

RECOMMENDATION 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

(Question ITU-R 233/7)

(2003)

The ITU Radiocommunication Assembly,

considering

- a) that the frequency band 35.5-36 GHz is allocated to the Earth exploration-satellite service (EESS) (active) and space research service (SRS) (active) on a primary basis with No. 5.551A of the Radio Regulations (RR);
- b) that the 35.5-36.0 GHz band is also allocated to the meteorological aids service and radiolocation service on a primary basis;
- c) that ITU-R studies have shown that sharing of the 35.5-36 GHz band is feasible between terrestrial radars and precipitation radars, spaceborne radar altimeters and scatterometers, as shown in Annex 1;
- d) that ITU-R studies have shown that stations from the fixed service allocated by RR No. 5.549 in the 35.5-36 GHz band are protected from emissions from EESS precipitation radars as shown in Annex 2;
- e) that a bandwidth of up to 500 MHz is needed for the wideband altimeter to precisely measure altitude,

recommends

- 1 that in order to ensure compatibility between radiolocation service and EESS (active) and SRS (active), the mean pfd at the Earth's surface from the spaceborne active sensor generated at any angle greater than 0.8° from the beam centre should not exceed $-73.3 \text{ dB(W/m}^2\text{)}$ in any 2 GHz band;
- 2 that compatibility with the fixed service is assured without any additional constraints on the EESS (active) as shown in Annex 2.

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 8 and 9.

** Radiocommunication Study Group 7 made editorial amendments to this Recommendation.

Annex 1

Compatibility of spaceborne active sensors with radiolocation systems operating in the 35.5-36 GHz band

1 Introduction

The frequency band 35.5-36 GHz is allocated to the EESS (active), space research (active), radiolocation and meteorological aids services on a primary basis. Although the 35.5-36 GHz band is allocated for meteorological aids, there is no known use of the band by this service.

ITU-R studies have shown that sharing between spaceborne active sensors and radiolocation systems in the band 35.5-36 GHz is feasible. This Recommendation presents the results of simulations to evaluate the levels of potential interference between spaceborne active sensors and radiolocation stations in the 35.5-36 GHz band.

2 Approach

2.1 Overview

A dynamic interference model was developed using a commercial interference simulation tool. Interference statistics were collected for interference from spaceborne active sensors into radiolocation systems and from radiolocation systems into spaceborne active sensors.

2.2 Spaceborne active sensor models

Table 1 lists the parameters of the spaceborne active sensors included in the simulations. These sensors include altimeters and precipitation radars that are planned to be implemented in constellations of three to nine satellites.

For the purposes of these simulations, a Walker delta pattern was assumed for each active sensor constellation with the parameters listed in Table 1.

In the absence of specific antenna side-lobe patterns for any of the active sensors, the antenna beam for each sensor was modelled using a parabolic antenna beam with a peak gain and 3 dB beamwidth as specified in Table 1. The antenna side-lobe patterns were modelled by a capped Bessel function which simulated an envelope of the antenna side-lobe peaks calculated for the standard circular aperture model using the following formula:

$$G(\theta) = \eta \cdot \left(\frac{\pi D}{\lambda} \right)^2 \left[\frac{2J_1 \left(\frac{\pi D}{\lambda} \cdot \sin(\theta) \right)}{\left(\frac{\pi D}{\lambda} \cdot \sin(\theta) \right)} \right]^2$$

A gain floor was set at -10 dBi for each antenna pattern.

