ITUPublications
Recommendations

International Telecommunication Union
Radiocommunication Sector

Recommendation ITU-R RS.2105-3

(06/2025)

RS Series: Remote sensing systems

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

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from https://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at https://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	**Remote sensing systems**
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2025

© ITU 2025

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

RECOMMENDATION ITU-R RS.2105-3

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

(2017-2021-2023-2025)

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

Earth exploration-satellite service (EESS (active)), remote sensing, synthetic aperture radar (SAR) imager, altimeter, 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
LFM	Linear FM
LHCP	Left hand circular polarization
LRM	Low resolution mode
LST	Local solar time
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 polarization
SAR	Synthetic aperture radar
SRS	Space research service
SSO	Sun-synchronous orbit
SWE	Snow water equivalent

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 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

Annex – Technical and operational parameters of EESS (active) systems using allocations between 40 MHz and 238 GHz 2

1 Introduction 3

2 Active sensor types and typical characteristics 3

3 Typical orbits 5

4 Active sensors interference and performance criteria 5

5 Sharing considerations for active sensors 5

5.1 Existing ITU-R Recommendations and Reports 5

5.2 Power flux-density levels due to active spaceborne sensors 7

5.3 Dynamics of antenna coupling with systems of other services 7

6 Definition of parameters 8

7 Parameters of typical systems 13

7.1 Typical parameters of active sensors operating in the 40-50 MHz band 13

7.2 Typical parameters of active sensors operating in the 432-438 MHz band 14

7.3 Typical parameters of active sensors operating in the 1 215-1 300 MHz band . 15

7.4 Typical parameters of active sensors operating in the 3 100-3 300 MHz band . 17

7.5 Typical parameters of active sensors operating in the 5 250-5 570 MHz band . 18

7.6 Typical parameters of active sensors operating in the 8 550-8 650 MHz band . 23

7.7 Typical parameters of active sensors operating in the 9 200-10 400 MHz band 23

7.8 Typical parameters of active sensors operating in the 13.25-13.75 GHz band .. 25

7.9 Typical parameters of active sensors operating in the 17.2-17.3 GHz band 30

7.10 Typical parameters of active sensors operating in the 24.05-24.25 GHz band .. 31

7.11 Typical parameters of active sensors operating in the 35.5-36.0 GHz band 32

7.12 Typical parameters of active sensors operating in the 78-79 GHz band 35

7.13 Typical parameters of active sensors operating in the 94-94.1 GHz band 36

7.14 Typical parameters of active sensors operating in the 133.5-134 GHz band 37

7.15 Typical parameters of active sensors operating in the 237.9-238 GHz band 38

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 radar (SAR) imagers – 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: 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 4: 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 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 imager**	**Scatterometer**	**Altimeter**	**Precipitation radar**	**Cloud profile radar**
Service area	Land/ice	Land/coastal/ ocean	Ocean/ice/land/ coastal	Ocean/ice/ coastal/ Inland water	Land/ocean	Land/ocean
Antenna beam	Wide beam	Fan beam, pencil beam	– Fan beams – Pencil beams	Pencil beam	Pencil beam	Pencil beam
Viewing geometry	Nadir-looking	Side-looking at 10°-60° off nadir	– Three/six fan beams in azimuth – One or more conically scanning beams	– Nadir-looking – Multi incidence looking	Scanning across-track around Nadir	Nadir-looking
Footprint/dynamics	Fixed at nadir	– Fixed to one side – ScanSAR – Stripmap – Spotlight	– Fixed in azimuth – Multiple conically scanning beams	– Fixed at nadir – Multi incidence looking	Scanning across nadir track	Fixed at nadir
RF bandwidth	10 MHz	≤ 10 to 1 200 MHz	5-80 kHz (ocean) or 1-4 MHz (land)	320-500 MHz	14 MHz	300 kHz

TABLE 1 (*end*)

