CEPT ECC
Electronic Communications Committee

ECC Report 378

Assessment of potential coordinated FSS (Earth-to-space) earth stations within the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz

approved 5 June 2026

0 EXECUTIVE SUMMARY

This Report provides initial information about assessment of potential individually licensed FSS (Earth-to-space) earth stations within of the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz, considering the establishment of a frequency sharing environment and more efficient use by FS links and coordinated FSS gateways (GWs) such as it is practised in other lower frequency bands. This is in line with the ECC's strategy to foster the use of higher frequency ranges. Such individually authorised GW uplinks would typically be authorised by means of individual authorisations.

This Report confirms the availability of the technology for individually authorised gateway uplinks operating above 92 GHz and provides justification about the need for spectrum. The need for coexistence and sharing studies is identified in this Report. Those studies are still to be triggered and conducted in order to support deployment of the technology in Europe, fostering innovation and economic growth while maintaining protections for incumbents. This can also accelerate broadband services delivery via satellite in Europe in the coming years. CEPT-wide mechanisms would provide certainty, avoiding fragmentation throughout Europe.

CEPT administrations are invited to consider this Report and may trigger further studies within ECC as appropriate.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
BR	Radiocommunication Bureau
CEPT	European Conference of Postal and Telecommunications Administrations
CPR	Cloud Profiling Radars
ECC	Electronic Communications Committee
EESS	Earth Exploration-Satellite Service
EFVS	Enhanced Flight Vision Systems
e.i.r.p.	Equivalent Isotropically Radiated Power
ES	Earth Station
FS	Fixed service
GW	Gateway
GSO	Geostationary Orbit
ISL	Inter-Satellite Link
NGSO	Non-geostationary Orbit
PFD	Power Flux Density
RAS	Radio Astronomy Service
RNS	Radionavigation Service
SD	Spectral Density
VLBI	Very Long Baseline Interferometry

1 INTRODUCTION

Operators of next-generation NGSO constellations as well as GSO satellite networks have designed their networks and systems to connect millions of people to high-speed, low-latency broadband as well as other narrowband applications wherever they live, work, or travel. Keeping pace with rapidly growing demand from all users requires sufficient network capacity, including robust backhaul capacity through a global network of gateway (GW) earth stations with suitable spectrum for the intended operations. Because of the asymmetric traffic demand significantly higher frequency resources are required for the forward links from the gateways (GWs) towards the user terminals.

Recent technological advancements in GW technology allow satellite operators to leverage increasingly higher frequency bands. Some NGSO operators have already started using E-band frequencies (71-76 GHz / 81-86 GHz) on an operational basis in Europe with significant benefits and no interference concerns, but still more capacity is required to keep up with rapidly growing consumer demand. As such, these operators plan to explore the possibility of using W-band, i.e. the frequency bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz, and they have already started applying on a country-by-country basis for this spectrum.

As an example, one could assume next generation GWs will require achieving greater than 200 Gbit/s uplink throughput per antenna to accommodate extremely dense user demand, for example 10000 active users consuming 20 Mbit/s each (minimum broadband speed considered in medium future over next 10-15 years). This is not achievable with FSS spectrum available under 86 GHz alone, necessitating the need to expand to use W-band spectrum.

As traditional NGSO/GSO spectrum becomes increasingly congested and ever-more consumers demand ever-better broadband, next-generation satellite operators have looked toward higher frequencies to keep pace. These higher frequencies present two distinct advantages: large, contiguous bandwidth that provides robust connectivity and small, efficient “pencil beams” that enable, in case of GW operations, many users to share the spectrum in close physical proximity without harmful interference. At the same time, these higher frequencies have a major drawback: they are extremely sensitive to weather.

To maximise these benefits while minimising the drawbacks, next-generation satellite operators have been designing and deploying multi-band GWs, i.e. GWs that can operate in different frequency ranges and dynamically select channels depending on the network requirements as well as weather conditions. Existing multi-band GWs already deployed in Europe use both Ka-band and E-band, but user demand continues to outpace the available spectrum.

This means that the technology is available, with significant benefits and no or limited interference concerns, but still more capacity is required to keep up with rapidly growing consumer demand. This Report is discussing therefore the subject in more detail.

The application is the GW uplink towards the satellites (Earth-to-space direction), at which the sharing studies on the potential use of W-band, i.e. 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz are principally open for NGSO and GSO satellite systems. Currently, those frequencies are allocated to passive services (radio astronomy, earth exploration, space research) and certain terrestrial radio services (mostly FS) but not for FSS use in Europe and globally. The bands remain used at low level at this stage for active services and it appears there is only a very limited number of operational FS microwave links in Europe now according to ECC Report 173 [2].

The results of studies could be used to establish a frequency sharing environment and more efficient use by FS links and individually authorised FSS GWs such as it is practise in other lower frequency bands. It is also in line with the ECC’s strategy to foster the use of higher frequency ranges.

It should be noted that that individually authorised FSS GW uplink use in those frequencies proposed to be studied should be implemented without imposing any constraints on FS usage or any other use inside the band(s) and adjacent.

As a second step, and depending on the results of the Report, CEPT would consider what other actions may be needed.

It should be noted that the FCC in the USA has recently provided an authorisation and order [5] which includes 92.0-94.0 GHz, 94.1-100 GHz, 102.0-109.5 GHz, and 111.8-114.25 GHz and arguing that the proposal to add FSS uplink allocations in these bands would facilitate the future growth and innovation of next-generation satellite services and present a “first-mover advantage” for U.S.-licensed operators while encouraging other administrations to seek similar allocations for satellite communications in these bands.

Operations at frequencies within 81-114.25 GHz can also be considered as a technical precursor to the usage of optical GW links, once such frequency use and related algorithms are installed successfully in a satellite constellation. In a further step in future, such frequency use could be potentially replaced on physical layer by optical links (not that this relation is only from a technical perspective since GW uplinks as well as optical uplinks are used during good weather conditions; this should not be understood as aiming or stipulating any proposal towards regulation of optical wavelengths).

The following sections include:

- Information about technology availability and timeline (section 2);
- Considerations about the need for spectrum for gateway uplinks above 92 GHz (section 3);
- Need for technical studies with other services (section 4).

2 TECHNOLOGY AVAILABILITY AND TIMELINES

The technology for GW antennas in 71-76 GHz/81-86 GHz is already available and in use.

The technology demonstration was already provided in some national projects also involving in some cases national space agencies (such as the German satellite project EIVE using the W-band[1]).

The German regulator informed to have notified use to the ITU, operating already several gateway stations with uplink frequencies within 81-86 GHz and will also start using frequencies above 92 GHz as of the first half of 2026 for first demonstration and use and strictly under Radio Regulations (RR) No. 4.4 conditions [1]. There are several use cases in preparation for several NGSO providers and at least one commercial operator is going to use GW uplink frequencies in parts of the bands above 92-114.25 GHz. Besides this, there are also non-commercial activities (governmental/ military use).

It should be noted that a considerable fraction of frequencies above 70 GHz is designated for non-civil use.

As the use above 92 GHz is also considered a pre-cursor for optical technology implementations, it is necessary to consider the subject 'long-term' as it is not unrelated to future usage of optical GW links, once such frequency use and related algorithms are installed successfully in a satellite constellation. This is another technology aspect in this context where European industry should not fall behind developments outside of Europe.

