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| U.S. Radiocommunication SectorFact Sheet |
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| **Document Title:** Proposed changes to the Working document towards preliminary draft new Report ITU-R [1.18 – EESS] |
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| **Purpose/Objective:** To modify the attachment to the chair’s report of the framework for compatibility and sharing studies to be performed under WRC-27 agenda item 1.18 (resolves 1) in accordance with Resolution 712 (WRC-23). |
| **Abstract:** Pursuant to Resolution 712 (WRC-23), Working Party (WP) 7C is the responsible group for WRC-27 agenda item 1.18 (resolves 1). As characteristics from contributing groups have been submitted, this proposed submission offers revisions to the study framework with the inclusion of methodologies and/or studies to address compatibility between the Earth exploration-satellite service and active services in adjacent and nearby bands. |
| **Fact Sheet Preparer**: Jason Szklany, ADS for NASA |

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| **Radiocommunication Study Groups** |  |
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|  |  |
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| Working document towards preliminary draft new Report ITU-R [1.18 – EESS] |
|  |

**Introduction**This input contribution includes proposed revisions to annex 17 of Document 7C/142-E, the working document towards PDNR ITU-R [1.18 – EESS].

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Simulation study matrix TOC

|  |  |
| --- | --- |
|  | Active service type |
| EESS (passive) Band (GHz) | MS | RLS | FSS | MSS | ISS | RNS | RNSS | FS |
| **86-92**  | section 4.2 and Annex 2 | section 4.3 and Annex 3 | section 4.4 and Annex 4 | N/A | N/A | N/A | N/A | Already addressed in Report F.2239-0(\*) |
| **114.24-116**  | section 4.2 and Annex 2 | N/A | N/A | N/A | N/A | N/A | N/A | section 4.8 and Annex 8 |
| **164-167** | section 4.2 and Annex 2 | N/A | section 4.4 and Annex 4 | section 4.5 and Annex 5 | section 4.6 and Annex 6 | N/A | N/A | section 4.8 and Annex 8 |
| **200-209** | section 4.2 and Annex 2 | N/A | section 4.4 and Annex 4 | N/A | section 4.6 and Annex 6 | section 4.3 and Annex 3 | section 4.7 and Annex 7 | section 4.8 and Annex 8 |
| \*: This scenario is not covered in Resolution **712 (WRC-23)**, since corresponding limits are already included in Resolution **750 (Rev.WRC-19)**. |

# Glossary and abbreviations

[TBD]

# Introduction

In *resolves* 1.18of Resolution **813 (WRC-23)**, the 2023 World Radiocommunication Conference (WRC-23) resolved “to consider, based on the results of ITU Radiocommunication Sector studies, possible regulatory measures regarding the protection of the Earth exploration-satellite service (passive) and the radio astronomy service in certain frequency bands above 76 GHz from unwanted emissions of active services, in accordance with Resolution **712 (WRC-23)**” as part of the agenda for WRC-27.

The WRC-2000 conference introduced several allocation changes in frequency bands above 71 GHz. Including primary allocations for the Earth exploration-satellite service (EESS) under certain conditions. Additionally, primary allocations were assigned to active services in frequency bands neighbouring those allocated to passive EESS above 86 GHz, also subject to specific conditions including No. **5.340**.

## 1.1 Table of EESS (passive) bands and active services under consideration

TABLE X

EESS (passive) frequency bands to be studied and corresponding active services to be included in this report

| EESS (passive) frequency band | Active service frequency band | Active satellite service (space-to-Earth) |
| --- | --- | --- |
| 86-92 GHz | 81-86 GHz | Fixed-satellite service (FSS), (Earth-to-space), mobile service (MS) |
| 92-94 GHz | MS, radiolocation service (RLS) |
| 114.25-116 GHz | 111.8-114.25 GHz | Fixed service (FS), MS |
| 164-167 GHz | 158.5-164 GHz | FS, FSS (space-to-Earth), MS, mobile-satellite service (MSS) (space-to-Earth) |
| 167-174.5 GHz | FS, FSS (space-to-Earth), inter-satellite service (ISS), MS |
| 200-209 GHz | 191.8-200 GHz | FS, ISS, MS, MSS, radionavigation service (RNS), radionavigation-satellite service (RNSS) |
| 209-217 GHz | FS, FSS (Earth-to-space), MS |

This information can also be described as in Table Y below organised by active services.

TABLE y

|  |  |  |
| --- | --- | --- |
| Active service | Active service frequency band | EESS (passive) frequency band |
| Fixed-satellite service (FSS) | 81-86 GHz (Earth-to-space) | 86-92 GHz |
| 158.5-164 GHz (space-to-Earth) | 164-167 GHz |
| 167-174.5 GHz (space-to-Earth) |
| 209-217 GHz (Earth-to-space) | 200-209 GHz |
|  |
| Inter-satellite service (ISS) | 167-174.5 GHz | 164-167 GHz |
| 191.8-200 GHz | 200-209 GHz |
|  |
| Mobile-satellite service (MSS) | 158.5-164 GHz (space-to-Earth) | 164-167 GHz |
| 191.8-200 GHz | 200-209 GHz |
|  |
| Mobile service (MS) | 81-86 GHz | 86-92 GHz |
| 92-94 GHz |
| 111.8-114.25 GHz | 114.25-116 GHz |
| 158.5-164 GHz | 164-167 GHz |
| 167-174.5 GHz |
| 191.8-200 GHz | 200-209 GHz |
| 209-217 GHz |
|  |
| Fixed service (FS) | 111.8-114.25 GHz | 114.25-116 GHz |
| 158.5-164 GHz | 164-167 GHz |
| 167-174.5 GHz |
| 191.8-200 GHz | 200-209 GHz |
| 209-217 GHz |
|  |
| Radiolocation service (RLS) | 92-94 GHz | 86-92 GHz |
|  |
| Radionavigation service (RNS) | 191.8-200 GHz | 200-209 GHz |
|  |
| Radionavigation-satellite service (RNSS) | 191.8-200 GHz | 200-209 GHz |

## 1.2 References and related ITU-R documents

## 1.3 Propagation models and technical and operational characteristics of other services and systems

|  |  |  |
| --- | --- | --- |
| Source | Services/Applications/Models | Information available at [Link to the received document] |
| WP 5B | Radiolocation and Radionavigation Services | [7C/61](https://www.itu.int/md/R23-WP7C-C-0061/en) |
| WP 4C | Mobile-Satellite Service | [7C/46](https://www.itu.int/md/R23-WP7C-C-0046/en) |
| WP 4C | Radionavigation-satellite | [7C/46](https://www.itu.int/md/R23-WP7C-C-0046/en) |
| WPs 3J/3M | Propagation aspects | [7C/81](https://www.itu.int/md/R23-WP7C-C-0081/en) |

Relevant ITU-R Recommendations and Reports

*Recommendations*

ITU-R RS.1813-2 *Reference antenna pattern for passive sensors operating in the Earth exploration-satellite service (passive) to be used in compatibility analyses in the frequency range 1.4-450 GHz*

ITU-R RS.1858 *Characterization and assessment of aggregate interference to the Earth exploration-satellite service (passive) sensor operations from multiple sources of man made emissions*

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*

ITU-R RS.2017-0 *Performance and interference criteria for satellite passive remote sensing*

*Contributed Recommendations*

[ITU-R M.2162-0](https://www.itu.int/rec/R-REC-M.2162/en) *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.*

*Reports*

ITU-R F.2239-0 *Coexistence between fixed service operating in 71-76 GHz, 81-86 GHz and 92-94 GHz bands and passive services*

# Technical and operational characteristics for EESS (passive) systems above 76 GHz

## 2.1 Cold Calibration characteristics

[TBD]

Editor’s note ; the cold calibration parameters are usually given in the parameter Tables from Recommendation ITU-R RS.1861.

## 2.2 86-92 GHz systems

The 86-92 GHz frequency band is essential for the measurement of clouds, oil spills, ice, snow, and rain. It is also used as a reference window for temperature soundings near 118 GHz.

