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| U.S. Radiocommunication Sector  Fact Sheet | |
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| **Document Title:** WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT  NEW REPORT ITU-R RA.[RAS-SAT 71-235 GHZ] Compatibility between RAS and active satellite services in the 71-235 GHz range | |
| **Author(s)/Contributors(s):**  Darcy Barron (UNM)  Josh Reding  Frank Schinzel | [dbarron2@unm.edu](mailto:dbarron2@unm.edu)  [josh.reding@aero.org](mailto:josh.reding@aero.org)  [fschinze@nrao.edu](mailto:fschinze@nrao.edu) |
| **Purpose/Objective:** Reconcile provided materials at previous 7D meeting to a WDPNR | |
| **Abstract:**  Annex 9 of the spring 7D chairman’s report is based on a previous contribution by the U.S. merged with additional contributions. This document aims to provide additional materials and reconcile provided materials by other parties with direct relevance to agenda item 1.18 *resolves 2*.  *[U.S. WP 7D Chair’s note: formatting of the input will be required if this document moves forward. There are some very mismatched font sizes and styles at present.]* | |

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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT  NEW REPORT ITU-R RA.[RAS-SAT 71-235 GHZ] | |

**Compatibility between RAS operating in the 76-81, 130-134, 164-167 and 226-231.5 GHz and adjacent active satellite services**

**Summary**

Annex 9 of the spring 7D chairman’s report is based on a previous contribution by the U.S. merged with additional contributions. This document aims to provide additional materials and reconcile provided materials by other parties with direct relevance to agenda item 1.18 *resolves 2*. To focus the report on providing a study on threshold values and general technical considerations for compatibility studies, Section 6 is proposed to be removed.

**Attachment**

ATTACHMENT

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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT  NEW REPORT ITU-R RA.[RAS-SAT 71-235 GHZ]  **Compatibility between RAS operating in the 76-81, 130-134, 164-167 and 226-231.5 GHz and adjacent active satellite services** | | |

# **1 Introduction**

{Editor’s note: administrations are invited to contribute to the development of this document with the objective of summarizing the general sections such as the Introduction}

This Report addresses compatibility between the RAS and the active satellite services in the 71-235 GHz range and adjacent and nearby frequency bands listed in Table 1.

Radio astronomy at mm-wavelengths is rapidly evolving and has become a key means for investigating the universe. It has been crucial in detecting numerous interstellar molecules, such as water and carbon monoxide in space, as well as many unknown on Earth. The millimeter radiation of molecules is only minimally absorbed or scattered by interstellar dust, which has allowed for these numerous discoveries made to date. Other topics of interest for which mm-wave observations yield key scientific insights include the observation of star and planet formation processes, study of emission from the vicinity of compact objects such as black holes, and study of the earliest galaxies.

To detect such faint naturally occurring signals of cosmic emissions at mm-wavelengths, parabolic reflectors are typically used, which can be combined interferometrically to achieve the highest possible spatial resolutions. The most productive facility currently in operation at the frequency bands covering 71-235 GHz is the Atacama Large Millimeter/submillimeter Array (ALMA), situated in Chile and which is expected to continue to receive technical upgrades well beyond 2030. Single dish telescopes and smaller interferometric facilities are also in operation around the world, all of which provide unique observational capabilities in these frequency bands. Most recently, a new facility that will include radio telescopes located across North America—the next generation Very Large Array (ngVLA) was rated among the top two projects in the U.S. National Academy of Sciences’ Astro2020 decadal survey (“Pathways to Discovery in Astronomy and Astrophysics for the 2020s”). The ngVLA will vastly improve observational capabilities in the 67-116 GHz range in the northern hemisphere and is expected to start construction in the 2020-2030 decade. In addition to interferometers, single-dish telescopes operate within this frequency range across the globe, including the Arizona Radio Observatory in the U.S.A., the Large Millimeter Telescope in Mexico, the Atacama Pathfinder Experiment in Chile, and the IRAM 30m Telescope in Spain.