TABLE 1

Spaceborne active sensor model characteristics

Type of sensor	Altimeter		Precipitation radar				
System name	O-AltiKa	O + P-AltiKa	TRMM follow-on/GPM PR-2			O + P-AltiKa	
Altitude (km)	800	650	400		750		650
Inclinaison	98.6	98.0	70.0		70.0		98.0
Number of satellites	3	8	9		9		8
Number of planes	3	4	3	3	3	3	4
Satellites per plane	1	2	3	3	3	3	2
Delta longitude	120	90	120	120	120	120	90
Inter-plane phasing	120	45	36	36	36	36	45
Antenna pointing	Nadir	Nadir	$\pm 37^\circ$ azimuth sweep at 250°/s	Nadir	$\pm 28^\circ$ azimuth sweep at 250°/s	Nadir	Nadir
Peak gain (dBi)	48.90	54.30	55.00	55.00	57.00	57.00	54.30
3 dB beamwidth (degrees)	0.78	0.42	0.50	0.50	0.50	0.50	0.42
Bandwidth (MHz)	480.00	480.00	5.30	5.30	5.30	5.30	4.40
Peak power (W)	2.0	2.0	200.0	200.0	200.0	200.0	2.0
Duty cycle (%)	42.2	42.2	10.9	20.0	10.9	20.0	27.0
Average power (dBW)	−0.73	−0.73	13.39	16.02	13.39	16.02	−2.68

2.3 Radiolocation models

This analysis modelled two radiometric imaging radar station types, two instrumentation radar (metric) station types and one seeker radar station type. The characteristics of these modelled systems are provided in Table 2.

In the absence of a reference antenna pattern for radiolocation stations in this band, the same capped Bessel function pattern and −10 dBi gain floor was used for the radiolocation stations as was used with the spaceborne active sensors. For the cases where the antenna beam was elliptical (e.g. the imager systems), the capped Bessel function was ellipticized to achieve the desired beamwidths across the principal axes of the beam.

TABLE 2

Characteristics of radiolocation systems in the 35.5-36 GHz band

Parameter	Radiolocation system type				
	Imager 1	Imager 2	Metric 1	Metric 2	Seeker
Sensor type	Passive	Active	Active	Active	Active
Modulation	–	Pulse	Pulse	Pulse	Linear frequency modulation
Compression ratio	–	–	–	–	200
Pulse width (µs)		0.05	0.25	0.05	10
Tx peak power (kW)	–	0.5	135	1	0.001
Pulse repetition frequency (kHz)	–	30	1	50	10
RF bandwidth	–	80	10	101	12
Antenna gain	35 dBi	30	52	51	28.7
Beamwidth (degrees)	0.5×3.0	0.75×10	0.25×0.25	0.5×0.5	4.4×4.4
Rx IF bandwidth (MHz)	2 GHz	40	6	185	100
Noise temperature (K)	850	–	–	–	–
Noise figure (dB)	–	4,5	10	10	5
Rx sensitivity (dBm)	–	–81	–95	–78	–93
Tuning	Fixed	Fixed	Fixed	Frequency hop	Fixed

2.4 Interference model

A simulation model was developed to calculate the cumulative distribution function (CDF) of the interfering power levels produced by spaceborne active sensors interfering with radiolocation stations on Earth, and the interfering power levels produced by ground-based radiolocation stations interfering with spaceborne active sensors.

Interference statistics were also collected during each simulation run, including the worst-case interference power, the percentage of time the interference power exceeded the specified interference criteria, and the duration of the longest interference event exceeding the specified interference criteria.

The interference power level I (dBW) was calculated using the following equation:

$$I = 10 \log P_t + 10 \log(\eta) + G_t - (32.44 + 20 \log(f \cdot R)) + G_r + OTR - L_{atm}$$

where:

P_t : interferer transmitter power (W)

η : interferer duty cycle (i.e. pulse duration times pulse repetition rate)

G_t : interferer antenna gain in direction of victim station (dBi)

f : victim station receive frequency (MHz)

R : slant range between interferer and victim station (km)

G_r : victim station antenna gain in direction of interferer (dBi)

OTR : receiver on-tune rejection (dB) = $10 \log(B_r/B_t)$ for $B_r < B_t$, 0 otherwise, where B_t is the bandwidth of the transmitter and B_r is the bandwidth of the receiver

L_{atm} : atmospheric absorption loss (dB).

