NASA

POTENTIAL DAMAGE TO RAS SITES BY EESS (ACTIVE)

(SFCG Action Item 30/8)

Abstract

This document investigates the technical parameter values of typical types of EESS (active) systems in order to assess potential damage to RAS sites. The maximum possible power flux-density (pfd) levels from the EESS (active) systems can then be compared to threshold levels for the RAS systems.

The purpose of this document is to present typical pfd levels from EESS (active) system for assessment of potential damage to RAS sites.

1. Introduction

There is no WRC-12 Agenda Item which addresses the potential damage to RAS sites by EESS (active).

SFCG action item 30/8 has item #3 which requests the follow:

"Investigate typical active sensor types and their associated parameters vis-à-vis potential damage to radio astronomy receivers as given in Document 7/92 Draft New Report ITU-R RA.[Damaging Levels] and advise SFCG-31 via a contribution."

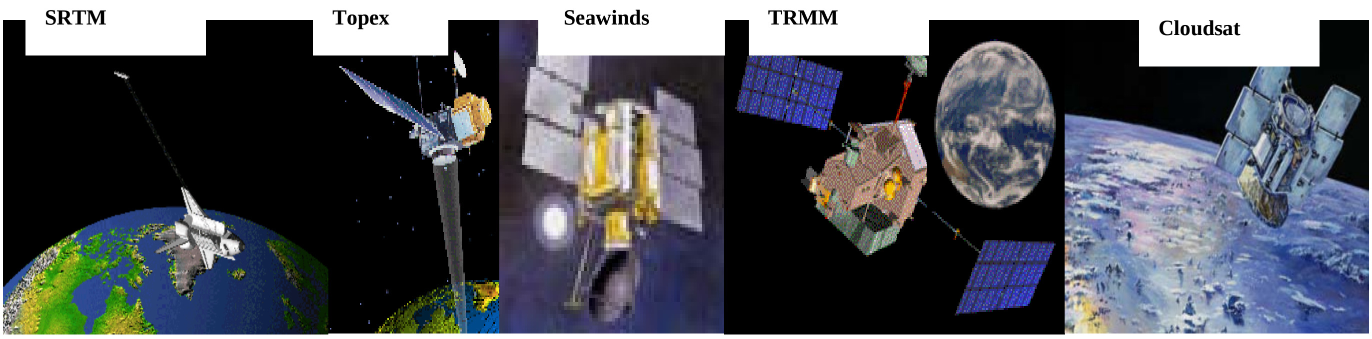
Since SFCG-30, the Draft New Report ITU-R RA.[Damaging Levels] in document 7/92 has been developed into Report ITU-R RA.2188 (10/2010).

This document presents the technical parameter values of typical types of EESS (active) systems in order to assess potential damage to RAS sites. The maximum possible pfd levels from the EESS (active) systems can then be compared to threshold levels for the RAS systems. This allows for assessment of potential damage to RAS sites.

2. Transmission Parameters and Maximum PFD Levels from Typical EESS (active) Systems

From the ITU-R EESS Handbook, there are five key active spaceborne sensor types: 1) Synthetic aperture radars (SAR) , 2) Altimeters, 3) Scatterometers 4) Precipitation radars , and 5) Cloud profile radars. Examples of the five types of spaceborne active sensors are shown below in Figure 1 and characteristics of the five key types of active spaceborne sensors are summarized in Table 1:

Figure 1. Examples of Five Types of Spaceborne Active Sensors



Typical characteristics of the five key types of active spaceborne sensors are summarized in Table 1.

Table 1 – Active Spaceborne Sensor Characteristics

Characteristic	**Sensor types**				
	SAR	**Altimeter**	**Scatterometer**	**Precipitation radars**	**Cloud profile radars**
Viewing geometry	Side-looking at 10°-55° off nadir	Nadir-looking	– Three/six fan beams in azimuth – One or more conically scanning beams	Nadir-looking	Nadir-looking
Footprint/-dynamics	– Fixed to one side – ScanSAR	Fixed at nadir	– Fixed in azimuth – Scanning	Scanning across nadir track	Fixed at nadir
Antenna beam	Fan beam	Pencil beam	– Fan beams – Pencil beams	Pencil beam	Pencil beam
Radiated peak power (W)	1 500-8 000	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
Bandwidth	20-300 MHz	320 MHz	5-80 kHz (ocean) or 1-4 MHz (land)	14 MHz	300 kHz
Duty factor (%)	1-5	46	31 (ocean) or 10 (land)	0.9	1-14
Service area	Land/coastal/ocean	Ocean/ice	Ocean/ice/land	Land/ocean	Land/ocean

The characteristics of examples of operational systems for each type of EESS (active) radars are shown below in Table 2.