Relevant characteristics of radio astronomy service (RAS) systems are provided in a number of ITU-R reports. A detailed description of technical and operational characteristics of RAS facilities operating in the mm-wavelength range is provided in Report [ITU-R RA.2510-0](https://www.itu.int/pub/R-REP-RA.2510). Information about widely-distributed RAS arrays operating above 200 GHz may be found in Report [ITU-R RA.2508](https://www.itu.int/pub/R-REP-RA.2508-2022). Technical and operational characteristics of broadband, background-limited detectors operating in the mm-wave regime is provided in Report [ITU-R RA.2512](https://www.itu.int/pub/R-REP-RA.2512-2022).

The frequency bands allocated to RAS enable observations of a multitude of physical phenomena, including thermal and non-thermal continuum emission and spectral line emission from atoms and molecules. Radio telescopes require sensitive receivers and a low noise environment in order to detect this extremely faint naturally occurring radio emission. The feasibility of sharing and compatibility must recognize the need to protect the passive services. The threshold emission levels detrimental to the RAS are listed in Recommendation [ITU-R RA.769-2](https://www.itu.int/rec/R-REC-RA.769/en) (see also RR No. **5.149** and RR No. **5.340**).

# **2 Protection criteria for RAS**

Resolution **712 (WRC-23)** addresses issues related to the protection of several passive services: *Resolves* 1 for EESS passive, *resolves* 2 for Radio Astronomy Service (RAS). In particular *resolves to invite the ITU Radiocommunication Sector to complete in time for the 2027 world radiocommunication conference* 2studies between the RAS *and the active satellite services in certain adjacent and nearby frequency bands listed in Table 1 below with a view to setting the relevant threshold levels for unwanted emissions from any GSO and non-GSO space stations and revising and updating Resolution* **739 (Rev.WRC-19)** *accordingly.*

The frequencies ranges under study are listed in the table below:

TABLE 1

RAS frequency bands studied and corresponding active services to be included in this report

|  |  |  |
| --- | --- | --- |
| Radio astronomy  frequency band | Active satellite service frequency band | Active satellite service  (space-to-Earth) |
| 76-81 GHz | 71-76 GHz | Fixed-satellite service (FSS), mobile-satellite service (MSS), broadcasting-satellite service (BSS) |
| 130-134 GHz | 123-130 GHz | FSS, MSS, radionavigation-satellite service (RNSS) |
| 164-167 GHz | 167-174.5 GHz | FSS |
| 226-231.5 GHz | 232-235 GHz | FSS |

## 2.1 Current sharing and protection requirements for RAS in the 76-235 GHz range

Between 76 and 235 GHz, the RAS currently shares 45% (43 GHz) of the band with active satellite services, which include amateur-satellite, broadcasting-satellite, EESS (active), fixed-satellite (FSS), inter-satellite, mobile-satellite (MSS), radionavigation-satellite (RNSS), and space research (active). A complete summary is provided in Report ITU-R RA.2510, while here we provide an excerpt focusing on FSS, MSS, BSS, and RNSS. Table 2 provides a summary of the applicable bands, highlighting both the relevant active services and RAS bands, including specific bands to be included in this report, as listed in Table 1. This provides the context within which studies are performed.

In most cases where sharing of RAS with active services is indicated, RR No. **5.149** applies, which encourages administrations to take all practicable steps to protect the RAS from harmful interference. This footnote includes caution that emissions from spaceborne or airborne stations can be particularly serious sources of interference to RAS, which is also the case for active satellite services. RR No **5.340**, also referenced for certain bands in Table 2, notes that all emissions are prohibited. 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 for the lower and upper part for the frequency range respectively as −129 to −119 dB(W/m2) and −228 to −218 dB(W/(m2 Hz)) for continuum observations, and −148 to −139 dB(W/m2) and −208 to −199 dB(W/(m2 Hz)).

TABLE 2

Overview of RAS frequency bands and bands of the active satellite services FSS, MSS, BSS   
and RNSS in the 71-235 GHz range