The ITU filing USASAT-NGSO-3-SX1 (API/A/14150 of BR IFIC 3057) of the USA submitted on 12 Aug. 2025 is also noted, with frequency assignments above 92 GHz included under RR No. 4.4. The USA has granted an operator authority to use W-band in DA-26-36A1 [5] on 9 January 2026. The frequency assignments are still at the API/A stage and have not been notified to the ITU for the time being.

Germany has submitted on 11 December 2025 the MARS-44 filing (API/A 14252 of BRIFIC 3064) to the ITU Radiocommunication Bureau (BR) with frequency assignments above 92 GHz in support of experimental use/demonstration in Germany. The frequency assignments are still at the API/A stage and have not been notified to the ITU for the time being. First use has started in Germany in 2026.

[1] https://www.sciencedirect.com/science/article/abs/pii/S0094576523001042

3 CONSIDERATIONS ABOUT THE NEED FOR SPECTRUM

3.1 DEMAND AND NEEDED CAPACITY

The example in Table 1 and Figure 1 show a single next generation GW antenna field (consisting of multiple GW antennas) required to serve 100000 residential users and 20000 mobile users, with a simultaneous active use factor of 10% and 15% respectively. At 10 Mbit/s downlink consumption per active user (considered as the absolute baseline), this equates to at least 130 Gbit/s of total uplink capacity from the GW antennas.

A notional GW link operating at a spectral efficiency of 4.5 bps/Hz on two polarisations would require approximately 14.5 GHz of combined uplink bandwidth to achieve the required uplink capacity.

Table 1: W-band GW Uplink Capacity Example

Actual situation:	Example 1 - Baseline		German National Example	
			Today	Medium Future
Number of residential users	100000		200000	200000
Activity ratio of residential users	10%		10%	10%
Number of mobile users	20000		50000	50000
Activity ratio of mobile users	15%		15%	15%
Average data rate in forward link	10 Mbps		20 Mbps	40 Mbps
Resulting throughput requirement	130 Gbps		550 Gbps	1100 Gbps
Average spectral efficiency in forward link	4.5 bps/Hz		4.5 bps/Hz	4.5 bps/Hz
Resulting total bandwidth requirement (both polarisations)	28.9 GHz		122.3 GHz	244.5 GHz
Number of (dislocated) GW antenna uplink beams serving the total bandwidth (incl. Frequency re-use, beam/satellite selection)	1		1	1
Resulting bandwidth requirement per antenna, per polarisation	14.5 GHz		61.2 GHz	122.3 GHz
Future Trending:	Example 1		National example Today	
	Yearly increase of users (averaged)			
Year 1	15.9%	16.7 GHz	15.9%	70.9 GHz
Year 2	12.6%	18.9 GHz	12.6%	79.8 GHz
Year 3	10.0%	20.7 GHz	10.0%	87.8 GHz
Year 4	8.0%	22.4 GHz	8.0%	94.8 GHz

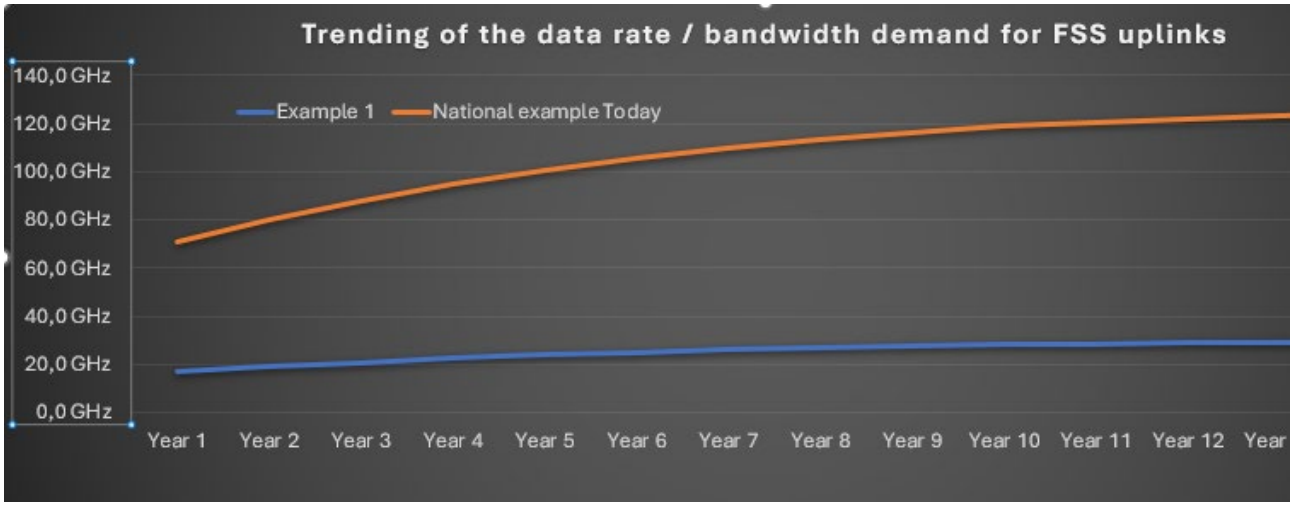


Figure 1: Trending - W-band GW Uplink Capacity Example

For the German National case, the Federal Network Agency commissioned to the Fraunhofer Institute several studies in 2023 to investigate the various means to provide universal broadband services to residential users as well as small and medium businesses and other users (government-related). The addressable market which is not served by terrestrial means (terrestrial fixed and mobile services) was considered as addressable and capturable market for satellite solutions assuming that the terrestrial alternatives are less expensive for users. The study for satellite related use is available in public [3].

The study looked into GSO as well as NGSO solutions and also investigated the potential capacity of the satellite solutions taking into account many aspects such as link performance, available resources, visible satellites and many more aspects such as regulatory constraints etc considered as playing an important role in providing capacity towards Germany.

Figure 2 shows the visibility of satellites for capacity estimates in case of a large NGSO constellation, which needs to be taken into account for the traffic distribution over beams for the GW infrastructure.

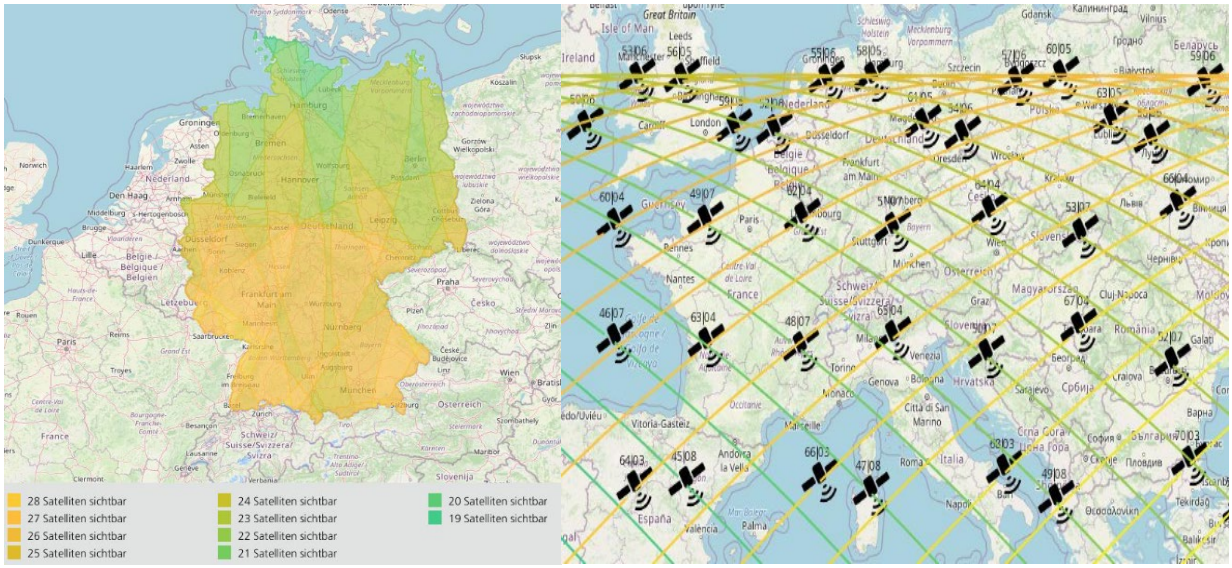


Figure 2: Visibility of satellites for capacity estimates in case of a large NGSO constellation