Table 2 – Characteristics of Operational EESS (active) Radars

Characteristics	Sensor Types				
	SIR-C SAR	***Jason Altimeter***	***ERS AMI Scatterometer***	***GPM Dual-frequency Precipitation Radar (DPR) ****	***Cloudsat Cloud Radar***
Radiated Peak Power	4400 W (1200 W)	20 W	4000 W	1013 W	1500 W
RF center frequency	1.25 GHz (5.3 GHz)	13.6 GHz	5.3 GHz	13.6 GHz	94.05 GHz
Waveform	Linear FM pulses	Linear FM pulses	Unmodulated Pulses	Unmodulated pulses	Unmodulated pulses
Viewing Geometry	Side-looking @20-55 deg off nadir	Nadir-looking	Three beams 29 deg from nadir	Nadir-looking	Nadir-looking
Footprint/ Dynamics	Fixed to one side	Fixed at nadir	Fixed to one side	Scanning across nadir track	Fixed at nadir
Swath width	15 to 90 km	26 km	500 km	245 km	1 to 2 km
Altitude	225 km	1336 km	785 km	400 km	705 km
Inclination	28 deg	66 deg	98.5 deg	66 deg	98.2 deg
Antenna Beam	Fan beam	Pencil beam	Fan beams	Pencil beam	Pencil beam
Spectrum Width	40 MHz	320 MHz	140 kHz	0.6 MHz	300 kHz

*Note: 2013 launch date scheduled for GPM DPR

Equation (1) gives the expression for calculation of the power flux density (pfd) level at the Earth's surface.

$$PFD = \frac{P_t G}{4\pi}\left(\frac{1}{\frac{h}{\cos\theta}}\right)^2 \qquad \text{W/m}^2 \qquad (1)$$

where:

- PFD: power flux density level at the Earth's surface (W/m^2)
- P_t: radar transmit power (W)
- G: antenna gain (dBi)
- h: orbital altitude (m)
- θ: incidence angle (deg).

Using equation (1), the pfd of typical spaceborne radars can be calculated from radar parameters in Table 2 as shown in Table 3:

Table 3 – Typical Power Flux Density Levels at Earth's Surface

Parameter	**Sensor type**				
	SAR	**Altimeter**	**Scatterometer**	**Precipitation radars**	**Cloud profile radars**
Radiated power (W)	4400	20	4000	1013	1500
Antenna gain (dB)	36.4	43.3	34	47.7	63.4
Orbital altiude (km)	225	1 336	785	400	705
Incidence Angle (deg)	21	0	32	0	0
PFD (dB(W/m^2))	–45.8	–77.2	–50.4	–45.3	–32.7

Table 4 shows the EESS (active) missions by frequency band used by the sensors.

Table 4 – Missions with EESS (active) sensors by Frequency Band

Frequency Band (MHz)	Bandwidth (MHz)	Missions Carrying Spaceborne Active Sensors				
		SAR	***Altimeter***	***Scatterometer***	***Precipitation Radar***	***Cloud Radar***
432-438	6	(SAR-P)				
1215-1300	85	[SIR-C], [JERS-1], ALOS, ERS-2, (Aquarius), (DESDynI), (SMAP)				
3100-3300	200	ALMAZ	(RA2)			
5250-5570	320	[SIR-C], [SRTM], RADARSATs, ERSs, ENVISAT (Sentianl-1)	TOPEX , JASONs	[ADEOS], ERS-2, MetOp		
8550-8650	100					
9500-9800	300	[X-SAR], [SRTM], COSMO-SkyMed, TerraSAR-X, (TanDEM-X)				
9975-10025	50					
13250-13750	500		TOPEX, JASONs, ERSs, ENVISAT, (RA-2)	[ADEOS], QuikSCAT, ENVISAT	TRMM, (GPM)	
17200-17300	100					
24050-24250	200					
35500-36000	500		(Altika-SARAL)		(GPM)	
78000-79000	1000					
94000-94100	100					CloudSAT, (EarthCARE)
133500-134000	500					
237900-238000	100					

In Table 5 are shown the orbital characteristics of some spacecraft which are instrumented with active spaceborne sensors. The repeat cycle is shown to show how often the potential RFI to the RAS sites will be repeated.

Table 5 – Orbital Characteristics of Active Spaceborne Sensor

Sensors	Repeat Cycle (days)	Altitude (km)	Swath Width (km)	Inclination (deg)
SARs				
RadarSAT-1/2	16/24	790	500 max	98.5
PALSAR	46	692	70	98.2
ERS-1/2	3,35,168/35	785	102.5	98.5
JERS-1/2	44/35	580	100	98.0
ALMAZ	3	300	45	73
ASAR	35	800	406 max	98.55
TerraSAR-L/X	18	514	200 max/ 100	97.4
Altimeters				
JASON-1/2	10	1336	26	66
RA2	35	780	16-20	98.5
Topex/Poseidon	10	1336	75	66
Scatterometers				
SeaWinds	2	803	1800	98.2
ERS-1/2	35	780	500	98.5
NSCAT	41	800	1400	98.6
ASCAT	29	835	360	98.7
RA-2	35	800	100	98.55
Precipitation Radars				
TRMM	49	350	220	35
GPM DPR	0.125 (3 hrs for core & 8-10 LEOs)	400	125-245	66
Cloud Radar				
Cloudsat	16	705	1-2	98.2

