| **US Radiocommunication Sector**  **FACT SHEET** | | | |
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| **Reference:** [Rec. ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) | | **Date:** 12 August 2024 | |
| **Document Title:** Working Document towards a Preliminary Draft New Recommendation ITU-R RS.[2105-2 + RADAR SOUNDER] | | | |
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| **Purpose/Objective**: This contribution is intended as an update to [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) to include information about a new active sensor type, namely the radar sounder. In particular, this is in response to the outcome of WRC-23 agenda item 1.12, which granted secondary allocation status to EESS (active) emissions over the frequency range 40‑50 MHz from spaceborne radar sounders, such as those characterized in [Recommendation ITU-R RS.2042-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2042-2-202312-I!!PDF-E.pdf). However, as the title of [Recommendation ITU-R RS.2105-2](../Input%20Documents/In%20particular,%20this%20is%20in%20response%20to%20the%20outcome%20of%20WRC-23%20agenda%20item%201.12,%20which%20granted%20secondary%20allocation%20status%20to%20EESS%20(active)%20emissions%20over%20the%20frequency%20range%2040%2050%20MHz%20from%20spaceborne%20radar%20sounders,%20such%20as%20those%20characterized%20in%20Recommendation%20ITU-R%20RS.2042-2.) would have to be changed to reflect this new frequency band, this contribution seeks to develop a new recommendation with this change in place, while using [Recommendation ITU-R RS.2105-2](../Input%20Documents/In%20particular,%20this%20is%20in%20response%20to%20the%20outcome%20of%20WRC-23%20agenda%20item%201.12,%20which%20granted%20secondary%20allocation%20status%20to%20EESS%20(active)%20emissions%20over%20the%20frequency%20range%2040%2050%20MHz%20from%20spaceborne%20radar%20sounders,%20such%20as%20those%20characterized%20in%20Recommendation%20ITU-R%20RS.2042-2.) as a foundation. As radar sounders cannot be classified in terms of any of the 5 basic types of active sensors as described in [Recommendation ITU-R RS.2105-2](../Input%20Documents/In%20particular,%20this%20is%20in%20response%20to%20the%20outcome%20of%20WRC-23%20agenda%20item%201.12,%20which%20granted%20secondary%20allocation%20status%20to%20EESS%20(active)%20emissions%20over%20the%20frequency%20range%2040%2050%20MHz%20from%20spaceborne%20radar%20sounders,%20such%20as%20those%20characterized%20in%20Recommendation%20ITU-R%20RS.2042-2.), they are characterized as a new basic type in this contribution. In addition, characteristics for the NISAR L-band SAR have been updated in the new Table 7 under the moniker SAR-C1, while those for the NISAR S-band SAR have been included in the new Table 8 under the moniker SAR-D4. | | | |
| **Abstract**: This contribution is essentially an update to [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) to incorporate information about a new active sensor type, namely the radar sounder. Specifically, this is in response to the outcome of WRC-23 agenda item 1.12, which granted secondary allocation status to EESS (active) emissions over the frequency range 40‑50 MHz from spaceborne radar sounders, such as those characterized in [Recommendation ITU-R RS.2042-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2042-2-202312-I!!PDF-E.pdf). However, as the title of [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf), namely “Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 432 MHz and 238 GHz”, would have to be changed to reflect this new frequency band, this contribution seeks to develop a new recommendation with this change in place, while using [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) as a foundation. In particular, the title of this new recommendation would be “Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 40 MHz and 238 GHz”. As radar sounders are used for ground-penetrating radar (GPR) applications, they cannot be characterized in terms of the 5 basic types of active sensors as described in [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf). Consequently, such sensors must be characterized as a new basic active sensor type, referred to here as the radar sounder type. In addition to introducing this sensor type, Tables 1, 2, and 3 are modified to include information related to the radar sounder type. Furthermore, a new subsection (Section 7.1) is added to reflect typical parameters of active sensors operating in the 40‑50 MHz band. Finally, characteristics for the NISAR L-band SAR have been updated in the new Table 7 under the moniker SAR-C1, while those for the NISAR S-band SAR have been included in the new Table 8 under the moniker SAR-D4. Changes are tracked with respect to [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) to highlight the fact that it is the foundation for this proposed new recommendation. | | | |
| **Fact Sheet Preparer:** Andre Tkacenko, NASA JPL | | | |

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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R RS.[2105-2 + RADAR SOUNDER] | |

This contribution is essentially an update to [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) to incorporate information about a new active sensor type, namely the radar sounder. Specifically, this is in response to the outcome of WRC-23 agenda item 1.12, which granted secondary allocation status to EESS (active) emissions over the frequency range 40‑50 MHz from spaceborne radar sounders, such as those characterized in [Recommendation ITU-R RS.2042-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2042-2-202312-I!!PDF-E.pdf).

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As radar sounders are used for ground-penetrating radar (GPR) applications, they cannot be characterized in terms of the 5 basic types of active sensors as described in [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf). Consequently, such sensors must be characterized as a new basic active sensor type, referred to here as the radar sounder type. In addition to introducing this sensor type, Tables 1, 2, and 3 have been modified to include information related to the radar sounder type. Furthermore, a new subsection (Section 7.1) has been added to reflect typical parameters of active sensors operating in the 40‑50 MHz band, which includes a new table, namely Table 5, which contains the characteristics of the EESS (active) spaceborne radar sounder characterized in [Recommendation ITU-R RS.2042-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2042-2-202312-I!!PDF-E.pdf).

Finally, characteristics for the NASA-ISRO Synthetic Aperture Radar (NISAR) L-band synthetic aperture radar (SAR) have been updated in the new Table 7 (previously Table 6), under the moniker SAR-C1, while those for the NISAR S-band SAR have been included in the new Table 8 (previously Table 7), under the moniker SAR-D4. Changes are tracked with respect to [Recommendation ITU-R RS.2105-2](https://www.itu.int/dms_pubrec/itu-r/rec/rs/R-REC-RS.2105-2-202312-I!!PDF-E.pdf) to highlight the fact that it is the foundation for this proposed new recommendation.

**Attachments:** 1

RECOMMENDATION ITU-R RS.[2105-2 + RADAR SOUNDER]

Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 40 MHz and 238 GHz

(202X)

Scope

This Recommendation provides technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 40 MHz and 238 GHz for utilisation in sharing and compatibility studies.

Keywords

EESS (active), earth exploration-satellite service, remote sensing, synthetic aperture radar, altimeters, precipitation radar, scatterometers, cloud profile radar

Abbreviations/Glossary

ARNS Aeronautical radionavigation service

CPR Cloud profile radar

EESS Earth exploration-satellite service

e.i.r.p. Effective isotropically radiated power

FM Frequency modulation

GPR Ground-penetrating radar

IFOV Instantaneous field of view

LHCP Left hand circular

LFM Linear FM

LST Local solar time

LRM Low resolution mode

Non-GSO Non-geostationary satellite orbit

NSS Non-sun-synchronous

pfd Power flux-density

PRF Pulse Repetition Frequency

RF Radio frequency

RHCP Right hand circular

SRS Space research service

SSO Sun-synchronous

SAR Synthetic aperture radars

The ITU Radiocommunication Assembly,

considering

*a)* that Earth exploration-satellite service (EESS) (active) observations may receive emissions from active services;

*b)* that EESS (active) is co-allocated with active services in certain bands;

*c)* that studies considering protection for and from EESS (active) systems are taking place within ITU-R;

*d)* that in order to perform compatibility and sharing studies with EESS (active) systems, the technical and operational characteristics of those systems must be known,

recognizing

*a)* that Recommendation [ITU-R RS.577](https://www.itu.int/rec/R-REC-RS.577/en) provides information on the bandwidths of active sensor systems envisaged to operate in the allocated bands between 40 MHz and 238 GHz;

*b)* that several ITU-R Recommendations and Reports provide information on the current and future characteristics of EESS (active) systems operating in several frequency bands (see Annex, Table 2),

recommends

that the technical and operational parameters presented in the Annex of this Recommendation should be taken into account in studies considering EESS (active) systems using allocations between 40 MHz and 238 GHz.

Annex  
  
Technical and operational parameters of EESS (active) systems   
using allocations between 40 MHz and 238 GHz

TABLE OF CONTENTS

*Page*

[1 Introduction 5](#_Toc86830999)

[2 Active sensor types and typical characteristics 5](#_Toc86831000)

[3 Typical orbits 6](#_Toc86831001)

[4 Active sensors interference and performance criteria 6](#_Toc86831002)

[5 Sharing considerations for active sensors 7](#_Toc86831003)

[6 Definition of parameters 10](#_Toc86831007)

[7 Parameters of typical systems 15](#_Toc86831008)

# 1 Introduction

Active sensors are used in the remote sensing of the Earth and its atmosphere by Earth exploration and meteorological satellites in certain frequency bands allocated to the Earth exploration-satellite service (EESS) (active). The products of these active sensor operations are used extensively in meteorology, climatology, and other disciplines for operational and scientific purposes.

The technical and operational parameters presented in this Recommendation shall be used in studies considering EESS (active) systems using allocations between 40 MHz and 238 GHz. However, it should be noted that some of the EESS (active) systems are under development and the typical values for certain parameters provided should be considered preliminary as these still may change.

# 2 Active sensor types and typical characteristics

There are six active spaceborne sensor types addressed in this Recommendation:

Type 1: Radar sounders – Sensors looking at nadir employing lower centre frequencies for ground‑penetrating radar (GPR) applications, which measure the radar return from the Earth’s surface and subsurface to identify and characterize underground features such as aquifers and ice sheets.

Type 2: Synthetic aperture radars (SAR) – Sensors looking to one side of the nadir track, collecting a phase and time history of the coherent radar echo from which a radar image of the Earth’s surface from the returned echo or topography from interferometric returns can be produced.

Type 3: Altimeters – Sensors looking at nadir, measuring the precise time between a transmit event and receive event, to extract the precise altitude of the Earth’s ocean surface.

Type 4: Scatterometers – Sensors pointing at various look angles relative to the sides of the nadir track, using the measurement of the return echo power variation with aspect angle to determine the roughness of land surface or to determine the wind direction and speed on the Earth’s ocean surface.

Type 5: Precipitation radars – Sensors scanning perpendicular to nadir track which measure the radar echo from rainfall in order to determine the rainfall rate over the Earth’s surface and the three-dimensional structure of rainfall.

Type 6: Cloud profile radars – Sensors looking at nadir which measure the radar echo return from clouds in order to determine the cloud reflectivity profile over the Earth’s surface.

Some typical characteristics of spaceborne active sensors are shown below in Table 1. The actual characteristic values of the systems operating in the various frequency bands provided in § 7 of this Recommendation may vary considerably from these typical characteristic values reflected in Table 1.

