

Recommendation ITU-R RS.1166-5

(12/2023)

RS Series: Remote sensing systems

Performance and interference criteria for active spaceborne sensors

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RA	Radio astronomy
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SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
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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.1166-5

Performance and interference criteria* for active spaceborne sensors

(1995-1998-1999-2006-2009-2023)

Scope

This Recommendation presents the performance and interference criteria for spaceborne active sensors in the bands allocated to the EESS (active). The Annex describes the technical bases for development of performance and interference criteria for various types of spaceborne active sensors. The sensor types include altimeters, scatterometers, precipitation radars, synthetic aperture radars and cloud profile radars.

Keywords

Earth Exploration-Satellite Service (active), remote sensing, active sensors, precipitation radar, synthetic aperture radar (SAR), altimeter, scatterometer, cloud profile radar

Abbreviations/Glossary

DPR	Dual precipitation radar
DSD	Drop size distribution
GPM	Global precipitation measurement
IFOV	Instantaneous field of view
ITCZ	Inter-tropical convergence zone
PR	Precipitation radar
TRMM	Tropical rainfall measuring mission
VPRF	Variable pulse repetition frequency

The ITU Radiocommunication Assembly,

considering

- a) that spaceborne active microwave remote sensing requires specific frequency ranges depending on the physical phenomena to be observed;
- b) that certain frequency bands have been allocated for spaceborne active microwave remote sensing;
- c) that these bands are also allocated to other radio services;
- d) that studies have established measurement sensitivity requirements;
- e) that performance requirements for active sensors can be stated in terms of precision of measurement of physical parameters and availability, measured at the satellite, assuming that degradation from other elements in the system is negligible;
- f) that definition of performance objectives for active spaceborne microwave sensors is a prerequisite for the establishment of the associated interference criteria;

* Interference criteria do not imply automatically sharing criteria.

g) that interference criteria are needed to ensure that systems can be designed to achieve adequate performance in the presence of interference, assess compatibility with systems in other services and, if needed, to assist in developing sharing criteria;

h) that Annex 1 presents the technical bases for performance and interference criteria based on representative active sensors,

recommends

1 that the performance criteria given in Table 1 should be applied to instruments used in active sensing of the Earth's land, oceans and atmosphere:

TABLE 1

Frequency band	Performance criteria for remote sensing instruments				
	Scatterometer	Altimeter	SAR imager	Precipitation radar	Cloud profile radars
432-438 MHz			Minimum reflectivity of -36 dB		
1 215-1 300 MHz	Minimum reflectivity of -32 dB		Minimum reflectivity of -36 dB		
3 100-3 300 MHz		Sea level precision ≤ 3 cm	Minimum reflectivity of -26 dB		
5 250-5 570 MHz	Wind speed ≥ 2 m/s	Sea level precision ≤ 2 cm	Minimum reflectivity of -30 dB over land and -33 dB over ocean		
8 550-8 650 MHz	Wind speed ≥ 3 m/s	Sea level precision ≤ 3 cm	Minimum reflectivity of -21 dB		
9 200-10 400 MHz	Wind speed ≥ 3 m/s	Sea level precision ≤ 3 cm	Minimum reflectivity of -18 dB		
13.25-13.75 GHz	Wind speed ≥ 3 m/s	Sea level precision ≤ 2 cm	Minimum reflectivity of -27 dB	Minimum rain rates from 0.7-0.75 mm/h	
17.2-17.3 GHz	Wind speed ≥ 3 m/s		Minimum reflectivity of -25 dB	Minimum rain rates from 0.7-0.75 mm/h	
24.05-24.25 GHz				Minimum rain rates from 0.7-0.75 mm/h	
35.5-36 GHz	Wind speed ≥ 3 m/s	Sea level precision ≤ 2 cm	Minimum reflectivity of -22 dB	Minimum rain rates from 0.05-0.2 mm/h	-24 dBZ $\pm 10\%$
78-79 GHz					-27 dBZ $\pm 10\%$
94-94.1 GHz				Minimum rain rates from 0.05 mm/h	-35 dBZ $\pm 10\%$
133.5-134 GHz					-34 dBZ $\pm 10\%$

TABLE 1 (*end*)

Frequency band	Performance criteria for remote sensing instruments				
	Scatterometer	Altimeter	SAR imager	Precipitation radar	Cloud profile radars
237.9-238 GHz					−44 dBZ ± 10%

dBZ: “Unit” radar reflectivity used in meteorology which represents a logarithmic power ratio (in decibels, or dB) with respect to radar reflectivity factor, Z, referred to a value of 1 mm⁶/m³.

SAR: Synthetic aperture radar.

2 that the interference and data availability criteria given in Table 2 be applied for instruments used for active sensing of the Earth’s land, oceans and atmosphere.

TABLE 2

Sensor type	Interference criteria		Data availability criteria (%)	
	Performance degradation	I/N (dB)	Systematic	Random
Synthetic aperture radar	10% degradation of standard deviation of pixel power	−6	99	95
Altimeter	4% degradation in height noise	−3	99	95
Scatterometer	8% degradation in measurement of normalized radar backscatter to deduce wind speeds	−5	99	95
Precipitation radar	7% increase in minimum rainfall rate	−10	99.8	99.8
Cloud profile radar	10% degradation in minimum cloud reflectivity	−10	99	95

For bands with secondary allocation, the interference criteria are provided only to indicate performance degradation with regard to primary services.