A value of 0 dB was used for the OTR, in all of the simulations reported in this Recommendation. Attenuation due to atmospheric absorption (dry air and water vapour), L_{atm} , is dependent upon the path length to the satellite through the Earth's atmosphere, and hence upon the elevation angle from the terrestrial radar to the satellite. The simulation program calculated the value for this atmospheric absorption loss based on Recommendation ITU-R P.676. All calculations were performed on the basis of co-channel operations at 35.75 GHz.

3 Interference analysis

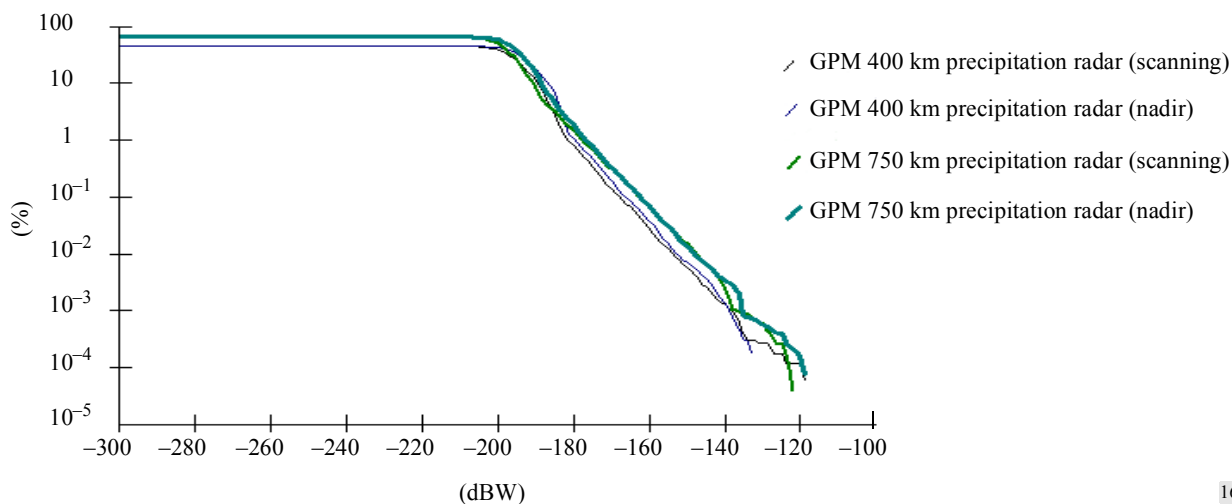
This section presents the results of dynamic simulations of interference between the spaceborne sensors described in Table 1 and the radiolocation stations described in Table 2 in terms of the CDFs presented below.

3.1 Spaceborne active sensor interference into radiolocation

Table 1 lists seven candidate active sensors that would be deployed in constellations of three to nine satellites. For each such constellation, a CDF of the level of interference power received at each type of radiolocation station was calculated assuming that the radiolocation station is located at 65° latitude. The imaging station antenna were assumed to be pointed at 0° elevation and the metric and seeker radars at 45° elevation. The simulation runs were conducted for the radiolocation station antennas pointed at an azimuth of 180° from true north (i.e. south-pointing). The simulation program calculated the interference levels at intervals of 0.5 s over a period of 30 days. The calculated interference levels at each time step were sorted into bins of 1 dB resolution for use in plotting each CDF. These CDFs are plotted in Figs. 1 through 10.