TABLE 1

Typical characteristics of active spaceborne sensors

| Characteristic | Sensor type | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Radar sounder | SAR | Altimeter | Scatterometer | Precipitation radar | Cloud profile radar |
| Service area | Land/ice | Land/coastal/ ocean | Ocean/ice/coastal/ Inland water | Ocean/ice/land/ coastal | Land/ocean | Land/ocean |
| Antenna beam | Wide beam | Fan beam | Pencil beam | – Fan beams  – Pencil beams | Pencil beam | Pencil beam |

TABLE 1 (*end*)

| Characteristic | Sensor type | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Radar sounder | SAR | Altimeter | Scatterometer | Precipitation radar | Cloud profile radar |
| Viewing geometry | Nadir-looking | Side-looking at 10‑60  off nadir | – Nadir-looking  – Multi incidence looking | – Three/six fan beams in azimuth  – One or more conically scanning beams | Scanning across-track around Nadir | Nadir-looking |
| Footprint/dynamics | Fixed at nadir | – Fixed to one side  – ScanSAR  – Spotlight | – Fixed at nadir  – Multi incidence looking | – Fixed in azimuth  – Multiple conically scanning beams | Scanning across nadir track | Fixed at nadir |
| RF bandwidth | 10 MHz | 20- 1 200 MHz | 320-500 MHz | 5-80 kHz (ocean) or  1-4 MHz (land) | 14 MHz | 300 kHz |
| Transmit peak power (W) | 100 | 1 500-16 000 | 20 | 100-5 000 | 600 | 1 000-1 500 |
| Waveform | Linear FM pulses | Linear FM pulses | Linear FM pulses | Interrupted CW or short pulses (ocean) or linear FM pulses (land) | Short pulses | Short pulses |
| Transmit duty  cycle (%) | 10.2 | 1-30 | 46 | 31 (ocean) or  10 (land) | 0.9 | 1-14 |

# 3 Typical orbits

EESS (active) systems operate in non-geostationary satellite orbit (non-GSO). Orbits are typically circular with an altitude between 350 and 1 400 km. Some EESS (active) systems operate in a sun‑synchronous orbit. Some sensors make measurements over the same area on the Earth every day, while others will repeat observations only after a longer (often more than two weeks) repeat period.

In certain circumstances, multiple satellites operate in formation. Formation flying EESS satellites allow the capability to measure different Earth system characteristics (land, ocean, atmosphere, cryosphere and solid Earth) using both multiple instruments and orientations. Measurements from multiple spacecraft will be separated within an amount of time shorter than the time constant of the phenomena being measured. Nominally, this separation is on the order of 5 to 15 min but can be as little as a few seconds.

# 4 Active sensors interference and performance criteria

The criteria for performance, interference and data availability are provided in Recommendation ITU‑R RS.1166 for the various types of active spaceborne sensors. Performance criteria for active spaceborne sensors are needed in order to develop interference criteria. Interference criteria, in turn, can be used to assess the compatibility of other active services and active sensors operating in common frequency bands.

# 5 Sharing considerations for active sensors

## 5.1 Existing ITU-R Recommendations and Reports

The sharing considerations for sharing between spaceborne active sensors in the EESS (active) and other services are provided in the ITU-R Recommendations and Reports listed in Table 2. These Recommendations and Reports are concerned with specific frequency bands or ranges of frequencies and the other services operating in those bands.

The sharing considerations for spaceborne active sensors include the level of the power flux-density (pfd) and received interference power at the Earth’s surface, the type of transmitted RF signal, the dynamics of the antenna coupling with systems of other services, and the types of systems in the other services.

TABLE 2

List of ITU-R documents with sharing considerations for active sensors

|  |  |
| --- | --- |
| Recommendations | |
| ITU-R [RS.1260](https://www.itu.int/rec/R-REC-RS.1260/en) | Feasibility of sharing between active spaceborne sensors and other services in the range 420-470MHz |
| ITU-R [RS.1261](https://www.itu.int/rec/R-REC-RS.1261/en) | Feasibility of sharing between spaceborne cloud radars and other services in the range of 92-95 GHz |
| ITU-R [RS.1280](https://www.itu.int/rec/R-REC-RS.1280/en) | Selection of active spaceborne sensor emission characteristics to mitigate the potential for interference to terrestrial radars operating in frequency bands 1-10 GHz |
| ITU-R [RS.1281](https://www.itu.int/rec/R-REC-RS.1281/en) | Protection of stations in the radiolocation service from emissions from active spaceborne sensors in the band 13.4-13.75 GHz |
| ITU-R [RS.1282](https://www.itu.int/rec/R-REC-RS.1282/en) | Feasibility of sharing between wind profiler radars and active spaceborne sensors in the vicinity of 1 260 MHz |
| ITU-R [RS.1347](https://www.itu.int/rec/R-REC-RS.1347/en) | Feasibility of sharing between radionavigation-satellite service receivers and the Earth exploration-satellite (active) and space research (active) services in the 1 215‑1 260 MHz band |
| ITU-R [RS.1628](https://www.itu.int/rec/R-REC-RS.1628/en) | Feasibility of sharing in the band 35.5-36 GHz between the Earth exploration-satellite service (active) and space research service (active), and other services allocated in this band |
| ITU-R [RS.1632](https://www.itu.int/rec/R-REC-RS.1632/en) | Sharing in the band 5 250-5 350 MHz between the Earth exploration-satellite service (active) and wireless access systems (including radio local area networks) in the mobile service |
| ITU-R [RS.1749](https://www.itu.int/rec/R-REC-RS.1749/en) | Mitigation technique to facilitate the use of the 1 215-1 300 MHz band by the Earth exploration-satellite service (active) and the space research service (active) |
| ITU-R RS.2042 | Typical technical and operating characteristics for spaceborne radar sounder systems using the 40‑50 MHz band |
| ITU-R [RS.2043](https://www.itu.int/rec/R-REC-RS.2043/en) | Characteristics of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz |
| ITU-R [RS.2065](https://www.itu.int/rec/R-REC-RS.2065/en) | Protection of space research service (SRS) space-to-earth links in the 8 400‑8 450 MHz and 8 450‑8 500 MHz bands from unwanted emissions of synthetic aperture radars operating in the earth exploration-satellite service (active) around 9 600 MHz |
| ITU-R [RS.2066](https://www.itu.int/rec/R-REC-RS.2066/en) | Protection of the radio astronomy service in the frequency band 10.6-10.7 GHz from unwanted emissions of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz |
| ITU-R [RS.2068](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2068) | Current and future use of the band near 13.5 GHz by spaceborne active sensors |

TABLE 2 (*end*)

|  |  |
| --- | --- |
| Recommendations | |
| [ITU-R RS.2094](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2094) | Studies related to the compatibility between Earth exploration-satellite service (active) and the radiodetermination service in the 9 300-9 500 MHz and 9 800-10 000 MHz bands and between Earth exploration-satellite service (active) and the fixed service in the 9 800-10 000 MHz band |
| [ITU-R RS.2178](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2178) | The essential role and global importance of radio spectrum use for Earth observations and for related applications |
| Reports | |
| [ITU-R RS.2273](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2273) | Potential interference from EESS (active) scatterometers into ARNS systems in the frequency band 1 215-1 300 MHz |
| [ITU-R RS.2274](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2274) | Spectrum requirements for spaceborne synthetic aperture radar applications planned in an extended allocation to the Earth exploration-satellite service around 9 600 MHz |
| [ITU-R RS.2310](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2310) | Worst-case interference levels from mainlobe-to-mainlobe antenna coupling of systems operating in the radiolocation service into active sensor receivers operating in the Earth exploration-satellite service (active) in the 35.5-36.0 GHz band |
| [ITU-R RS.2311](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2311) | Pulsed radio frequency signal impact measurements and possible mitigation techniques between Earth exploration-satellite service (active) systems and RNSS systems and networks in the band 1 215-1 300 MHz |
| [ITU-R RS.2313](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2313) | Sharing analyses of wideband Earth exploration-satellite service (active) transmissions with stations in the radio determination service operating in the frequency bands 8 700‑9 300 MHz and 9 900-10 500 MHz |
| ITU-R [RS.2314](http://www.itu.int/pub/R-REP-RS/publications.aspx?lang=en&parent=R-REP-RS.2314) | Sharing analyses of wideband EESS SAR transmissions with stations in the fixed, mobile, amateur, and amateur-satellite services operating in the frequency bands 8 700‑9 300 MHz and 9 900-10 500 MHz |
| ITU-R RS.2536 | Sharing and compatibility studies related to spaceborne radar sounders in the 40‑50 MHz frequency band |

## 5.2 Power flux-density levels due to active spaceborne sensors

The characteristics of the various types of active spaceborne sensors as shown in Table 1 indicate that the transmitted peak power and therefore the power levels received at the Earth’s surface will vary significantly. Table 3 shows the active sensor pfd levels at the Earth’s surface for some typical sensor configurations.

TABLE 3

Typical pfd levels at Earth’s surface

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Sensor type | | | | | |
| Radar sounder | SAR | Altimeter | Scatterometer | Precipitation radar | Cloud profile radar |
| Transmit peak power (W) | 100 | 1 500 | 20 | 100 | 578 | 630 |
| Antenna gain (dBi) | 10 | 36.4 | 43.3 | 34 | 47.7 | 63.4 |
| Altitude (km) | 400 | 695 | 1 344 | 1 145 | 350 | 400 |
| pfd (dB(W/m2)) | -93.03 | −59.67 | −77.25 | −78.17 | −46.55 | −31.64 |

## 5.3 Dynamics of antenna coupling with systems of other services

The viewing geometry and footprint/dynamics of the active sensors are shown in Table 1. All six types of active sensors are mounted on spacecraft looking down at the Earth’s surface.

The SARs have a look angle, which is the angle between nadir and the beam centre, of 10 degrees to 55 degrees. The scatterometers have a look angle of about 40 degrees from nadir.

The radar sounders, altimeters, precipitation radars, and cloud profile radars are nadir looking. Typical terrestrial search radars cover low elevation angles, therefore they do not have mainlobe-to-mainlobe coupling with altimeters, precipitation radars, or cloud profile radars.

The spaceborne sensor beams scan past the terrestrial systems as the spacecraft proceeds in its orbit. For a sensor beamwidth of 2 degrees, the beam scans past the terrestrial system in about 2‑3 seconds. The SARs typically look down to the side of the nadir track either at a commanded look angle or at various look angles for ScanSAR modes. The scatterometers are either fixed at various azimuth angles or are conically scanned about nadir with one or more beams. For a sensor beamwidth of 2 degrees, the conically scanning beam scans past the terrestrial system in less than 25 milliseconds for a scan rate of 15 rpm. Typical terrestrial search radars also scan 360 degrees in azimuth at rates of 5 to 10 rpm so that the terrestrial radar beam with a 1-degree beamwidth scans past the spaceborne sensor in only 30 to 60 milliseconds. The precipitation radars typically are nadir looking and scan across the nadir track. For a sensor beamwidth of 0.7 degrees, the cross-track scanning beam of the precipitation radar scans past the terrestrial system in only 12.5 milliseconds at a scan rate of about 57 degrees/second. The radar sounders, altimeters, and cloud profile radars are typically nadir looking.