| Frequency range (GHz) | FSS/MSS/BSS/RNSS service allocation | RAS status | Footnote referencing RAS |
| --- | --- | --- | --- |
| 71-74 | FSS (space-to-Earth) MSS (space-to-Earth) | None | None |
| 74-76 | FSS (space-to-Earth) BSS | None | None |
| 76-77.5 | None | Co-primary with other active services | **5.149** |
| 77.5-79 | None | Secondary | **5.149** |
| 79-81 | None | Co-primary with other active services | **5.149** |
| 81-84 | FSS (Earth-to-space) MSS (Earth-to-space) | Co-primary with other active services | **5.149** |
| 84-86 | FSS (Earth-to-space) | Co-primary with other active services | **5.149** |
| 86-92 | None | Co-primary with other passive services | **5.340** |
| 92-94 | None | Co-primary with other active services | **5.149** |
| 94-94.1 | None | Secondary | **None** |
| 94.1-95 | None | Co-primary with other active services | **5.149** |
| 95-100 | RNSS | Co-primary with other active services | **5.149** |
| 100-102 | None | Co-primary with other passive services | **5.340** |
| 102-105 | None | Co-primary with other active services | **5.149** |
| 105-109.5 | None | Co-primary with other active and passive services | **5.149** |
| 109.5-111.8 | None | Co-primary with other passive services | **5.340** |
| 111.8-114.25 | None | Co-primary with other active and passive services | **5.149** |
| 114.25-116 | None | Co-primary with other passive services | **5.340** |
| 123-130 | FSS (space-to-Earth) MSS (space-to-Earth) RNSS | Secondary | **5.562D**, **5.149** |
| 130-134 | None | Co-primary with other active services | **5.149** |
| 134-136 | None | Secondary | **None** |
| 136-148.5 | None | Co-primary with other active services | **5.149** |
| 148.5-151.5 | None | Co-primary with other passive services | **5.340** |
| 151.5-158.5 | None | Co-primary with other active services | **5.149** |
| 158.5-164 | FSS (space-to-Earth) MSS (space-to-Earth) | None | None |
| 164-167 | None | Co-primary with other passive services | **5.340** |
| 167-174.5 | FSS (space-to-Earth) | None | **5.149, 5.562D** |
| 182-185 | None | Co-primary with other passive services | **5.340** |
| 190-191.8 | None | None | **5.340** |
| 191.8-200 | MSS, RNSS | None | **5.149** |
| 200-209 | None | Co-primary with passive services | **5.340** |
| 209-226 | FSS (Earth-to-space) | Co-primary with active and passive services | **5.149** |
| 226-231.5 | None | Co-primary with passive services | **5.340** |
| 232-235 | FSS (space-to-Earth) | None | None |

## 2.2 Threshold interference levels for observations above 76 GHz

This section provides pfd additional calculations not provided in Rec. ITU-R RA.769-2 as well as epfd for specific frequencies above 76 GHz and for updated receiver noise temperatures, reflecting current state of the art of deployed systems.

The interference power threshold *I* described in Annex 1 from Recommendation ITU-R RA.769 (corresponding to for continuum and spectral lines observations[[1]](#footnote-1), specific for VLBI observations) is needed to compute the values from Tables 1 and 2 from Resolution **739 (Rev.WRC-19**). *I* depend on several parameters such as the frequency of observation, the integration time *t*, the receiver bandwidth and the radio-telescope system temperature *Tsys*. *Tsys*is the addition of *TA*, the minimum antenna noise temperature (the sum of the antenna temperature components from the cosmic background, the Earth’s atmosphere and from the ground radiation in the sidelobes) and *TR*, the receiver noise temperature.

Since values from Rec ITU-R RA.769-2 are based on a 2000s integration time, it is assumed that *t*=2000 s.

Whatever the nature of the observation (continuum, spectral line or *Very Long Baseline Interferometry VLBI*) is considered, the receiver noise temperature remains the same as it’s independent of the measurement bandwidth unlike the antenna noise temperature *TA*. Section 1.5 from Recommendation ITU-R RA.769-2 announces for where *h* is the Planck’s constant and the centre frequency. Noting that frequency ranges under study are higher 70 GHz and that from 89 GHz, based on Recommendation ITU-R RA.769-2, it can be concluded that:

As stated in Section 1.4 from Recommendation ITU-R RA.769-2 for continuum observations, *Above 71 GHz a value of 8 GHz is used, which is a representative bandwidth generally used on radio astronomy receivers in this range*. Moreover, for spectral lines observations, the *channel bandwidth used to compute the detrimental levels above 71 GHz is 1 000 kHz (1 MHz) in all cases*. Although no direct information regarding the bandwidth over which VLBI measurements are performed, one could notice that bandwidth mentioned in Resolution **739 (WRC-19)** for VLBI always matches with those used for spectral lines observations. It’s then proposed to apply the same bandwidth for spectral lines and VLBI observations above 71 GHz i.e. 1 MHz.