The study came to a result that our of the about 50 million potential users in Germany, about 200000 could be captured by satellite solutions within the coming decade and that available satellite capacity over Germany would just be sufficient to meet this demand.

At the end of 2025, such use figures are almost achieved in Germany, mainly served through NGSO solutions. It turned out that one underestimate consists in the aspect that, provided that terminals are small and easy to install for users and the performance is the same as for terrestrial solutions (good data speed and low latency), there is a fraction of the addressable market that is even ready to pay higher prices than for comparable terrestrial solutions and that also mobile/ nomadic use may come in more and more. This explains the higher than forecasted service take-up expected in the German study.

A crucial assumption is the bandwidth requirement per user in medium and long-term. From the baseline of 10 Mbit/s, this will increase at least to 60 Mbit/s in about one decade.

3.2 DISTRIBUTION OVER THE GATEWAY INFRASTRUCTURE BEAMS

Assuming a reference bandwidth per GW beam carrier of 500 MHz or 1 GHz, allows to calculate the number of GW beams needed in Forward (uplink) direction towards users. I.e. the number of beams in this Report is estimated on the basis of these reference bandwidths to be used typically in one of the available frequency bands.

Furthermore, it must be taken into account that the provision of additional frequency resources takes time for regulators to facilitate this through the appropriate regulatory study and decision-making processes.

Th assumptions above assume application of total averaging of the traffic which is never going to be achieved, i.e. some peak/average factor is also to be considered. Other factors (efficiency factors) come into the calculation due to the specific way a satellite constellation works, need for adaptive coding, co-existence with other providers (coordination)), regulatory constrains etc.

Not all FSS frequency resources will be available everywhere due to civil/mil restrictions, coordinated versus uncoordinated use, interference and also the need to have some capacity reserve (margin). Higher frequency resources in E-band and W-band may only be fully usable during good weather conditions.

Depending on the reference bandwidth per beam (typically 500 MHz or 1 GHz) the consideration therefore results to at least about 250-500 beams, which may increase even further depending on the future performance requirements and service take up. This provides justification to the need to consider multiple frequency band options for larger satellite networks and systems, mainly for GW uplinks in FSS, including bands above 92 GHz.

It should be taken into account that restrictions exist in other bands:

- 27.5-30 GHz: Only partially available due to other uses including FS usage, see also ECC Decision (05)01 [6];
- 42.5-43.5 GHz, 47.2-50.2 GHz, 50.4-51.4 GHz: Partially not open to commercial services in many countries as well as other use (FS), uncoordinated FSS in future etc., restrictions due to radio astronomy;
- 51.4-52.4 GHz: studies under WRC-27 AI 1.3, band is not open to NGSO usage at this stage;
- 81-86 GHz: considerable fraction of spectrum is not open to civil use in many countries. May also be used by terrestrial fixed and mobile services;
- > 92 GHz: some frequencies allocated to non-civil use only in many CEPT countries.

4 NEED FOR TECHNICAL STUDIES

The following indicates needs for studies in future. The main types of technical studies needed to ensure compatibility of FSS uplink operations of (individually authorised) GWs within all or parts of 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz (note that passive bands under RR No. 5.340 are excluded from the proposal) with relevant existing use are:

- Protection of EESS passive sensors in adjacent bands, i.e. 86-92 GHz and 114.25-122 GHz. Initial results are already available for 86-92 GHz, under WRC-27 agenda item 1.18 (resolves 1) (see revisions in the working document towards draft new Report under ITU-R RS.[1.18 – EESS] [7] in ITU-R WP 7C). It is agreed that the mask in Recommendation ITU-R SM.1541 [8] is not sufficient to ensure protection of EESS (passive). This analysis indicates that this mask should be replaced by another mask similar to the one provided for System B (StarLink), or an unwanted emission limit of either -45.7 dBW/GHz for NGSO FSS systems and -38.4 dBW/GHz for GSO FSS systems, or -37.9 dBW/6 GHz for NGSO FSS systems and -30.6 dBW/GHz for GSO FSS systems. Further work is needed to finalise these levels as well as to assess the aggregate effect of all FSS systems deployed together, as well as the need for apportionment of the EESS (passive) protection criterion. Similar analysis will be required for the cases covered by the present work item. It can be highlighted that METOP-SG_EUM was launched and notified in 2025 with an instrument operating in 115.2853-122.2153 GHz. It is further noted that Resolution 750 (Rev.WRC-19) [9] is applicable for FS in 92-94 GHz and under study for allocations in 111.8-114.25 GHz under WRC-27 AI 1.18. Technical studies would be required;
- Protection of EESS (active) in the adjacent band 94-94.1 GHz. This band is used for cloud profiling radars (CPR), such as the one operating on the EARTHCARE mission from ESA. Technical studies would be required;
- Protection of in-band FS service in their frequency bands, i. e. 92.125-93.875 GHz, 94.325-99.825 GHz, 102.125-109.375 GHz (10 GHz duplex), 112.025-114.025 GHz (19.9 GHz duplex) (see ECC Recommendation (18)02 [11]) containing FS channelisation arrangements, also including an unwanted emission mask for protection of EESS passive (see ECC Recommendation (18)02, annex 4). National coordination between FSS uplinks and FS receivers at frequencies above 92 GHz is definitely feasible and can be considered to be a national matter and CEPT ECC may assist in developing guidance on this aspect, as appropriate. Microwave link lengths are short at those frequencies, FSS uplink antenna pattern use higher elevations and with extreme small beamwidth as well as propagation conditions facilitate sharing. For information purposes, a dynamic simulation methodology is discussed in section 4.3 (note that this is not replacing any official study at a later stage);
- Protection of the radio astronomy service (RAS) primary allocations in all of these bands, also taking into account those adjacent bands in which RR No. 5.340 applies, prohibiting all emissions applies in the adjacent bands 86-92 GHz, 100-102 GHz, 109.5-111.8 GHz and 114.25-116 GHz. Furthermore, the proposed bands are subject to No. RR 5.149 and RR Article 29 (RAS), which states that all practicable steps must be taken to protect the RAS from harmful interference, and that emissions from spaceborne or airborne stations can be particularly serious sources of interference to the RAS (the latter aspect is alleviated by investigating use only in uplink direction in this case). However, specified minimum distances to be coordinated with specified radio astronomy observatories may be needed for such individually authorised FSS GWs. This can be considered to be a national matter and CEPT ECC may assist in developing guidance on this aspect. A further concern raised relates to reflexion/diffraction caused by satellites (see section 4.4.5);
- Based on the absence of a current FSS (earth-to-space) allocation and need to operate under RR No. 4.4, further frequency regulatory considerations are necessary (see section 4.5);
- Protection of the in-band radionavigation service in the frequency band 95-100 GHz. The new generation of Enhanced Flight Vision Systems (EFVS) under development are based on radar technology operating in 95-100 GHz (W band). This frequency band is allocated to radionavigation service (RNS) as primary services in the Radio Regulations, and further technical studies are required to define the required protection from the earth stations (see section 4.6).