Characteristic	Sensor type					
	Radar sounder	**SAR imager**	**Scatterometer**	**Altimeter**	**Precipitation radar**	**Cloud profile radar**
Transmit peak power (W)	100	1 500-16 000	100-5 000	20	600	1 000-1 500
Waveform	Linear FM pulses	Linear FM pulses	Interrupted CW or short pulses (ocean) or linear FM pulses (land)	Linear FM pulses	Short pulses	Short pulses
Transmit duty cycle (%)	10.2	1-30	31 (ocean) or 10 (land)	46	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	Feasibility of sharing between active spaceborne sensors and other services in the range 420-470 MHz
ITU-R RS.1261	Feasibility of sharing between spaceborne cloud radars and other services in the range of 92-95 GHz
ITU-R RS.1280	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	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	Feasibility of sharing between wind profiler radars and active spaceborne sensors in the vicinity of 1 260 MHz
ITU-R RS.1347	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	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	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	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	Characteristics of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz
ITU-R RS.2065	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	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	Current and future use of the band near 13.5 GHz by spaceborne active sensors
ITU-R 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.2165	Evaluation of the potential for pulsed interference from planned and future spaceborne synthetic aperture radar sensors in the earth exploration-satellite (active) service to radionavigation-satellite service receivers in the 1 215-1 300 MHz band
ITU-R RS.2178	The essential role and global importance of radio spectrum use for Earth observations and for related applications

TABLE 2 (*end*)

Reports	
ITU-R RS.2273	Potential interference from EESS (active) scatterometers into ARNS systems in the frequency band 1 215-1 300 MHz
ITU-R 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	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	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	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	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
ITU-R RS.2537	Representative technical characteristics of EESS (active) spaceborne synthetic aperture radar sensors and receiving earth stations in the RNSS and a general analytic method used in evaluating the potential for pulsed radio frequency interference to receiving earth stations in the RNSS in the 1 215-1 300 MHz 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 imager**	**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/m^2))	−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 radar sounders, 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 § 1 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 (m) or Antenna size or Antenna diameter/size	Diameter of the antenna reflector (when applicable), or length and width of the planar array (when applicable)
Antenna peak transmit/receive gain (dBi) and/or Antenna peak transmit gain (dBi) and/or Antenna peak receive gain (dBi)	The peak antenna transmit/receive gain is the ratio of the power transmitted/received/received by an isotropic antenna, respectively. 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, the diameter *D* of the reflector (when applicable), and the wavelength λ of the transmitted/received emission (with *D* and λ in the same units): $$Maximum_antenna_gain = \eta \left(\pi \frac{D}{\lambda}\right)^2$$ For the case of planar array antennas, the maximum gain can be estimated by using the antenna efficiency η, the length *l* and width *w* of the planar array (when applicable) and the wavelength λ of the transmitted/received emission (where *l*, *w* and λ are in the same units) with the formula: $$Maximum_antenna_gain = \eta\ 4\pi\ lw/\lambda^2$$
Polarization	The plane describing the direction of oscillation for all waves of the incoming/outgoing radiation. For circular polarization, this plane rotates around the direction of propagation. Specification of linear (horizontal (H) or vertical (V)) or circular polarization (right-hand circular polarization (RHCP) or left-hand circular polarization (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 the half power beamwidth (HPBW)), θ_{3dB}, is defined as the angle between the two directions in which the radiation intensity is one-half the maximum value.

