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| U.S. Radiocommunication SectorFact Sheet |
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| **Ref.** WRC-27 AI 1.18ITU-R Recommendation RA.769-2Document 7D/128-E Annex 4 | **Date:** 02/07/2025 |
| **Document Title:** Additions to 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 |
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| **Purpose/Objective:** To provide relevant information and recommend protections for radio astronomy systems and very long baseline interferometry networks operating above 76 GHz. |
| **Abstract:** This new draft Report was introduced at a previous 7D meeting, based on a US contribution, and was attached as Annex 4 to the chairman’s report Document 7D/128. Here we provide additional input to this draft document providing protection criteria and considerations for the radio astronomy service (RAS) and very long baseline interferometry (VLBI) networks in selected frequency bands above 76 GHz listed in Table 2 of WRC-27 Agenda Item 1.18, to inform any required regulatory measures regarding the protection of RAS and VLBI systems in accordance with Resolves 2 of the Agenda Item. |

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| ADDITIONS TO 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 |

**Summary**

This new draft Report has been in preparation at previous 7D meetings and was attached as Annex 4 to the latest chairman’s report Document 7D/128. Here additions minor editorial improvements are proposed, providing protection criteria and other considerations for the radio astronomy service (RAS) and very long baseline interferometry (VLBI) networks in selected frequency bands above 76 GHz listed in Table 2 of WRC-27 Agenda Item 1.18, and to inform any required regulatory measures regarding the protection of RAS and VLBI systems in accordance with Resolves 2 of the Agenda Item. The additions were made in Section 5 and can be recognized through track changes.

**Attachment**

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| **Radiocommunication Study Groups** |  |
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| Working document towards a preliminary draft new Report ITU-R [RAS-SAT 71-235 GHz] |
| Compatibility between RAS and active satellite services in the 71-235 GHz range |

# 1 Introduction

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 not absorbed by interstellar clouds of 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 Array (ALMA), situated in Chile and which is expected to continue to receive technical upgrades well beyond 2030. 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, or the Pico Veleta Telescope in Spain.

Relevant characteristics of 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). Of widely-distributed RAS arrays operating above 200 GHz is provided in Report . Technical and operational characteristics of broadband, background-limited detectors operating in the mm-wave regime is provided in Report .

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. Many of the RAS allocations in the International Table of Frequency Allocations are also listed in Radio Regulations (RR) No. **5.149**, where Administrations are urged to take all practicable steps to protect the RAS, or RR No. **5.340**, where all emissions are prohibited (see Table 2). 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).

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

# 2 Protection criteria for RAS

{Editor's note: Proposal to update Resolution **739 (Rev.WRC-19)** as a first step before doing the compatibility studies to have the parameters to do these studies}

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 |
| 76-81 | 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** |
| 94.1-95 | 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 | Co-primary with other active services |  |
| 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** |
| 151-158.5 | 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** |
| 182-185 | None | Co-primary with other passive services | **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 additional calculations not provided in Rec. ITU-R RA.769-2 for specific frequencies above 76 GHz and for updated receiver noise temperatures, reflecting current state of the art of deployed systems.

TABLE 1

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frequency (GHz)** | **Minimum antenna noise temperature (K)** | **Receiver noise temperature (K)** | **pfd (dB(W/m^2))** | **Spectral pfd (dB(W/m^2 Hz)))** |
| 76 | 12 | 25 | -131 | -230 |
| 130 | 14 | 30 | -125 | -224 |
| 167 | 14 | 40 | -122 | -221 |
| 232 | 20 | 40 | -119 | -218 |

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

TABLE 2

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

|  |  |  |
| --- | --- | --- |
| **Frequency (GHz)** | **pfd (dB(W/m^2))** | **Spectral pfd (dB(W/m^2 Hz)))** |
| 76 | -150 | -210 |
| 130 | -145 | -205 |
| 167 | -142 | -202 |
| 232 | -139 | -199 |

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

*{Minimum antenna noise temperature pending verification}*

{Provide description for derivation of interference levels for VLBI observations lacking from RA.769.}

TABLE 3

**Threshold interference levels for VLBI observations above 76 GHz**

|  |  |
| --- | --- |
| **Frequency (GHz)** | **Threshold level (dB(W/m2 ⋅ Hz)))** |
| 76 | [-165] |
| 130 | [-160] |
| 167 | [-157] |
| 232 | [-154] |

*{Frequencies were selected to be adjacent to satellite service allocations listed in Table 2 of ITU-R Res. 712 (WRC-23). This table should be expanded to include continuum and spectral line threshold levels. Values are not accurate and are just provided as estimates, pending proper calculation.}*

# 3 Satellite system characteristics

{Editor’s note: Reply liaison statement (LS) received from WP 4C. Waiting RLS from WP 4A}

# 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

[Unwanted emission threshold levels; additional characteristics and protection criteria for RAS; summary of studies and subsections describing conducted studies]

## 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 receivreceiv systems into saturation.

{Provide example here how to calculate RAS antenna incident power levels from GSO satellite systems and pointing separations required to not adversely affect RAS observations in adjacent bands.}

## 5.2 Considerations for non-GSO satellites

Active satellite systems in non-GSO orbits operate as constellations aggregate interference for each system be taken into account to determine appropriate threshold levels to protect observations.

{Provide example of how threshold levels for non-GSO systems can be derived that take aggregate into account without adversely affecting adjacent RAS bands.}

# 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*

# 8 List of acronyms and abbreviations

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