# 6 Definition of parameters

This section provides definitions of the parameters used to characterize the operations of the active sensors provided in this Recommendation.

TABLE 4

Definitions of parameters

| Parameter | Definition |
| --- | --- |
| Sensor type | One of the six types described in the Introduction of this Recommendation |
| **Orbit parameters** | |
| Type of orbit | Such as: circular or elliptical, sun-synchronous (SSO) or non-sun-synchronous (NSS) |
| Altitude (km) | The height above the mean sea level |
| Inclination (degrees) | Angle between the equator and the plane of the orbit |
| Ascending Node LST | The local solar time (LST) of the ascending node is that local solar time for which the ascending orbit of the spacecraft crosses the equator |
| Eccentricity | The ratio of the distance between the foci of the (elliptical) orbit to the length of the major axis |
| Repeat period (days) | The time for the footprint of the antenna beam to return to (approximately) the same geographic location. |

TABLE 4 (*continued*)

| Parameter | Definition |
| --- | --- |
| **Sensor antenna parameters**  Antenna characteristics vary among sensors. | |
| Antenna type | Such as: Parabolic offset fed to active phased array, Passive waveguide to active phased array, Planar slotted waveguide array |
| Number of beams | The number of beams is the number of locations on Earth from which data are acquired at one time. |
| Antenna diameter (or size) | Diameter of the antenna reflector (when applicable), or length and width of the planar array (when applicable). |
| Antenna Peak (Transmit and Receive) Gain (dBi) | The maximum (peak) antenna gain can be the measured value, or, if it is not known, it can be computed.  For the case of parabolic reflectors, the maximum antenna gain can be estimated by using the antenna efficiency η and *D* diameter of the reflector (when applicable):  For the case of planar array antennas, the maximum gain can be estimated by using the length l and width w of the planar array (when applicable) with the formula: |
| Polarization | Specification of linear (H or V) or circular polarization (RHCP or LHCP).  NOTE – where “HV” polarization is listed, “H” polarization is transmitted and “V” polarization is received and vice versa for “VH” polarization. |
| −3 dB beamwidth (degrees) | The −3 dB beamwidth (also called, half power beamwidth), θ3dB, is defined as the angle between the two directions in which the radiation intensity is one-half the maximum value. |
| Instantaneous field of view IFOV | The instantaneous field of view (IFOV) is the area over which the measurement is made by the detector. By knowing the altitude of the satellite, the dimension of the IFOV can be calculated on the Earth’s surface at the nadir point: the IFOV is generally expressed in km × km. The IFOV is a measure of the size of the resolution element. |
| In a scanning system the IFOV refers to the solid angle subtended by the detector when the scanning motion is stopped. For conical scan radars, two values are usually computed:  – along-track: in the direction of the platform motion (along the in‑track direction);  – cross-track: in the direction orthogonal to the motion of the sensor platform.  For nadir scan radars, such as that shown in Fig. 1, the nadir IFOV = *H*θ3dB, where *H* is the height of the satellite and θ3dB is the half-power beamwidth. |
| Antenna incidence angle at Earth (degrees) | The angle between the pointing direction and the normal to the Earth’s surface. It is the angle *i* as in Fig. 1 (in some cases, the off-nadir angle is provided). |
| Azimuth scan rate (rpm) | The azimuth scan rate is the number of 360 degrees revolutions per minute that the antenna scans in azimuth. |

TABLE 4 (*continued*)

| Parameter | Definition |
| --- | --- |
| Antenna beam look angle (degrees) | The antenna beam look angle, α, is the angle between the antenna boresight axis and nadir, sometimes called the off-nadir pointing angle. Some systems provide instead the information of the incident angle, *i*. They are the angle α and i, as shown in Fig. 1 |
| Antenna beam azimuth angle (degrees) | The antenna beam azimuth angle is the angle between the antenna boresight axis and velocity vector in the plane defined by the velocity vector and the negative orbit normal vector (see Fig. 2) |
| Antenna elevation beamwidth (degrees) | The antenna elevation beamwidth is the angle in the elevation or cross-track direction between the −3 dB points of the beam |
| Antenna azimuth beamwidth (degrees) | The antenna azimuth beamwidth is the angle in the azimuth or along-track direction between the −3 dB points of the beam |
| Swath width (km) | The swath width is defined as the linear ground distance covered in the cross-track direction. |
| Main beam efficiency (%) | The main beam area is defined as the angular size of a cone with an opening angle equal to 2.5 times the measured −3 dB beamwidth. The main beam efficiency is defined as the ratio of the energy received in the main beam to the energy received in the complete antenna pattern |
| Beam dynamics | The beam dynamics is defined as follows:  – For conical scans, it is the rotating speed of the beam  – For nadir scans, it is the number of scans per second |
| Sensor antenna pattern | Antenna gain as a function of off-axis angle |
| **Transmitter characteristics** | |
| RF centre frequency (MHz) | The RF centre frequency is that frequency about which the bandwidth of the transmitted signal is centred |
| RF bandwidth (MHz) | The RF bandwidth is the −3 dB bandwidth of the transmitted signal. For compatibility analysis, this is also typically used as the receiver bandwidth |
| Transmit Pk pwr (W) | The transmit peak power is the peak power of the envelope of the transmitted waveform |
| Transmit Ave. pwr (W) | The transmit average power is the product of the peak power of the envelope of the transmitted waveform times the transmit duty cycle |
| Pulsewidth (μs) | The pulsewidth is the half power duration of the transmitted pulse |
| Pulse repetition frequency (PRF) (Hz) | The pulse repetition frequency is the frequency of the transmitted pulse waveforms |
| Chirp rate (MHz/μs) | The chirp rate for a linear FM (LFM) pulse is the ratio of the RF bandwidth in MHz and the pulsewidth in μs |
| Transmit duty cycle (%) | The transmit duty cycle is the product of the transmitted pulsewidth and the pulse repetition frequency |
| Operational duty cycle (%) | The percentage of time that the transmitter is active per orbit (this may vary according to the operational mode) |
| e.i.r.p. ave (dBW) | The average effective isotropically radiated power (e.i.r.p.) is the amount of power that a theoretical isotropic antenna would radiate to produce the average power density observed in the direction of maximum antenna gain; the e.i.r.p. is the product of the transmit average power and the antenna peak gain in dBW |

TABLE 4 (*end*)

| Parameter | Definition |
| --- | --- |
| e.i.r.p. peak (dBW) | The peak effective isotropically radiated power (e.i.r.p.) is the amount of power that a theoretical isotropic antenna would radiate to produce the peak power density observed in the direction of maximum antenna gain; the peak e.i.r.p. is the product of the transmit peak power and the antenna peak gain in dBW |
| **Sensor receiver parameters** | |
| Sensor dwell time | The *sensor dwell time* corresponds to the period of time allocated for the echo measurement of the instantaneous area of observation by the detector of a sensor |
| Sensitivity (dBZ) | The sensitivity of a precipitation radar or cloud profile radar is the *minimum* detectable reflectivity Z (mm6/m3) of the precipitation or cloud profile radar in dBZ |
| System noise figure (dB)  or  System noise temperature (K) | The system noise figure is the ratio of the input signal-to-noise power ratio (*S*/*N*)*i* to the output signal-to-noise power ratio (*S*/*N*)*o*. The system noise temperature is effectively the antenna noise temperature plus the first stage receiver noise temperature; the other system noise temperature contributions can usually be neglected when the first stage receiver gain is greater than 16 dB. |
| **Measurement spatial resolution** | |
| Range resolution | The *spatial resolution* is often defined as the ability to distinguish between two closely spaced objects on an image. It is generally expressed in both range or horizontal (usually cross-track) and azimuth, or vertical (along-track) resolutions. (Note that “vertical”, in this sense, does not refer to altitude.) |
| Azimuth resolution |

FIGURE 1

Scanning configuration typical of conical scanning scatterometers

Diagram

Description automatically generated

FIGURE 2

Plane defined by velocity vector and negative orbit normal vector

Diagram, engineering drawing

Description automatically generated

# 7 Parameters of typical systems

This section provides typical parameters of active sensors for EESS (active) bands between 40 MHz and 238 GHz. A consistent set of parameters is used for each band to support worst-case static analyses and dynamic analyses.

## 7.1 Typical parameters of active sensors operating in the 40‑50 MHz band

The 45 MHz radar sounders are active microwave sensors using the frequency band 40‑50 MHz to achieve a trade-off between penetration depth and resolution, which can be used to provide detailed mapping of the spatial distribution of shallow aquifers (on the order to 10‑100 m in depth) in arid regions, as well as to perform basal interface topography and determine ice-sheet thickness (on the order of 5 km). Typical characteristics of 45 MHz radar sounders are shown in Table 5. Additional information can be found in Recommendation ITU-R RS.2042-2.

TABLE 5

Characteristics of EESS (active) missions in the 40‑50 MHz band

| Parameter | SNDR-A1 |
| --- | --- |
| Sensor type | Radar sounder |
| Type of orbit | Circular, SSO |
| Altitude (km) | 400 |
| Inclination (degrees) | 97 |
| Ascending node LST | 04:00 |
| Repeat period (days) | 548 |
| Antenna type | 9‑element cross Yagi |
| Number of beams | 1 |
| Antenna Peak (Transmit and Receive) Gain (dBi) | 10 |
| Polarization | Circular |
| Azimuth scan rate (rpm) | 0 |
| Antenna beam look angle (degrees) | 0 |
| Antenna beam azimuth angle (degrees) | 0 |
| Antenna elevation beamwidth (degrees) | 40 |
| Antenna azimuth beamwidth (degrees) | 40 |
| RF centre frequency (MHz) | 45 |
| RF bandwidth (MHz) | 10 |
| Transmit Pk pwr (W) | 100 |
| Transmit Ave. pwr (W) | 10.2 |
| Pulsewidth (μs) | 85 |
| Pulse repetition frequency (PRF) (Hz) | 1 200 |
| Chirp rate (MHz/μs) | 0.1176 |
| Transmit duty cycle (%) | 10.2 |
| e.i.r.p. ave (dBW) | 20.1 |
| e.i.r.p. peak (dBW) | 30.0 |
| System noise figure (dB) | 5 |

## 7.2 Typical parameters of active sensors operating in the 432-438 MHz band

The 435 MHz SARs are active microwave sensors using the frequency band 432-438 MHz to achieve weather-independent and day and night land observation. The lower frequencies enable penetration of the vegetation canopies in order to provide global vegetation models to improve the quantification of the global terrestrial carbon cycle. Typical characteristics of 435 MHz SARs are shown in Table 6.