TABLE 4 (*continued*)

Parameter	Definition
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 = $H\theta_{3dB}$, where H is the height of the satellite and θ_{3dB} 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.
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

TABLE 4 (*continued*)

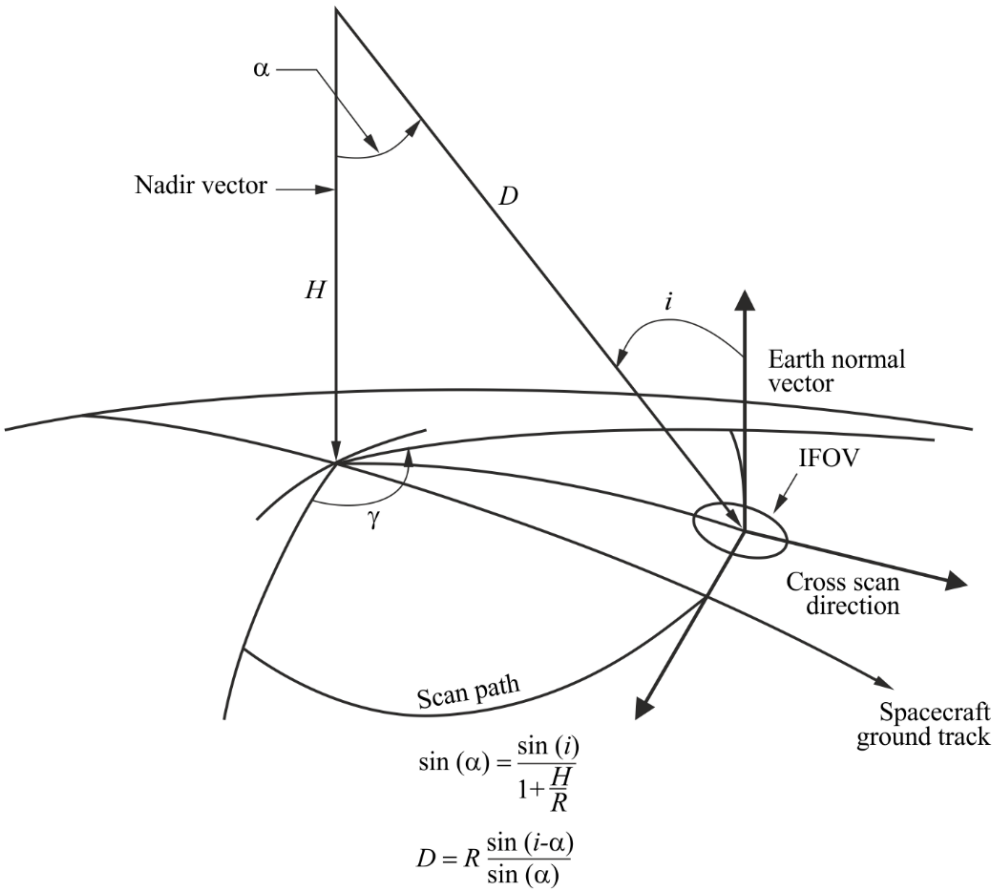
Parameter	Definition
Transmitter characteristics	
RF centre frequency (MHz)	The RF centre frequency is that frequency about which the bandwidth of the transmitted signal is centred
RF bandwidth (MHz)	The RF bandwidth is the −3 dB bandwidth of the transmitted signal. For compatibility analysis, this is also typically used as the receiver bandwidth
Transmit peak power (W)	The transmit peak power is the peak power of the envelope of the transmitted waveform.
Transmit average power (W)	The transmit average power is the product of the peak power of the envelope of the transmitted waveform times the transmit duty cycle.
Pulse width (μs)	The pulse width is the half power duration of the transmitted pulse.
PRF (Hz)	The pulse repetition frequency (PRF) 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).
Peak e.i.r.p. (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.
Average e.i.r.p. (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 average e.i.r.p. is the product of the transmit average 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, or field of view, by the detector of a sensor.
Sensitivity (dBZ)	The sensitivity of a precipitation radar or cloud profile radar is the *minimum* detectable reflectivity Z (mm^6/m^3) 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 $(S/N)_o$. Noise temperature is a measure expressing the available noise power introduced by a component or source. 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.

