea surface temperature, sea surface winds and ocean topography, often in conjunction with other bands. More details can be found under AI 1.16.

A general configuration includes FSS systems on GSO, Medium Earth Orbit (MEO) and LEO satellites. The orbital altitude of MEO satellites is approximately 8000 km, while LEO satellites are located at an altitude between 350 and 1500 km. Transmissions between satellites within the same altitude range are not permitted. Figure 4.6 illustrates the paths of FSS transmissions and potential interference to EESS sensors when one GSO satellite and two NGSO satellites (MEO and LEO) are considered. The transmissions between the three FSS satellites are marked in green. As for AI 1.16, interference can reach the remote sensing instrument either directly or after reflection on the Earth surface. The direct and reflected interference paths are in red and blue color, respectively.

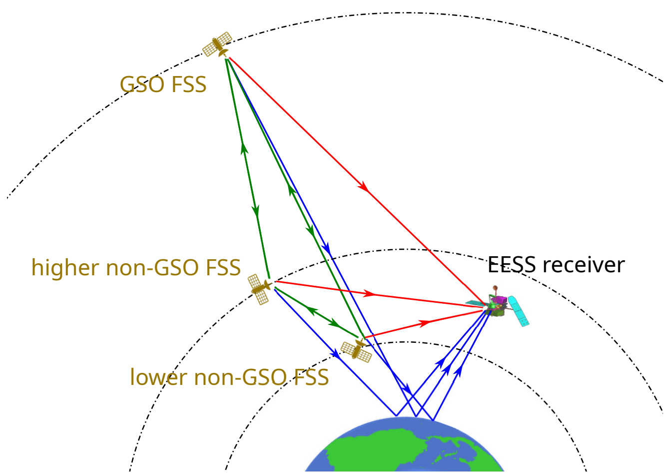

Figure 4.6: FSS transmissions and paths of interference to the EESS sensor.

IEEE GRSS View

Many of the concerns for this agenda item are similar to those for AI 1.16. However, this agenda item includes operations of both GSO and NGSO systems as ISS. GSO FSS operations are already permitted both in the 18.6-18.8 GHz band and at 18.1-18.6 GHz and 18.8-20.2 GHz, therefore it is argued that addition of this service will not considerably change the RFI environment given the small number of GSO satellites expected to use the ISS allocation. However, it must be noted that this assumption does not hold true for NGSO FSS operations which are not currently authorized to provide service to Earth stations located on bodies of water such as the oceans. Extending ISS to FSS NGSO operations would expand the current interference environment globally in much the same way that FSS NGSO support of ESIMs under agenda item 1.16 would, albeit with an expected fewer number of ISS links than it would be expected for ESIM links.

EEE GRSS supports establishing technical conditions and regulatory provisions for satellite-to-satellite operations in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz, or portions thereof, including new ISS allocations, as appropriate. IEEE GRSS recommends that regulatory solutions ensure that satellite-to-satellite operations in the 18.1-18.6 GHz and 18.8-20.2 GHz will not result in increased adjacent band interference to EESS (passive) operations in the 18.6-18.8 GHz band. Frequency overlap with agenda item 1.16 needs to be taken into account.

4.9 Agenda Item 1.18

Agenda Item 1.18 will consider studies relating to spectrum needs and potential new allocations to the mobile-satellite service for future development of narrowband mobile-satellite systems, in accordance with Resolution **248 (WRC-19)**.

This agenda item calls for studies for consideration of new allocations to the mobile satellite service, for low-data rate systems for the collection of data from, and management of, terrestrial devices, in the following bands:

- 1695-1710 MHz in Region 2,
- 2010-2025 MHz in Region 1,
- 3300-3315 MHz, 3385-3400 MHz in Region 2.

The mobile-satellite service (MSS) is a radiocommunication service between mobile Earth stations and one or more space stations, or between space stations used by this service; or between mobile Earth stations by means of one or more space stations. MMS provides two-way voice and data communications to global users who are on the go or in remote locations; terminals range in size from handheld to laptop-size units. Terminals can also be mounted in a vehicle, with communications maintained while the vehicle is moving.

This agenda item is the responsibility of ITU-R WP 4C with WP 7C as a contributing group.