TABLE 6

Characteristics of EESS (active) missions in the 432-438 MHz band

| Parameter | SAR-B1 |
| --- | --- |
| Sensor type | SAR |
| Type of orbit | SSO |
| Altitude (km) | 665 |
| Inclination (degrees) | 98.1 |
| Ascending node LST | 06:00 |
| Repeat period (days) | 17 |
| Number of beams | 1 |
| Antenna diameter (m) | 12 |
| Antenna Pk Xmt gain (dBi) | 33.6 |
| Antenna Pk Rcv gain (dBi) | 33.6 |
| Polarization | linear H, V |
| Azimuth scan rate (rpm) | 0 |
| Antenna beam look angle (degrees) | 22.7, 25.9, 28.2 |
| Antenna beam azimuth angle (degrees) | 86.2-93.8 |
| Antenna elevation beamwidth (degrees) | 4.8 |
| Antenna azimuth beamwidth (degrees) | 3.2 |
| RF centre frequency (MHz) | 435 |
| RF bandwidth (MHz) | 6 |
| Transmit peak pwr (W) | 170 |
| Transmit average pwr (W) | 10 |
| Pulsewidth (μs) | 38 |
| Pulse repetition frequency max (Hz) | 1 550 |
| Chirp rate (MHz/μs) | 0.200, 0.182, 0.1861 |
| Transmit duty cycle (%) | 5.9 |
| e.i.r.p. ave (dBW) | 43.6 |
| e.i.r.p. peak (dBW) | 55.9 |
| System noise figure (dB) | 3 |

## 7.3 Typical parameters of active sensors operating in the 1 215-1 300 MHz band

The 1.25 GHz SARs are active microwave sensors using the frequency band 1 215‑1 300 MHz to achieve weather-independent and day and night land observation. The SARs may have several modes, including fine resolution mapping modes, medium resolution mapping modes, and scanSAR modes. Typical characteristics of SARs operated in the 1 215-1 300 MHz band are shown in Table 7.

Table 7 shows the characteristics of the typical land scatterometer operated in the band 1 215‑1 300 MHz.

TABLE 7

Characteristics of EESS (active) missions in the band 1 215-1 300 MHz

| Parameter | SCAT-C1 | SCAT-C2 | SAR-C1 | SAR-C2 | SAR-C3 | SAR-C4 |
| --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Scatterometer | Scatterometer | SAR | SAR | SAR | SAR |
| Type of orbit | Circular, SSO | Circular, SSO | Circular, SSO | Circular, SSO | Near circular, SSO | Circular, SSO |
| Altitude (km) | 670 | 657 | 747 | 628 | 693 | 628 |
| Inclination (degrees) | 98 | 98 | 98.4 | 97.9 | 98.18 | 97.9 |
| Ascending node LST | 18:00 | 18:00 | 06:00 | 12:00\* | 18:00 | 12:00\* |
| Repeat period (days) | 3 | 7 | 12 | 14 | 12 | 14 |
| Antenna type | Offset parabolic reflector | Three-feed offset parabolic reflector | Deployable mesh reflector | Planar phased array | Planar phased array | Planar phased array |
| Number of beams | 1 | 3 | 1 | 1 | 1 | 1 |
| Antenna size/diameter | 6 m | 2.5 m | 12 m | 9.9 m × 2.9 m | 11 m × 3.6 m | 9.9 × 3.9 m |
| Antenna peak transmit gain (dBi) | 36 | 28.1 | 35 | 34.7 | 33.5 (dual pol), 34.6 (quad pol), 39.5 (Wave mode) (1) | 35.2 |
| Antenna peak receive gain (dBi) | 36 | 28.1 | 45 | 36.6 | 25.4 | 33.4 |
| Polarization | Dual, linear H,V | Dual, linear H,V | Dual/quad, circular, linear H,V | Dual/quad, circular, linear H,V | Single/dual/ quad, linear  H, V | Dual/quad, linear H,V |
| Azimuth scan rate (rpm) | 13.0-14.6 | 0 | 0 | 0 | 0 | 0 |
| Antenna beam look angle (degrees) | 34 | 25.9/33.9/40.3 | 37 (transmit), 20-40 (receive) | 7.2-59 | 25.2-38.7 | 7.2-59 |
| Antenna beam azimuth angle (degrees) | 0-360 | 99.7/74.8/ 96.5 | -90 | ±90/±3.5 | 90 | ±90/±3.5 |
| Antenna elev. beamwidth (degrees) | 2.5 | 6.5/6.7/7.1 | 11.5 | 4.3-4.6 | 3.36 (transmit), 13.45 (receive) | 3.5 |
| Antenna az. beamwidth (degrees) | 2.5 | 6.5/6.7/7.1 | 0.9 | 1.3-2.1 | 1.1 (transmit), 5.5 (receive) | 1.2-2.1 |
| RF centre frequency (MHz) | 1 215-1 300 | 1 260 | 1 215-1 300 | 1 236.5/ 1 257.5 | 1 215-1 300 | 1 236.5/ 1 257.5/ 1 278.5 |

TABLE 7 (*end*)

| Parameter | SCAT-C1 | SCAT-C2 | SAR-C1 | SAR-C2 | SAR-C3 | SAR-C4 |
| --- | --- | --- | --- | --- | --- | --- |
| RF bandwidth (MHz) | 1 | 4 | 5, 20, 40, 77 | 1 484 | 40-85 | 28-84 |
| Transmit Pk pwr (W) | 200 | 200 | 1 334 | 3 944-6 120 | 9 000 | 5 390-8 680 |
| Transmit Ave. pwr (W) | 28 | – | 9.7-102.2 | 453-454 | 600 (dual pol), 720 (quad pol) | 490-960 |
| Pulsewidth (μs) | 15 | 1 000 | 4.4-40 | 18-71 | 10-80 | 21-67 |
| Pulse repetition frequency (PRF) (Hz) | 3 500 | 100 | 1 543.2‑3 086.4 | 1 050-3 640 | 1 300-3 800 | 1 100-  3 955 (2) |
| Chirp rate (MHz/μs) | 0.067 | 0.004 | 0.20‑2.00 | 0.21-1.95 | 0.15-0.93 | 0.42-3.68 |
| Transmit duty cycle (%) | 5.25 | 10 | 0.7‑7.7 | 6.8-11.5 | 6.7-8 (2% for Wave mode) (1) | 6.4-9.1(2) |
| e.i.r.p. peak (dBW) | 60 | 51.1 | 66.3 | 70.7-74.5 | 78 | 74.5 |
| System noise figure (dB) | 4.0 | 7.0 | 3.9 | 4.9 | 3.3 | 2.6 |
| (1) Wave mode is used only over ocean.  (2) In some observation modes, non-constant pulse repetition frequency (PRF) operation will be conducted within this PRF range. | | | | | | |

## 7.4 Typical parameters of active sensors operating in the 3 100-3 300 MHz band

Typical characteristics of 3.1 GHz SAR are shown in Table 8.

TABLE 8

Characteristics of EESS (active) missions in the 3 100-3 300 MHz band

| Parameter | SAR-D1 | SAR-D2 | SAR-D3 | SAR-D4 |
| --- | --- | --- | --- | --- |
| Sensor type | SAR | SAR | SAR | SAR |
| Type of orbit | Circular, SSO | Circular | Circular | Circular, SSO |
| Altitude (km) | 500 | 503-536 | 503-536 | 747 |
| Inclination (degrees) | 97.3 | 97.4 | 97.4 | 98.4 |
| Ascending node LST | 06:00 | 09:00±1:00 | 10:00±1:00 | 06:00 |
| Repeat cycle, days | 31 | 16 | 16 | 12 |
| Antenna type | – | Parabolic Dish | Parabolic Dish | Deployable mesh reflector |
| Number of beams | 9 | – | – | 24 |
| Antenna diameter or size | – | 6 m | 6 m | 12 m |
| Antenna peak gain (dBi) | 37.6 | 42 | 44 | 38 |
| Polarization | VV | H,V | H,V | Dual/quad, circular, linear H, V |
| Azimuth scan rate (rpm) | 0 | 0 | 0 | 0 |
| Antenna beam look angle (degrees) | 25-47 | 25-55 | 20-55 | 37 |
| Antenna beam azimuth angle (degrees) | 90 | 90/−90 | 90/−90 | –90 (offset feed at ‑3.5 w.r.t. nadir) |
| Antenna elevation beamwidth (degrees) | 2.5 | 1 | 1 | 11 |
| Antenna azimuth beamwidth (degrees) | 1 | 1 | 1 | 0.5 |
| RF centre frequency (MHz) | 3 200 | 3 200 | 3 200 | 3 200 |
| RF bandwidth (MHz) | 60 | 50/200 | 50/200 | 10/25/37.5/75 |
| Transmit Pk pwr (W) | 3 000 | 5 000 | 11 220 | 37 857 |
| Transmit Ave. pwr (W) | 300 | – | – | 2 082 |
| Pulsewidth (μs) | 27 | 10 | 1-16 | 10‑25 |
| Chirp rate (MHz/μs) | 2.22 | 5/20 | 5/20 | 1‑3 |
| Transmit duty cycle (%) | 10 | Variable, max 20% | Variable, max 20% | 5.50 |
| System noise figure (dB) | 2 | 3 | 3 | 5 |

## 7.5 Typical parameters of active sensors operating in the 5 250-5 570 MHz band

The typical characteristics of for several types of SAR sensors, altimeters and scatterometers operating in the 5 250-5 570 MHz band are shown in Tables 9, 10, and 11.

It should be noted that the service area for most of these active sensors is global, as it is the case for SAR-E4, SAR-E5, SAR-E6, and SAR-E1 (a two-satellite constellation).