TABLE 4 (*end*)

Parameter	Definition
Measurement spatial resolution	
Range resolution (m)	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 (m)	

FIGURE 1

Scanning configuration typical of conical scanning scatterometers

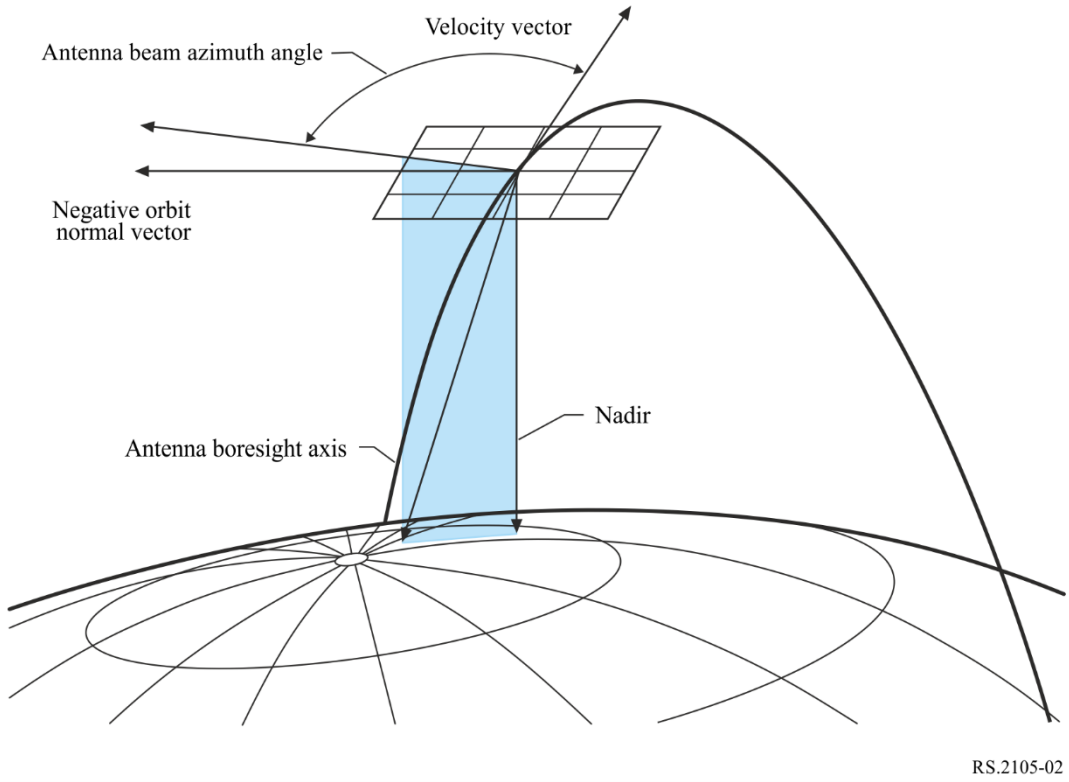


i: Incidence angle at footprint centre
α: Angle off nadir
γ: Total scan angle
H: Height above mean sea level
D: Distance to field of view centre
R: Radius of Earth (not shown in diagram)

