



**Recommendation ITU-R RS.2065-0**  
**(12/2014)**

**Protection of space research service  
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**

**RS Series**  
**Remote sensing systems**

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<b>RS</b>	<b>Remote sensing systems</b>
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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.2065-0

**Protection of space research service 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**

(2014)

**Scope**

This Recommendation provides mitigation techniques that can reduce the unwanted emissions of Earth exploration-satellite service (EESS) (active) systems in the space research service (SRS) band and recommends that EESS (active) systems fully protect the operations of SRS (deep space) missions during their critical events and prevent damages to the SRS earth station receivers at all times.

**Keywords**

Critical events, damages, deep space, earth stations, EESS (active), interference, mitigation, protection, criterion, receiver, SAR, saturation, space-to-Earth, space research service, SRS, synthetic aperture radar, unwanted emissions

**Abbreviations/Glossary**

EESS	Earth exploration satellite service
LFM	Linear FM (frequency modulation)
SAR	Synthetic aperture radar
SRS	Space research service
TR	Transmit and receive

**Related ITU Recommendations, Reports**

Recommendation ITU-R RS.2043	Characteristics of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz
Recommendation ITU-R SA.609	Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites
Recommendation ITU-R SA.1014	Telecommunication requirements for manned and unmanned deep-space research
Recommendation ITU-R SA.1157	Protection criteria for deep-space research
Recommendation ITU-R SM.1541	Unwanted emissions in the out-of-band domain
Report ITU-R RS.2308	Radio frequency compatibility of unwanted emissions from 9 GHz EESS synthetic aperture radars with the Earth exploration-satellite service (passive), space research service (passive), space research service and radio astronomy service operating in the frequency bands 8 400-8 500 MHz and 10.6-10.7 GHz, respectively

The ITU Radiocommunication Assembly,

*considering*

- a) that the frequency band 9 300-9 800 MHz is allocated to EESS (active) on primary basis;
- b) that the frequency band 9 800-9 900 MHz is allocated to EESS (active) on secondary basis;
- c) that the frequency band 8 400-8 450 MHz is allocated to SRS (deep space) space-to-Earth links on primary basis;
- d) that the frequency band 8 450-8 500 MHz is allocated to SRS on primary basis for space-to-Earth links;
- e) that systems operating active radars in the frequency band 9 300-9 900 MHz use high power emissions in the space-to-Earth direction;
- f) that SRS (deep space) earth stations operating in the frequency band 8 400-8 450 MHz as described in Recommendation ITU-R SA.1014, use extremely sensitive receivers;
- g) that these SRS earth stations also support SRS missions such as Lagrange and lunar missions in the frequency band 8 450-8 500 MHz;
- h) that protection criteria of the SRS (deep space) missions in the frequency band 8 400-8 450 MHz is given in Recommendation ITU-R SA.1157 and the protection criteria of the SRS missions in the 8 450-8 500 MHz band is given in Recommendation ITU-R SA.609;
- i) that the unwanted emissions of EESS (active) operating in the frequency band 9 300-9 900 MHz may exceed the SRS (deep space) protection criterion in the 8 400-8 450 MHz band;
- j) that the frequency band 8 400-8 450 MHz is used by nearly all SRS (deep space) missions for support of their routine and critical events and the frequency band 8 450-8 500 MHz is used by nearly all SRS Lagrange and lunar missions;
- k) that SRS (deep space) critical events such as launch, orbit insertion, planetary fly-by, and entry-descend-landing, including sample return, often determine the success of deep space missions;
- l) that interference during the SRS (deep space) missions' critical events can lead to the loss of critical data, or may even jeopardize the health and safety of a spacecraft;
- m) that, during routine operations of the SRS (deep space) missions, unwanted emissions of EESS (active) exceeding the protection criterion of SRS (deep space) with a very small probability may be acceptable;
- n) that unwanted emissions of EESS (active) may exceed the saturation levels and the damage levels of SRS earth station receivers described in Annex 1,

*recommends*

- 1** that EESS SAR systems should use the methods described in Annex 2 to reduce their unwanted emissions in the frequency band 8 400-8 500 MHz in order to:
- a) avoid damaging the SRS earth station receivers at all times;
  - b) reduce the probability of saturating SRS earth station receivers;
  - c) avoid causing interference exceeding the protection criteria of the SRS (deep space) earth stations during critical events;