Resolution **248 (WRC-19)** states "that the studies envisaged under resolves to invite the ITU Radiocommunication Sector in this Resolution are to be limited to those systems with space stations that have a maximum equivalent isotropically radiated power (e.i.r.p.) of 27 dBW or less, with a beamwidth of no more than 120 degrees, and Earth stations that individually communicate no more than once every 15 minutes, for no more than 4 seconds at a time, with a maximum e.i.r.p. of 7 dBW."

Use and importance of the potentially affected bands

The frequency band 1695-1710 MHz is allocated to the MetSat service and is primarily used for NGSO MetSat data downlinks to Earth stations around the world, thus potentially affecting MetSat systems from other regions as well. The Polar Operational Polar Operational Enviromental Satellite (POES) operated by NOAA utilize 1698, 1702.2 and 1707 MHz (center frequencies) for High Rate Picture Transmission (HRPT) in the space-to-Earth direction. The ARGOS Advanced Data Collection System (A-DCS) Hosted Payload (HoPS) on the Orbital Test Bed 3 (OTB-3) spacecraft (and on future OCEANSAT-3, MetOp-SG and Kineis satellites) utilizes 1703 MHz in support of the ARGOS mission to collect, process and disseminate environmental data from fixed and mobile platforms around the world.

Also, the frequency band 1695-1700 MHz is allocated to the Meteorological Aids on a primary basis in all three regions. UWB microwave radiometers may also collect measurements in this frequency range but without an EESS (passive) allocation to claim protection from interference. The only frequency band used for remote sensing measurement that could be affected by decisions related to this agenda item is 3.1-3.3 GHz for EESS (active) sensors. This is a secondary allocation at S-band. The S-band is a good intermediate frequency that has many of the long-wavelength advantages of the L-band (good penetration of low vegetation, low temporal decorrelation, low tropospheric propagation losses), as well as some of the advantages of higher frequencies (smaller antennas, lower degree of ionospheric effects, ability to measure rain when operated at high power in ground-based applications). Current and planned sensors are the Chinese HJ-1C SAR mission, the UK NovaSAR-1 mission, and the joint NISAR mission to be launched in 2023. A list of systems operating in this band can be found in Table 3. Although it is a secondary service in the S-band, rare RFI cases have been reported.

IEEE GRSS View

IEEE GRSS supports protection of current and future MetSat operations in the band 1695-1710 MHz. If and application of the constraints identified in Resolution **248 (WRC-19)** on the MSS parameters. Decisions regarding the 3300-3315 MHz band should take into consideration the impact on the adjacent 3.1-3.3 GHz EESS (active) band, even though this is only a secondary allocation. Compatibility between MSS and EESS (active) under this agenda item also needs to consider the criteria set forward in Recommendation RS.1166 [9].

4.10 Agenda Item 1.19

Agenda Item 1.19 will consider a new primary allocation to the fixed-satellite service in the space-to-Earth direction in the frequency band 17.3-17.7 GHz in Region 2, while protecting existing primary services in the band, in accordance with Resolution **174 (WRC-19)**.

Resolution **174 (WRC-19)** invites the ITU Radiocommunication Sector to conduct, and complete in time for WRC-23, sharing and compatibility studies between the FSS (space-to-Earth) and the BSS (space-to-Earth) and between the FSS (space-to-Earth) and the FSS (Earth-to-space), in order to consider a possible new primary allocation to the FSS (space-to-Earth) in the frequency band 17.3-17.7 GHz for Region 2, while ensuring the protection of existing primary allocations in the same and adjacent frequency bands, as appropriate, and without imposing any additional constraints on existing allocations to the BSS (space-to-Earth) and the FSS (Earth-to-space).

Working Party (WP) 4A is the Responsible group to conduct the studies. WP 7C is a Contributing group. Fixed-satellite service is a radiocommunication service between Earth stations at given positions and one or more satellite. An important application of this kind of system is satellite Internet connectivity. In Region 1 the band 17.3-17.7 GHz is already allocated to the FSS in the space-to-Earth direction. A new allocation in Region 2 would progress the principle of Regional harmonization, allowing for synchronization of frequency bands across both Regions.

Broadcasting-satellite service is a radiocommunication service in which signals transmitted or re-transmitted by space stations are intended for direct reception by the general public. A common application is satellite television, which delivers television programming to viewers by relaying it from a communications satellite orbiting the Earth directly to the viewer's location. The signals are received via an outdoor parabolic antenna commonly and a low-noise block downconverter.

The frequency band 17.2-17.3 GHz is allocated to EESS (active) and could potentially be affected by reflection of FSS and BSS out-of-band emissions over the Earth surface.