RS.2105-01

FIGURE 2

Plane defined by velocity vector and negative orbit normal vector



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-AA1
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/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 peak power (W)	100
Transmit average power (W)	10.2
Pulse width (μs)	85
PRF (Hz)	1 200
Chirp rate (MHz/μs)	0.1176
Transmit duty cycle (%)	10.2
Operational duty cycle (%)	6.25
Peak e.i.r.p. (dBW)	30.0
Average e.i.r.p. (dBW)	20.1
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-A1
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 peak transmit gain (dBi)	33.6
Antenna peak receive 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 power (W)	170
Transmit average power (W)	10
Pulse width (μs)	38
PRF (Hz)	1 550 (maximum)
Chirp rate (MHz/μs)	0.200, 0.182, 0.1861
Transmit duty cycle (%)	5.9
Peak e.i.r.p. (dBW)	55.9
Average e.i.r.p. (dBW)	43.6
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-B1	SCAT-B2	SAR-B1	SAR-B2	SAR-B3	SAR-B4
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	00:00	18:00	00:00
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 diameter/size (m)	6	2.5	12	9.9 × 2.9	11 × 3.6	9.9 × 3.9
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 elevation 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 azimuth 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-B1	SCAT-B2	SAR-B1	SAR-B2	SAR-B3	SAR-B4
RF bandwidth (MHz)	1	4	5, 20, 40, 77	14-84	40-85	28-84
Transmit peak power (W)	200	200	1 334	3 944-6 120	9 000	5 390-8 680
Transmit average power (W)	28	–	9.7-102.2	453-454	600 (dual pol), 720 (quad pol)	490-960
Pulse width (μs)	15	1 000	4.4-40	18-71	10-80	21-67
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)
Peak e.i.r.p. (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-C1	SAR-C2	SAR-C3	SAR-C4
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 period (days)	31	16	16	12
Antenna type	–	Parabolic Dish	Parabolic Dish	Deployable mesh reflector
Number of beams	9	–	–	24
Antenna diameter (m)	–	6	6	12
Antenna peak transmit/receive gain (dBi)	37.6	42	44	38

TABLE 8 (*end*)

Parameter	SAR-C1	SAR-C2	SAR-C3	SAR-C4
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 peak power (W)	3 000	5 000	11 220	37 857
Transmit average power (W)	300	–	–	2 082
Pulse width (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-D4, SAR-D5, SAR-D6, and SAR-D1 (a two-satellite constellation).

TABLE 9

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

Mission	SAR-D1	SAR-D2	SAR-D3	SAR-D4	SAR-D5	SAR-D6	SAR-D7	SAR-D8
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	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 peak transmit gain (dBi)	43.5 to 45.3	40 to 45	35	49 (2)	45 (3)	45 (3)	48	38.7
Antenna peak receive gain (dBi)	43.5 to 44.8	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 elevation 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 azimuth 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-D1	SAR-D2	SAR-D3	SAR-D4	SAR-D5	SAR-D6	SAR-D7	SAR-D8
Transmit peak power (W)	4 140	2 500	4 000	2 400 or 3 700	1 490	1 990	15 360	5 000
Transmit average power (W)	370	200	260	300	180	240	1 900	750
Pulse width (μs)	5 to 53	16 to 41	20	21, 42	10 to 50	10 to 50	15 to 50	17.5 to 25.5
PRF (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%
Peak e.i.r.p. (dBW)	80	78.0	71.0	83.5 (4)	76.7	78.0	89.8	75.7
Average e.i.r.p. (dBW)	70 (for 9% duty cycle)	68.0	68	≈73 (5)	67.67	69.0	≈80.7	67.5
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) Maximum e.i.r.p. during pulse transmission.

(5) Average e.i.r.p. over a pulse repetition interval.