No consideration is given at this time to the future situation (if there was an FSS (Earth-to-space) allocation between different FSS operators. WRC-23 concluded under AI 9.3 that frequency assignments of satellite networks and systems notified under RR No. 4.4 are not subject to coordination between each other.

4.1 SYSTEM DESCRIPTION

The characteristics of a studied NGSO system are presented below.

Table 2: GW Earth station characteristics

Description	Values
ES Gain Pattern	Recommendation ITU-R S.580 [20] with max 62 dBi gain; the use of Recommendation ITU-R S.580 may result in a conservative analysis, since actual antenna patterns in these band perform better than Recommendation ITU-R S.580
ES Max *e.i.r.p.* Density	40 dBW/MHz (see Note1)
Number of Uplink Beams per GW Site	32
Minimum Elevation Angle per Uplink Beam	15°
FSS ES Pointing Strategy	See satellite selection mechanism presented in Annex 1
Note1: The maximum *e.i.r.p.* value that will be used is 40 dBW/MHz and different from the maximum values from the filings.	

Typically, a large satellite network or systems may use several dozens of GW sites over Europe. The availability of several band options in future, together with satellite capabilities to handle high capacity and ISLs on the other hand my make it possible to reduce the number of GW sites. Such GW antennas can be small with the antenna aperture being only 1 m above the earth surface.

The example antenna patterns for 86-92 GHz and 114.25-122 GHz show the pencil beam shaping and related Equivalent Isotropically Radiated Power (*e.i.r.p.*) density are shown in Figure 3 and Figure 4, respectively. A typical 3 dB beamwidth is 0.1°.

It is to be expected that any coexistence analysis would consider specific information about anticipated FSS GW station operating parameters including deployment densities, earth station elevation angles, antenna characteristics (e.g., antenna polarisation, antenna pattern mask), station *e.i.r.p.*, and operating bandwidths including out-of-band performance).

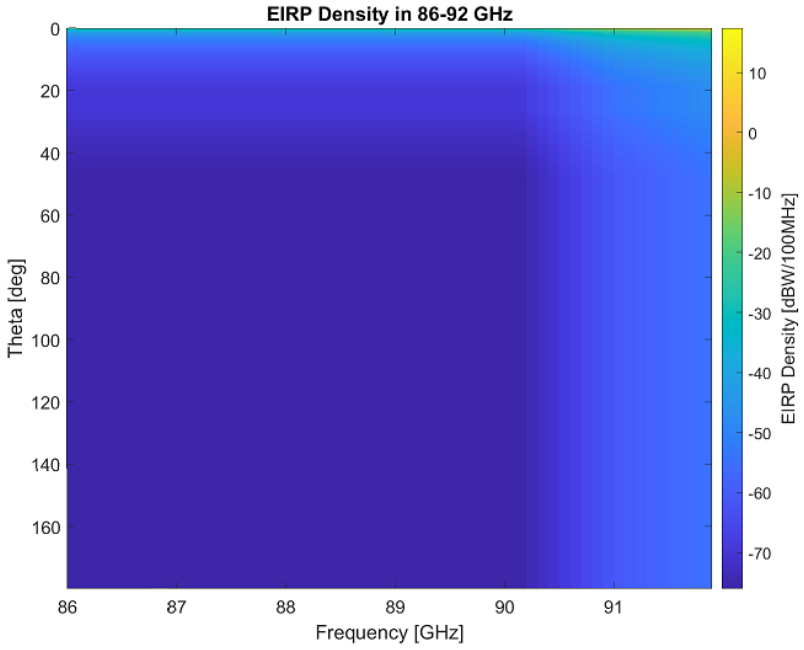


Figure 3: *e.i.r.p.* density in 86-92 GHz

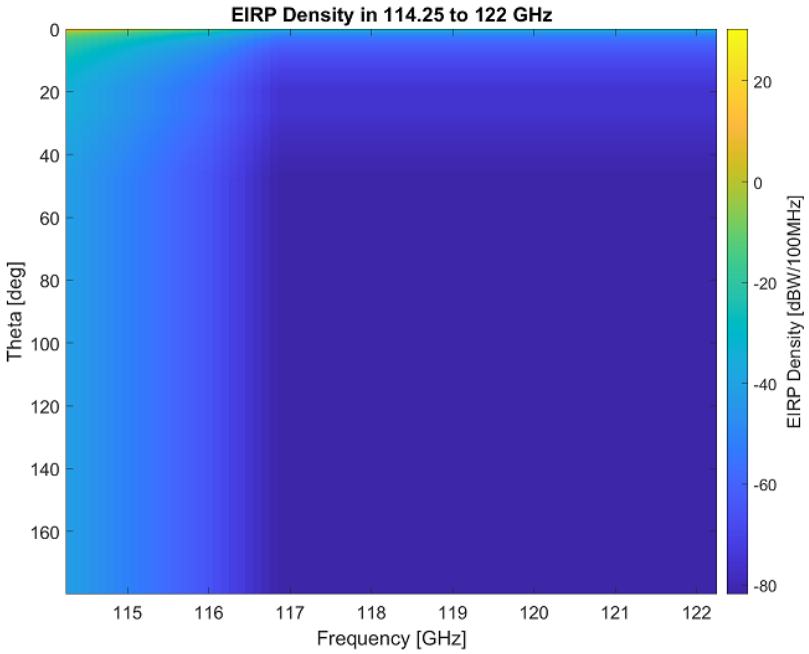


Figure 4: *e.i.r.p.* density in 114.25-122 GHz

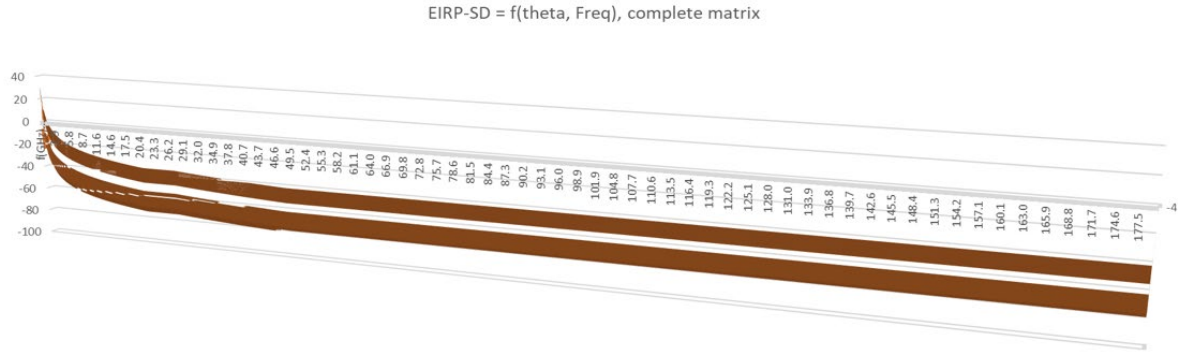


Figure 5: *e.i.r.p.* spectral density (SD) mask examples

Note: The notional mask examples are design examples and no proposed masks for the regulatory approach as this may be the result of future studies. These masks are not the same as the WRC-27 AI 1.18 mask because the example includes W-band operations. They are not symmetric in 86-92 MHz and above 114.25 GHz due to differences in power amplifier out-of-band roll-off. Figure 5 shows a complete matrix of *e.i.r.p.* spectral density masks examples.

