

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R RS.2105-0
(07/2017)

**Typical technical and operational
characteristics of Earth exploration-satellite
service (active) systems using allocations
between 432 MHz and 238 GHz**

RS Series
Remote sensing systems



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RA	Radio astronomy
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SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R RS.2105-0

Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 432 MHz and 238 GHz

(2017)

Scope

This Recommendation provides technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 432 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

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 432 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 432 MHz and 238 GHz.

Annex

Technical and operational parameters of EESS (active) systems using allocations between 432 MHz and 238 GHz

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 432 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 five active spaceborne sensor types addressed in this Recommendation:

- Type 1: 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 2: 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 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: 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 5: 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				
	SAR	Altimeter	Scatterometer	Precipitation radars	Cloud profile radars
Service area	Land/coastal/ocean	Ocean/ice/coastal/ Inland water	Ocean/ice/land/coastal	Land/ocean	Land/ocean
Antenna beam	Fan beam	Pencil beam	– Fan beams – Pencil beams	Pencil beam	Pencil beam
Viewing geometry	Side-looking at 10°-55° 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 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	20- 1 200 MHz	320-500 MHz	5-80 kHz (ocean) or 1-4 MHz (land)	14 MHz	300 kHz
Transmit peak power (W)	1 500-7 600	20	100-5 000	600	1 000-1 500
Waveform	Linear FM pulses	Linear FM pulses	Interrupted CW or short pulses (ocean) or linear FM pulses (land)	Short pulses	Short pulses
Transmit duty cycle (%)	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 Recommendations with sharing considerations for active sensors

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.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

TABLE 2 (*end*)**List of ITU-R Reports with sharing considerations for active sensors**

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.2178	The essential role and global importance of radio spectrum use for Earth observations and for related applications
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

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				
	SAR	Altimeter	Scatterometer	Precipitation radars	Cloud profile radars
Transmit peak power (W)	1 500	20	100	578	630
Antenna gain (dBi)	36.4	43.3	34	47.7	63.4
Altitude (km)	695	1 344	1 145	350	400
pfd (dB(W/m ²))	-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 five 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 altimeters, precipitation radars and the 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 deg./s. The 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 five 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 & 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): $\text{Maximum_antenna_gain} = \eta \left(\pi \frac{D}{\lambda} \right)^2$ For the case of planar array antennas, the maximum gain can be estimated by using the length l and width w of the planar array (when applicable) with the formula: $\text{Maximum_antenna_gain} = \eta 4\pi l w / \lambda^2$
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), $\theta_{3\text{dB}}$, 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. 3, the nadir IFOV = $H\theta_{3\text{dB}}$, where H is the height of the satellite and $\theta_{3\text{dB}}$ is the half-power beamwidth. See also Fig. 1
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 (μ s)	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/ μ s)	The chirp rate for a linear FM (LFM) pulse is the ratio of the RF bandwidth in MHz and the pulsewidth in μ sec.
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.