TABLE 10

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

Mission	ALT-D1	ALT-D2 (1)	ALT-D3	ALT-D4 (1)	ALT-D5	ALT-D6
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 diameter (m)	1.2	1.2	1.4	1.2	1.2	1.5
Antenna peak transmit gain (dBi)	32	32	35	33.5	32.0	33.6
Antenna peak receive 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 elevation beamwidth (degrees)	3.4	3.4	2.3	3.4	3.4	3
Antenna azimuth 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 peak power (W)	17	32	20	25	17	15.8
Transmit average power (W)	0.51	0.4 (LRM), 0.25 (SAR)	8.2	< 2	0.51	0.51, 0.71
Pulse width (μs)	106.0	49	102.4	32	106.0	110.5
PRF (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
Peak e.i.r.p. (dBW)	44.8	49.5	48	47.47	44.3	45.6
Average e.i.r.p. (dBW)	29.5	30.8 (LRM), 28.4 (SAR)	44.1	36.51	29.2	30.7, 32.1
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-D1	SCAT-D2
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	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 peak transmit gain (dBi)	24-32	23-31 (1)
Antenna peak receive 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 elevation beamwidth (degrees)	23.6 (mid beams) 23.9 (side beams)	28 (mid beams) 30 (side beams)
Antenna azimuth 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 peak power (W)	120	2 512
Transmit average power (W)	29 (mid beams) 36.5 (side beams)	92
Pulse width (μs)	10 000	1 000
PRF (Hz)	28.259	32
Chirp rate (MHz/μs)	0.00002	0.00002
Transmit duty cycle (%)	28.29	3.68
Peak e.i.r.p. (dBW)	53	57-65
Average e.i.r.p. (dBW)	39-47	42-50
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-E1
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 peak transmit/receive 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 azimuth beamwidth (degrees)	0.4
RF centre frequency (MHz)	8 600
RF bandwidth (MHz)	10, 20
Transmit peak power (W)	3 500
Transmit average power (W)	243
Pulse width (μs)	40
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-F1	SAR-F2	SAR-F3	SAR-F4	SAR-F5	SAR-F6	SAR-F7	SCAT-F8
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 peak transmit/receive 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 (degree)	15-60	21-44	30-40	37.8	15-45	18-50	15-55	90
Antenna beam azimuth angle (degree)	90	90	90	90	90	90	90	N/A
Antenna elevation beamwidth (degrees)	2.54	1.32	1.5	1.34	2.5	1.13	1-1.2	26
Antenna azimuth beamwidth (degree)	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 peak power (W)	2 000	7 600	3 000	7 600	2 260	7 000	1 800	1 600
Transmit average power (W)	400	836	270	836	452	2 100	–	–
Pulse width (μs)	47	18-31	20-30	18-31	47	50	36	2
PRF (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 13.5 GHz altimeters are shown in Table 14.

Typical ocean scatterometers, operating around 13.5 GHz, infer 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 13.5 GHz scatterometers.

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

Snow water equivalent (SWE) retrieval radars are multi-frequency SAR imager type sensors looking to one side of the nadir track, using the backscatter measurement sensitivity to SWE through the volume scattering properties of dry snow to retrieve snow mass information. Typical characteristics of SAR imager type SWE retrieval radars operating at 13.5 GHz are shown in Table 17.

TABLE 14

Characteristics of altimeters in the 13.25-13.75 GHz band

Mission	ALT-G1	ALT-G3	ALT-G4	ALT-G5	ALT-G6 (Note 1)	ALT-G7 (Note 1)	ALT-G8	ALT-G9
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	N/A	N/A	22:00	N/A	–	N/A
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/size	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 peak transmit gain (dBi)	41.2	43	43.2	42	42	42.1	42.2	42.3
Antenna peak receive 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
Antenna elevation beamwidth (degrees)	1.2	0.9	1.27	1.2	1.27	1.35	1.5	1
Antenna azimuth 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

TABLE 14 (*end*)