From section 1.1 of Annex 1 from Recommendation ITU-R RA.769-2, the interference threshold for continuum and spectral lines observations is as follows:

(1)

From sections 1.1 and 2.3 from Rec ITU-R RA.769-2, the interference threshold for VLBI observations is as follows:

(2)

where *k* relates to the Boltzmann constant.

The power flux density (pfd) interference threshold is as follows:

TABLE 3

Threshold levels of interference detrimental to radio astronomy continuum observations above 76 GHz

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Frequency (GHz) | Centre Frequency (GHz) | Minimum antenna noise temperature (K) | Receiver noise temperature (K) | pfd (dB(W/m^2)) | Spectral pfd (dB(W/m^2 Hz))) |
| 76-81 | 78.5 | 12 | 25 | -131 | -230 |
| 130-134 | 132 | 14 | 30 | -125 | -224 |
| 164-167 | 165.5 | 14 | 32 | -123 | -222 |
| 226-231.5 | 228.5 | 20 | 40 | -119 | -218 |

*The bandwidth assumed is 8 GHz for all bands for 2000s integration.*

TABLE 4

Threshold levels of interference detrimental to radio astronomy spectral-line observations above 76 GHz

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency (GHz) | Centre Frequency (GHz) | pfd (dB(W/m^2)) | Spectral pfd (dB(W/m^2 Hz))) |
| 76-81 | 78.5 | -150 | -210 |
| 130-134 | 132 | -145 | -205 |
| 164-167 | 165.5 | -143 | -203 |
| 226-231.5 | 228.5 | -139 | -199 |

*The bandwidth assumed is 1 MHz for all bands for 2000s integration.*

TABLE 5

Threshold interference levels for VLBI observations above 76 GHz

|  |  |
| --- | --- |
| Frequency  (GHz) | Threshold level  (dB(W/m2 ⋅ Hz))) |
| 78.5 | -174 |
| 132 | -168 |
| 165.5 | -166 |
| 228.5 | -162 |

Peak gain of the radio-telescope antenna is generally provided in Recommendation ITU-R RA.1631. A revision of this recommendation is proposed to extend the typical maximum antenna gain for RAS allocated bands up to 275 GHz. Following the method described under Recommendation ITU-R RA.1631, the typical maximum antenna gain values for RAS allocated bands under consideration in this report are provided in Table 6.

Table 6

*Typical maximum antenna gain for RAS allocated bands above 76 GHz*

|  |  |
| --- | --- |
| Frequency (GHz) |  |
| 76-81 GHz | 98 dBi |
| 130-134 GHz | 94 dBi |
| 164-167 GHz | 96 dBi |
| 226-231.5 GHz | 98 dBi |



# 3 Satellite system characteristics

{Editor’s note: Reply liaison statement (LS) received from WP 4C. Waiting RLS from WP 4A. This section will require an update upon receiving a response from WP 4A.}

Tables 1 and 2 of Annex in this document summarize system characteristics that could be used in compatibility studies within the context of WRC-27 agenda item 1.18. Additionally, systems listed in the Master International Frequency Register (MIFR) with frequency assignments in the 71-76 GHz and 81-86 GHz bands could also be used for compatibility studies.

In the non-GSO systems listed in the tables 1 and 2 of the Annex, it is important to assume a constant power flux density (pfd) for the Fixed-satellite Service (FSS), which is allocated in the following frequency bands: 71-76 GHz, 81-86 GHz, 123-130 GHz, 158.5-164 GHz, 167-174.5 GHz, 209-217 GHz, and 232-235 GHz.

Mobile-satellite Service (MSS) is allocated in the following frequency bands: 71-74 GHz, 81-84 GHz, 123-130 GHz, 158.5-164 GHz, and 191.8-200 GHz. Radionavigation-Satellite Service (RNSS) is also allocated in the 123-130 GHz and 191.8-200 GHz bands.

Information on the technical and operational characteristics of MSS and RNSS networks and systems can be found in the relevant ITU filings.

With regard to the modeling of these MSS and RNSS systems, Recommendation ITU-R M.1583, which provides guidance on interference calculations between non-geostationary Mobile-Satellite Service (MSS) or Radionavigation-Satellite Service (RNSS) systems and radio astronomy telescope sites, is suggested for modeling interference levels.