**2** that, as a last resort, if *recommends 1* cannot be satisfied fully by the application of the methods described in Annex 2, operators of EESS SAR systems should predict any remaining potential interference events and mitigate them by coordinating their operations with the operators of SRS missions at least seven days before an event for EESS SAR routine operations and at least 24 hours for EESS SAR acquisition of images in cases of emergency such as disaster management;

**3** that in order to facilitate the use of some of the mitigation techniques as well as operational coordination, operators of EESS SAR and SRS systems should share the orbital and telecom characteristics of their respective operations, including the up-to-date trajectory of their missions, antenna pointing, and schedule of critical events;

**4** that when applying *recommends 1, 2 and 3*, the damage and saturation levels of Table 1 of Annex 1 should apply;

**5** that *recommends 1, 2, 3 and 4* should only apply to the SRS earth stations listed in Recommendation ITU-R SA.1014.

## Annex 1

### Damage and saturation to front end of the SRS deep-space earth station receivers

The locations and characteristics of SRS deep-space receivers are described in Recommendation ITU-R SA.1014. The United States of America's civil space agency, the National Aeronautics and Space Administration (NASA), and the European Space Agency (ESA) have provided characteristics of saturation and potential damage levels to their deep-space earth station receivers. These levels are summarized in the Table A1-1 below.

TABLE A1-1

**Saturation and damage levels of SRS (deep space) earth station receivers**

Parameter	Unit	NASA	ESA
Frequency band	MHz	8 200-8 700	8 400-8 500
Saturation level	dBW	-115	-117
Damage level	dBW	-105	-107

These saturation and damage levels are measured directly at the input terminal of the receiver front ends. NASA's SRS deep-space earth station receivers are designed to also support NASA's solar system radar operating in the 8 500-8 700 MHz band, which is allocated to the radiolocation service.

SRS earth stations as described in Recommendation ITU-R SA.1014 are designed to also support SRS missions such as Lagrange missions and lunar missions in the 8 450-8 500 MHz band. These damage levels should not be exceeded at any time. The unwanted emission from the EESS (active) should be below the saturation level during the critical events of SRS deep-space missions. SRS earth stations that are not described in Recommendation ITU-R SA.1014 typically use different RF front-end technologies. They are typically less susceptible to saturation and damages from the unwanted emissions of EESS (active).



## Annex 2

### **Mitigation techniques for reducing unwanted emissions in the SRS in the frequency bands 8 400-8 450 MHz and 8 450-8 500 MHz from the EESS (active) systems operating around 9 600 MHz**

This Annex presents the computations of the theoretical unwanted emissions of EESS (active) systems around 9 600 MHz using the parameters for SAR-1, SAR-2 and SAR-3 from Recommendation ITU-R RS.2043. Several mitigation techniques to reduce the unwanted emissions of EESS (active) system in the 8 400-8 450 MHz SRS deep space band and in the 8 450-8 500 MHz SRS band are discussed.

#### **1 Protection of SRS space-to-Earth links**

Recommendation ITU-R SA.1157 gives the protection criterion of deep-space research earth stations as  $-221$  dB(W/Hz) for the SRS frequency band 8 400-8 450 MHz. The calculation of non-line-of-sight interference due to trans-horizon propagation should be based on weather statistics that apply for 0.001% of the time. Recommendation ITU-R SA.1157 provides the protection criterion for receiver systems in SRS deep-space systems. Compliance to the protection criterion for these assets determines the mission success of SRS deep-space missions. Harmful interference during mission critical events, e.g. orbit insertions, planetary fly-bys, and entry-decent-and-landing (EDL) phases, can cause potential loss of a spacecraft or the loss of irreplaceable data. There are also critical events such as one-time scientific observations where a spacecraft penetrates the atmosphere of a planet or a moon, or it impacts a moon, a planet, an asteroid, or a comet. The spacecraft may be destroyed in the process. The data transmitted during the approach or the moments before and during the impacts define the success of the missions. Therefore, the protection of SRS deep space spacecraft and earth stations during mission critical events, to the extent demanded by Recommendation ITU-R SA.1157, is crucial for the success of SRS deep-space missions.

In addition, spacecraft emergencies for deep space systems should be considered as critical events.

Additionally, Recommendation ITU-R SA.609 gives the protection criterion of space research earth stations as  $-216$  dB (W/Hz) for the SRS frequency band 8 450-8 500 MHz. The calculation of interference that may result from atmospheric and precipitation effects should be based on weather statistics for 0.1% of the time for unmanned missions such as Lagrange and lunar missions.

#### **2 Characteristics of EESS (active) systems around 9 600 MHz**

The 9 300-9 900 MHz band, typically identified by as the 9 600 MHz EESS (active) band, is used by SAR systems. Recommendation ITU-R RS.2043 provides the characteristics of three SAR systems operating in band.