Table 3: NGSO Orbital Parameters as given in the ITU filing

ITU Filing Name	Mars E-1 Config 1 (29988 satellites)								
Number of planes	28	28	28	30	48	48	48	12	18
Satellites per plane	120	120	120	120	110	110	110	12	18
Orbital altitude (km)	535	530	525	360	350	345	340	604	614
Inclination (deg)	33	43	53	96.9	38	46	53	148	115.7

4.2 EUROPEAN EESS (PASSIVE) SENSORS OPERATING IN 86-92 GHZ AND 114.25-122 GHZ

The set of current and future European EESS passive sensors operated by ESA and EUMETSAT in Table 4 was distilled from Recommendation ITU-R RS.1861, tables 33-35 [12].

Table 4: Overview of EESS European passive Sensors

Sensor in Recommendation ITU-R RS.1861	Band	Sensor	Satellite
L4	86-92 GHz	AMSU-A	Metop-A, Metop-B
L5	86-92 GHz	MHS	Metop-A, Metop-B
L9	86-92 GHz	MWS	Metop-SG-A
L10	86-92 GHz	MWI	Metop-SG-B
L13	86-92 GHz	AWS	AWS PFM
L16	86-92 GHz	HRMR (See Note1)	Sentinel-6A
M6	115.25-122.25 GHz	MWI	Metop-SG-B
Note1: HRMR is also planned for implementation on future ESA satellite CRISTAL			

Document Annex 10 to 7C/381-E [20] table 1, ITU-R WP 7C Report, includes latest information about ongoing studies at the time of writing this Report with regard to the protection of EESS (passive) by means of limits of unwanted emission power from FSS (E-to-s) within 86-92 GHz.

4.3 EUROPEAN EESS (ACTIVE) SENSORS OPERATING IN 94-94.1 GHZ

The following information on current and future European EESS sensors operated by ESA was distilled from Recommendation ITU-R RS.2105 [21], tables 33-35.

Table 5: Overview of EESS European Active Sensor

Sensor in Recommendation ITU-R RS.2105	Band	Sensor	Satellite
CPR-L2	94-94.1 GHz	CPR	EarthCARE

4.4 W-BAND DYNAMIC SIMULATION METHODOLOGY FOR FIXED LINK INTERFERENCE FROM NGSO EARTH-TO-SPACE LINKS

4.4.1 Introduction

To evaluate interference into FS links, a methodology using a dynamic simulation was conducted consisting of 32 antennas at the same GW tracking satellites over time. The objective is to determine the 80th percentile aggregate *e.i.r.p.* toward the horizon as a function of elevation angle.

At each time step, the off-axis angle and gain discrimination is calculated from each individual antenna to a grid of points spanning from -10 to +5° elevation and 0-360° azimuth with 0.25° bin size. The aggregate sidelobe *e.i.r.p.* is determined by summing the individual contributions at every point in the (azimuth, elevation) grid. A time history is kept for each bin. Based on the time series for each bin, the 80th percentile aggregate *e.i.r.p.* is determined as a function of elevation angle.

The following are indicative results. It should be noted that appropriate studies would need to be conducted in future. The order of magnitude of required coordination between GW FSS uplinks and FS victim receives seems however to be dominantly of national nature given the expected limited coordination distances.

4.4.2 Results in the 92-95 GHz

The GW Earth station characteristics are those in Table 2.

Figure 6 shows the simulated 80th percentile aggregate *e.i.r.p.* vs. elevation angle.

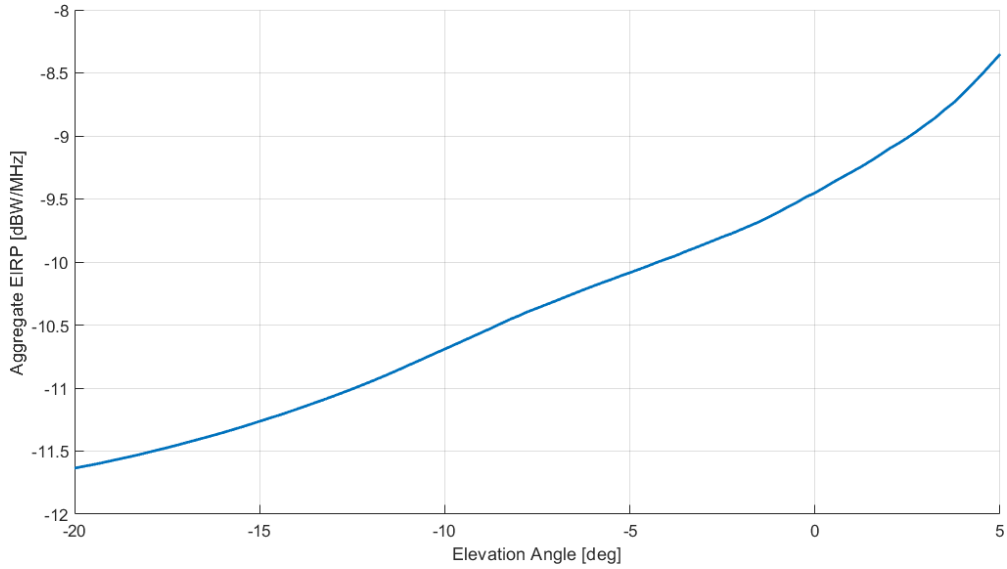


Figure 6: Aggregate *e.i.r.p.* vs. elevation angle (80th percentile)

Figure 7 shows the required separation distance to the victim in free-space needed to meet I/N of -10 dB, as a function of off-axis angle. This assumes a receiver noise figure of 8 dB.