Relevant characteristics are given in Tables 33 and 34 of Recommendation ITU-R RS.1861-1, reproduced in Annex 1.

## 2.3 114.25-116 GHz systems

The frequency range 114.25-122.25 GHz is of primary interest for atmospheric temperature profiling (O2absorption lines).

Relevant characteristics are given in Tables 35 to 41 of Recommendation ITU-R RS.1861-1, reproduced in Annex 1.

## 2.4 164-167 GHz systems

The 164-167 GHz frequency band is of primary interest to measure N2O, cloud water and ice, rain, CO, and ClO. These bands are also used as a reference window for water vapor sounding channels by leveraging their increased sensitivity to surface characteristics.

Relevant characteristics are given in Tables 44 and 45 of Recommendation ITU-R RS.1861-1, reproduced in Annex 1.

## 2.5 200-209 GHz systems

Relevant characteristics are given in Table 57 of Recommendation ITU-R RS.1861-1, reproduced in Annex 1.

# 3 Protection criteria for EESS (passive)

## 3.1 Introduction

[TBD]

## 3.2 Protection criteria

| Frequency band(s) (GHz) | Reference bandwidth(MHz) | Maximum interference level (dBW) | Percentage of area or time permissible interference level may be exceeded(1) (%) | Scan mode (N, C, L)(2) |
| --- | --- | --- | --- | --- |
| 86-92 | 100 | −169 | 0.01 | N, C |
| 114.25-116 | 10 | −189 | 1 | L |
| 115.25-122.25 | 200/10(3) | −166/−189(3) | 0.01/1(3) | N, L |
| 164-167 | 200/10(3) | −163/−189(3) | 0.01/1(3) | N, C, L |
| 200-209 | 3 | −194 | 1 | L |
| (1) For a 0.01% level, the measurement area is a square on the Earth of 2 000 000 km2, unless otherwise justified; for a 0.1% level, the measurement area is a square on the Earth of 10 000 000 km2 unless otherwise justified; for a 1% level, the measurement time is 24 h, unless otherwise justified.(2) N: Nadir, Nadir scan modes concentrate on sounding or viewing the Earth’s surface at angles of nearly perpendicular incidence. The scan terminates at the surface or at various levels in the atmosphere according to the weighting functions. L: Limb, Limb scan modes view the atmosphere “on edge” and terminate in space rather than at the surface, and accordingly are weighted zero at the surface and maximum at the tangent point height. C: Conical, Conical scan modes view the Earth’s surface by rotating the antenna at an offset angle from the nadir direction.(3) First number for nadir or conical scanning modes and second number for microwave limb sounding applications. |

These protection criteria are aggregate for all sources of interference. In the context of WRC-27 agenda item 1.18, it is noted that the EESS (passive) sensors will potentially receive unwanted emissions from multiple different services operating in bands below or above the band allocated to EESS (passive). This situation is summarized in the following figure.



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#  4 General overview of the active systems under consideration

## 4.1 Introduction

This section provides technical characteristics of the active services that are envisaged to be considered under this agenda item for the purpose of conducting the compatibility and sharing studies. To avoid lengthening this document, the information received from the expert groups will be included in the document using hyperlinks.

## 4.2 Mobile service

The following scenario are under study.

|  |  |
| --- | --- |
| MS frequency bands | EESS (passive) frequency band |
| 81-86 GHz | 86-92 GHz |
| 92-94 GHz |
| 111.8-114.25 GHz | 114.25-116 GHz |
| 158.5-164 GHz | 164-167 GHz |
| 167-174.5 GHz |
| 191.8-200 GHz | 200-209 GHz |
| 209-217 GHz |

### 4.2.1 92-94 GHz RSTT characteristics

As noted by WP5A in Document [7C/173](https://www.itu.int/dms_ties/itu-r/md/23/wp7c/c/R23-WP7C-C-0173%21%21MSW-E.docx), characteristics of RSTT stations operating in 92‑94 GHz can be identified in Report ITU-R M.2500-0 on Table 6.

[Report ITU-R M.2500-0 includes static and dynamic studies in section 2 of Annex 3 completed between EESS (passive) systems in 86-92 GHz and RSTT stations deployed on high-speed rail lines in a single administration. Relevant information from these studies and results will be included in further revisions of this study document.]

## 4.3 Radiolocation and radionavigation services

The following scenario are under study:

|  |  |  |
| --- | --- | --- |
|  | RLS and RNS frequency bands | EESS (passive) frequency band |
| Radiolocation service (RLS) | 92-94 GHz | 86-92 GHz |
| Radionavigation service (RNS) | 191.8-200 GHz | 200-209 GHz |

Working Party 5B noted in Document 7C/61 that the technical and operation characteristics could be found in Recommendation [ITU-R M.2162-0](https://www.itu.int/rec/R-REC-M.2162/en). Recommendation ITU-R M.2162-0 only contains systems up to 100 GHz, which covers just a portion of the bands that are considered in Resolution 813 **(WRC-23)**.

### 4.3.1 Ground weather radars

Recommendation ITU-R M.2162-0 includes the technical and operational characteristics of the ground weather radar at 94-100 GHz, which is shown in Table 4.5.1.1.

Table 4.5.1.1

Characteristics of radars in the 94-100 GHz range

| Parameter  | Radar A |
| --- | --- |
| Application  | Weather (heavy rainfall detection) |
| Deployment area  | Worldwide, fixed site |
| Tuning range (GHz)  | 94-100 |
| Transmitter type  | Solid state |
| Tx power into antenna (peak) (W)  | 0.5-1 |
| Polarization  | Linear |
| Pulse duration (ms)  | 0.04-0.16 |
| Frequency modulation  | FMCW |
| Pulse repetition period (µs)  | 80-160 |
| Antenna type  | Parabolic |
| Radar height relative to the ground (m)  | 1 |
| Antenna gain (dBi)  | 54 |
| Antenna diameter (m)  | 0.6 |
| Antenna beamwidth in azimuth (degrees)  | 0.4 |
| Antenna beamwidth in elevation (degrees)  | 0.4 |
| Antenna peak side-lobe (SL) levels (dBi)  | 24 |
| Antenna pattern type  | Rec. ITU-R M.1851, COS2 pattern |
| Receiver noise floor (dBm) (see Rec. ITU-R M.1461 below eq. (4))  | −105 … −93.2 |
| Receiver noise figure (dB)  | 7 |
| RF emission bandwidth (MHz)  | Up to 24 |
| Receiver IF 3 dB bandwidth (MHz)  | 1.5-24 |
| *I*/*N* protection criterion (dB)  | −6 |

### 4.3.2 Airport foreign object debris detection in 92-100 GHz Band

Recommendation ITU-R M.2162-0 includes the technical and operational characteristics of the foreign object debris detection radars at 92-100 GHz, which is shown in Table 4.5.2.1. The channel plan for the foreign object debris detection radars is showing in Figure 4.5.2.1.

Table 4.5.2.1

Characteristics of foreign object debris detection system radars in the 92-100 GHz

| Parameters  | Values |
| --- | --- |
| Frequency range (GHz)  | 92 … 100 |
| Channel bandwidth (GHz)  | 0.58 … 7.98 |
| Channel plan  | See Fig. 1 |
| Transmit peak power (mW)  | 100-200 |
| Sweep frequency (FMCW) (kHz)  | 1.250 |
| Antenna type  | Cassegrain |
| Antenna gain (dBi)  | 44 |
| Antenna pattern  | Rec. ITU-R F.699 |
| Antenna height (m)  | 4 … 8 |
| Full width at half maximum antenna gain (3 dB beamwidth) (degrees)  | Elevation: 1.0, Azimuth: 1.0 |
| Antenna rotation speed (rpm)  | 15 |
| Detection distance (m)  | 200 … 500 |
| Radiated rotation angle in azimuth (degree)  | ±60 |
| Radar cross section specification (dB/m2)  | −20 |
| Range resolution (cm)  | 3 … 50 |
| Emission bandwidth (−3 dB) (MHz)  | 1 |
| Emission bandwidth (−20 dB) (MHz)  | 3.5 |
| Adjacent channel leakage ration (dBc)  | < −70 |
| Receiver noise figure (dB)  | 10 |
| *I*/*N* protection criteria (dB)  | −6 |

Figure 4.5.2.1

Channel plan for foreign object debris detection system radars in the 92-100 GHz



[[PDNR ITU-R M.[FOD\_EESS\_SHARE]](https://www.itu.int/md/R23-WP5B-C-0216/en) from WP5B contains sharing and compatibility studies for frequency ranges 92-100 GHz. Relevant information from these studies and results will be included in further revisions of this study document.]