TABLE 9

Characteristics of SAR sensors in the 5 250-5 570 MHz band

| Mission | SAR-E1 | SAR-E2 | SAR-E3 | SAR-E4 | SAR-E5 | SAR-E6 | SAR-E7 | SAR-E8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | SAR | SAR | SAR | SAR | SAR | SAR | SAR | SAR |
| Type of orbit | Circular SSO | SSO, circular | SSO | Near circular | Near circular | Near circular | Near circular | Near circular |
| Altitude (km) | 693 | 764 | 536 | 792-813 | 586.9-615.2 | 586.9-615.2 | 755 | 410-420 |
| Inclination (degrees) | 98.18 | 98.6 | 97 | 98.6 | 97.74 | 97.74 | 98.4 | 51.6 |
| Ascending node LST | 18:00/6:00 (1) | 10:30 | 6:00 | 6:00 | 6:00 | 6:00 (TBC) | 18:00 | N/A |
| Repeat period (days) | 12 | 35 | 13 | 24 | 12 | 12 (TBC) | 29 | – |
| Antenna type | Phase array | Phase array | Planar phased array | Planar phased array | Planar phased array | Planar phased array | Planar phased array | Phased array |
| Number of beams | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Antenna size/diameter | 12.3 m × 0.8 m | 10 m × 1.3 m | 10 m × 3 m | 15 m × 1.5 m | 6.88 m × 1.37 m | 6.88 m × 1.37 m | 15 m × 1.232 m | 2.5 m × 1.2 m |
| Antenna Pk Xmt gain (dBi) | 43.5 to 45.3 | 40 to 45 | 35 | 49 (2) | 45 (3) | 45 (3) | 48 | 38.7 |
| Pk Rcv gain (dBi) | 43.5 to 44.8 | Antenna 40 to 45 | 35 | 49 (3) | 45 (3) | 45 (3) | 48 | 38.7 |
| Polarization | V, H | H, V | Linear H, V | HH, HV, VH, VV | HH, VV, HV, VH, CH, CV | HH, VV, HV, VH, CH, CV | HH, HV, VH, VV | H, V |
| Antenna beam look angle (degrees) | 20-47 (3) | 15-45 | 10-45 | 9-50 | 16-51 | 16-53 | 10-60 | 15-40 |
| Antenna beam azimuth angle (degrees) | 90 | 90 | 90 | 0 | 0 | 0 | 0 | 0/180 |
| Antenna elev. beamwidth (degrees) | 6 to 8 | 2.5 | 4.6 | 1.88 (for focused beam) | 2.05 (for focused beam) | 2.05 (for focused beam) | 2.288 | 3.15 |
| Antenna az. beamwidth (degrees) | 0.3 | 0.3 | 1.4 | 0.19 | 0.42(for focused beam) | 0.42(for focused beam) | 0.188 | 1.6 |
| Swath width (km) | 20-410 | 10-405 | 10-225 | 18-500 | 20-500 | 20-500 | 10-650 | 40-400 |
| RF centre frequency (MHz) | 5 405 | 5 331 | 5 350 | 5 405 | 5 405 | 5 405 | 5 400 | 5 350 |
| RF bandwidth (MHz) | 100 | 16 | 18.75-75 | 11.6, 17.3, 30, 50, 100 | 14-100 | 14-300 | 2 -240 | 36.3 |

TABLE 9 (*end*)

| Mission | SAR-E1 | SAR-E2 | SAR-E3 | SAR-E4 | SAR-E5 | SAR-E6 | SAR-E7 | SAR-E8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Transmit Pk pwr (W) | 4 140 | 2 500 | 4 000 | 2 400 or  3 700 | 1 490 | 1 990 | 15 360 | 5 000 |
| Transmit Ave. pwr (W) | 370 | 200 | 260 | 300 | 180 | 240 | 1 900 | 750 |
| Pulsewidth (μs) | 5 to 53 | 16 to 41 | 2 0 | 21, 42 | 10 to 50 | 10 to 50 | 15 to 50 | 17.5 to 25.5 |
| Pulse repetition frequency (Hz) | 1 450-2 000 | 1 600‑2 100 | 3 250 | 1 000-2 800 | 2 000-7 000 | 2 000-7 000 | 1 100 Hz ~  4 500 Hz | 6 000-8 560 |
| Chirp rate (MHz/μs) | 0.34-3.75 | 0.39 | 0.937-3.75 | 0.27 to 2.38 | 0.14 to 10 | 0.14 to 10 | 0.13 to 6.85 | 1.41 to 2.05 |
| Transmit duty cycle (%) | 0.5-9.0 depending on ops mode | 8.61 | 6.5 | Variable, max 8% | Variable, max 12% | Variable, max 12% | Variable, max 20% | Variable max 15% |
| e.i.r.p. ave (dBW) | 70 (for 9% duty cycle) | 68.0 | 68 | Approx. 73 (4) | 67.67 | 69.0 | Approx. 80.7 | 67.5 |
| e.i.r.p. peak (dBW) | 80 | 78.0 | 71.0 | 83.5 (5) | 76.7 | 78.0 | 89.8 | 75.7 |
| System noise figure (dB) | 3.2 | 4.5 | 5.8 | 6 | 6 | 6 | 4 | 4/6 |
| (1) This system is a two-satellites constellation.  (2) Lower gain can be used for the wider beams.  (3) Antenna beam ‘incident angles’.  (4) Average e.i.r.p. over a pulse repetition interval.  (5) Maximum e.i.r.p. during pulse transmission. | | | | | | | | |

TABLE 10

Characteristics of altimeters in the 5 250-5 570 MHz band

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Mission | ALT-E1 | ALT-E2 (1) | ALT-E3 | ALT-E4 (1) | ALT-E5 | ALT-E6 |
| Sensor type | Altimeter | Altimeter | Altimeter | Altimeter | Altimeter | Altimeter |
| Type of orbit | NSS | Circular, SSO | SSO | NSS | NSS | Circular, SSO |
| Altitude (km) | 1 336 | 814 | 963 | 1 336 | 890 | 1 000 |
| Inclination (degrees) | 66 | 98.65 | 99.3 | 66 | 78 | 99.4 |
| Ascending node LST | NSS | 22:00 | 06:00 | NSS | NSS | – |
| Repeat period (days) | 10 | 27 | 14 | 10 | 21 | 14 |
| Antenna type | Parabolic reflector | Parabolic reflector | Parabolic reflector | Parabolic reflector | Parabolic reflector | Parabolic reflector |
| Number of beams | 1 | 1 | 1 | 1 | 1 | 1 |
| Antenna size/diameter | 1.2 m | 1.2 m | 1.4 m | 1.2 m | 1.2 m | 1.5 m |
| Antenna Pk Xmt gain (dBi) | 32 | 32 | 35 | 33.5 | 32.0 | 33.6 |
| Antenna Pk Rcv gain (dBi) | 32 | 32 | 43 | 33.5 | 32.0 | 33.6 |
| Polarization | linear | linear | linear VV | linear | linear | linear |
| Azimuth scan rate (rpm) | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna beam look angle (degrees) | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna beam azimuth angle (degrees) | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna elev. beamwidth (degrees) | 3.4 | 3.4 | 2.3 | 3.4 | 3.4 | 3 |
| Antenna az. beamwidth (degrees) | 3.4 | 3.4 | 2.3 | 3.4 | 3.4 | 3 |
| Swath width (km) | 79.4 | 48.4 | 38.7 | 97 | 52.9 | 51.4 |
| RF centre frequency (MHz) | 5 300 | 5 410 | 5 250 | 5 410 | 5 300 | 5 300 |
| RF bandwidth (MHz) | 100, 320 | 320 | 160 | 320 | 100, 320 | 100, 320 |
| Transmit Pk pwr (W) | 17 | 32 | 20 | 25 | 17 | 15.8 |
| Transmit Ave. pwr (W) | 0.51 | 0.4 (LRM), 0.25 (SAR) | 8.2 | < 2 | 0.51 | 0.51, 0.71 |
| Pulsewidth (μs) | 106.0 | 49 | 102.4 | 32 | 106.0 | 110.5 |
| Pulse repetition frequency (Hz) | 300 | 275 (LRM), 157 (SAR) | 670 | 2 060-9 280 | 300 | 294, 412 |
| Chirp rate (MHz/μs) | 0.9, 3.0 | 6.5 | 1.56 | 9.69 | 0.9, 3.0 | 0.9, 2.9 |
| Transmit duty cycle (%) | 3.1 | 1.5 (LRM), 0.7 (SAR) | 40.96 | 30 | 3.1 | 3.2, 4.5 |
| e.i.r.p. ave (dBW) | 29.5 | 30.8 (LRM), 28.4 (SAR) | 44.1 | 36.51 | 29.2 | 30.7, 32.1 |
| e.i.r.p. peak (dBW) | 44.8 | 49.5 | 48 | 47.47 | 44.3 | 45.6 |
| System noise figure (dB) | 4.45 | 3.8 | 3.5 | 3.5 | 4.45 | 5.75 |
| (1) Dual frequency radar altimeter (C/Ku Band) which performs measurements either in low resolution mode (LRM) or synthetic aperture radar mode (Nadir-SAR). LRM mode is the conventional altimeter pulse limited mode with interleaved C/Ku Band pulses, while Nadir-SAR mode is the high along track resolution mode based on SAR processing. The system is a two‑satellite constellation. | | | | | | |

TABLE 11

Characteristics of scatterometers in the 5 250-5 570 MHz band

| Mission | SCAT-E1 | SCAT-E2 |
| --- | --- | --- |
| Sensor type | Scatterometer | Scatterometer |
| Type of orbit | SSO | SSO |
| Altitude (km) | 832 | 832 |
| Inclination (degrees) | 98.7 | 98.7 |
| Ascending node LST | 21:30 | 21:30 |
| Repeat period (days) | 29 | 29 |
| Antenna type | Six fan beam‑antennas  (slotted WG arrays) | Six fan beam‑antennas  (slotted WG arrays) |
| Number of beams | 6 | 6 |
| Antenna size/diameter | 2.251 m × 0.337 m (mid), 3.003 m × 0.253 m (side) | 2.757 m × 0.315 m (mid),  3.02 m × 0.315 m (side) |
| Antenna Pk Xmt gain (dBi) | 24-32 | 23-31 (1) |
| Antenna Pk Rcv gain (dBi) | 24-32 | 23-31 |
| Polarization | linear VV for all beams | linear VV for all 6 beams + VH/HV and linear HH for the 2 mid‑beams |
| Azimuth scan rate (rpm) | 0 | 0 |
| Antenna beam look angle (degrees) | 22-45.6 (mid beams) 29.5-53.4 (side beams) | 17.5-45.5 (mid beams) 24-54 (side beams) |
| Antenna beam azimuth angle (degrees) | 45, 90, 135, 225, 270, 315 | 45, 90, 135, 225, 270, 315 |
| Antenna elev. beamwidth (degrees) | 23.6 (mid beams) 23.9 (side beams) | 28 (mid beams) 30 (side beams) |
| Antenna az. beamwidth (degrees) | 1.5 (mid beams) 1.2 (side beams) | 1.3 |
| Swath width (km) | 550 on each side of the orbit plane | 665 on each side of the orbit plane |
| RF centre frequency (MHz) | 5 255 | 5 355 |
| RF bandwidth (MHz) | 0.5 | 2 |
| Transmit Pk pwr (W) | 120 | 2 512 |
| Transmit Ave. pwr (W) | 29 (mid beams) 36.5 (side beams) | 92 |
| Pulsewidth (μs) | 10 000 | 1 000 |
| Pulse repetition frequency (PRF) Hz | 28.259 | 32 |
| Chirp rate (MHz/μs) | 0.00002 | 0.00002 |
| Transmit duty cycle (%) | 28.29 | 3.68 |
| e.i.r.p. ave (dBW) | 39-47 | 42-50 |
| e.i.r.p. peak (dBW) | 53 | 57-65 |
| System noise figure (dB) | 3.0 | 3.5 |
| (1) Antenna gain varies depending on antenna location (mid or side), and incident angle. | | |

## 7.6 Typical parameters of active sensors operating in the 8 550-8 650 MHz band

The typical characteristics of 8.6 GHz SARs are shown in Table 12.