Use and importance of the 17.2-17.3 GHz frequency range

There are currently no known operational satellites operating in the 17.2-17.3 GHz band. The Ku-band is also being used for relatively new measurements of snow depth and snow water equivalent by airborne systems. There is interest among European and U.S. investigators in deploying a snow measurement system from space that would potentially utilize the allocation at 17.2-17.3 GHz from space for the first time.

IEEE GRSS View

IEEE GRSS also supports technical conditions and regulatory provisions for a new primary allocation to FSS in the space-to-Earth direction in the frequency band 17.3-17.7 GHz in Region 2 that ensure that the resulting FSS operations will not result in increased adjacent band interference to EESS (active) sensors in the 17.2-17.3 GHz band.

4.11 Agenda Item 9.1 (Topic a)

Agenda Item 9.1 (Topic a) will review, in accordance with Resolution **657 (WRC-19)**, the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services.

Resolution **657 (WRC-19)** calls for studies on technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services. No regulatory action is to be taken at WRC-23 as a result of this agenda item.

Space weather refers to the environmental conditions of the space surrounding Earth, in particular in the magnetosphere, ionosphere, thermosphere, and exosphere. A variety of instruments studies the phenomena associated with space weather, such as geomagnetic storms and solar wind. Since space weather can affect satellite instruments, humans on space stations and during spaceflight and also ground systems, it is very important to collect measurements that can be used in predicting space weather events.

Space weather sensors using radio frequency have traditionally been operating outside the regulatory framework of the ITU, and this agenda item is a first attempt to provide protection to these applications. A number of ITU-R reports are being developed under the work for this agenda item, including one on space weather sensor systems using radio spectrum, one on spectrum requirements and one on interference criteria.

IEEE GRSS View

Regulatory actions are not possible under this agenda item; therefore, IEEE GRSS recommends that the studies should be used to determine the scope of a future WRC agenda item that will provide appropriate recognition and protection to space weather sensors. IEEE GRSS also supports the development of the above-mentioned reports to establish a technical background for future decisions.

4.12 Agenda Item 9.1 (Topic b)

Agenda Item 9.1 (Topic b) will review, in accordance with Resolution **774 (WRC-19)**, the amateur service and the amateur-satellite service allocations in the frequency band 1240 - 1300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite (space-to-Earth) service operating in the same band.

Resolution **774 (WRC-19)** calls for the detailed review of the different systems and applications used in the amateur service (ARS) and amateur-satellite service (ARSS) allocations within the frequency band 1240-1300 MHz and resolves 2 calls for studies of possible technical and operational measures to ensure the protection of RNSS (space-to-Earth) receivers from the amateur and amateur-satellite services within the frequency band 1240-1300 MHz, without considering the removal of these amateur and amateur-satellite services allocations, taking into account the results of the review.

This agenda item is the responsibility of ITU-R WP 5A with WP 7C as a contributing group. WP 4C is responsible for developing studies on the *resolves to invite ITU-R* 2 of Resolution **774 (WRC-19)**. This agenda item will not result in any regulatory changes.

Amateur service is defined as a radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest. Amateur satellite service refers to as a radiocommunication service using space stations on Earth satellites for the same purposes as those of the amateur service.

The frequency band 1215-1300 MHz is allocated to be used by EESS (active) and could potentially be affected.

Use and importance of the 1215-1300 MHz frequency range

The EESS (active) allocation at the L-band is from 1215 to 1300 MHz. The L-band has been extensively used for SAR remote sensing, because the L-band is insensitive to clouds and rain and offers a moderate level of vegetation and surface penetration. It is ideal for many scientific measurements, including soil moisture mapping, sea ice mapping, and soil moisture and biomass estimation. In addition, L-band is good for detecting surface deformations associated with seismic and other natural hazards, land-use assessment, and crop characterization.

Currently, numerous L-band SAR missions are operated, including the Japanese ALOS series, Argentina SAOCOM and the Chinese Lutan-1 system. Future planned systems include the NASA NISAR mission, German Tandem-L, European Rose-L, etc. Table 4.8 contains a list of some missions operating or planning to operate in the 1215-1300 MHz frequency range. Based on the interference experienced in ALOS and Lutan-1 data, the majority of the RFI issues is caused by radiolocation radars for L-band SAR. The power level of amateur service transmissions is relatively low, and thus not easy to exceed the I/N threshold for radar receiver, which makes it not being a big threat to accurate remote sensing.