TABLE A2-1  
**Characteristics of SAR-1, SAR-2 and SAR-3 systems**

Parameter	SAR-1	SAR-2	SAR-3
Orbital altitude (km)	400	619	506
Orbital inclination (degrees)	57	98	98
RF centre frequency (GHz)	9.6	9.6	9.6
Peak radiated power (W)	1 500	5 000	25 000
Pulse modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp
Chirp bandwidth (MHz)	10	400	450
Pulse duration ( $\mu$ s)	33.8	10-80	1-10
Pulse repetition rate (pps)	1 736	2 000-4 500	410-515
Duty cycle (%)	5.9	2.0-28.0	0.04-0.5
Range compression ratio	338	< 12 000	450-4 500
Antenna type	Slotted waveguide	Planar array	Planar phased array
Antenna peak gain (dBi)	44.0	44.0-46.0	39.5-42.5
e.i.r.p. (dBW)	75.8	83.0	83.5-88.5
Antenna orientation from Nadir	20° to 55°	34°	20° to 44°
Antenna beamwidth	5.5° (El) 0.14° (Az)	1.6-2.3° (El) 0.3° (Az)	1.1-2.3° (El) 1.15° (Az)
Antenna polarization	Linear vertical	Linear HH or VV	Linear horizontal/vertical
System noise temperature (K)	551	500	600

### 3 Unwanted emission of EESS (active) systems in the frequency range 8 400-8 500 MHz

The theoretical unwanted emission levels of the three SAR systems described in Table A2-1 in the frequency band 8 400-8 450 MHz are shown in Table A2-2. The linear FM (LFM) SAR systems are assumed to have 10-ns rise-time and 10-ns fall-time with trapezoidal waveforms. The pulse durations for SAR-2 and SAR-3 systems are 10  $\mu$ s and 1  $\mu$ s, respectively. The SRS deep space earth station antenna gain is 74 dBi.

TABLE A2-2

**Unwanted emissions from SAR-1, SAR-2, and SAR-3 in the 8 400-8 450 MHz band**

Parameter	SAR-1	SAR-2	SAR-3
e.i.r.p. (dBW)	76	83	86
Bandwidth (MHz)	10	400	450
Minimum slant range (km)	424	654	536
Space loss (dB)	-164	-167	-166
Rx antenna peak gain (dBi)	74	74	74
Polarization loss (dB)	-3	-3	-3
Spectral roll-off (dB)	-109	-86	-78
Rx interference PSD (dB(W/Hz))	-196	-185	-174
Deep-space protection criterion (dB(W/Hz))	-221	-221	-221
Exceedance of protection criterion (dB)	25	36	47

Table A2-2 shows that the unwanted emissions of SAR-1, SAR-2, and SAR-3 systems exceed the deep space protection criterion by 25-47 dB. The unwanted emissions from the SAR systems are computed based on theoretical roll-off of SAR signals. Higher unwanted emissions are possible if EESS (active) systems include components such as high-efficiency power amplifiers operating in saturation modes. Computation of unwanted emissions of the SAR systems using Annex 8 of Recommendation ITU-R SM.1541 results in higher wanted emissions, and hence, higher interference to the deep-space space-to-Earth links in the frequency band 8 400-8 450 MHz. To compute the attenuation levels needed to protect SRS (deep space) operations and to protect the SRS receivers from damages, the unwanted emissions of EESS (active) hardware, rather than theoretical values, should be used.

The level of unwanted emissions falling in the frequency band 8 450-8 500 MHz would even be higher due to the reduced frequency separation. Although studies show that there would not be any harmful interference issue for this band, there may be a risk of saturation and damage of the earth station receivers in case of direct illumination, which requires specific mitigation techniques to also apply in this band.

#### 4 Mitigation techniques

Several interference mitigating techniques are described in this section. Potential interference from the unwanted emissions of EESS (active) systems can be reduced using one or a combination of some of the techniques described. Generally, the first three techniques, pulse shaping, antenna pointing, and filtering, can significantly reduce the unwanted emissions of EESS (active) systems.