TABLE 12

Characteristics of EESS (active) missions in the 8 550-8 650 MHz band

| Parameter | SAR-F1 |
| --- | --- |
| Sensor type | SAR |
| Type of orbit | Circular, NSS |
| Altitude (km) | 400 |
| Inclination (degrees) | 57 |
| Repeat period (days) | 3 |
| Number of beams | 1 |
| Antenna type | Slotted waveguide |
| Antenna (Transmit and Receive) peak gain (dBi) | 44.0 |
| Polarization | Linear H,V |
| Azimuth scan rate (rpm) | 0 |
| Antenna beam look angle (degrees) | 20-55 |
| Antenna beam azimuth angle (degrees) | 90 |
| Antenna elevation beamwidth (degrees) | 2.5 |
| Antenna az. beamwidth (degrees) | 0.4 |
| RF centre frequency (MHz) | 8 600 |
| RF bandwidth (MHz) | 10, 20 |
| Transmit Pk pwr (W) | 3 500 |
| Transmit Ave. pwr (W) | 243 |
| Pulsewidth (μs) | 40 |
| Pulse repetition frequency (PRF) (Hz) | 1 395-1 736 |
| Chirp rate (MHz/μs) | 1.0, 0.5 |
| Transmit duty cycle (%) | 7 |
| System noise figure (dB) | 4.3 |

## 7.7 Typical parameters of active sensors operating in the 9 200-10 400 MHz band

The typical characteristics of SARs, operating in the 9 200-10 400 MHz band, are shown in Table 13. Additional information is contained in Recommendation ITU-R RS.2043.

TABLE 13

Characteristics of EESS (active) missions in 9 200-10 400 MHz band

| Parameter | SAR-G1 | SAR-G2 | SAR-G3 | SAR-G4 | SAR-G5 | SAR-G6 | SAR-G7 | SCAT-G8 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | SAR | SAR | SAR | SAR | SAR | SAR | SAR | Scatterometer |
| Type of orbit | Circular, SSO | Circular, SSO | SSO | SSO | SSO | Circular, SSO | Circular | Circular |
| Altitude (km) | 514 | 620 | 512 | 620 | 514 | 514 | 650..850 | 835 |
| Inclination (degrees) | 97.4 | 97.8 | 97.9 | 97.8 | 97.44 | 97.4 | 97..99 | 98.85 |
| Ascending node LST | 18:00 | 06:00 | 06:00 | 06:00 | 18:00 | 18:00 | N/A | 19:30 |
| Repeat period (days) | 11 | 16 | 5 | 16 | 11 | 11 | – | – |
| Antenna type | Active phased array | Planar array | Offset linear array fed reflector | Planar array | Active phased array | Active phased array | Phased array | Phased array |
| Number of beams | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Antenna (Transmit and Receive)  peak gain (dBi) | 45.5 | 45.5 | 46 | 46.8 | 43.4 | 47 | 45.6 | 39.5/38.5 |
| Polarization | Linear VV | Linear HH | Linear VV, VH | Linear HH | Linear HH, VV | Linear HH, VV | Linear HH, VV | Linear, VV |
| Azimuth scan rate (rpm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna beam look angle (degrees) | 15-60 | 21-44 | 30-40 | 37.8 | 15-45 | 18-50 | 15-55 | 90 |
| Antenna beam az. angle (degrees) | 90 | 90 | 90 | 90 | 90 | 90 | 90 | N/A |
| Antenna elev. beamwidth (degrees) | 2.54 | 1.32 | 1.5 | 1.34 | 2.5 | 1.13 | 1-1.2 | 26 |
| Antenna az. beamwidth (degrees) | 0.37 | 0.32 | 0.5 | 0.32 | 0.4 | 0.53 | 0.4-0.45 | 0.13 |
| RF centre frequency (MHz) | 9 650 | 9 600 | 9 600 | 9 500 | 9 650 | 9 800 | 9 600 | 9 623.275 |
| RF bandwidth (MHz) | 150, 300 | 41-118 | 10 | 40-300 | 5-300 | 1 200 | 600 | 0.5 |
| Transmit Pk pwr (W) | 2 000 | 7 600 | 3 000 | 7 600 | 2 260 | 7 000 | 1 800 | 1 600 |
| Transmit Ave. pwr (W) | 400 | 836 | 270 | 836 | 452 | 2 100 | – | – |
| Pulsewidth (μs) | 47 | 18-31 | 20-30 | 18-31 | 47 | 50 | 36 | 2 |
| Pulse repetition frequency (Hz) | 2 000-6 500 | 2 850-3 230 | 1 000-3 000 | 1 000-3 000 | 3 000-6 500 | 6 000 | – | – |
| Chirp rate (MHz/μs) | 3.2, 6.8 | 3.81 | 0.5-0.67 | 3.81-9.7 | 0.85-6.38 | 24 | 16.6 | N/A |
| Transmit duty cycle (%) | 20 | 7-11 | 2-9 | 7-11 | 20 | 30 | Variable,  max 15% | Variable,  max 15% |
| System noise figure (dB) | 2.9 | 1.0 | 3 | 1.0 | 5.0 | 3 | 4 | 4 |

## 7.8 Typical parameters of active sensors operating in the 13.25-13.75 GHz band

The typical characteristics of the 13.5 GHz altimeter are shown in Table 14.

The typical ocean scatterometer, operating around 13.4 GHz, infers the ocean surface wind speed and direction from measurements of the ocean surface backscatter coefficient from several different azimuth angles as the antenna beams rotate about nadir. Table 15 shows the characteristics of the 13.4 GHz scatterometer.

Typical characteristics of 13.5 GHz precipitation radars are shown in Table 16.

TABLE 14

Characteristics of altimeters in the 13.25-13.75 GHz band

| Mission | ALT-H1 | ALT-H3 | ALT-H4 | ALT-H5 | ALT-H6  (Note 1) | ALT-H7  (Note 1) | ALT-H8 | ALT-H9 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Altimeter | Altimeter | Altimeter | Altimeter | Altimeter | Altimeter | Altimeter | Altimeter |
| Type of orbit | SSO | SSO | NSS | NSS | SSO | NSS | Circular SSO | NSS |
| Altitude (km) | 764 | 963 | 1 336 | 717 | 814 | 1 336 | 1 000 | 714 |
| Inclination (degrees) | 98.6 | 99.3 | 66 | 92 | 98.65 | 66 | 99.4 | 92 |
| Ascending node LST\* | 10:30 | 06:00 | NA | NA | 22:00 | NA | – | NA |
| Repeat period (days) | 35 | 14 | 10 | 369 (1) | 27 | 10 | 14 | 367 |
| Number of beams | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Antenna diameter | 1.2 m | 1.4 m | 1.2 m | 2 reflectors 1.2 × 1.1 m | 1.2 m | 1.2 m | 1.5 m | 2 reflectors 1.4 m × 1.25 m |
| Antenna Pk Xmt gain (dBi) | 41.2 | 43 | 43.2 | 42 | 42 | 42.1 | 42.2 | 42.3 |
| Antenna Pk Rcv gain (dBi) | 41.2 | 43 | 43.2 | 42 | 42 | 42.1 | 42.2 | 42.3 |
| Polarization | linear | VV | linear | linear | linear | linear | linear | Linear |
| Azimuth scan rate (rpm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna beam look angle (degrees) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna beam azimuth angle (degrees) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 14 (*end*)

| Mission | ALT-H1 | ALT-H3 | ALT-H4 | ALT-H5 | ALT-H6  (Note 1) | ALT-H7  (Note 1) | ALT-H8 | ALT-H9 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna elev. beamwidth (degrees) | 1.2 | 0.9 | 1.27 | 1.2 | 1.27 | 1.35 | 1.5 | 1 |
| Antenna az. beamwidth (degrees) | 1.2 | 0.9 | 1.27 | 1.1 | 1.27 | 1.35 | 1.5 | 1 |
| RF centre frequency (MHz) | 13 575 | 13 580 | 13 575 | 13 575 | 13 575 | 13 575 | 13.575 | 13 500 |
| RF bandwidth (MHz) | 320, 80, 20 | 320 | 320 | 320 | 350 | 320 | 320 | 500 |
| Transmit Pk pwr (W) | 60 | 20 | 25 | 25 | 7.1 | 8 | 5.6 | 21.7 (2); 24.4 (3) |
| Transmit Ave. pwr (W) | 2.16 | 8.2 | 5.41 | 2.22 | 0.66 | <4 | 1.27 | 19.1 (2); 7.1 (3) |
| Pulsewidth (μs) | 20 | 102.4 | 106.0 | 50 | 49 | 32 | 110.5 | 49 (2); 18 (3) |
| Pulse repetition frequency (Hz) | 1 795.33 | 2 000 | 2 060 | 1 970 (LRM) 1818.1 (SAR mode) | 1 924 (LRM)  1782.5 (SAR mode) | 2 060-9 280 | 2 060 | 18 000 (2); 15 500 to 16 800 (3) |
| Chirp rate (MHz/μs) | 16, 4, 1 | 3.12 | 3.02 | 7.11 | 7.14 | 9.69 | 2.9 | 10.2 (2); 27.8 (3) |
| Transmit duty cycle (%) | 3.6 | 40.96 | 21.63 | 8.88 | 1.35-2.65, 9.31 | 30 | 22.7 | 88.2 (2); 29.1 (3) |
| e.i.r.p. ave (dBW) | 44.5 | 52.1 | 49.33 | 45.5 | 40.2 | 48.02 | 43.2 | 55.1 (2); 50.8 (3) |
| e.i.r.p. peak (dBW) | 59.0 | 56.0 | 56 | 60.0 | 50.5 | 51.03 | 49.7 | 55.7 (2); 56.2 (3) |
| System noise figure (dB) | 2.5, 3.0 | 2.8 | 2.6 | 1.9 (4) | 3.1 | 2.5 | 5.75 | 2.8 |
| (1) 30-day subcycle.  (2) Closed burst mode.  (3) Open burst mode.  (4) Receiver noise figure. | | | | | | | | |

NOTE 1 – ALT-H5 and ALT-H6 are dual frequency radar altimeters (C/Ku Band) which performs measurements either in low resolution mode (LRM) or synthetic aperture radar mode (Nadir-SAR). LRM mode is the conventional altimeter pulse limited mode with interleaved C/Ku Band pulses, while Nadir-SAR mode is the high along track resolution mode based on SAR processing. The ALT-H6 system is in preparation and will be a two-satellite constellation with two satellites in the same orbit with 180 deg. phase difference.