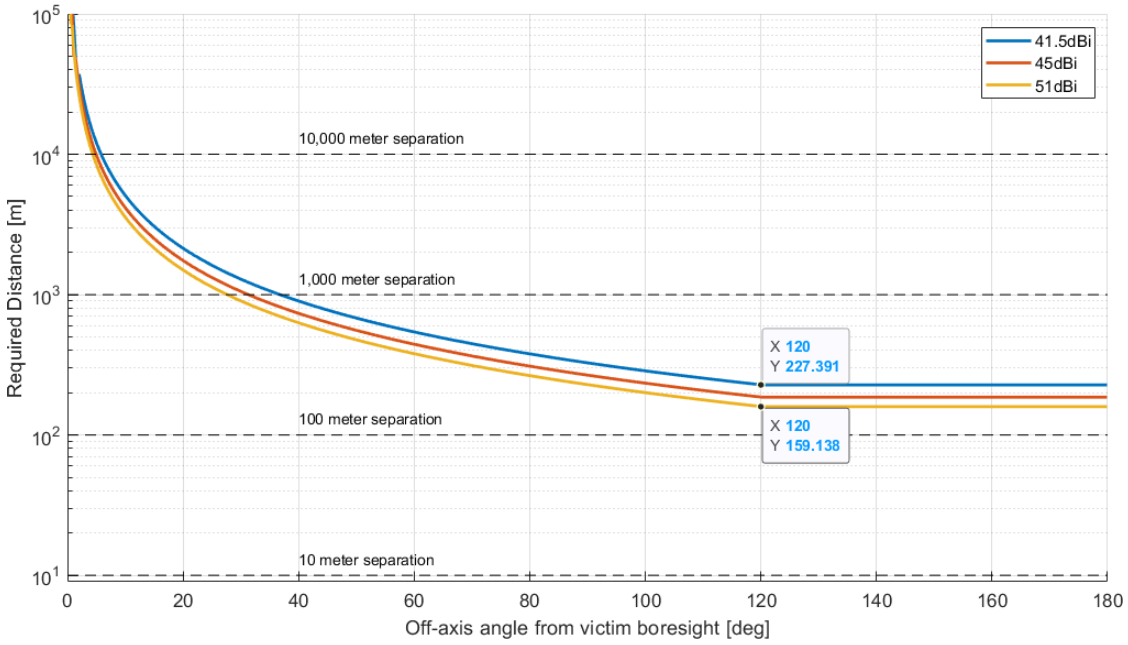


Figure 7: Required separation distance to meet long-term I/N of -10 dB as a function of victim off-axis angle, with receiver noise figure of 8 dB

Note that these results are calculated in free-space. Further accounting for buildings, clutter, and shielding in the surroundings will often mitigate interference further, at times in a significant manner.

4.5 PROTECTION OF THE RADIO ASTRONOMY SERVICE

4.5.1 Introduction

Radio astronomy at mm-wavelengths is rapidly evolving and has become a key method for investigating the universe. The millimetre radiation of molecules is not absorbed by interstellar clouds of dust, which has allowed its usage in the detection of several scientific phenomena's that might not be possible through other frequency bands. In the frequency bands under consideration in the range 92-116 GHz (3-4 mm) range, propagation characteristics are largely driven by atmospheric characteristics, such as water vapor content, which plays a significant role in site selection for radio astronomy systems. RAS allocations and protections in the Radio Regulations in this range are also motivated by atmospheric windows and propagation characteristics.

In the mm-range a lot of fundamental molecular transitions can be found (N2H+1-0, CN1-0, CO10 and isotopes are among the prominent ones), and most of the of the known molecules in the interstellar clouds were detected in the mm-range (137 in the range 50–300 out of the 240 known species) [4]. Also, it is a range where observations are sensitive to thermal dust emission, and the lower dust opacity, compared to higher frequencies, allows to peer deeper into the central regions of protoplanetary disks. Lastly, for good millimetre sites, this frequency range is the workhorse of the observatories, as the band is quite transparent under most conditions, contrary to higher frequency bands.

Many European observatories will soon be equipped with a novel tri-band receiver for Very Long Baseline Interferometry (VLBI) observations, with one of the three bands being the 3-4 mm band. This will be a boast for mm-VLBI, as the tri-band receiver will allow to improve the atmosphere phase shift calibration significantly.

4.5.2 Frequency band allocations

Table 6 lists the type of assignment made to RAS and includes the relevant referenced footnotes in the International Table of Frequency Allocations. Except for the frequency band 94-94.1 GHz, the entire band from 86 to 116 GHz is primary for the RAS. RR No. 5.149 refers to those bands where administrations are urged to take all practicable steps to protect the RAS and applies to both frequency bands where RAS is co-primary and to frequency bands where RAS has secondary status. RR No. 5.340 refers to those bands where all emissions are prohibited and applies to the adjacent ranges where RAS is co-primary with other passive services. These bands are used simultaneously for both continuum and spectral line observations. The interference threshold levels detrimental to the RAS are given in Recommendation ITU-R RA.769 [13].

Table 6: RAS allocations in the relevant frequency range

Frequency band	RAS allocations	Remarks
92-94 GHz	86–94 GHz (Primary) 94–94.1 GHz (Secondary)	92-94 GHz (RR 5.149)
94.1-100 GHz	Primary RAS band	94.1-100 GHz (RR 5.149)
102-109.5 GHz	Primary RAS band	102-109.5 GHz (RR 5.149) 105-109.5 GHz (RR. 5.562B)
111.8-114.25 GHz	Primary RAS band	111.25-114.25 GHz (RR 5.149) 111.8-114.25 (RR 5.562B)

4.5.3 Radio observatories in Europe

Table 7 presents a list of European RAS stations, which frequently operate in the 3-4 mm band.

Table 7: RAS stations in CEPT equipped with mm-band receiving systems

RAS station	Country	Geographic longitude	Geographic latitude
Lustbühel	Austria	15° 29' 34"	47° 04' 03"
Metsähovi	Finland	24° 23′ 36″	60° 13′ 05″
NOEMA	France	05° 54′ 29″	44° 38′ 02″
Effelsberg	Germany	06° 53′ 01″	50° 31′ 29″
BEST	Hungary	19° 32′ 23″	47° 54′ 22″
Medicina	Italy	11° 38′ 49″	44° 31′ 15″
Noto		14° 59′ 20″	36° 52′ 33″
Sardinia		09° 14′ 42″	39° 29′ 34″
IRAM 30m	Spain	–03° 23′ 34″	37° 03′ 58″
Yebes		–03° 05′ 13″	40° 31′ 29″
Onsala	Sweden	11° 55′ 04″	57° 23′ 35″

4.5.4 Need for coordination

Previous studies on the compatibility between FSS GW stations and radio astronomy stations in lower bands showed varying sizes of coordination zones on the level of unwanted emission and the atmospheric absorption. Report ITU-R S.2463-0 [14] showed distances in the range of 26 km and 228 km around RAS sites for the frequency band 51.4-54.25 GHz (Figure 8). It needs to be noted in this context that Report ITU-R S.2463-0 was considered when using GW earth station transmissions toward GSO satellites using higher uplink *e.i.r.p.* than NGSO GWs as described in section 4.1, Table 2. Further studies will be required to evaluate the sizes of coordination zones around the existing radio observatories in Europe and provide guidance to administrations on the methodology to calculate the sizes of these zones.

FIGURE 11

Compatibility analysis scenario

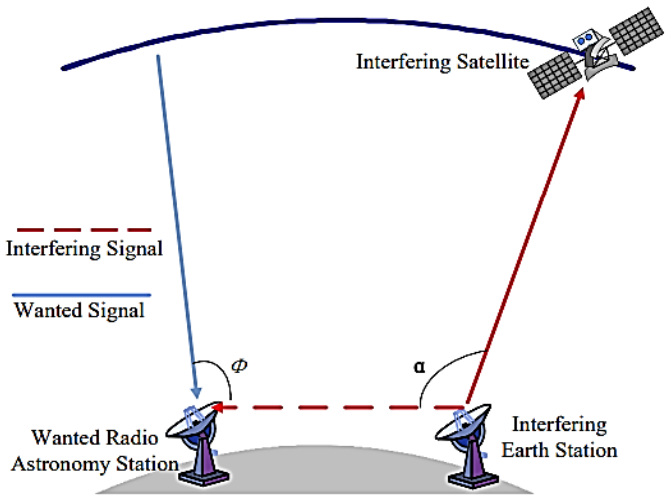


Figure 8: Interference scenario from FSS GW stations into the RAS stations (Source: Report ITU-R S.2463-0 [14])

Recommendation ITU-R RA.1272-1 [15] ("Protection of radio astronomy measurements above 60 GHz from ground based interference") recommends that coordination zones be established around mm-wave astronomical observatories, for all frequencies above 60 GHz where practicable; and that the threshold levels of interference detrimental to radio astronomy of Recommendation ITU-R RA.769, tables 1 and 2 [13] be used to define coordination zones for observations in the frequency range between 71 and 275 GHz, following the procedure outlined in Recommendation ITU-R RA.1031 [16].