##### 4.1 Pulse shaping

Pulse shaping changes the envelope of the LFM chirp pulses to reduce the unwanted emissions of the radar. Compared to a LFM system with 10-ns rise-time and 10-ns fall-time, pulse shaping with trapezoid waveforms and raised-cosine waveforms with 100-ns rise time and 100-ns fall-time can theoretically reduce the unwanted emissions of LFM radars by about 17 dB to 26 dB. Table A2-3 shows that the 100-ns rise-time and 100-ns fall-time trapezoid waveform can reduce the unwanted emission of SAR-1 system to be below the protection level of SRS deep space, although the unwanted emissions of SAR-2 and SAR-3 still exceed the protection level. With the raised-cosine pulse shaping, the unwanted emissions of all three SAR systems are below the protection criterion.



It should be noted that imperfections and nonlinearities of various components in the EESS (active) transmit chain will likely increase the unwanted emissions.

TABLE A2-3

**Unwanted emissions of EESS (active) with 100-ns rise-time and fall-time trapezoid waveform in the 8 400-8 450 MHz band**

Parameter	SAR-1	SAR-2	SAR-3
e.i.r.p. (dBW)	76	83	86
Bandwidth (MHz)	10	400	450
Minimum slant range (km)	424	654	536
Space loss (dB)	-164	-167	-166
Rx antenna peak gain (dBi)	74	74	74
Polarization loss (dB)	-3	-3	-3
Spectral roll-off (dB)	-135	-106	-95
Rx interference PSD (dB(W/Hz))	-222	-205	-191
Deep-space protection criterion (dB(W/Hz))	-221	-221	-221
Exceedance of protection criterion (dB)	-1	16	30

TABLE A2-4

**Unwanted emissions of EESS (active) with 100-ns rise-time and fall-time raised-cosine waveform in the 8 400-8 450 MHz band**

Parameter	SAR-1	SAR-2	SAR-3
e.i.r.p. (dBW)	76	83	86
Bandwidth (MHz)	10	400	450
Minimum slant range (km)	424	654	536
Space loss (dB)	-164	-167	-166
Rx antenna peak gain (dBi)	74	74	74
Polarization loss (dB)	-3	-3	-3
Spectral roll-off (dB)	-168	-147	-137
Rx interference PSD (dB(W/Hz))	-255	-246	-233
Deep-space protection criterion (dB(W/Hz))	-221	-221	-221
Exceedance of protection criterion (dB)	-34	-25	-12

## 4.2 Antenna pointing

All three SAR systems in Report ITU-R RS.2094 have highly directional antennas. For example, the antenna peak gain of SAR-2 system is between 43 dBi and 46 dBi. The antenna pattern rolls-off quickly in horizontal (or azimuth) direction to -3 dBi. If SAR-2 can point the antenna away from the SRS earth stations such that the antenna gain is -3 dBi towards the SRS earth stations, the unwanted emission of SAR-2 system can be reduced by 46 to 49 dB. Similar technique will also work for SAR-1 and SAR-3 systems.

### 4.3 Filtering

Depending on the implementations of EESS (active) systems, transmit filters and waveguides with steep cut-off below the EESS (active) band can be implemented to limit the unwanted emissions of the systems. Filtering techniques have been successfully implemented by EESS space-to-Earth links in the frequency band 8 025-8 400 MHz to reduce the unwanted emissions of EESS space-to-Earth links by 40 dB and more in the frequency band 8 400-8 450 MHz.

SAR systems may use phased array antennas which are composed of several hundreds of transmission and receive (TR) modules including high-power amplifiers. Any output filtering would have to be applied to the high power stages of these modules and, thus, increases the system complexity, costs, and performance losses of the radar.

However, if needed, an appropriate notch filter may be added in the transmission chain in order to attenuate to the best possible extend the unwanted emissions of the SAR, in a limited bandwidth.

### 4.4 Selection of sweep range and pulse width

The spectral roll-off of the unwanted emission for LFM radar is a function of both the frequency sweep range and the pulse width of the LFM chirp signal. The unwanted emission increases as the chirp sweep range increases. It also increases as the pulse width of the chirp signal decreases. It may be possible for an EESS (active) operator to vary the radar sweep range and pulse duration to reduce the unwanted emission, especially when the EESS (active) antenna is pointing near as SRS deep-space earth station. The effectiveness of these techniques is limited. They may reduce the unwanted emission of an EESS (active) system by just a few decibels.

### 4.5 Geographic separation

It is also possible to reduce the interference from EESS (active) systems through geographic separation. EESS (active) systems may keep a minimum slant range from an SRS earth station using the information in Recommendation ITU-R SA.1014 to maintain a minimum free space loss resulting in an exclusion zone. Taken to extreme, EESS (active) systems may refrain from transmission whenever there is line-of-sight between the EESS (active) systems and one of these SRS earth stations.

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