3. Threshold PFD Levels of RAS Sites

From Report ITU-R RA.2188 (10/2010), “PFD and E.I.R.P. Levels Potentially Damaging to Radio Astronomy Receivers”, there are damaging input power levels to the RAS receivers and corresponding incident pfd levels for two cases; 1) frequencies up to 90 GHz for HFET amplifiers and 2) frequencies above 90 GHz for SIS mixer input stages. Tables1and 2 from Report ITU-R RA.2188 (10/2010) are re-labeled as Tables 6 and 7 for this document and shown below:

Table 6 – Representative antenna diameters and values of F_d, the potentially damaging pfd for HFET input stages from 1-90 GHz (Table 1 from **REPORT ITU-R RA.2188 (10/2010)**)

Frequency (GHz)	**RA antenna diameter (m)**	**RA antenna effective area (m^2)**	**P_d (mW)**	**F_d (dB W m^{-2})**	**e.i.r.p.$_d$ at 400 km (dB W)**
1-20	25	344	15	–43	80
1-20	100	5 500	15	–55	68
20-50	25	344	10	–45	78
20-50	100	5 500	10	–57	66
50-90	25	344	5	–48	75
50-90	100	5 500	5	–60	63

Table 7 – Representative values of F_d, the potentially damaging pfd for SIS mixer receivers at 90-275 GHz, for representative radio astronomy sites (Table 2 from **REPORT ITU-R RA.2188 (10/2010)**)

Observatory[1]	**Junction area ($\mu m)^2$**	**Number of junctions**	**Antenna diameter (m)**	**Antenna effective area (m^2)**	**P_d (mW)**	**F_d (dB W m^{-2})**	**e.i.r.p.$_d$ at 400 km (dB W)**
ALMA	3.8	8	12	79.2	55	–32	91
CARMA 6 m	1.21	1	6	19.8	4	–37	86
CARMA 6 m	2.24	1	6	19.8	5	–36	87
CARMA 10 m	1.44	2	10	55.0	9	–38	85
CARMA 10 m	3.8	4	10	55.0	27	–33	90
IRAM Bure	4.0	2	15	124	14	–40	83
IRAM Veleta	2.25	6	30	495	32	–42	81
IRAM Veleta	1.44	4	30	495	17	–45	78
Kitt Peak	8.55	6	12	79.2	62	–31	92
Onsala	4.01	2	20.1	222	14	–42	81

[1] Observatory locations are: ALMA, Atacama desert, Chile; CARMA, Cedar Flat, California, U.S.A.; IRAM, Plateau de Bure, France and Pico Veleta, Spain; Kitt Peak, Arizona, U.S.A.; Onsala, Sweden. For more information on these and other radiotelescope sites see http://www.iucaf.org or http://tinyurl.com/yrvszk

From Report ITU-R RA.2188 (10/2010), in summary, incident pfd above –60 dB(W/m^2) are potentially damaging at frequencies up to 90 GHz, while incident power flux-densities above –45 dB(W/m^2) are potentially damaging at frequencies above 90 GHz.

4. Comparison of PFD Levels from Typical EESS (active) with RAS Thresholds

In comparing the typical pfd levels from EESS (active) in Table 3 to the RAS threshold values, Table 8 shows the margins for the typical pfd levels of the five active sensor types. Only the spaceborne altimeter has a positive margin such that the maximum pfd level is below the RAS threshold value by about 17 dB. The other types of EESS (active) sensors, the SAR, scatterometer, precipitation radar, and cloud profile radar have negative margins such that the maximum pfd levels are above the RAS threshold value by 10 to 15 dB.

Table 8 – Comparison of Typical Power Flux Density Levels
at Earth's Surface with RAS Threshold Values

Parameter	Sensor type				
	SAR	Altimeter	Scatterometer	Precipitation radars	Cloud profile radars
Radiated power (W)	4400	20	4000	1013	1500
Antenna gain (dB)	36.4	43.3	34	47.7	63.4
Orbital altiude (km)	225	1 336	785	400	705
Incidence Angle (deg)	21	0	32	0	0
PFD (dB(W/m^2))	-45.8	-77.2	-50.4	-45.3	-32.7
RAS Threshold (dB(W/m^2))	-60	-60	-60	-60	-45
Margin (dB)	-14.2	+17.2	-9.6	-14.7	-12.3

5. Conclusions

This document presents the technical parameter values of typical types of EESS (active) systems in order to assess potential damage to RAS sites. The maximum possible pfd levels from the EESS (active) systems can then be compared to threshold levels for the RAS systems. This allows for assessment of potential damage to RAS sites.

In comparing the typical pfd levels from EESS (active) to the RAS threshold values, only the spaceborne altimeter has a positive margin such that the maximum pfd level is below the RAS threshold value by about 17 dB. The other types of EESS (active) sensors, the SAR, scatterometer, precipitation radar, and cloud profile radar have negative margins such that the maximum pfd levels are above the RAS threshold value by 10 to 15 dB