TABLE 15

Characteristics of scatterometers in the 13.25-13.75 GHz band

| Mission | SCAT-H1 | SCAT-H2 | SCAT-H3 | SCAT-H4 |
| --- | --- | --- | --- | --- |
| Sensor type | Scatterometer | Scatterometer | Scatterometer | Scatterometer |
| Type of orbit | SSO | SSO | SSO | SSO |
| Altitude (km) | 803 | 963 | 720 | 836 |
| Inclination (degrees) | 98.6 | 99.3 | 98.28 | 98.75 |
| Ascending node LST | 06:00 | 06:00 | 12:00 (desc node) | 06:00 |
| Repeat period (days) | 4 | 14 | 2 | 5.5 |
| Number of beams | 2 | 2 | 2 | 4 |
| Antenna diameter | 1 m | 1.3 m | 1 m | 3 m |
| Antenna Pk Xmt gain (dBi) | 41 | 42 | 39.5 | 48 |
| Antenna Pk Rcv gain (dBi) | 41 | 42 | 39.5 | 48 |
| Polarization | H (inner), V (outer) | HH, VV | HH, VV | HH, VV |
| Azimuth scan rate (rpm) | 18 | 19.0 | 21.14 | 15 |
| Antenna beam look angle (degrees) | 40, 46 | 35, 41 | 43.63 (HH), 49.09 (VV) | 36, 40 |
| Antenna beam azimuth angle (degrees) | 0-360 | 0-360 | 0-360 | 0-360 |
| Antenna elev. beamwidth (degrees) | 1.6 | 1 | 1.67 | 0.9 |
| Antenna az. beamwidth (degrees) | 1.6 | 1 | 1.47 | 0.3 |
| RF centre frequency (MHz) | 13 402 | 13 255.5 | 13 515 | 13 350 |
| RF bandwidth (MHz) | 0.53 | 3-6 | 0.4 | 2 |
| Transmit Pk pwr (W) | 100 | 120 | 100 | 1 000 |
| Transmit Ave. pwr (W) | 30.6 | 28.8 | 27 | 450 |
| e.i.r.p. peak (dBW) | 61.0 | 62.8 | 20 | 78.0 |
| Pulsewidth (μs) | 1 700 | 650-1 200 | 1 350 | 1 500 |
| Pulse repetition frequency (PRF) (Hz) | 180 | 100-200 | 200 | 300 |
| Chirp rate (MHz/μs) | 0.000311765 | 0.005 | 0.0003 | 0.0013 |
| Transmit duty cycle (%) | 30.6 | 24 | 27.0 | 45 |
| e.i.r.p. ave (dBW) | 55.9 | 56.6 | 53.8 | 74.5 |
| e.i.r.p. peak (dBW) | 61.0 | 62.8 | 59.5 | 78.0 |
| System noise figure (dB) | 3.4 | 4.2 | 3.0 | 3.5 |

TABLE 16

Characteristics of precipitation radars in the 13.25-13.75 GHz band

| Mission | PR-H1 | PR-H2 | PR-H3 |
| --- | --- | --- | --- |
| Sensor type | Precipitation Radar | Precipitation Radar | Precipitation Radar |
| Type of orbit | NSS | NSS | NSS |
| Altitude (km) | 410 | 407 | 400 |
| Inclination (degrees) | 50 | 65 | 50 |
| Repeat period (days) | 11 | 82 | 6 |
| Number of beams | 2 | 1 | 4 |
| Antenna diameter (m) | 2 | 2.1 × 2.1 | 5.3 |
| Antenna Pk (Xmt and Rcv) gain (dBi) | 47 | 47.4 | 55 |
| Polarization | HH | H | HH,HV |
| Azimuth scan rate (s/scan) | 0.7 | 0.7 | 0.42 |
| Antenna beam look angle (degrees) | ±20 | ±17 | ±31 |
| Antenna beam azimuth angle (degrees) | ±90 | ±90 | ±90 |
| Antenna elev. beamwidth (degrees) | 0.7 | 0.7 | 0.28 |
| Antenna az. beamwidth (degrees) | 0.7 | 0.7 | 0.28 |
| RF centre frequency (MHz) | 13 647, 13 653 | 13 597, 13 603 | 13 626, 13 642,  13 658, 13 674 |
| Number of beams | 2 | 49 | 4 |
| RF bandwidth (MHz) | 0.6 × 2 | 0.6 + 0.6 | 8 × 4 |
| Transmit Pk pwr (W) | 1 000 | 1 000 | 2 000 |
| Transmit Ave. pwr (W) | 7.2 | 12.1 | 360 |
| Pulsewidth (μs) | 1.6 | 1.6 | 40 |
| Pulse repetition frequency (PRF) (Hz) | 4 500 | 4 485 | 4 500 |
| Chirp rate (MHz/μs) | NA\* | NA\* | 0.2 |
| Transmit duty cycle (%) | 0.72 | 1.21/0.67 | 18 |
| e.i.r.p. ave (dBW) | 55.6 | 55.7 | 80.6 |
| e.i.r.p. peak (dBW) | 77.0 | 77.4 | 88.0 |
| System noise figure (dB) | 5 | 5.1 | 3.5 |
| \* Unmodulated pulse. | | | |

## 7.9 Typical parameters of active sensors operating in the 17.2-17.3 GHz band

Typical characteristics of 17.25 GHz SAR radars are shown in Table 17.

TABLE 17

Characteristics of EESS (active) missions in the 17.2-17.3 GHz band

| Parameter | SAR-I1 |
| --- | --- |
| Sensor type | SAR |
| Type of orbit | Circular SSO |
| Altitude (km) | 512 |
| Inclination (degrees) | 97.9 |
| Ascending node LST | 06:00 |
| Repeat period (days) | 5 |
| Antenna type | Offset linear array fed reflector |
| Number of beams | 1 |
| Antenna (Transmit and Receive) peak gain (dBi) | 49 |
| Polarization | Linear VV, VH |
| Azimuth scan rate (rpm) | 0 |
| Antenna beam look angle (degrees) | 30-40 |
| Antenna beam azimuth angle (degrees) | 90 |
| Antenna elev. beamwidth (degrees) | 0.9 |
| Antenna az. beamwidth (degrees) | 0.3 |
| RF centre frequency (MHz) | 17 250 |
| RF bandwidth (MHz) | 10 |
| Transmit Pk pwr (W) | 4 000 |
| Transmit Ave. pwr (W) | 360 |
| Pulsewidth (μs) | 20-30 |
| Pulse repetition frequency (PRF) (μs) | 1 000-3 000 |
| Chirp rate (MHz/μs) | 0.5-0.67 |
| Transmit duty cycle (%) | 2-9 |
| System noise figure (dB) | 5 |

## 7.10 Typical parameters of active sensors operating in the 24.05-24.25 GHz band

The typical characteristics of spaceborne radars operating in the 24.05-24.25 GHz band are shown in Table 18 with typical parameter values including the characteristics of the example radar. The spectrum is intended for use by precipitation radars and scatterometers.

TABLE 18

Characteristics of EESS (active) missions in the 24.05-24.25 GHz band

| Parameter | SCAT-J1 | PR-J1 |
| --- | --- | --- |
| Sensor type | Scatterometer | Precipitation radar |
| Type of orbit | Circular, NSS | Circular, NSS |
| Altitude (km) | 803 | 350 |
| Inclination (degrees) | 98.6 | 35 |
| Repeat period (days) | 4 | 46 |
| Antenna type | 0.56 m dia offset reflector | 1.18 m Slotted waveguide array |
| Number of beams | 2 | 1 |
| Antenna (Transmit and Receive)  peak gain, (dBi) | 41 | 47.4 |
| Polarization | H (inner), V (outer) | H |
| Azimuth scan rate, rpm or s/scan | 18 | 0.6 s/scan |
| Antenna beam look angle (degrees) | 40, 46 | ±17 |
| Antenna beam azimuth angle (degrees) | 0-360 | ±90 |
| Antenna elev. beamwidth (degrees) | 1.6 | 0.71 |
| Antenna az. beamwidth (degrees) | 1.6 | 0.71 |
| RF centre frequency (MHz) | 24 150 | 24 150 |
| RF bandwidth (MHz) | 0.53 | 0.6 |
| Transmit Pk pwr (W) | 100 | 578 |
| Transmit Ave. pwr (W) | 30.6 | 2.57 |
| Pulsewidth (μs) | 1 700 | 1.6 |
| Pulse repetition frequency (PRF), (Hz) | 180 | 2776 |
| Chirp rate (MHz/μs) | 0.0003118 | NA |
| Transmit duty cycle (%) | 30.6 | 0.44 |
| System noise figure (dB) | 5 | 7 |

## 7.11 Typical parameters of active sensors operating in the 35.5-36.0 GHz band

Typical characteristics of SAR, radar altimeters and precipitation radars operating in 35.5‑36.0 GHz are shown in Table 19.

TABLE 19

Characteristics of EESS (active) missions in the 35.5-36 GHz band

| Parameter | ALT-K1 | ALT-K2  (Note 1) | ALT-K3 | SAR-K1  (Note 2) | PR-K1 | PR-K2 | PR-K3 | PR-K4 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sensor type | Altimeter | Altimeter | Altimeter | SAR | Precipitation Radar | Precipitation Radar | Precipitation Radar | Precipitation Radar |
| Type of orbit | SSO | NSS | NSS | SSO | SSO | NSS | NSS | NSS |
| Altitude (km) | 800 | 891 | 714 | 780 | 650 | 407 | 410 | 600 |
| Inclination (degrees) | 98.53 | 77.6 | 92 | 98.6 | 98.2 | 65 | 50 | 50 |
| Ascending node LST (1) | 18:00 | NA | NA | 18:00 | 13:00 | NA | NA | NA |
| Repeat period (days) | 35 | 22 | 367 | 11 | 53 | 82 | 11 | 6 |
| Antenna size/diameter | 1.0 m | 5 m × 0.26 m | 1.4 m × 1.25 m | 3 m × 0.6 m (xmt), 3 m × 2 m (rcv) | 2.5 m × 5 m | 0.8 × 0.81.6 m | 1.2 m | 2.1 m |
| Antenna Pk Xmt gain (dBi) | 49.3 | 48.5 | 50.2 | 49.5 | 60.4 | 47.4 | 47 | 55 |
| Antenna Pk Rcv gain (dBi) | 49.3 | 48.5 | 50.2 | 55.0 | 60.4 | 47.4 | 47 | 55 |
| Polarization | circular | H, V | Linear | H,V | H,V | H | HH | HH, HV |
| Azimuth scan rate (rpm) | 0 | 0 | 0 | 0 | 0 | 0.7 s/scan (2) | 0.7 s/scan | 0.42 s/scan |
| Antenna beam look angle (degrees) | 0 | 0 | 0 | 30 | ±2.4 | ±17 | ±20 | ±31 |
| Antenna beam azimuth angle (degrees) | 0 | 0 | 0 | 90 | 90 | 90 | ±90 | ±90 |
| Antenna elev. beamwidth (degrees) | 0.6 | 2.7 | 0.4 | 2.9 | 0.2 | 0.7 | 0.7 | 0.28 |
| Antenna az. beamwidth (degrees) | 0.6 | 0.10 | 0.4 | 0.16 | 0.1 | 0.7 | 0.7 | 0.25 |
| RF centre frequency (MHz) | 35 750 | 35 750 | 35 750 | 35 750 | 35 600 | 35 547, 35 553 | 35 547, 35 553 | 35 526, 35 542, 35 558, 35 574 |
| RF bandwidth (MHz) | 480 | 210 | 500 | 40 | 2.5 | 0.6+0.6, 0.3+0.3 | 0.6 × 2 | 8 × 4 |