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## 4.4 Fixed-satellite services

The following scenario are under study:

|  |  |  |
| --- | --- | --- |
| Active service | Active service frequency band | EESS (passive) frequency band |
| Fixed-satellite service (FSS) | 81-86 GHz (Earth-to-space) | 86-92 GHz |
| 158.5-164 GHz (space-to-Earth) | 164-167 GHz |
| 167-174.5 GHz (space-to-Earth) |
| 209-217 GHz (Earth-to-space) | 200-209 GHz |

Working Party 4A provided system characteristics for agenda item 1.18 studies in Document 7C/165E.

## 4.5 Mobile-Satellite Service

The following scenario are under study:

|  |  |  |
| --- | --- | --- |
| Active service | Active service frequency band | EESS (passive) frequency band |
| Mobile-satellite service (MSS) | 158.5-164 GHz (space-to-Earth) | 164-167 GHz |
| 191.8-200 GHz | 200-209 GHz |

The expert working group noted in Document [7C/46](https://www.itu.int/md/R23-WP7C-C-0046/en) there are no technical and operational parameters for this band and that information can be found in relevant ITU filings.

…/…

## 4.6 Inter-satellite services

The following scenario are under study:

|  |  |  |
| --- | --- | --- |
| Active service | Active service frequency band | EESS (passive) frequency band |
| Inter-satellite service (ISS) | 167-174.5 GHz | 164-167 GHz |
| 191.8-200 GHz | 200-209 GHz |

…/…

## 4.7 Radionavigation-satellite service

The following scenario is under study:

|  |  |  |
| --- | --- | --- |
| Active service | Active service frequency band | EESS (passive) frequency band |
| Radionavigation-satellite service (RNSS) | 191.8-200 GHz | 200-209 GHz |

The expert working group noted in Document 7C/46 there is no technical and operational parameters for this band and that information can be found in relevant ITU filings. Working Party 4C also suggested using Recommendation ITU-R M.1583 to model the RNSS systems.

…/…

## 4.8 Fixed service

The following scenario are under study:

|  |  |
| --- | --- |
| FS frequency bands | EESS (passive) frequency band |
| 111.8-114.25 GHz | 114.25-116 GHz |
| 158.5-164 GHz | 164-167 GHz |
| 167-174.5 GHz |
| 191.8-200 GHz | 200-209 GHz |
| 209-217 GHz |

…/…

Table xxx

Resolution 750 levels for Fixed service

|  |  |  |  |
| --- | --- | --- | --- |
| **EESS (passive) frequency band** | **Active service frequency band** | **Active service** | **Limits of unwanted emission power from active service stations in a specified bandwidth within the EESS (passive) frequency band1** |
| 86-92 GHz5 | 81-86 GHz | Fixed | -41 - 14(-86) dBW/100 MHz for 86.05 87 GHz-55 dBW/100 MHz for 87 91.95 GHz where is the centre frequency of the 100MHz reference bandwidth expressed in GHz |
| 92-94 GHz | Fixed | -41 - 14(92-) dBW/100 MHz for 91 91.95 GHz-55 dBW/100 MHz for 86.05 91 GHzwhere is the centre frequency of the 100MHz reference bandwidth expressed in GHz |

1 The unwanted emission power level is to be understood here as the level measured at the antenna port.

5 Other maximum unwanted emission levels may be developed based on different scenarios provided in Report ITU-R F.2239 for the frequency band 86-92 GHz.

It should be noted that the scenarios related to the FS bands 111.8-114.25 GHz, 158.5-164 GHz and 167-174.5 GHz are already addressed within WP 5C and currently part of the preliminary draft new [Recommendation /Report] ITU-R F.[EESS-PROTECTION].

The work is on-going in WP 5C with cooperation of WP 7C.

# 5 Simulations

Depending on the scenarios and the active radio service, different simulations methodologies have been used, as described in the sections below.

## 5.1 Simulations for 86-92 GHz frequency band

**Introduction**

[TBD]

### 5.1.1 Study 1 [USA]

#### 5.1.1.1 Simulation Methodologies

##### 5.1.1.1.1 EESS (passive) Dynamic Simulation Methodology

Assessments of the aggregate RFI expected from the specific active services into EESS (passive) operating in the 86-92 GHz frequency band are achieved by dynamic simulations. The analysis will be conducted in which the orbit of the EESS (passive) spacecraft under investigation is dynamically simulated, retaining only the data points when the EESS (passive) sensor antenna boresight points within a defined Measurement Area of Interest (MAI), as defined in Recommendation ITU-R RS.2017. Calculations will be performed to determine the potential interference from each of the current active stations into the EESS (passive) sensors under study and will consider the aggregate effect from multiple active stations. The simulation will propagate the satellite based on its orbital parameters, and the simulation step size is selected to be an irrational number to ensure that the beam dynamics of the passive sensor do not exhibit periodic behaviour. At each simulation step, a snapshot of the interference scenario will be generated where the directional vectors from each active source to the EESS (passive) sensor will be computed along with the gain of the transmit and receive antennas using their respective antenna patterns.

The interfering signal power level, (W), received by a spaceborne radiometer at the simulation step from the active station is calculated from:

 (A1-1)

where:

 : active station out of band transmitter power in the EESS (passive) band, accounting for frequency dependent rejection

 : active station antenna gain towards spaceborne sensor

 : spaceborne receive antenna gain towards terrestrial source

  : atmospheric losses (Rec. ITU-R P.676)

 : Free Space Path Loss

 : losses due to polarization mismatch

 : losses due to clutter (Rec. ITU-R P.2108).

The aggregate interference at the simulation step, (W), is calculated by the summation of the received interference from all active stations within line of sight of EESS (passive):

 (A1-2)

Thus, the aggregate interference can be represented in the logarithmic domain as:

 (A1-3)

Using the resulting data containing received interfering power levels, a CCDF curve will be generated to assess interference observed over the MAI.

###### 5.1.1.1.1.1 Definition of Simulation MAI

As given specified within Recommendation ITU-R RS.2017, the protection criteria for the passive band covered under agenda item 1.18 applies to any square (unless otherwise justified) measurement area on the Earth of 2 000 000 km2 for EESS (passive) or a percentage of measurement time as indicated in the protection criteria, for the 86-92 GHz, 114.25-116 GHz and 164-167 GHz bands.

For EESS (passive) Limb sounders in the 114.25-116 GHz, 164-167 GHz and 200-209 GHz bands, a measurement time of 24 h applies, unless otherwise justified.

[MAI zones to be included in further revision of this study document]

##### 5.1.1.1.2 Mobile service deployment methodology

[RSTT and its potential impacts to EESS (passive) in the 86-92 GHz frequency band was studied in Report ITU-R M.2500-0 and will be included in further revisions of this study document.]

##### 5.1.1.1.3 Fixed-satellite service deployment methodology

[Editor’s Note: This section will contain the methodology for simulating the fixed-satellite service in study 1.]

5.1.1.1.4 Radiolocation service deployment methodology[[PDNR ITU-R M.[FOD\_EESS\_SHARE]](https://www.itu.int/md/R23-WP5B-C-0216/en) from WP5B contains sharing and compatibility studies for frequency ranges 92-100 GHz. Relevant information from these studies and results will be included in further revisions of this study document.]

##### 5.1.1.1.5 Fixed service deployment methodology

As this service has existing limits of unwanted emission power defined in Resolution 750, those levels are applied in this simulation and included Section 4.8 on Table xxx for reference.