The band from 1215 MHz to 1300 MHz is also used by by the Global Positioning System (GPS) L2, Glonass G2, and Galileo E6 signals for Global Navigation Satellite System (GNSS) navigation, but also as signals of opportunity for Earth Observation by means of GNSS Radio Occultation (GNSS-RO) and GNSS Reflectometry (GNSS-R). These bands are allocated to Radio-location Services (ground radars) and RNSS on a primary basis, thence the GNSS signals in these bands are more vulnerable to interference than the ones assigned in the following ARNS bands: 1) the band 1559 MHz to 1610 MHz which is used by GPS L1, Glonass G1, Galileo E1, Beidou B1 GNSS signals, as well as by the QZSS regional augmentation system, 2) the band 1215.6 to 1350 MHz which is used by GPS L2, GLONASS G2 and Galileo E6 signals as well as radio-location services (ground radars) and

Satellite Name	Instrument Type	Agency	Launch	End of life	Center Frequency	Bandwidth
ALOS-2	SAR	JAXA	2014-05-24	⩾2023	1.275 GHz	84 MHz
SAOCOM-1A	SAR	CONAE	2018-10-07	⩾2023	1.275 GHz	50 MHz
SAOCOM-1B	SAR	CONAE	2020-08-30	⩾2025	1.275 GHz	50 MHz
SAOCOM-2A	SAR	CONAE	⩾2025	⩾2030	1.275 GHz	50 MHz
SAOCOM-2B	SAR	CONAE	⩾2026	⩾2031	1.275 GHz	50 MHz
Lutan-1	SAR	SAST	2022-1-26	⩾2032	1.26 GHz	80 MHz
NISAR	SAR	NASA/ ISRO	⩾2024	⩾2026	1.26 GHz	85 MHz
Tandem-L	SAR	DLR	⩾2024	⩾2036	1.26 GHz	85 MHz

Table 4.8: Some relevant existing and planned EESS (active) sensors using the 1215-1300 MHz band.

RNSS on a primary basis, thence the signals in these bands are more vulnerable to interference than the previous ones, and 3) the band 1164 MHz to 1214 MHz, which is used by GPS L5, Galileo E5a and E5b, The above bands are currently used for Earth Observation by means of GNSS-RO (sample missions: COSMIC-2, FY-3C onwards, Spire Global, PAZ, CICERO, CLARREO-1, GRAS, TOPCAT, Sentinel-6, . . .) and GNSS-Reflectometry (sample missions: Cyclone Global Navigation Satellite System (CYGNSS), Spire Global, FSSCat, FY-3E onwards, HydroGNSS. . .). As shown in Figure Figure 4.7, while accounting for only 7% of the total observations in the assimilation system, GNSS-RO, here called GPS Radio Occultation (GPS-RO), has the 4th largest impact on NWP. These observations are critically important, but prone to RFI.

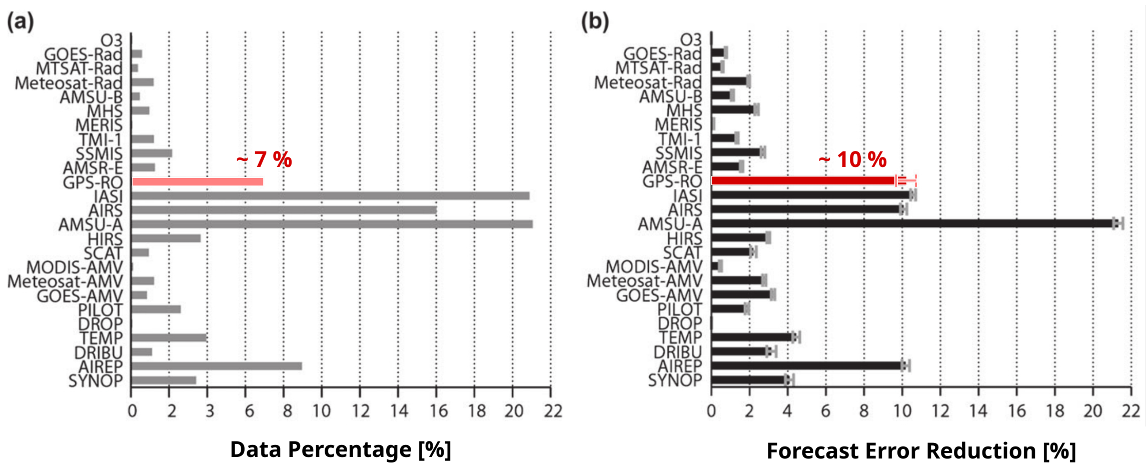

Figure 4.7: Evaluation of various observations assimilated by the ECMWF.