Mission	ALT-G1	ALT-G3	ALT-G4	ALT-G5	ALT-G6 (Note 1)	ALT-G7 (Note 1)	ALT-G8	ALT-G9
Transmit peak power (W)	60	20	25	25	7.1	8	5.6	21.7 (2); 24.4 (3)
Transmit average power (W)	2.16	8.2	5.41	2.22	0.66	<4	1.27	19.1 (2); 7.1 (3)
Pulse width (μs)	20	102.4	106.0	50	49	32	110.5	49 (2); 18 (3)
PRF (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)
Peak e.i.r.p. (dBW)	59.0	56.0	56	60.0	50.5	51.03	49.7	55.7 (2); 56.2 (3)
Average e.i.r.p. (dBW)	44.5	52.1	49.33	45.5	40.2	48.02	43.2	55.1 (2); 50.8 (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-G5 and ALT-G6 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-G6 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-G1	SCAT-G2	SCAT-G3	SCAT-G4
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 (m)	1	1.3	1	3
Antenna peak transmit gain (dBi)	41	42	39.5	48
Antenna peak receive 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 elevation beamwidth (degrees)	1.6	1	1.67	0.9
Antenna azimuth 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 peak power (W)	100	120	100	1 000
Transmit average power (W)	30.6	28.8	27	450
Peak e.i.r.p. (dBW)	61.0	62.8	20	78.0
Pulse width (μs)	1 700	650-1 200	1 350	1 500
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
Peak e.i.r.p. (dBW)	61.0	62.8	59.5	78.0
Average e.i.r.p. (dBW)	55.9	56.6	53.8	74.5
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-G1	PR-G2	PR-G3
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/size	2 m	2.1 m × 2.1 m	5.3 m
Antenna peak transmit/receive 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 elevation beamwidth (degrees)	0.7	0.7	0.28
Antenna azimuth 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 peak power (W)	1 000	1 000	2 000
Transmit average power (W)	7.2	12.1	360
Pulse width (μs)	1.6	1.6	40
PRF (Hz)	4 500	4 485	4 500
Chirp rate (MHz/μs)	N/A [1]	N/A [1]	0.2
Transmit duty cycle (%)	0.72	1.21/0.67	18
Peak e.i.r.p. (dBW)	77.0	77.4	88.0
Average e.i.r.p. (dBW)	55.6	55.7	80.6
System noise figure (dB)	5	5.1	3.5

[1] Unmodulated pulse.

TABLE 17

Characteristics of SAR imager in the 13.25-13.75 GHz band

Parameter	SAR-G1
Sensor type	SAR (SWE retrieval radar)
Type of orbit	SSO
Altitude (km)	521-550
Inclination (degrees)	97.48
Ascending node LST	06:00
Repeat period (days)	27
Antenna type	Phased Array
Number of beams	1
Antenna peak transmit/receive gain (dBi)	44-47
Polarization	Linear VV, VH
Azimuth scan rate (rpm)	0
Antenna beam look angle (degrees)	37
Antenna beam azimuth angle (degrees)	90
Antenna elevation beamwidth (degrees)	1.4
Antenna azimuth beamwidth (degrees)	0.2-0.5
RF centre frequency (MHz)	13 500
RF bandwidth (MHz)	8
Transmit peak power (W)	≤ 2 000
Transmit average power (W)	≤ 358.8
Pulse width (μs)	8-26
PRF (Hz)	4 800-6 900
Chirp rate (MHz/μs)	0.31-1.00
Transmit duty cycle (%)	≤ 17.94
Operational duty cycle (%)	≤ 25
System noise figure (dB)	5

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 18, including the typical characteristics of SWE retrieval radar operating at 17.25 GHz.

TABLE 18

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

Parameter	SAR-H1	SAR-H2
Sensor type	SAR	SAR (SWE retrieval radar)
Type of orbit	Circular SSO	SSO
Altitude (km)	512	521-550
Inclination (degrees)	97.9	97.48
Ascending node LST	06:00	06:00
Repeat period (days)	5	27
Antenna type	Offset linear array fed reflector	Phased array
Number of beams	1	1
Antenna peak transmit/receive gain (dBi)	49	46-49
Polarization	Linear VV, VH	Linear VV, VH
Azimuth scan rate (rpm)	0	0
Antenna beam look angle (degrees)	30-40	37
Antenna beam azimuth angle (degrees)	90	90
Antenna elevation beamwidth (degrees)	0.9	1.1
Antenna azimuth beamwidth (degrees)	0.3	0.17-0.35
RF centre frequency (MHz)	17 250	17 250
RF bandwidth (MHz)	10	8
Transmit peak power (W)	4 000	≤ 2 000
Transmit average power (W)	360	≤ 358.8
Pulse width (μs)	20-30	8-26
PRF (Hz)	1 000-3 000	4 800-6 900
Chirp rate (MHz/μs)	0.5-0.67	0.31-1.00
Transmit duty cycle (%)	2-9	≤ 17.94
Operational duty cycle (%)	–	≤ 25
System noise figure (dB)	5	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 19 with typical parameter values including the characteristics of the example radar. The spectrum is intended for use by precipitation radars and scatterometers.