#### 5.1.1.2 General Simulation parameters

[Editor’s Note: This section will contain details of the study methodology as it relates to each modelled system]

The general simulation assumptions and parameters for Study 1 are summarized in Tables 5.1.1.2-1.

Table 5.1.1.2-1

General Simulation Parameters for Study 1

|  |  |  |
| --- | --- | --- |
| Parameter | Unit | Value |
| Maximum Interference Level | dBW/100MHz | -169 |
| Percent of time permissible interference level may be exceeded | Percent (%) | 0.01 |
| Measurement Area of Interest (MAI)  | km2 | 2 000 000 |
| Number of Monte Carlo simulations | Count | [TBD] |
| Study Duration | Year | 1 |
| Study Step Size | Second | π/2 |
| [TBD] |  |  |

## 5.2 Simulations for 114.25 – 116 GHz frequency band

### 5.2.1 Study 1 [USA]

**Introduction**

[TBD]

**Introduction**

[TBD]

#### 5.2.1.1 Simulation Methodologies

##### 5.2.1.1.1 EESS (passive) Dynamic Simulation Methodology

Assessments of the aggregate RFI expected from the specific active services into EESS (passive) operating in the 114.25-116 GHz frequency band is achieved by dynamic simulations. The analysis will be conducted in which the orbit of the EESS (passive) spacecraft under investigation is dynamically simulated, retaining only the data points when the EESS (passive) sensor antenna boresight points within a defined Measurement Area of Interest (MAI), as defined in Recommendation ITU-R RS.2017. Calculations will be performed to determine the potential interference from each of the current active stations into the EESS (passive) sensors under study and will consider the aggregate effect from multiple active stations.

The simulation will propagate the satellite based on its orbital parameters, and the simulation step size is selected to be an irrational number to ensure that the beam dynamics of the passive sensor do not exhibit periodic behaviour. At each simulation step, a snapshot of the interference scenario will be generated where the directional vectors from each active source to the EESS (passive) sensor will be computed along with the gain of the transmit and receive antennas using their respective antenna patterns.

The interfering signal power level, (W), received by a spaceborne radiometer at the simulation step from the active station is calculated from:

 (A1-1)

where:

 : active station out of band transmitter power in the EESS (passive) band, accounting for frequency dependent rejection

 : active station antenna gain towards spaceborne sensor

 : spaceborne receive antenna gain towards terrestrial source

  : atmospheric losses (Rec. ITU-R P.676)

 : Free Space Path Loss

 : losses due to polarization mismatch

 : losses due to clutter (Rec. ITU-R P.2108).

The aggregate interference at the simulation step, (W), is calculated by the summation of the received interference from all active stations within line of sight of EESS (passive):

 (A1-2)

Thus, the aggregate interference can be represented in the logarithmic domain as:

 (A1-3)

Using the resulting data containing received interfering power levels, a CCDF curve will be generated to assess interference observed over the MAI.

###### 5.1.1.1.1.1 Definition of Simulation MAI

As given specified within Recommendation ITU-R RS.2017, the protection criteria for the passive band covered under agenda item 1.18 applies to any square (unless otherwise justified) measurement area on the Earth of 2 000 000 km2 for EESS (passive) or a percentage of measurement time as indicated in the protection criteria, for the 86-92 GHz, 114.25-116 GHz and 164-167 GHz bands.

For EESS (passive) Limb sounders in the 114.25-116 GHz, 164-167 GHz and 200-209 GHz bands, a measurement time of 24 h applies, unless otherwise justified.

[MAI zones to be included in further revision of this study document]

##### 5.2.1.1.2 Mobile service deployment methodology

[Editor’s Note: This section will contain the methodology for simulating the mobile service in simulation 1.]

##### 5.2.1.1.3 Fixed service deployment methodology

[Editor’s Note: This section will contain the methodology for simulating the fixed service in simulation 1 noting that studies are contained in 5C document PRELIMINARY DRAFT NEW REPORT ITU-R F.[EESS-PROTECTION].]

#### 5.2.1.2 General Simulation parameters

## 5.3 Simulations for 164 – 167 GHz frequency band

### 5.3.1 Study 1 [USA]

**Introduction**

[TBD]

#### 5.3.1.1 Simulation Methodologies

##### 5.3.1.1.1 EESS (passive) Dynamic Simulation Methodology

Assessments of the aggregate RFI expected from the specific active services into EESS (passive) operating in the 164-167 GHz frequency band is achieved by dynamic simulations. The analysis will be conducted in which the orbit of the EESS (passive) spacecraft under investigation is dynamically simulated, retaining only the data points when the EESS (passive) sensor antenna boresight points within a defined Measurement Area of Interest (MAI), as defined in Recommendation ITU-R RS.2017. Calculations will be performed to determine the potential interference from each of the current active stations into the EESS (passive) sensors under study and will consider the aggregate effect from multiple active stations.

The simulation will propagate the satellite based on its orbital parameters, and the simulation step size is selected to be an irrational number to ensure that the beam dynamics of the passive sensor do not exhibit periodic behaviour. At each simulation step, a snapshot of the interference scenario will be generated where the directional vectors from each active source to the EESS (passive) sensor will be computed along with the gain of the transmit and receive antennas using their respective antenna patterns.

The interfering signal power level, (W), received by a spaceborne radiometer at the simulation step from the active station is calculated from:

 (A1-1)

where:

 : active station out of band transmitter power in the EESS (passive) band, accounting for frequency dependent rejection

 : active station antenna gain towards spaceborne sensor

 : spaceborne receive antenna gain towards terrestrial source

  : atmospheric losses (Rec. ITU-R P.676)

 : Free Space Path Loss

 : losses due to polarization mismatch

 : losses due to clutter (Rec. ITU-R P.2108).

The aggregate interference at the simulation step, (W), is calculated by the summation of the received interference from all active stations within line of sight of EESS (passive):

 (A1-2)

Thus, the aggregate interference can be represented in the logarithmic domain as:

 (A1-3)

Using the resulting data containing received interfering power levels, a CCDF curve will be generated to assess interference observed over the MAI.

###### 5.3.1.1.1.1 Definition of Simulation MAI

As given specified within Recommendation ITU-R RS.2017, the protection criteria for the passive band covered under agenda item 1.18 applies to any square (unless otherwise justified) measurement area on the Earth of 2 000 000 km2 for EESS (passive) or a percentage of measurement time as indicated in the protection criteria, for the 86-92 GHz, 114.25-116 GHz and 164-167 GHz bands.

For EESS (passive) Limb sounders in the 114.25-116 GHz, 164-167 GHz and 200-209 GHz bands, a measurement time of 24 h applies, unless otherwise justified.

[MAI zones to be included in further revision of this study document]

##### 5.3.1.1.2 Fixed service deployment methodology

[Editor’s Note: This section will contain the methodology for simulating the fixed service in simulation 1 noting that studies are contained in 5C document PRELIMINARY DRAFT NEW REPORT ITU-R F.[EESS-PROTECTION].]

#### 5.3.1.2 General Simulation parameters

## 5.4 Simulations for 200 – 209 GHz frequency band

### 5.4.1 Study 1 [USA]

**Introduction**

[TBD]

#### 5.4.1.1 Simulation Methodologies

##### 5.4.1.1.1 EESS (passive) Dynamic Simulation Methodology

Assessments of the aggregate RFI expected from the specific active services into EESS (passive) operating in the 200-209 GHz frequency band is achieved by dynamic simulations. The analysis will be conducted in which the orbit of the EESS (passive) spacecraft under investigation is dynamically simulated, retaining only the data points when the EESS (passive) sensor antenna boresight points within a defined Measurement Area of Interest (MAI), as defined in Recommendation ITU-R RS.2017. Calculations will be performed to determine the potential interference from each of the current active stations into the EESS (passive) sensors under study and will consider the aggregate effect from multiple active stations.

The simulation will propagate the satellite based on its orbital parameters, and the simulation step size is selected to be an irrational number to ensure that the beam dynamics of the passive sensor do not exhibit periodic behaviour. At each simulation step, a snapshot of the interference scenario will be generated where the directional vectors from each active source to the EESS (passive) sensor will be computed along with the gain of the transmit and receive antennas using their respective antenna patterns.