IEEE GRSS View

Given the low potential for interference with EESS (active) in the band 1215-1300 MHz from the amateur and amateur-satellite services, IEEE GRSS does not oppose the review of the existing allocations in the band 1215-1300 MHz, as long as any possible changes that may be considered in future WRC agendas will not adversely impact the operation of EESS (active) over the entire 1 215-1 300 MHz frequency range.

4.13 Agenda Item 9.1 (Topic d)

Agenda Item 9.1 (Topic d) will consider protection of EESS (passive) in the frequency band 36-37 GHz from NGSO FSS space stations.

WRC-19 agenda item 1.6 sought technical and regulatory provisions to facilitate the operation of FSS satellite systems on non-geostationary satellite orbit ("NGSO") in the frequency bands 37.5-42.5 GHz (space-to-Earth), and 47.2-50.2 GHz and 50.4-51.4 GHz (both Earth-to-space), while ensuring protection of GSO and EESS services.Under studies performed for WRC-19 agenda item 1.6, an analysis on the protection of EESS (passive) sensors operating in the band 36-37 GHz from NGSO FSS space stations in large constellations in the band 37.5-38 GHz was submitted to the ITU-R. This preliminary study indicated that it may be necessary to apply an unwanted e.i.r.p. limit of -34 dB(W/100 MHz) to FSS NGSO space stations for all angles greater than 71.4° from nadir. However, interference into the cold calibration channel of the EESS (passive) sensor operating in the frequency band 36-37 GHz was not studied under WRC-19 agenda item 1.6, but was nonetheless identified as an issue of concern by EESS remote sensing interests. On this basis, WRC-19 invited the ITU-R to conduct further study of this topic and develop Recommendations and/or Reports, as appropriate, and report back to WRC-23 to take action, if necessary. Furthermore, WRC-19 agreed that modifications to Resolution **750 (Rev.WRC-19)** should not be considered under these studies since the frequency band 36-37 GHz is not referenced in **RR No. 5.340**. In any case, WRC agenda item 9 issues are prohibited from studying and providing methods to modify the Radio Regulations at a WRC.

Non-GSO FSS systems that could operate in the 37.5-42.5 GHz band include telecommunication satellites in large constellations for global broadband Internet coverage.

Use and importance of the 36-37 GHz frequency range for passive sensors

The 36-37 GHz frequency band channel is essential for observing global atmospheric water vapor, precipitation, clouds,. freeze/thaw processes, sea-ice, snow, sea-surface temperature, sea-surface winds and ocean topography. Similar to the 18.6 GHz frequency band presented before, this band is usually acquired simultaneously with other channels in order to make relative retrievals to obtain geo-physical parameters.

Because of its importance, several missions operate or plan to operate in this band. Table 4.9 contains a list of some of the missions that operate or plan to operate in the 36-37 GHz frequency range.

IEEE GRSS View

IEEE GRSS supports evaluating the impact of NGSO FSS operations in the band 37.5-38 GHz on EESS (passive) sensors in the band 36-37 GHz, including the interference impact on the cold-sky calibration of passive sensors as a basis for a future agenda item.