TABLE 19

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

Parameter	SCAT-I1	PR-I1
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 peak transmit/receive 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 elevation beamwidth (degrees)	1.6	0.71
Antenna azimuth beamwidth (degrees)	1.6	0.71
RF centre frequency (MHz)	24 150	24 150
RF bandwidth (MHz)	0.53	0.6
Transmit peak power (W)	100	578
Transmit average power (W)	30.6	2.57
Pulse width (μs)	1 700	1.6
PRF (Hz)	180	2776
Chirp rate (MHz/μs)	0.0003118	N/A
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 20.

TABLE 20

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

Parameter	ALT-J1	ALT-J2 (Note 1)	ALT-J3	SAR-J1 (Note 2)	PR-J1	PR-J2	PR-J3	PR-J4
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	18:00	N/A	N/A	18:00	13:00	N/A	N/A	N/A
Repeat period (days)	35	22	367	11	53	82	11	6
Antenna diameter/size (m)	1.0	5 × 0.26	1.4 × 1.25	3 × 0.6 (xmt), 3 × 2 (rcv)	2.5 × 5	0.8 × 0.8	1.2	2.1
Antenna peak transmit gain (dBi)	49.3	48.5	50.2	49.5	60.4	47.4	47	55
Antenna peak receive 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 elevation beamwidth (degrees)	0.6	2.7	0.4	2.9	0.2	0.7	0.7	0.28
Antenna azimuth 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 20 (*end*)

Parameter	ALT-J1	ALT-J2 (Note 1)	ALT-J3	SAR-J1 (Note 2)	PR-J1	PR-J2	PR-J3	PR-J4
Transmit peak power (W)	2	1 368	3.8 [3]; 4.3 [4]	3 000	1 500	140	150	300
Transmit average power (W)	0.856	40.51	3.4 [3]; 1.3 [4]	300	19.3	2.56	27	54
Pulse width (µs)	107	6.7	49 [3]; 18 [4]	36.1	1.67	1.6, 3.2	1.6/10/20/40	40
PRF (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	N/A[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
Peak e.i.r.p. (dBW)	52.3	79.9	56 [3]; 56.6 [4]	74.3	92.2	68.9	68.8	79.8
Average e.i.r.p. (dBW)	48.6	64.6	55.5 [3]; 51.2 [4]	84.3	73.3	47.1	61.4	72.4
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 21 with typical parameter values including the characteristics of the example radar.

TABLE 21

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

Parameter	PR-K1
Sensor type	Precipitation Radar
Type of orbit	Circular, NSS
Altitude (km)	400
Inclination (degrees)	60
Repeat period (days)	23
Antenna type	Parabolic reflector
Antenna peak transmit/receive 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 peak power (W)	1 000
Transmit average power (W)	14
Pulse width (μs)	3.33
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 22 shows typical characteristics of the CPR operating in the 94-94.1 GHz band.

TABLE 22

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

Parameter	CPR-L1	CPR-L2
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 peak transmit/receive 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 peak power (W)	1 000	2 200
Transmit average power (W)	21.31	44
Pulse width (μs)	3.33	3.3
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 23 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 23

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

Parameter	CPR-M1
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 peak transmit/receive 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 peak power (W)	300
Pulse width (μs)	1.6
PRF (Hz)	4 000
Range resolution (m)	250
Horizontal resolution (km)	0.2 × 0.7
System noise figure (dB)	8

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

Table 24 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 24

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

Parameter	CPR-N1
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 peak transmit/receive 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 peak power (W)	80
Pulse width (μs)	1.6
PRF (Hz)	4 000
Range resolution (m)	250
Horizontal resolution (km)	0.1 × 0.7
System noise figure (dB)	11