FIGURE 1

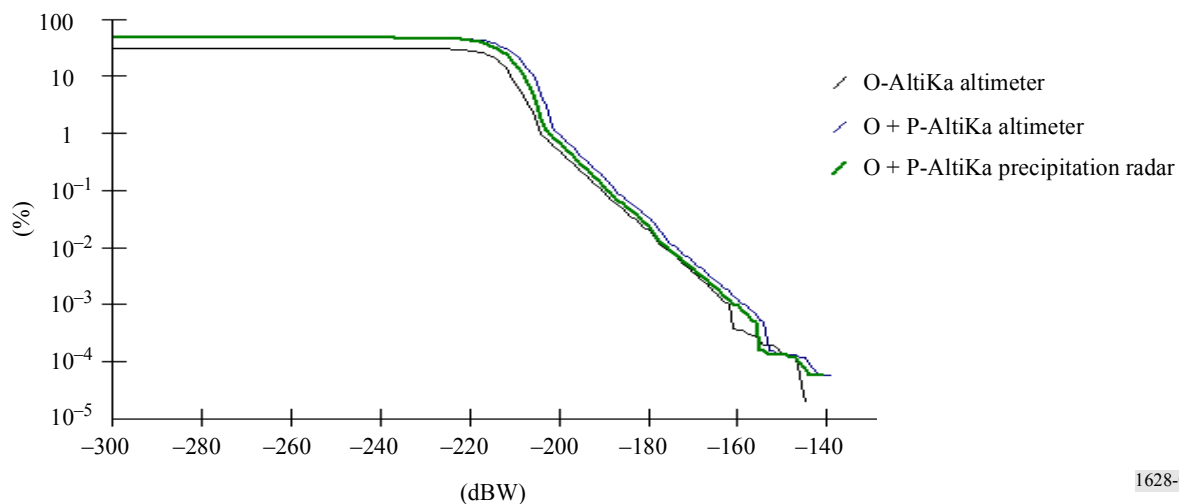
Interference CDF for GPM precipitation radars into south-pointing imager Radar 1



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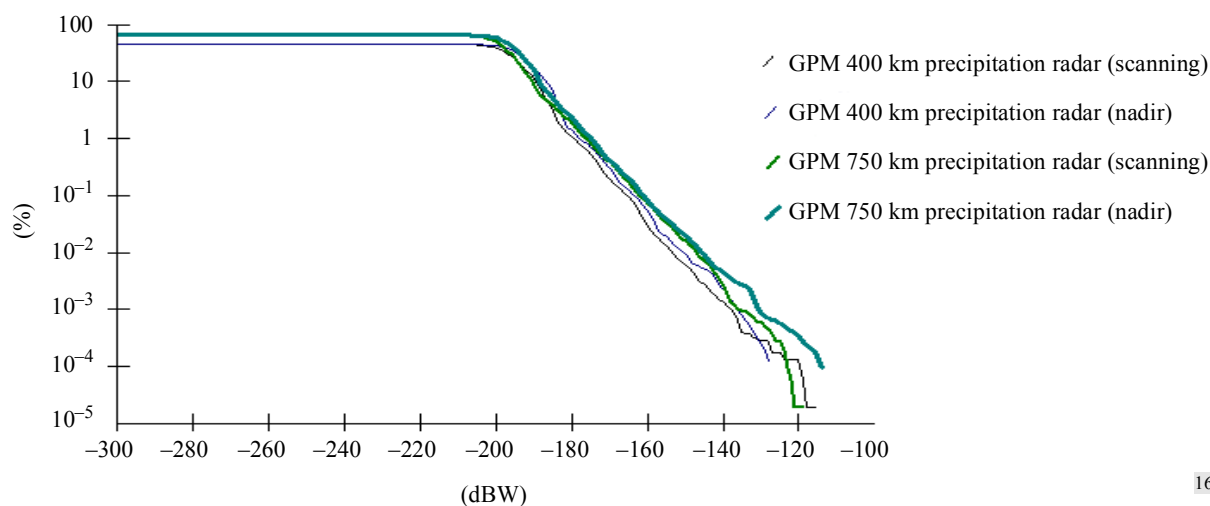
FIGURE 2

Interference CDF for AltiKa altimeters and precipitation radar into south-pointing imager Radar 1