Satellite Name	Instrument Name	Agency	Launch	End of life	Frequency	Bandwidth
Aqua	AMSR-E	NASA	2002-05-04	$\geqslant$2025	36.5 GHz	1000 MHz
CIMR	CIMR	ESA	$\geqslant$2028	$\geqslant$2033	36.5 GHz	300 MHz
Coriolis	WindSat	US DoD	2003-01-06	$\geqslant$2023	37 GHz	2000 MHz
DMSP-F17	SSMIS	US DoD	2006-11-04	$\geqslant$2025	37 GHz	1580 MHz
DMSP-F18	SSMIS	US DoD	2009-10-18	$\geqslant$2025	37 GHz	1580 MHz
FY-3C	MWRI-1	CMA	2013-09-23	$\geqslant$2023	36.5 GHz	400 MHz
FY-3D	MWRI-1	CMA	2017-11-14	$\geqslant$2023	36.5 GHz	400 MHz
FY-3F	MWRI-2	CMA	$\geqslant$2023	$\geqslant$2029	36.5 GHz	1000 MHz
GCOM-W	AMSR-2	JAXA	2012-05-17	$\geqslant$2023	36.5 GHz	1000 MHz
GOSAT-GW	AMSR-3	JAXA	$\geqslant$2024	$\geqslant$2031	36.5 GHz	200 MHz
GPM	GMI	NASA	2014-02-27	$\geqslant$2027	36.5 GHz	1000 MHz
HY-2A	MWI	NSOAS	2011-08-16	$\geqslant$2023	37 GHz	1000 MHz
HY-2B	MWI	NSOAS	2018-10-24	$\geqslant$2023	37 GHz	1000 MHz
Meteor-M N2	MTVZA-GY	RosHydroMet	2014-07-08	$\geqslant$2023	36.7 GHz	400 MHz
Meteor-M N2-2	MTVZA-GY	RosHydroMet	2019-07-05	$\geqslant$2024	36.7 GHz	400 MHz
Meteor-M N2-3	MTVZA-GY	RosHydroMet	$\geqslant$2023	$\geqslant$2027	36.7 GHz	400 MHz
SARAL	Altika	CNES	2013-02-25	$\geqslant$2023	36.5 GHz	200 MHz
Sentinel-3A	MWR	ESA	2016-02-16	$\geqslant$2023	36.5 GHz	1000 MHz
Sentinel-3B	MWR	ESA	2018-04-25	$\geqslant$2025	36.5 GHz	1000 MHz
WSF-M1	WSF-M	US DoD	$\geqslant$2024	$\geqslant$2030	36.75 GHz	500 MHz

Table 4.9: Examples of existing and planned EESS (passive) sensors using the 36-37 GHz band.

References

[1] *Radio Regulations*. International Telecommunication Union, 2020. URL: https://www.itu.int/pub/R-REG-RR (cited on page 8).

[2] *ITU-R Recommendation RS.2017: Performance and interference criteria for satellite passive remote sensing*. International Telecommunication Union, 2012. URL: https://www.itu.int/rec/R-REC-RS.2017 (cited on pages 10, 13).

[3] *Report of the meeting of Working Party 7C (Geneva, 4-11 October 2023), Document 529, Annex 6,* ITU-R, Radiocommunication Sector of the ITU, 2023. URL: https://www.itu.int/md/R19-WP7C-C-0529/en (cited on page 13).

[4] Caillet Thibaut. “The planned difficulties of Sea Surface Temperature measurements in band 6.9 and 7.3 GHz”. In: *2023 XXXVth General Assembly and Scientific Symposium of the International Union of Radio Science (URSI GASS)*. 2023, pages 1–4. DOI: 10.23919/URSIGASS57860.2023.10265373 (cited on page 13).

[5] David M. Le Vine and Emmanuel P. Dinnat. “The Multifrequency Future for Remote Sensing of Sea Surface Salinity from Space”. In: *Remote Sensing* 12.9 (2020). ISSN: 2072-4292. DOI: 10.3390/rs12091381. URL: https://www.mdpi.com/2072-4292/12/9/1381 (cited on page 15).

[6] Anthony Freeman, Xiaoqing Pi, and Essam Heggy. “Radar Sounding Through the Earth’s Ionosphere at 45 MHz”. In: *IEEE Transactions on Geoscience and Remote Sensing* 55.10 (2017), pages 5833–5842. DOI: 10.1109/TGRS.2017.2715838 (cited on page 22).

[7] Darren McKague, John J. Puckett, and Christopher Ruf. “Characterization of K-band radio frequency interference from AMSR-E, WindSat and SSM/I”. In: *2010 IEEE International Geoscience and Remote Sensing Symposium*. 2010, pages 2492–2494. DOI: 10.1109/IGARSS.2010.5651860 (cited on page 28).

[8] *Report of the meeting of Working Party 7C (Geneva, 4-11 October 2023), Document 529, Annex 12,* ITU-R, Radiocommunication Sector of the ITU, 2023. URL: https://www.itu.int/md/R19-WP7C-C-0529/en (cited on page 28).

[9] *ITU-R Recommendation RS.1166: Performance and interference criteria for active spaceborne sensors*. International Telecommunication Union, 2009. URL: https://www.itu.int/rec/R-REC-RS.1166/en (cited on page 33).