# 4 Propagation characteristics

{Editor’s note: Information in this section should be checked, considering the Reply LS received from WPs 3J/3M}

Above 71 GHz, atmospheric absorption is a key factor in compatibility studies, but also varies widely depending on the particular atmospheric characteristics considered, e.g., the presence of oxygen and water vapor. Overall propagation loss can vary greatly with respect to, e.g., frequency, altitude, water vapor content, and elevation angle. Thus, care must be taken to understand the entirety of the particular propagation loss scenario and to limit active emissions to levels that do not cause harmful interference to RAS systems. Compatibility studies must be carried out using the most transparent atmospheric conditions relevant to the site in question, usually the 10th percentile lowest attenuation weather conditions.

The three most important elements for compatibility include (1) site elevation (and atmospheric conditions); (2) site location for any ground-based terrain shielding, attenuation due to clutter, etc.; (3) transmitter characteristics, including power level, beam size/shape, and whether the transmitter is ground-based, air borne, or in space. For active satellite service compatibility, ground-based terrain shielding does not play a role, where interference is primarily driven through line-of-sight effects and beam-sidelobe coupling.

Section 3 of Report ITU-R RA.2510-0 provides a summary of atmospheric attenuation characteristics in the frequency range of concern and thus will not be repeated in this Report.

While Earth curvature, scattering and terrain shielding can add attenuation and decrease the separation distance to meet the Recommendation ITU-R RA.769-2 power limits, this is primarily for ground-based transmitters. For airborne and space-based transmitters, as described in RR No. **5.149**, much larger separation distances are needed to avoid levels of harmful interference.

{Atmospheric Considerations for Compatibility, Attenuation levels etc. and other considerations; factors as provided by WPs 3J/3M}

# 5 Compatibility of active satellite services with RAS

Protection criteria used for radioastronomical measurements and the acceptable data loss levels are laid out in Recommendation ITU-R RA.769-2 and Recommendation ITU-R RA.1513-2 respectively.

Recommendation ITU-R RA.769-2 provides the methods to calculate threshold interference levels as the received input power, power flux density, and spectral power flux density, for a given set of values for integration time, frequency, bandwidth, and antenna- and system temperature of the receiving radio astronomical system. It also provides a set of tables listing those values for continuum and line observations for a number of representative frequencies (with allocations to RAS in the ITU Radio Regulations (RR)). Recommendation ITU-R RA.769-2 assumes an integration time of 2000 seconds to calculate sensitivities and interference levels in Tables 1 and 2, but actual integration times used in astronomical observations cover a wide range of values and the calculated values could be adjusted accordingly.

Recommendation ITU-R RA.1513-2 discusses and specifies the practicability of meeting the requirement of threshold interference levels for radio astronomy and recommends data loss percentages for interference ("levels of data loss"), in particular through unwanted emission, for which an interferer may exceed the levels recommended in Recommendation ITU-R RA.769-2. The total recommended data loss percentage for the aggregate interference from all systems, above the threshold from Recommendation ITU-R RA.769-2, is 5 percent, while the recommended data loss percentage for a single system is 2 percent.

Further discussion on how to apply these criteria can be found in section 6.

## 5.1 Considerations for GSO satellites

Typically geostationary orbit (GSO) satellites occupy a specific band in astronomical declination, which is geographic latitude dependent. The severity of satellite transmissions for observations is a strong function of the angular offset between the particular satellite and the antenna. For the Very Large Array (VLA) in New Mexico, USA, it appears that significant degradation can occur if antennas point within about 10 degrees of a satellite. The great majority of GSO satellites as seen from the VLA are found along a band of about -5.5 degrees in declination. Thus, for observation planning it is important to know satellite locations, specific transmission frequencies, and power levels, as well as information of transmission beams. To date there exists no comprehensive database that provides this information in one place would impacts on observations by pointing of telescopes at particular positions in the sky, where power levels would drive broad-band receiving systems into saturation.