The interfering signal power level, (W), received by a spaceborne radiometer at the simulation step from the active station is calculated from:

 (A1-1)

where:

 : active station out of band transmitter power in the EESS (passive) band, accounting for frequency dependent rejection

 : active station antenna gain towards spaceborne sensor

 : spaceborne receive antenna gain towards terrestrial source

  : atmospheric losses (Rec. ITU-R P.676)

 : Free Space Path Loss

 : losses due to polarization mismatch

 : losses due to clutter (Rec. ITU-R P.2108).

The aggregate interference at the simulation step, (W), is calculated by the summation of the received interference from all active stations within line of sight of EESS (passive):

 (A1-2)

Thus, the aggregate interference can be represented in the logarithmic domain as:

 (A1-3)

Using the resulting data containing received interfering power levels, a CCDF curve will be generated to assess interference observed over the MAI.

###### 5.4.1.1.1.1 Definition of Simulation MAI

As given specified within Recommendation ITU-R RS.2017, the protection criteria for the passive band covered under agenda item 1.18 applies to any square (unless otherwise justified) measurement area on the Earth of 2 000 000 km2 for EESS (passive) or a percentage of measurement time as indicated in the protection criteria, for the 86-92 GHz, 114.25-116 GHz and 164-167 GHz bands.

For EESS (passive) Limb sounders in the 114.25-116 GHz, 164-167 GHz and 200-209 GHz bands, a measurement time of 24 h applies, unless otherwise justified.

[MAI zones to be included in further revision of this study document]

#### 5.4.1.2 General Simulation parameters

# 6 Summary of the technical analysis

The present section provides the summary results of the technical analyses performed under this agenda item.

The resulting interference into EESS (passive) from the services in each of the simulations specified in section 5 are provided as multiple complementary cumulative distribution functions (CCDFs) in three figures per study. To assess and compare the impact of each individual source of interference, the first figure displays an aggregate interference CCDF for each active service operating adjacent to the EESS (passive) band.

*[Results to be provided in future WP 7C meetings.]*

The second figure provides the aggregate interference CCDF from each service, to enable assessing total interference by service type if the service has allocations below and above the EESS (passive) band.

*[Results to be provided in future WP 7C meetings.]*

Lastly, a third figure provides three CCDF curves - the total aggregate interference from services below the band, the total aggregate interference from services above the band, and total aggregate interference from all systems in the study.

*[Results to be provided in future WP 7C meetings.]*To avoid lengthening the core part of this Report, the detailed technical analyses are described in the following annexes:

Annex 2: Technical analysis related to the mobile service

Annex 3: Technical analysis related to the radionavigation service and radiolocation service

Annex 4: Technical analysis related to the fixed-satellite service

Annex 5: Technical analysis related to the mobile-satellite service

Annex 6: Technical analysis related to the inter-satellite service

Annex 7: Technical analysis related to the radionavigation-satellite service

Annex 8: Technical analysis related to the fixed service

[TBD]

List of Annexes

Annex 1: EESS (passive) parameters

Annex 2: ….

ANNEX 1

Technical and operational characteristics for EESS (passive) systems
above 76 GHz

## 1.1 86-92 GHz systems

Typical parameters of passive sensors operating in the 86-92 GHz frequency band

The 86-92 GHz frequency band is essential for the measurement of clouds, oil spills, ice, snow, and rain. It is also used as a reference window for temperature soundings near 118 GHz.

Tables A1.1 and A1.2 summarize the parameters of passive sensors that are or will be operating within the 86 and 92 GHz frequency band (see section 6.13 of Recommendation ITU-R RS.1861‑1).

TABLE A1.1

EESS (passive) sensor characteristics operating in the 86-92 GHz frequency band

|  | Sensor L1 | Sensor L4 | Sensor L5 | Sensor L6 | Sensor L7 | Sensor L8 | Sensor L9 | Sensor L10 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Conical scan | Mechanical nadir scan | Mechanical nadir scan | Mechanical nadir scan | Conical scan | Conical scan | Mechanical nadir scan | Conical scan |
| **Orbit parameters** |
| Altitude (km) | 867 | 833822 \* | 833822 \* | 824 | 835 | 700 | 830 | 830 |
| Inclination (degree) | 20 | 98.698.7 \* | 98.698.7 \* | 98.7 | 98.85 | 98.2 | 98.7 | 98.7 |
| Eccentricity | 0 | 00.001\* | 00.001\* | 0 | 0 | 0.002 | 0.001 | 0.001 |
| Repeat period (days) | 7 | 929 \* | 929 \* | 9 |  | 16 | 29 | 29 |
| **Sensor antenna parameters** |
| Number of beams | 1 | 30 earth fields per 8 s scan period | 30 earth fields per 8 s scan period1 beam (steerable in 90 earth fields per scan period)\* | 2 | 2 | 2 | 1 | 1 |
| Antenna size (m) | 0.65 | 0.15 | 0.30.22 \* | 0.203 | 0.65 | 2 | 0.35 | 0.76 |
| Maximum beam gain (dBi) | 50 | 34.4 | 4744.8 \* | 37.9 | 52.5 | 62.4 | 43 | 55.1 |
| Polarization | H, V | HQV \* | HQV \* | QV | H, V | H, V | QH/QV | V, H |
| −3 dB beamwidth (degree) | 0.43 | 3.3 | 1.1 | 2.2 | 0.6 | 0.15 | 1.15 | 0.33 |

TABLE A1.1 (*Cont.*)

|  | Sensor L1 | Sensor L4 | Sensor L5 | Sensor L6 | Sensor L7 | Sensor L8 | Sensor L9 | Sensor L10 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Instantaneous field of view (km) | 10 km × 17 km | Nadir FOV: 48.5 kmOuter FOV: 149.1 × 79.4 km147 × 79 km\* | Nadir FOV: 16 km (1.1°)Outer FOV: 53 × 27 km\* | Nadir FOV: 31.6 km × 31.6 kmOuter FOV: 136.7 × 60 km | 17 km × 40 km | A: 5.1 km × 2.9 kmB: 5.0 km × 2.9 km | Nadir FOV: 17 km(218 km2)Outer FOV: 55 × 28 km(1 225 km²) | 7 × 12 km(68 km²) |
| Off-nadir pointing angle (degree) | 44.5 | ±48.33 cross-track | ±48.9549.4\* | ±52.725 cross-track | 53.3 | 47.5° | ±49.31 cross-track | 44.8 |
| Incidence angle at Earth (degree) | 53.5° | 30 positions57.5°\* | Various angles from 0° 59°\* |  | 65° | 55° | 0° (nadir)58.9° | 52.8° |
| Swath width (km) | 1 700 | 2 343 2 186 \* | 2 343 2 193 \* | 2 500 | 1600 | 1 450 | 2 220 | 1 700 |
| Antenna efficiency | 0.27 | 0.14 | 0.64 | 0.17 | 0.81 | 0.52 | 0.6 | 0.6 |
| Beam dynamics | 20 rpm | 8 s scan period | 8/3 s scan period | 8/3 s scan period cross-track; 96 earth fields per scan period | 2.5 s scan period, clockwise | 40 rpm | 2.254 s | 45 rpm (1.33 s) |
| Sensor antenna pattern |  |  |  |  |  |  | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 |
| Cold calibration ant. gain (dBi) | N/A | 34.4 | 34.444.8 \* | 37.9 | 44 | 43.4 |  |  |
| Cold calibration angle (degrees re. satellite track) | N/A | 90°−90° ± 3.9°\* | End of scan (at 48.95°)−90° ± 3.9°\* | 0 | 315° | 115.5º | 78° to 83° | 165.5° to 203° |
| Cold calibration angle (degrees re. nadir direction) | N/A | 83.33° | 83.33°73.6(66° to 81°)\* | 82.175° | 90° | 97.0º |  |  |