TABLE 19 (*end*)

| Parameter | ALT-K1 | ALT-K2  (Note 1) | ALT-K3 | SAR-K1  (Note 2) | PR-K1 | PR-K2 | PR-K3 | | PR-K4 | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Transmit Pk pwr (W) | 2 | 1 368 | 3.8 (3); 4.3 (4) | 3 000 | 1 500 | 140 | 150 | 300 | |
| Transmit Ave. pwr (W) | 0.856 | 40.51 | 3.4 (3); 1.3 (4) | 300 | 19.3 | 2.56 | 27 | 54 | |
| Pulsewidth (μs) | 107 | 6.7 | 49 (3); 18 (4) | 36.1 | 1.67 | 1.6, 3.2 | 1.6/10/20/40 | 40 | |
| Pulse repetition frequency (PRF)  max (Hz) | 4 000 | 4 420 | 18 000 (3);  15 500 to 16 800 (4) | 2 770 | 7 700 | 4 485 | 4 500 | 4 500 | |
| Chirp rate (MHz/μs) | 4.49 | 31.34 | 10.2 (3); 27.8 (4) | 1.108 | 1.54 | NA(1) | 0.015-0.375 | | 0.2 | |
| Transmit duty cycle (%) | 42.8 | 2.96 | 88.2 (3); 29.1 (4) | 10.0 | 1.28 | 1.83 | 0.7-18 | | 18 | |
| e.i.r.p. ave (dBW) | 48.6 | 64.6 | 55.5 (3); 51.2 (4) | 84.3 | 73.3 | 47.1 | 61.4 | | 72.4 | |
| e.i.r.p. peak (dBW) | 52.3 | 79.9 | 56 (3); 56.6 (4) | 74.3 | 92.2 | 68.9 | 68.8 | | 79.8 | |
| System noise figure (dB) | 3.9 | 4 | 4.1 | 4.5 | 4 | 6.3 | 6 | | 3.5 | |
| (1) Unmodulated pulse.  (2) The azimuth scan rate in seconds per scan is the time needed to scan from side to side (across‑track) during one cycle.  (3) Closed burst mode.  (4) Open burst mode. | | | | | | | | | | |
| NOTE 1 – This altimeter system is a Radar Interferometer instrument containing two Ka‑band SAR antennas at opposite ends of a 10-metre boom with both antennas transmitting and receiving the emitted radar pulses along both sides of the orbital track. Look angles are limited to less than 4.5 degrees providing a 120-km wide swath.  The 210-MHz bandwidth achieves cross-track ground resolutions varying from about 10 m in the far swath to about 60 m in the near swath. A resolution of about 2 metres in the long track direction is derived by means of synthetic aperture processing.  NOTE 2 – Ka-Band SAR mission for single pass interferometry still in conceptual phase. Under consideration a single satellite with multiple antennas or two satellites in formation. | | | | | | | | | | |

## 

## 7.12 Typical parameters of active sensors operating in the 78-79 GHz band

The typical characteristics of spaceborne radars operating in the 78-79 GHz band are shown in Table 20 with typical parameter values including the characteristics of the example radar.

TABLE 20

Typical characteristics of EESS (active) missions in the 78-79 GHz band

| Parameter | PR-L1 |
| --- | --- |
| Sensor type | Precipitation Radar |
| Type of orbit | Circular, NSS |
| Altitude (km) | 400 |
| Inclination (degrees) | 60 |
| Repeat period (days) | 23 |
| Antenna type | Parabolic reflector |
| Antenna (Transmit and Receive) peak gain (dBi) | 61.7 |
| Polarization | Linear H |
| Azimuth scan rate (rpm) | 0.197 |
| Antenna beam look angle (degrees) | 0 |
| Antenna beam azimuth angle (degrees) | ±17 |
| Antenna elevation beamwidth (degrees) | 0.71 |
| Antenna azimuth beamwidth (degrees) | 0.71 |
| RF centre frequency (MHz) | 78.500 |
| RF bandwidth (MHz) | 0.8 |
| Transmit Pk pwr (W) | 1 000 |
| Transmit Ave. pwr (W) | 14 |
| Pulsewidth (μs) | 3.33 |
| Pulse repetition frequency (PRF), (Hz) | 4 250 |
| Chirp rate (MHz/μs) | N/A |
| Transmit duty cycle (%) | 1.42 |
| System noise figure (dB) | 3 |

## 7.13 Typical parameters of active sensors operating in the 94-94.1 GHz band

Table 21 shows typical characteristics of the CPR operating in the 94-94.1 GHz band.

TABLE 21

Characteristics of EESS (active) missions in the 94-94.1 GHz band

| Parameter | CPR-M1 | CPR-M2 |
| --- | --- | --- |
| Sensor type | Cloud profiling radar | Cloud profiling radar |
| Type of orbit | SSO | SSO |
| Altitude (km) | 705 | 393 |
| Inclination (degrees) | 98.2 | 97 |
| Ascending Node LST | 13:30 | 02:00 |
| Repeat period (days) | 16 | 25 |
| Antenna type | Parabolic reflector to offset cassegrain antenna | Parabolic reflector |
| Antenna diameter (m) | 1.85-2.5 | 2.5 |
| Antenna (transmit and receive) peak gain (dBi) | 63.1-65.2 | 66 |
| Polarization | linear | LHC (transmit),  RHC (receive) |
| Incidence angle at Earth (degrees) | 0 | 0 |
| Azimuth scan rate (rpm) | 0 | 0 |
| Antenna beam look angle (degrees) | 0 | 0 |
| Antenna beam azimuth angle (degrees) | 0 | 0 |
| Antenna elevation beamwidth (degrees) | 0.12 | 0.095 |
| Antenna azimuth beamwidth (degrees) | 0.12 | 0.095 |
| Beam width (degrees) | 0.095-0.108 | 0.095 |
| RF centre frequency (MHz) | 94.050 | 94.050 |
| RF bandwidth (MHz) | 0.36 | 7 |
| Transmit Pk pwr (W) | 1 000 | 2 200 |
| Transmit Ave. pwr (W) | 21.31 | 44 |
| Pulsewidth (μs) | 3.33 | 3.3 |
| Pulse repetition frequency (PRF) (Hz) | 4 300 | 1 800-7 500 |
| Chirp rate (MHz/μs) | N/A (1) | 2.1 |
| Transmit duty cycle (%) | 1.33 | 2 |
| Minimum sensitivity (dBz) | −30 to −35 | −30 to −35 |
| Horizontal resolution | 0.7-1.9 km | 800 m |
| Vertical resolution (m) | 250-500 | 500 |
| Doppler range (m/s) | ±10 | ±10 |
| Doppler accuracy (m/s) | 1 | 1 |
| System noise figure (dB) | 7 | 7 |
| (1) The sensor uses an unmodulated pulse. | | |

## 7.14 Typical parameters of active sensors operating in the 133.5-134 GHz band

Table 22 shows typical characteristics of a CPR with a centre frequency of 133.75 GHz. Very high frequencies are needed for sensitivity to small ice particles.

TABLE 22

Characteristics of EESS (active) missions in the 133.5-134 GHz band

| Parameter | CPR-N1 |
| --- | --- |
| Sensor type | Cloud profiling radar |
| Type of orbit | SSO |
| Altitude (km) | 705 |
| Inclination (degrees) | 98.2 |
| Ascending node LST | 13:30 |
| Repeat period (days) | 16 |
| Antenna diameter (m) | 3 |
| Antenna (transmit and receive) peak gain (dBi) | 75 |
| Polarization | linear |
| Azimuth scan rate (rpm) | 0 |
| Antenna beam look angle (degrees) | 0 |
| Antenna beam azimuth angle (degrees) | 0 |
| Antenna elevation beamwidth (degrees) | 0.043 |
| Antenna azimuth beamwidth (degrees) | 0.043 |
| RF centre frequency (GHz) | 133.75 |
| RF bandwidth (MHz) | 0.65 |
| Transmit Pk power (W) | 300 |
| Pulsewidth (μs) | 1.6 |
| Pulse repetition frequency (PRF), (Hz) | 4 000 |
| Range resolution (m) | 250 |
| Horizontal resolution | 0.2 × 0.7 km |
| System noise figure (dB) | 8 |

## 7.15 Typical parameters of active sensors operating in the 237.9-238 GHz band

Table 23 shows typical characteristics of a CPR with a centre frequency of 237.95 GHz. Very high frequencies are needed for sensitivity to small ice particles.

TABLE 23

Characteristics of EESS (active) missions in the 237.9-238 GHz band

| Parameter | CPR-O1 |
| --- | --- |
| Sensor type | Cloud profiling radar |
| Type of orbit | SSO |
| Altitude (km) | 705 |
| Orbital inclination (degrees) | 98.2 |
| Ascending node LST | 13:30 |
| Repeat period (days) | 16 |
| Antenna diameter (m) | 3 |
| Antenna (Transmit and Receive) peak gain (dBi) | 78 |
| Polarization | Linear |
| Azimuth scan rate (rpm) | 0 |
| Antenna beam look angle (degrees) | 0 |
| Antenna beam azimuth angle (degrees) | 0 |
| Antenna elevation beamwidth (degrees) | 0.024 |
| Antenna azimuth beamwidth (degrees) | 0.024 |
| RF centre frequency (GHz) | 237.95 |
| RF bandwidth (MHz) | 0.65 |
| Transmit Pk power (W) | 80 |
| Pulsewidth (μs) | 1.6 |
| Pulse repetition frequency (PRF) (Hz) | 4 000 |
| Range resolution (m) | 250 |
| Horizontal resolution | 0.1 × 0.7 km |
| System noise figure (dB) | 11 |