Recommendation ITU-R RA.1031 dealing with protection of the RAS in frequency bands shared with active services provides a practicable guideline for establishing coordination zones around radio astronomy stations to protect the RAS from interference caused by transmitting earth stations used for space radiocommunication services that share frequency bands with the RAS. It is recommended that the coordination zone may be calculated, taking account of the methodology contained in Recommendation ITU-R RA.1031, annex 1.

4.5.5 Technical studies include reflexion/diffraction caused by satellites

Some administrations have considered in the last years the deployment of high *e.i.r.p.* radars for space satellite tracking/ space observation in frequency bands with the radio astronomy as a primary service.

A concern has been expressed that radar emissions toward satellites could be seen as transmission similar to earth stations uplinks, though investigations indicate that the peak emissions and power spectral densities of such space observation radars are considerably higher. Before authorising such transmissions, it was needed to study the impact of the reflexion/diffraction from satellites on national radio astronomy receivers. It was proposed to investigate this aspect further to ensure the protection of the radio astronomy is ensured before deployment of such station in Europe.

4.6 PROTECTION OF THE RADIONAVIGATION SERVICE

4.6.1 Introduction

Enhanced Flight Vision Systems (EFVS) is a system, that consist in displaying an image provided by a forward-looking sensor in a Heads-Up Display, to enhance pilots' natural vision and allow approach and landing in degraded weather conditions. EFVS systems use different sensing technologies, which include forward-looking infrared, millimetre wave radar or low-light level intensification; additional technologies may be developed in the future.

EFVS operations as reflected in the ICAO Annex 6 [22] offer the following benefits:

- They provide options for aircraft operators to land in very poor visual conditions on runways not equipped with expensive high performance Instrument Landing Systems rated CAT II/III;
- Although the operator should assess the suitability of the selected aerodrome, they do not require additional airport infrastructure;
- They do not require new approaches to be designed and expand capacities of already published Instrument Approach Procedures (IAP);
- They contribute to reducing the environmental footprint, by allowing direct access to secondary airports, reducing diversions as well as holding times and go-arounds;
- They reinforce crew awareness of the surrounding environment during approach, landing and taxiing, and thus, with appropriate training, contribute to flight safety in critical phases of the flight.

The current worldwide fleet of aircraft equipped with EFVS is estimated at over 3000, mostly in the business aviation and cargo sectors. A few regional aircraft have recently been equipped as well, and new developments are underway with the two largest commercial aircraft manufacturers. For most operators or aircraft owners, investment in this technology is motivated by the need to serve secondary airports in the largest range of weather conditions, as well as by the value found in such systems in terms of situational awareness.

4.6.2 Frequency band allocations

The following table shows the extract of the ECA Table for the frequency band considered for airborne EFVS radars, radionavigation usage.

Table 8: Service allocations in the relevant frequency range

RR Region 1 Allocation and RR footnotes applicable to CEPT	*European Common Allocation and ECA Footnotes*	*Applications*	*ECC/ERC harmonisation measure*	*Standard*	*Notes*
95 GHz - 100 GHz					
FIXED MOBILE RADIO ASTRONOMY RADIOLOCATION RADIONAVIGATION RADIONAVIGATION-SATELLITE 5.149 5.554	FIXED MOBILE RADIO ASTRONOMY RADIOLOCATION RADIONAVIGATION RADIONAVIGATION-SATELLITE 5.149 5.554	Fixed	ECC/REC/(18)02		
		Radio astronomy			Continuum and spectral line observations

RR No. 5.149 refers to those bands where administrations are urged to take all practicable steps to protect the radio astronomy service and applies to both frequency bands where RAS is co-primary and to frequency bands where RAS has secondary status

RR No. 5.554 refers to the authorization of satellite links connecting land stations at specified fixed points only when used in conjunction with the mobile-satellite service or the radionavigation-satellite service.

4.6.3 EFVS radar characteristics

The below table provides the technical and operational characteristics of typical EFVS radar sensor used for pilot's enhanced situation awareness and landing assistance. These characteristics should be used when conducting sharing and compatibility studies, as recommended in Recommendation ITU-R M.2162-0 [23].

Table 9: Characteristics of landing assistance radars in the frequency range 95-100 GHz

Parameter	Characteristic
Application	Landing assistance
Deployment area	Worldwide, airborne
Frequency range (GHz)	95.1-99.5
Transmit peak power (W)	0.5-1
Polarization	Linear
Pulse duration (μs)	100-200
Frequency modulation	FMCW
Antenna type	Active electronically scanned array
Radar height relative to the ground (m)	200..0 (Airborne – Final approach segment)
Antenna gain (dBi)	34-38
Antenna width (m)	0.4
Antenna beam width in azimuth (degrees)	0.5
Antenna scanning range in azimuth (degrees)	±15
Antenna beam width in elevation (degrees)	15

Parameter	Characteristic
Antenna scanning range in elevation (degrees)	±30[2]
Receiver noise figure (dB)	8-10
RF emission bandwidth (MHz)	30-60
Channel bandwidth (MHz)	80
Maximum channels number	4
I/N[3] protection criteria[4]	–6

4.7 CURRENT FREQUENCY ALLOCATION SITUATION AND NEED FOR REGULATORY CONSIDERATIONS

There are currently no space allocations for transmission in the RR for the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz. The bands are dedicated to passive services and transmission that could disrupt scientific measurements of the RAS or EESS (passive) shall be avoided. The bands are used by active services too as outlined in section 4 of this Report by FS channelisation arrangements, though the number of such microwave links is still small and their related link lengths (typically max. 1-2 km) are limited (see ECC Report 173 [2] for further information).

As can be seen in ECC Report 357 [17] and ECC Report 373 [18], transmissions from earth stations imply to operate with notified filing under RR No. 4.4 by a notifying administration at this stage. RR Nos. 11.2 and 11.3 imply the need for earth stations to be notified by each country where those stations are deployed. Due to the fact that uplinks are concerned the administrations should be known in case of interference issues. A mechanism should be established to know the CEPT countries authorising such station and inform the other CEPT countries.

As the ITU Radiocommunication Bureau (BR) does not verify and check RR No. 4.4 frequency assignments. CEPT administrations therefore need to address the administrative and technical issues. It is expected that solutions used in ECC Report 357 could potentially be replicated, i.e. a prior commitment letters from CEPT administrations authorising such deployments to comply with harmonised conditions and protection measures for the incumbent services. Such commitment letters would constitute an ITU agreement defining acceptable interference with other CEPT nations that could be the basis of complain when infringements are observed.

Operations under RR No. 4.4 also implies that no status, any form of coordination or international recognition is in place.