TABLE A1.1 (*End*)

|  | Sensor L1 | Sensor L4 | Sensor L5 | Sensor L6 | Sensor L7 | Sensor L8 | Sensor L9 | Sensor L10 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sensor receiver parameters** |
| Sensor integration time (ms) | 2 | 180165 \* | 18518 \* | 18 | 5 | 1.2 | 13.7 | 1 to 8 |
| Channel bandwidth (MHz) | 2 700 MHz centred at 89 GHz | 6 000 MHz centred at 89 GHz | Centred at 89 GHz ±500 MHz, each with a bandwidth of 1 000 MHz2 800 MHz centred at 89 GHz\* | 2 000 MHz centred at 87‑91.9 GHz | 2.5 GHz centred at 91.655 GHz | 3 000 MHz centred at 89 GHz | 4 000 MHzCentred at 89 GHz | 4 000 MHz Centred at 89 GHz |
| **Measurement spatial resolution** |
| Horizontal resolution (km) | 10 | 40.548 \* | 40.516 \* | 32 | 16 | 2.9 |  |  |
| Vertical resolution (km) | N/A | 48 | 16 | 32 | 16 | 5.1 |  |  |
| NOTE – \* indicates that a particular sensor is flown on different missions, with different orbit and sensor parameters. |

TABLE A1.2

EESS (passive) sensor characteristics operating in the 86-92 GHz frequency band

|  | Sensor L11 | Sensor L12 | Sensor L13 | Sensor L14 | Sensor L15 | Sensor L16 | Sensor L17 | Sensor GSO-L1 | Sensor GSO-L2 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Conical scan | Conical scan | Cross-track nadir scan | Conical scan | Mechanical nadir scan | Nadir | Conical scan | Wide strip and thin circle combined scanning radiometer | Interferometric radiometer |
| **Orbit parameters** |
| Altitude (km) | 830 | 407 | 595 | 407 | 550 | 1 336 | 665.96 | 35800 | 35800 |
| Inclination (degree) | 98.85 | 50 | 97.79 | 65 | 30 | 66 | 98.06 | N/A | N/A |
| Eccentricity | 0 | 0.003 | 0.001 | 0 | 0 | 0 | 0.0015 | N/A | N/A |
| Repeat period  |  |  | 9 days/30 min (single satellite/constellation) | 43.5 days | 18.6 days | 9.92 days | 3 days | N/A | N/A |
| **Sensor antenna parameters** |
| Number of beams | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| Antenna size (m) | 1 | 1.1 | 0.16 | 1.22 | 0.083 | 1 | 2 | 5 | 5 |
| Maximum beam gain (dBi) | 57.4 | 58 | 41.3 | 53.8 | 35.0 | 57.0 | 62.4 | 69.5 | 71.1 |
| Polarization | V, H | H, V | QH/QV | H/V | H/V | Single Linear | H, V | V | V |
| −3 dB beamwidth (degree) | 0.27 | 0.4 | 1.75 | 0.38 | 2.89 | 0.31 | 0.15 | 0.07 | 0.05 |
| Instantaneous field of view (km) | 8 × 18(105 km²) | 7.5 × 4.5 | Nadir FOV: 18 (259 km²)Outer FOV: 35 × 76 (2 076 km²)  | 7.2 × 4.4 | Nadir IFOV: 27.7 Outer IFOV: 195.6 × 65.6 | 7 × 7  | A: 5 × 3B: 5 × 3 | 39 × 39  | N/A |
| Off-nadir pointing angle (degree) | 53.3 | 48.6 | 54.4 | 48.5 | ±60 cross-track | 3.4 along-track | 47.7 | N/A | N/A |
| Incidence angle at Earth (degree) | 65 | 53 | 0 (nadir)62.8 | 52.8 | ≤ 70.2 | 4.1 | 55 | N/A | N/A |
| Swath width (km) | 2 200 | 800 | 1 900 | 921 | 2480 | 7 | 1535 | 8 scan stripes, each strip 0.9×7.2, thin circle diameter 1.1 | Full disk |
| Antenna efficiency | 0.63 | 0.60 |  |  | 0.53 | 0.56 | 0.50 | 0.60 | 0.60 |
| Beam dynamics | 2.5 s scan period, counter clockwise | 30 rpm | 1.1 s (45 rpm) | 32 rpm | 2 s scan period | N/A | 40 rpm | General scan:0.64/minLocal scan:25.75 rpm | Full disk: 10 min |
| Sensor antenna pattern | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑RRS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 |
| Cold calibration ant. gain (dBi) | 45  | 55  | 41.3  | 37.7  | 35.0  | N/A | 43.4  |  |  |
| Cold calibration angle (degrees re. satellite track) | 315° | 180° | 78° to 83° | 206.7° (CCW) | 0° | N/A | 118.7º |  | N/A |
| Cold calibration angle (degrees re. nadir direction) | 90° | 90° |  | 107.5° | 120° | N/A | 94.6º |  |  |
| **Sensor receiver parameters** |
| Sensor integration time (ms) | 5 | 2.08 | 2 | 3.6 | 8.3 | 125 | 1.2 |  | 20 |
| Channel bandwidth | 2.5 GHz centred at 91.655 GHz | 3000 MHz centred at 89 GHz | 4 000 MHz centred at 89 GHz | 6 000 MHz centred at 89 GHz | 1 000 MHz centred at 90.256 GHz | 5 GHz centred at 90 GHz | 3 000 MHz centred at 89 GHz | 2000 MHz centred at 88.2 GHz | 2000 MHz centred at 88.2 GHz |
| **Measurement spatial resolution** |
| Horizontal resolution (km) | 16 | 8.7 |  | 4.4 | 27.7 | 7 | 3 | 39 (nadir) | 30 (nadir) |
| Vertical resolution (km) | 16 | 7.5 |  | 7.2 | 27.7 | 7 | 5 | 39 (nadir) | 30 (nadir) |

## 1.2 114.25-116 GHz systems

Typical parameters of passive sensors operating in the 114.25-122.25 GHz frequency band

The frequency range 114.25-122.25 GHz is of primary interest for atmospheric temperature profiling (O2absorption lines).

Tables A1.3 to A1.9 summarizes the parameters of passive sensors that are or will be operating in the frequency range of 114.25 and 122.25 GHz. (see section 6.14 of Recommendation ITU-R RS.1861-1)

TABLE A1.3

EESS (passive) sensor characteristics operating in the 114.25 - 122.25 GHz frequency band