In order to calculate the interference threshold levels for the frequency bands described in Table 1 from this document, if the active satellites system is a set of GSO space stations, the interference threshold can be expressed through the power flux density (pfd) **per GSO space station** threshold as follows:

Noting that this Recommendation states: *The values given are for an antenna having a gain, in the direction of arrival of the interference, equal to that of an isotropic antenna (which has an effective area of c 2 /4π f 2 , where c is the speed of the light and f the frequency). The gain of an isotropic radiator, 0 dBi, is used as a general representative value for the side-lobe level*, (in linear scale) leading:

Additionally, levels should be adjusted by -15 dB, as noted in Recommendation ITU-R RA.769-2, to correspond to a 5 degree angular discrimination using the radio telescope antenna pattern from Recommendation ITU-R SA.509. This discrimination is not noted in Table 1 of **Resolution 739 (Rev. WRC-19).**

Table 7

**pfd threshold for unwanted emissions from any GSO space station (dBW/m2) with angular discrimination adjustment applied**

|  |  |  |  |
| --- | --- | --- | --- |
| **Radio astronomy frequency band** | **pfd  continuum** | **pfd  spectral line** | **pfd  VLBI** |
| 76-81 GHz | −146 | −165 | −129 |
| 130-134 GHz | −140 | −160 | −123 |
| 164-167 GHz | −138 | −158 | −121 |
| 226-231.5 GHz | -134 | −154 | −117 |

## 5.2 Considerations for non-GSO satellites

In order to calculate the interference threshold levels for the frequency bands described in Table 1 from this document, if the active satellites system is a set of non-GSO space stations, the interference threshold can be expressed through the equivalent power flux density (epfd) **per non-GSO satellites system** using the peak gain of the radio-telescope antenna as follows:

In addition, active satellite systems in non-GSO orbits operate as constellations, aggregate interference for each system should be taken into account to determine appropriate threshold levels to protect observations. This will depend on system specific technical parameters.

Table 8

**epfd threshold for unwanted emissions from non-GSO satellites system (dBW/m2)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Radio astronomy frequency band** | **epfd continuum** | **epfd  spectral line** | **epfd  VLBI** |
| 76-81 GHz | −229 | −248 | −212 |
| 130-134 GHz | −219 | −239 | −202 |
| 164-167 GHz | −219 | −239 | −202 |
| 226-231.5 GHz | -217 | −237 | −200 |

# 6 Compatibility criteria

{Mitigations to Enhance Sharing; Description of possible compatibility strategies such as geographic exclusion zones, or time duplexing}

# 7 References and related ITU-R documents

Report [ITU-R RA.2131](https://www.itu.int/pub/R-REP-RA.2131) – *Supplementary information on the detrimental threshold levels of interference to radio astronomy observations in Recommendation ITU-R RA.769*

Report [ITU-R RA.2457](https://www.itu.int/pub/publications.aspx?lang=en&parent=R-REP-RA.2457) – *Coexistence between the radio astronomy service and radiolocation service applications in the frequency band 76-81 GHz*

Report [ITU-R RA.2508](https://www.itu.int/pub/R-REP-RA.2508) – *Widely-distributed radio astronomy array systems operating above 200 GHz*

Report [ITU-R RA.2510](https://www.itu.int/pub/R-REP-RA.2510) – *Technical and operational characteristics of radio astronomy systems in the 67-116 GHz (3-4 mm) range*

Report [ITU-R RA.2512](https://www.itu.int/pub/R-REP-RA.2512) – *Technical and operational characteristics of broadband, background-limited detectors operating in the millimetre-wave regime*

Recommendation [ITU-R RA.769-2](https://www.itu.int/rec/R-REC-RA.769/en) – *Protection criteria used for radio astronomical measurements*

Recommendation [ITU-R RA.1750](https://www.itu.int/rec/R-REC-RA.1750/en) – *Mutual planning between the Earth exploration-satellite service (active) and the radio astronomy service in the 94 GHz and 130 GHz bands*

Recommendation ITU-R RA.1631-0 – *Reference radio astronomy antenna pattern to be used for compatibility analyses between non-GSO systems and radio astronomy service stations based on the epfd concept*

Recommendation SM.1541-7–*Unwanted emissions in the out-of-band domain*

Recommendation ITU-R RA.1513-2 – *Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy service on a primary basis*

Recommendation ITU-R M.1583-1 – [ITU-R M.1583](https://www.itu.int/rec/R-REC-M.1583/en)–*Interference calculations between non-geostationary mobile-satellite service or radionavigation-satellite service systems and radioastronomy radio astronomy telescope sites*