Annex 1

Performance and interference criteria for spaceborne active sensors

TABLE OF CONTENTS

1	Introduction	5
1.1	Systematic and Random interference	5
2	Altimeters	5
2.1	Performance criteria.....	6
2.2	Interference criteria.....	6
3	Scatterometers	7
3.1	Performance criteria.....	7
3.2	Interference criteria.....	9
4	Precipitation radars	11
4.1	Precipitation radars based upon GPM DPR.....	11
5	Synthetic aperture radars	14
5.1	Performance criteria of SARs	14
5.2	Interference criteria of SAR.....	15
6	Cloud profile radars	19
6.1	Performance criteria for 94 GHz cloud profile radar.....	19
6.2	Interference criteria for 94 GHz cloud profile radar.....	19
6.3	Availability criteria of the cloud profile radar	20
7	Measurement area of interest for the evaluation of systematic interference	20
8	Transient impulse interference considerations	20
8.1	Determination of peak transient power for some modulation schemes.....	20
9	Typical EESS (active) sensor parameters to be used in determining impact from differing types of interference.....	22

1 Introduction

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 radionavigation and radiolocation systems and active sensors in common frequency bands.

This Annex presents the technical basis for development of performance and interference criteria for various types of spaceborne active sensors. The sensor types include altimeters, scatterometers, precipitation radars, synthetic aperture radars, and cloud profile radars.

The criteria are based on current and planned space borne active sensor science system designs and associated operating requirements. Future space borne active sensor science systems, beyond the ones considered in this recommendation, would have to be examined to determine if they could accept the same levels of interfering signals and associated spatial and temporal conditions.

1.1 Systematic and Random interference

recommends 2 states that the interference and data availability criteria given in Table 2 be applied for instruments used for active sensing of the Earth's land, oceans and atmosphere. Table 2 provides the data availability criteria as it applies to two types of interference: systematic and random.

Systematic interference is defined as interference which occurs repeatedly at the same location. When systematic interference is present, the data availability criteria in Table 2 of 99% should be applied for all sensor types except for the precipitation radar, for which 99.8% applies.

Application of the systematic data availability to sharing and compatibility analyses first involves a determination of the interference under investigation as to its reoccurrence in the repeated sensor measurement of a specific location. If the interference under investigation is found to reoccur repeatedly in sensor measurements of the same location, albeit possibly with different kinds of signal originating from that location (e.g., frequency hopping radars; scanning radars), then the interference is deemed to be systematic interference; therefore, the systematic interference data availability criterion should be used in the evaluation of the study results.

Random interference is described as interference events causing brief individual outages (i.e. most outages lasting 2 s or less) and which are randomly dispersed over all observation time and areas. For the purposes of the sharing and compatibility analyses performed, this would apply to the observation time and the measurement area chosen for evaluation of the data availability criteria. Random interference has less serious consequences than systematic interference so that the random data availability criteria in the presence of random interference is 95% except for precipitation radars, for which it is 99.8%.

Application of the systematic data availability to sharing and compatibility analyses first involves a determination of the interference under investigation as to which type of interference should be evaluated; that is, Systematic or Random. The analysis should then determine the number of interference events exceeding the interference threshold criteria that occur in a measurement area of interest and the summary of results should provide an evaluation of that result in regard to the applicable data availability criteria.

2 Altimeters

This section presents information on the performance and interference criteria for spaceborne altimeters in the frequency bands 3.1-3.3 GHz, 5.25-5.57 GHz, 8.55-8.65 GHz, 9.2-10.4 GHz¹, 13.25-13.75 GHz and 35.5-36 GHz.

¹ Altimeters operate anywhere in the frequency band 9.2-10.4 GHz with a bandwidth of 300 MHz.

2.1 Performance criteria

Spaceborne altimeters produce, after data processing, measurement of sea level with a precision of at least 2 or 3 cm depending on the band. An increase of 0.1 cm in the height noise due to interference would not materially affect the data and would be acceptable. In other words, a 4% degradation in height noise due to interference could be tolerated as it would not preclude meeting current mission objectives.

A requirement for altimeter missions is acquisition of at least 90% of all possible data over oceans and measurable bodies of water within land masses. The design goal is higher than this minimum requirement and has been established as the acquisition of 95% of all possible measurable data. Observations must be taken to include measurements as close to the land-sea interface as possible (about 15 km from the land-sea interface, altimeter waveform distortions occur and prevent accurate height estimation). The budget for lost data must accommodate all sources of loss including those due to spacecraft systems, the altimeter instrument, manoeuvres, interference, etc.

The availability requirement for altimetry data is 95%, assuming that the associated individual outages are brief and randomly dispersed over all observation time and areas (i.e. most outages lasting 2 s or less). It should be noted that although determining if the 95% availability requirement can be met is a relatively straightforward analysis, it is difficult to analyse outages for its characteristic of random dispersion over all observation time and geographic areas.

The impact of interference that is always present at a given sensor measurement area is much more serious than that of random interference, because valid measurements can never be obtained from those geographical areas. To address this serious concern, the requirement for altimeters is to be able to obtain valid data for a minimum of 99% of the time over each measurement area of interest.

2.2 Interference criteria

Typical altimeters have link budgets that result in S/N of 13 dB (except for 35.5-36 GHz altimeters) in the receiver range resolution bandwidth of 39.9 dB/Hz (9 772.3 Hz). The altimeter height noise varies as $1 + 2/(S/N)$. For a return signal having a S/N of 13 dB before interference, the addition of interference causes the following increase in height measurement noise as provided in Table 3:

TABLE 3
Increase of altimeter height measurement noise vs Interference level²

Interference level	S / N (dB)		Degradation (%)	
	Non-white interference	White interference	Non-white interference	White interference
None	13	13	Baseline	Baseline
10 dB below noise	12.6	12.99	1	0.05
3 dB below noise	11.25	12.5	4.5	1
Equal to noise	10	11.5	9	3.8
10 dB above noise	2.6	3	91	82

² Except for 35.5-36 GHz altimeters.