|  | Sensor M1 | Sensor M2 | Sensor M3 | Sensor M4 | Sensor M5 | Sensor M6 | Sensor GSO‑M1 | Sensor GSO-M2 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Limb sounder | Conical scan | Conical scan | Nadir scan | Mechanical nadir scan | Conical scan | Raster scan | Wide strip and thin circle combined scan |
| **Orbit parameters** |
| Altitude (km) | 705 | 407 | 836 | 836 | 550 | 830 | 35 800 | 35 800 |
| Inclination (degree) | 98.2 | 50 | 98.75 | 98.75 | 30 | 98.7 | N/A | N/A |
| Eccentricity | 0 | 0.003 | 0.003 | 0.003 | 0 | 0.001 | N/A | N/A |
| Repeat period (days) | 16  |  | 5.5  | 5.5  | 18.6  | 29  | N/A | N/A |
| **Sensor antenna parameters** |
| Number of beams | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Antenna size (m) | 1.6 (V) × 0.8 (H) | 1.1 | 1.1 | 0.22 | 0.083 | 0.76 | 3 | 5 |
| Maximum beam gain (dBi) | 62 | 60.5 | 60.5 | 46.5 | 37.8 | 55.5 | 69.2 | 70.5 |
| Polarization | H, V | V | V | H | H/V | V | H | H |
| −3 dB beamwidth (degree) | 0.119 × 0.245 | 0.35 | 0.35 | 1.8 | 2.41 | 0.33 | 0.06 | 0.055 |
| Instantaneous field of view (km) | 6.5 × 13 | 5.8 × 3.7 | 11.5 × 7.4 | Nadir: 26  | Nadir IFOV: 23.1Outer IFOV: 162.6 × 54.7 | 7 × 12(68 km²) | Nadir: 37  | Nadir: 34  |
| Off-nadir pointing angle | Limb | 46.1° | 42.6° | ±53.35° cross-track | ±60° cross-track | 44.8° | N/A | N/A |
| Incidence angle at Earth (degree) | N/A | 50 | 50 | 0 (nadir) | ≤ 70.2 | 52.8 | N/A | N/A |
| Swath width (km) | N/A | 800 | 1 400 | 2 000 | 2 480 | 1 700 | Full disk | 8 scan stripes, each strip 0.9×7.2, thin circle diameter 1.1 |
| Antenna efficiency | 0.80 | 0.604 | 0.604 | 0.604 | 0.56 | 0.6 | 0.60 | 0.60 |
| Beam dynamics | Scans continuously in tangent height from the surface to ~92 km in 24.7 s, 240 scans/orbit | 30 rpm | 30 rpm | 8/3 s scan period1.71 s for 96 earth fields per scan period | 2 s scan period | 45 rpm (1.33 s) | Full disk: 45 min | General scan:0.64°/minLocal scan:25.75 rpm |
| Sensor antenna pattern | See Rec. ITU-R RS.1813 with minor mods (see NOTE below) | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 | See Rec. ITU‑R RS.1813 |
| Cold calibration ant. gain (dBi) | N/A | 57.5 | 57.5 | 46.5 | 37.8 |  |  |  |
| Cold calibration angle (degrees re. satellite track) | N/A | 180° | 180° | 90° | 0° | 165.5° to 203° | N/A |  |
| Cold calibration angle (degrees re. nadir direction) | N/A | 90° | 90° | 74° | 120° |  |  |  |
| **Sensor receiver parameters** |
| Sensor integration time | 0.166 s | 2.08 ms | 2.08 ms | 17 ms | 8.3 ms | 1 to 8 ms | 10 ms |  |
| Channel bandwidth | See Table 36 | See Table 37 | See Table 37 | See Table 38 | See Table 39 | See Table 40 | See Table 38 | See Table 41 |
| **Measurement spatial resolution** |
| Horizontal resolution (km) | 13 | 7.7 | 15.3 | 42 (nadir) | 23.1 |  | 49 (nadir) |  |
| Vertical resolution (km) | 6.5 | 5.8 | 11.5 | 26 (nadir) | 23.1 |  | 37 (nadir) |  |
| NOTE – The antenna model from Recommendation ITU-R RS.1813-1 can be adjusted to support elliptical reflectors with the following modifications:• The maximum antenna gain be defined as: .• The antenna diameter be defined as: . Therefore, the antenna diameter becomes a function of the angle (α ϵ [0°, 90°]) in the plane that is perpendicular to the antenna boresight vector and between the intended direction of emission and the antenna beam’s major axis.• The existing functions for G(φ) and φm should be evaluated for each point in the alpha/phi space. |

TABLE A1.4

Sensor M1 passive sensor characteristics for channels between 114.25 and 116 GHz

|  |  |
| --- | --- |
| Centre frequency (GHz) | Channel bandwidth (MHz) |
| 115.3 | 500 |

TABLE A1.5

Sensor M2 and M3 passive sensor characteristics
for channels between 114.25 and 122.25 GHz

|  |  |  |
| --- | --- | --- |
| Centre frequency (GHz) | Channel bandwidth (MHz) | Polarization |
| 118.7503 ± 3.2 | 1 000 | V |

TABLE A1.6

Sensor M4 and GSO-M1 passive sensor characteristics for channels between
114.25 and 122.25 GHz

|  |  |  |
| --- | --- | --- |
| Centre frequency (GHz) | Channel bandwidth (MHz) | Polarization |
| 118.7503 ± 3.0 | 2 000 | H |

TABLE A1.7

Sensor M5 passive sensor characteristics for channels between 114.25 and 122.25 GHz

|  |  |
| --- | --- |
| Centre frequency (GHz) | Channel bandwidth (MHz) |
| 114.5 | 1000 |
| 115.95 | 800 |

TABLE A1.8

Sensor M6 passive sensor characteristics for channels between 114.25 and 122.25 GHz

|  |  |
| --- | --- |
| Centre frequency (GHz) | Channel bandwidth (MHz) |
| 118.75 ± 3.2 | 2 × 500 |

TABLE A1.9

Sensor GSO-M2 passive sensor characteristics for channels between 114.25 and 122.25 GHz

|  |  |  |
| --- | --- | --- |
| Centre frequency (GHz) | Channel bandwidth (MHz) | Polarization |
| 118.7503 ± 3.0 | 2 000 | H |
| 118.7503 ± 5.0 | 2 000 | H |

## 1.3 164-167 GHz systems

Typical parameters of passive sensors operating in the 164-167 GHz frequency band

The 164-167 GHz frequency band is of primary interest to measure N2O, cloud water and ice, rain, CO, and ClO.

Tables A1.10 and A1.11 summarize the parameters of passive sensors that are or will be operating in the 164-167 GHz frequency band. (see section 6.17 of Recommendation ITU-R RS.1861-1)

TABLE A1.10

EESS (passive) sensor characteristics operating in the 164-167 GHz frequency band

|  | Sensor P2 | Sensor P3 | Sensor P4 | Sensor P5 | Sensor P6 |
| --- | --- | --- | --- | --- | --- |
| Sensor type | Mechanical nadir scan | Conical scan | Conical scan | Conical scan | Nadir scan |
| **Orbit parameters** |
| Altitude (km) | 824 | 830 | 407 | 836 | 836 |
| Inclination (degree) | 98.7 | 98.85 | 50 | 98.75 | 98.75 |
| Eccentricity  | 0 | 0 | 0.003 | 0.003 | 0.003 |
| Repeat period (days) | 9 |  |  | 5.5 | 5.5 |
| **Sensor antenna parameters** |
| Number of beams | 2 | 1 | 1 | 1 | 1 |
| Antenna size (m) | 0.127 | 1 | 0.8 | 0.8 | 0.22 |
| Maximum beam gain (dBi) | 43.9 | 62.6 | 60.6 | 60.6 | 49.4 |
| Polarization | QH | V | V | V | V |
| −3 dB beamwidth (degree) | 1.1 | 0.15 | 0.35 | 0.35 | 1.2 |
| Instantaneous field of view | Nadir FOV: 15.8 kmOuter FOV: 68.4 × 30 km | 4 km × 9 km | 6.5 km × 3.9 km | 12.9 km × 7.8 km | Nadir: 18 km |
| Off-nadir pointing angle (degree) | ±52.725 cross-track | 53.3 | 48.6 | 44.9 | ±53.35 cross‑track |
| Incidence angle at Earth (degree) | 0 | 65° | 53° | 53° | 0° (nadir) |
| Swath width (km) | 2 500 | 2 200 | 800 | 1 400 | 2 000 |
| Antenna efficiency | 0.51 | 0.61 | 0.597 | 0.597 | 0.61 |
| Beam dynamics | 8/3 s scan period cross‑track; 96 earth fields per scan period | 2.5 s scan period, counter clockwise | 30 rpm | 30 rpm | 8/3 s scan period1.71 s for 96 earth fields per scan period |
| Sensor antenna pattern |  | Rec. ITU‑R [RS.1813](http://www.itu.int/rec/R-REC-RS.1813/en) | Rec. ITU‑R [RS.1813](http://www.itu.int/rec/R-REC-RS.1813/en) | Rec. ITU‑R [RS.1813](http://www.itu.int/rec/R-REC-RS.1813/en) | Rec. ITU‑R [RS.1813](http://www.itu.int/rec/R-REC-RS.1813/en) |
| Cold calibration ant. gain (dBi) | 43.9 | 49.4 | 57.6 | 57.6 | 49.4 |
| Cold calibration angle (degrees re. satellite track) | 0° | 315° | 180° | 180° | 90° |
| Cold calibration angle (degrees re. nadir direction) | 82.175° | 90° | 90° | 90° | 74° |
| **Sensor receiver parameters** |
| Sensor integration time (ms) | 18 | 5 | 2.08 | 2.08 | 17 |
| Channel bandwidth | 3 000 MHz centred at 164-167 GHz | 3 000 MHz centred at 165.5 GHz | 1 350 MHz centred at 165.5 ± 0.75 GHz | 1 350 MHz centred at 165.5 ± 0.75 GHz | 1 500 MHz centred at 166 GHz |
| **Measurement spatial resolution** |
| Horizontal resolution (km) | 32 | 32 | 8.1 | 16.1 | 34 (nadir) |
| Vertical resolution (km) | 32 | 32 | 6.5 | 12.9 | 18 (nadir) |