Appendices

Radiocommunication Services

RR Article	Name of Service	Acronym
1.20	Fixed service	FS
1.21	Fixed-satellite service	FSS
1.22	Intersatellite service	ISS
1.23	Space operation service	SOS
1.24	Mobile service	MS
1.25	Mobile-satellite service	MSS
1.26	Land mobile service	LMS
1.27	Land mobile-satellite service	LMSS
1.28	Maritime mobile service	MMS
1.29	Maritime mobile-satellite service	MMSS
1.30	Port operations service	POS
1.31	Ship movement service	SMS
1.32	Aeronautical mobile service	AMS
1.33	Aeronautical mobile (R) service	AM(R)S
1.34	Aeronautical mobile (OR) service	AMS(OR)
1.35	Aeronautical mobile-satellite service	AMSS
1.36	Aeronautical mobile-satellite (R) service	AMS(R)S
1.37	Aeronautical mobile-satellite (OR) service	AMS(OR)S
1.38	Broadcasting service	BS
1.39	Broadcasting-satellite service	BSS
1.40	Radiodetermination service	RDS
1.41	Radiodetermination-satellite service	DRSS
1.42	Radionavigation service	RNS
1.43	Radionavigation-satellite service	RNSS
1.44	Maritime radionavigation service	MRNS
1.45	Maritime radionavigation-satellite service	MRNSS
1.46	Aeronautical radionavigation service	ARNS
1.47	Aeronautical radionavigation-satellite service	ARNSS
1.48	Radiolocation service	RLS
1.49	Radiolocation-satellite service	RLSS
1.50	Meteorological aids service	MetAids
1.51	Earth-exploration satellite service	EESS
1.52	Meteorological-satellite service	MetSat
1.53	Standard frequency and time signal service	SFTS
1.54	Standard frequency and time signal-satellite service	SFTSS
1.55	Space research service	SRS
1.56	Amateur service	ARS
1.57	Amateur-satellite service	ARSS
1.58	Radio astronomy service	RAS
1.59	Safety service	None
1.60	Special service	None

Space Agencies and Other Organizations

Abbreviation	Name
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
CMA	China Meteorological Administration
CAST	Chinese Academy of Space Technology
CNES	Centre National d'Études Spatiales (French Space Agency)
CONAE	Comisión Nacional de Actividades Espaciales (Argentinian Space Agency)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
ISRO	Indian Space Research Organization
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
NSOAS	National Satellite Ocean Application Service (China)
RosHydroMet	Russian Federal Service for Hydrometeorology and Environmental Monitoring
UKSA	United Kingdom Space Agency
US DoD	United States Department of Defense (USA)
SAST	Shanghai Academy of Spaceflight Technology
WMO	World Meteorological Organization

Acronyms

CYGNSS Cyclone Global Navigation Satellite System
DMSP Defense Meteorological Satellite Program
ESIM Earth Stations In Motion
FARS Frequency Allocations in Remote Sensing
GMI GPM Microwave Imager
GNSS Global Navigation Satellite System
GNSS-R GNSS Reflectometry
GNSS-RO GNSS Radio Occultation
GPS Global Positioning System
GPS-RO GPS Radio Occultation
GRSS Geoscience and Remote Sensing Society
GSO Geo-Stationary Orbit
HAPS High Altitude Platform Station
HIBS High Altitude Platform Stations as IMT Base Stations
HRPT High Rate Picture Transmission
ICI Ice Cloud Imager
IEEE Institute of Electrical and Electronics Engineers
IMT International Mobile Telecommunication
ITU International Telecommunications Union
LEO Low Earth Orbit
MEO Medium Earth Orbit
MetOp-SG Meteorological Operational Satellite Second Generation
MLS Microwave Limb Sounder
NGSO Non-Geostationary Orbit
NISAR NASA-ISRO Synthetic Aperture Radar
NWP Numerical Weather Prediction
OTB-3 Orbital Test Bed 3
PDF Power Flux Density
POES Polar Operational Enviromental Satellite
RR Radio Regulations
SAR Synthetic Aperture Radar
SDG Sustainable Development Goals
SG Study Group
SSMIS Special Sensor Microwave Image/Sounder
SST Sea Surface Temperature
TDRSS Tracking and Data Relay Satellite System
WP Working Party
WRC World Radiocommunication Conference
WRC-23 World Radiocommunication Conference 2023