[2] The radar has no scanning in elevation, the beam is fixed with a down tilt of –6°, and the aircraft pitch variation is not compensated.

[3] In the absence of performance requirements.

[4] The protection criterion does not include aeronautical safety margin.

5 CONCLUSIONS

The present report provides initial information about assessment of potential individually authorised FSS (Earth-to-space) earth stations within the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8 - 114.25 GHz, considering the establishment of a frequency sharing environment and more efficient use by FS links and individually authorised FSS GWs such as it is practised in other lower frequency bands. This is in line with the ECC's strategy to foster the use of higher frequency ranges. Such GW uplinks would typically be authorised by means of individual authorisations.

The sections included:

- Information about technology availability and timeline (section 2);
- Considerations about the need for spectrum for GW uplinks above 92 GHz (section 3);
- Need for technical studies with other services (section 4).

CEPT administrations are invited to consider this Report and may trigger further studies within ECC as appropriate.

ANNEX 1: HIGHEST ELEVATION WITH TRACK OPTIMISATION PSEUDOCODE

Inputs:

- ϵ_0: minimum elevation angle of the NGSO system;
- α_0: minimum GSO arc avoidance angle of the NGSO system;
- lat: GSO ES latitude identified by Recommendation ITU-R S.1503 [19] algorithm;
- lon: GSO ES longitude identified by Recommendation ITU-R S.1503 algorithm;
- t: current time step;
- T: track duration, defined as in seconds to hold tracked satellites;
- P: percentile of timesteps to calculate the time-averaged angular separation over (%) to determine the time window M seconds over which the time-averaged angular separation metric is analysed, M = Max([floor(T * P / 100), 1]). If M = 1, there is no time-averaging in calculating the angular separation;
- reference_vectors[N,2]: list of N (az, el) pairs corresponding to the reference vectors for the N latitudes in the PFD mask. The vector (0°, 90°) is equivalent to the zenith vector specified by the highest elevation selection;
- num_track: maximum number of co-frequency NGSO satellites to/from a given location (Nco);
- all_sats[N, T]: position of all N NGSO satellites between time step t and t + T – 1.

Assumptions:

- Ability to plan satellite beam assignment for at least T time steps in the future;
- Once assigned, beams are held and tracked for T time steps until a new satellite selection is initiated.

Init:

hold_counter = 0

prev_selected_sats = []

At timestep t:

If (hold_counter = 0):

    selected_sats = GetLowestAvgRefVecSeparation(all_sats, lat, lon, P, ϵ_0, α_0)

Else:

    selected_sats = prev_selected_sats

    prev_selected_sats = selected_sats

hold_counter = (hold_counter + 1) mod T

GetLowestAvgRefVecSeparation(all_sats, lat, lon, P, $\boldsymbol{\epsilon_0}$, $\boldsymbol{\alpha_0}$):

- Step 1: Filter out all_sats to only those visible at (lat, lon) for all T. The number of satellites satisfying the above criteria is N_vis. If N_vis = 0 then return null. Assign all timesteps for the position of these satellites to visible_sats[N_vis, T];

- Step 2: Filter out visible_sats to only those satellites with elevation angle above ϵ_0 and GSO arc avoidance angle $\alpha > \alpha_0$ for all T. The number of satellites satisfying the above criteria is N_elig. If N_elig = 0 then return null. Assign all timesteps for the position of these satellites to elig_sats[N_elig, T];
- Step 3: Compute for each satellite in elig_sats the angular separation from the applicable reference vector in reference_vectors[N,2] at that latitude and assign it to sep_elig_sats[N_elig, T];
- Step 4: Sort sep_elig_sats by separation angle for each of the N_elig satellites individually in descending order and assign the M highest separation samples to p_sep_samps[N_elig, M];
- Step 5: Calculate the mean separation angle over the time window M in seconds for each of the N_elig satellites in p_sep_samps, assign this to avg_sep_samps[N_elig];
- Step 6: Return up to num_track rows in elig_sats corresponding to the indices of the num_track lowest values in avg_sep_samps.

ANNEX 2: LIST OF REFERENCES

[1] ITU Radio Regulations, Edition of 2024

[2] ECC Report 173: “Fixed Service in Europe Current use and future trends post 2022”, approved April 2012, latest amendment June 2023

[3] Consideration of satellite solutions for broadband services - Study commissioned by the Federal Network Agency Germany to the Fraunhofer Institute, available here

[4] Mc Guire 2021: ”2021 Census of Interstellar, Circumstellar, Extragalactic, Protoplanetary Disk, and Exoplanetary Molecules”, available here

[5] Federal Communications Commission (USA) DA-26-36A1: Authorization and Order including W-Bands:92.0-94.0 GHz, 94.1-95.0 GHz, 95.0-100.0 GHz, 102.0-109.5 GHz and 111.8-114.25 GHz.

[6] ECC Decision (05)01: ”The use of the band 27.5-29.5 GHz by the Fixed Service and uncoordinated Earth stations of the Fixed-Satellite Service (Earth-to-space)”, approved March 2005, latest amendment March 2019

[7] Annex 13 to Document 7C/317-E, 29 September 2025: Working Document Towards Preliminary Draft New Report ITU-R RS.[1.18 – EESS]

[8] Recommendation ITU-R SM.1541-7: “Unwanted emissions in the out-of-band domain”

[9] ITU Resolution 750 (Rev.WRC-19): “Compatibility between the Earth exploration-satellite service (passive) and relevant active services”

[10] ECC Recommendation (18)02: “Radio frequency channel/block arrangements for Fixed Service systems operating in the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz”, approved September 2018

[11] Recommendation ITU-R RS.1861-1: “Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz”

[12] Recommendation ITU-R RA.769-2: “Protection criteria used for radio astronomical measurements”

[13] Report ITU-R S.2463-0: “Sharing with incumbent services in the 51.4-52.4 GHz band and adjacent and nearby bands”

[14] Recommendation ITU-R RA.1272-1: “Protection of radio astronomy measurements above 60 GHz from ground-based interference”

[15] Recommendation ITU-R RA.1031-3: “Protection of the radio astronomy service in frequency bands shared with active services”

[16] ECC Report 357: “Regulatory analyses of satellite use in the band 862-870 MHz to communicate with terrestrial SRD”, approved June 2024

[17] ECC Report 373: “Exploring the regulatory and technical elements with respect to national authorisation of satellite based Direct-to-Device (D2D) communications via existing available smartphones”, approved 13 February 2026

[18] Recommendation ITU-R S.1503-4: “Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite service systems or networks with limits contained in Article 22 of the Radio Regulations”

[19] Recommendation ITU-R S.580: "Radiation diagrams for use as design objectives for antennas of earth stations operating with geostationary satellites"

[20] Annex 10 to 7C/381-E, 12 March 2026: "Working Document Towards Preliminary Draft New Report ITU-R RS.[1.18 – EESS]"

[21] Recommendation ITU-R RS.2105: "Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 40 MHz and 238 GHz"

[22] Annex 6 to the Convention on International Civil Aviation (ICAO): Operation of Aircraft - Part I, International Commercial Air Transport - Aeroplanes

[23] Recommendation ITU-R M.2162-0: "Technical and operational characteristics of radiolocation systems operating in the frequency range 92-100 GHz and radionavigation systems operating in the frequency range 95-100 GHz"