TABLE A1.11

EESS (passive) sensor characteristics operating in the 164-167 GHz frequency band

|  | Sensor P7 | Sensor P8 | Sensor P9 | Sensor P10 | Sensor P11 | Sensor P12 | Sensor GSO‑P1 | Sensor GSO-P2 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Cross-track nadir scan | Conical scan | Nadir | Conical scan | Nadir scan | Conical scan | Raster scan | Wide strip and thin circle combined scan |
| **Orbit parameters** |
| Altitude (km) | 595 | 407 | 1 336 | 665.96 | 830 | 830 | 35 800 | 35 800 |
| Inclination (degree) | 97.79 | 65 | 66 | 98.06 | 98.7 | 98.7 | N/A | N/A |
| Eccentricity | 0.001 | 0 | 0 | 0.0015 | 0.001 | 0.001 | N/A | N/A |
| Repeat period | 9 days/30 min (single satellite/constellation) | 43.5 days | 9.92 days | 3 days | 29 days | 29 days | N/A | N/A |
| **Sensor antenna parameters** |
| Number of beams | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Antenna size (m) | 0.16 | 1.22 | 1 | 2 | 0.35 | 0.76 | 3 | 5 |
| Maximum beam gain (dBi) | 46.6 | 54.3 | 61.0 | 57.2 | 43 | 56.3 | 72.1 | 73 |
| Polarization | QH/QV | H/V | Single Linear | V | QH/QV | V | V | V |
| −3 dB beamwidth (degree) | 0.8 | 0.37 | 0.18 | 0.23 × 0.30 | 1.15 | 0.33 | 0.04 | 0.04 |
| Instantaneous field of view | Nadir FOV: 8 km(54 km²)Outer FOV: 16 × 35(433 km²) | 6.3 × 4.1 km | 4 × 4 km | 4 km × 9 km | Nadir FOV: 17 km(218 km²)Outer FOV: 55 × 28 km(1 225 km²) | 7 × 12 km(68 km²) | Nadir: 26 km | Nadir: 25 km |
| Off-nadir pointing angle (degree) | 54.4 | 45.4 | 3.4 along-track | 45.5 | ±49.31 cross-track | 44.8 | N/A | N/A |
| Incidence angle at Earth (degree) | 0 (nadir)62.8 | 49.2 | 4.1 | 51.9 | 0 (nadir)58.9 | 52.8 | N/A | N/A |

TABLE 2.4.2 (*End*)

|  | Sensor P7 | Sensor P8 | Sensor P9 | Sensor P10 | Sensor P11 | Sensor P12 | Sensor GSO-P1 | Sensor GSO-P2 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Swath width (km) | 1900 | 819 | 4 | 1 398 | 2 220 | 1 700 | Full disk | 8 scan stripes, each strip 0.9×7.2, thin circle diameter 1.1 |
| Antenna efficiency |  |  | 0.42 |  | 0.6 | 0.6 | 0.60 | 0.60 |
| Beam dynamics | 1.1 s (45 rpm) | 32 rpm | N/A | 40 rpm | 2.254 s | 45 rpm (1.33 s) | Full disk: 45 min | General scan:0.64/minLocal scan:25.75 rpm |
| Sensor antenna pattern | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑R RS.1813 | Rec. ITU‑RRS.1813 |
| Cold calibration ant. gain (dBi) | 46.6 | 43.1 | N/A | 37.0 |  | N/A |  |  |
| Cold calibration angle (degrees re. satellite track) | 78° to 83° | 206.7° (CCW) | N/A | 118.7° | 78° to 83° | 165.5° to 203° | N/A |  |
| Cold calibration angle (degrees re. nadir direction) |  | 107.5° | N/A | 94.6° |  | N/A |  |  |
| **Sensor receiver parameters** |
| Sensor integration time (ms) | 2 | 3.6 | 125 | 2.5 | 13.7 | 1 to 8 | 10 | 10 |
| Channel bandwidth | 2 800 MHz centred at 165.5 GHz | 4 000 MHz centred at 166 GHz | 5 GHzcentred at 168 GHz | 4 000 MHz centred at 165.5 GHz | 2 × 1 350 MHz centred at 165.5 ± 0.725 GHz | 2 × 1 425 MHz centred at165.5 ± 0.73 GHz | 3 000 MHz centred at 165.5 GHz | 3 000 MHz centred at 165.5 GHz |
| **Measurement spatial resolution** |
| Horizontal resolution (km) |  | 4.1 | 4 | 4 |  |  | 39 (nadir) | 35 (nadir) |
| Vertical resolution (km) |  | 6.3 | 4 | 9 |  |  | 26 (nadir) | 25 (nadir) |

## 1.4 200-209 GHz systems

Typical parameters of passive sensors operating in the 200-209 GHz frequency band

Table A1.12 summarizes the parameters of passive sensors that are or will be operating in the 200‑209 GHz frequency band. (see section 6.19 of Recommendation RS.1861-1)

TABLE A1.12

EESS (passive) sensor characteristics operating in the 200-209 GHz frequency band

|  | Sensor S1 | Sensor S2 |
| --- | --- | --- |
| Sensor type | Mechanical nadir scan | Limb sounder |
| **Orbit parameters** |  |
| Altitude (km) | 550 | 705 |
| Inclination (degree) | 30 | 98.2 |
| Eccentricity | 0 | 0 |
| Repeat period (days) | 18.6 | 16 |
| **Sensor antenna parameters** |  |
| Number of beams | 1 | 1 |
| Antenna size (m) | 0.083 | 1.6 (V) × 0.8 (H) |
| Maximum beam gain (dBi) | 44.1 | 65 |
| Polarization | H/V | V |
| −3 dB beamwidth (degree) | 1.64 | 0.078 × 0.152 |
| Instantaneous field of view (km) | Nadir IFOV: 15.7Outer IFOV: 110.2 × 37.2 | 4.1 × 8.0 |
| Off-nadir pointing angle | ±60° cross-track | N/A |
| Incidence angle at Earth (degree) | ≤ 70.2 | N/A |
| Swath width (km) | 2 480 | N/A |
| Antenna efficiency | 0.81 | 0.55 |
| Beam dynamics | 2 s scan period | Scans continuously in tangent height from the surface to ~9 km in 24.7 s, 240 scans/orbit |
| Sensor antenna pattern | Rec. ITU-R RS.1813 | Rec. ITU-R RS.1813 with minor mods(see NOTE in § 6.14) |
| Cold calibration ant. gain (dBi) | 44.1 | N/A |
| Cold calibration angle (degrees re. satellite track) | 0° | N/A |
| Cold calibration angle (degrees re. nadir direction) | 120° | N/A |
| **Sensor receiver parameters** |  |
| Sensor integration time | 8.3 ms | 0.166 s |
| Channel bandwidth | 2 000 MHz centred at 204.80 GHz | 1 250 MHz centred at 200.9798, 204.3566, and 206.1367 GHz |
| **Measurement spatial resolution** |  |
| Horizontal resolution (km) | 15.7 | 8.0 |
| Vertical resolution (km) | 15.7 | 4.1 |

Annex 2

Technical analysis related to the Mobile service

TBD

Annex 3

Technical analysis related to the radionavigation service
and radiolocation service

TBD

Annex 4

Technical analysis related to the fixed-satellite service

TBD

Annex 5

Technical analysis related to the mobile-satellite service

TBD

Annex 6

Technical analysis related to the inter-satellite service

TBD

Annex 7

Technical analysis related to the radionavigation satellite service

TBD

Annex 8

Technical analysis related to the Fixed service

TBD