Recommendation ITU-R S.1586-1 – *Calculation of unwanted emission levels produced by a non-geostationary fixed-satellite service system at radio astronomy sites*

# 8 List of acronyms and abbreviations

Annex 1

Characteristics of satellite systems

[WP 4A, 7D/139]

Table 1

Orbit configuration

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | System A | System B[[2]](#footnote-2) | System C |
| Height (km) | 590, 610, 630 | 525, 530, 535 | 35 786 |
| Number of planes | 28, 36, 34 | 28, 28, (24,4) | 1 |
| Satellites per plane | 28, 36, 34 | 120, 120, (28,27) | 1 |
| Inclination angle (deg) | 33, 42, 51.9 | 53, 43, 33 | 0 |
| RAAN | Equally spaced | Equally spaced |  |

TABLE 2

Operational characteristics

| Parameter | For System A | For System A | For System B | For System B | System C | System C | System B | System B | System B |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency (GHz) | 71-76 | 81-86 | 71-76 | 81-86 | 71-76 | 81-86 | 123-130 | 158.5-164 | 167-174.5 |
| Peak antenna gain (dBi) | 41.9 or 48 | 53.6 (D: 1 m, 59.6 (D: 2 m, ), 64.5 (D: 3.5 m) | 52 | 60.9 (D: 1.85 m) | 50 | 50 (D:0.6 m) | 52 | 52 | 52 |
| Antenna Pattern | Rec. S.1528 Recommend 1.2 for main beam  Recommend 1.4 for side lobes (beyond 15°) | Rec. ITU-R S.580-6 | Rec S.1528  Recommend 1.2 for main beam  Recommend 1.4 for side lobes (beyond 15°) | Rec. ITU-R S.580‑6 | For satellite: AP 7 Annex 3 Section 3  G1 = −13 dB  Beamwidth = 0.42 deg | For earth station: S.580 | Rec S.1528  Recommend 1.2 for main beam  Recommend 1.4 for side lobes (beyond 10°) | Rec S.1528  Recommend 1.2 for main beam  Recommend 1.4 for side lobes (beyond 10°) | Rec S.1528  Recommend 1.2 for main beam  Recommend 1.4 for side lobes (beyond 10°) |
| Input power density (dBW/Hz) | −106.2 to −86.2  Max power only used while compensating for low elevation angles or rain fade attenuation | −97 to −77  Max power only used while compensating for low elevation angles or rain fade attenuation | −103 to −83.57  Max power only used while compensating for low elevation angles or rain fade attenuation | −93 to −80.8  Max power only used while compensating for low elevation angles or rain fade attenuation | −77.8[[3]](#footnote-3) | −77.8 | – | – | – |
| Minimum elevation angle (degrees) | 20 | 20 | 15 | 15 | 3 | 3 | 15 | 15 | 15 |
| Bandwidth (MHz) | 100 | 100 | 1250 | 1250 | 180 | 180 | 1 250 | 1 250 | 1 250 |
| Satellite selection | Random | Random | Random | Random | Fixed | Fixed | Random | Random | Random |
| Out of band emission mask | ITU-R SM.1541‑6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 | ITU-R SM.1541-6 |
| Number of co-frequency beams | 32 | 32 | 32 | 32 | 1 | 1 | 32 | 32 | 32 |
| Max power flux density on the ground  dBW/m2/MHz | −104 | N/A | −106 | N/A | −129.85 | N/A | –106 | –106 | –106 |
| Worst[[4]](#footnote-4) gateway density per 2 000 000 km2 | – | 5 | – | 76 | N/A | 25 | – | – | – |

1. See Section 1.1, Tables 1 and 2. [↑](#footnote-ref-1)
2. Altitude 535 km, Inclination 33 deg, 24 planes with 28 satellites per plane and 4 planes with 27 satellites per plane. [↑](#footnote-ref-2)
3. This is an average input power spectral density meaning there could be higher and lower power spectral densities employed by the System C satellite. [↑](#footnote-ref-3)
4. The worst density is provided in the table. To scale for larger area, the density should be considered together with a factor of 0.65 to account for the fact that the worst density isn’t feasible on a wider scale. For instance, density of 10 in 2 million km2, if scaled to 10 million km2 is: 10 × 10 000 000/2 000 000 × 0.65 = 32.5. [↑](#footnote-ref-4)