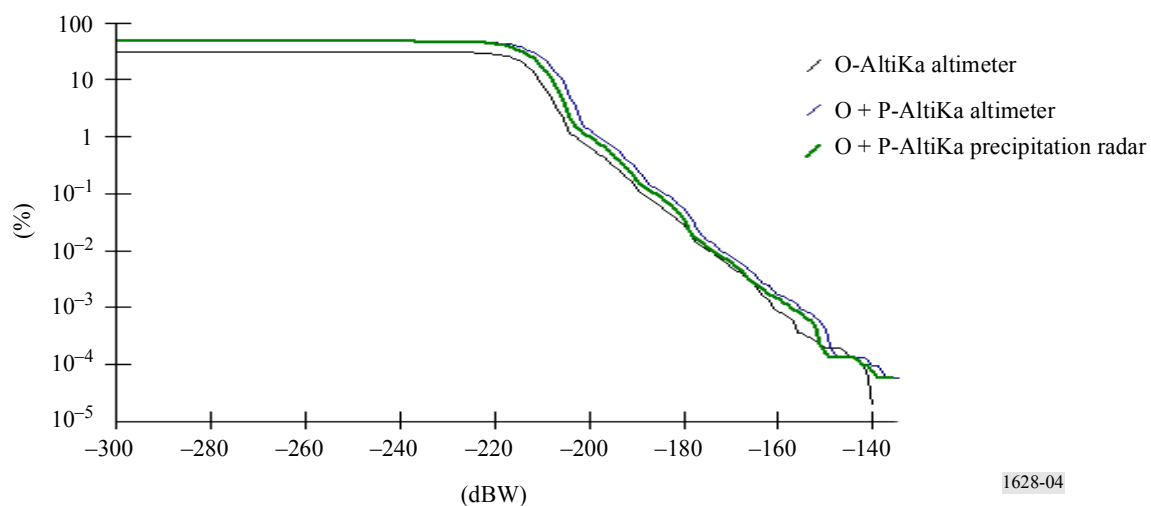
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FIGURE 3

Interference CDF for GPM precipitation radars into south-pointing imager Radar 2

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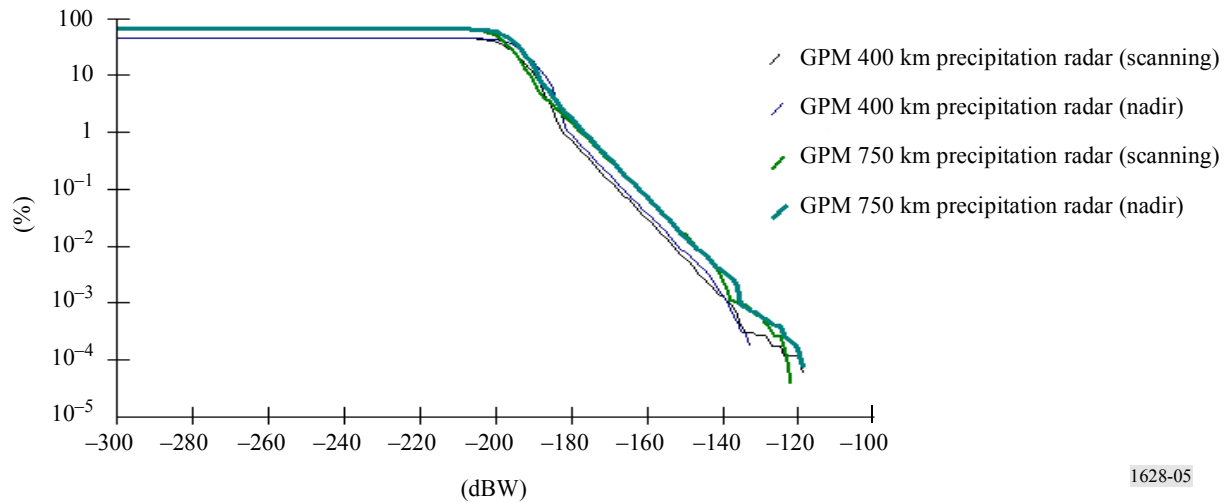
FIGURE 4

Interference CDF for AltiKa altimeters and precipitation radar into south-pointing imager Radar 2

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FIGURE 5

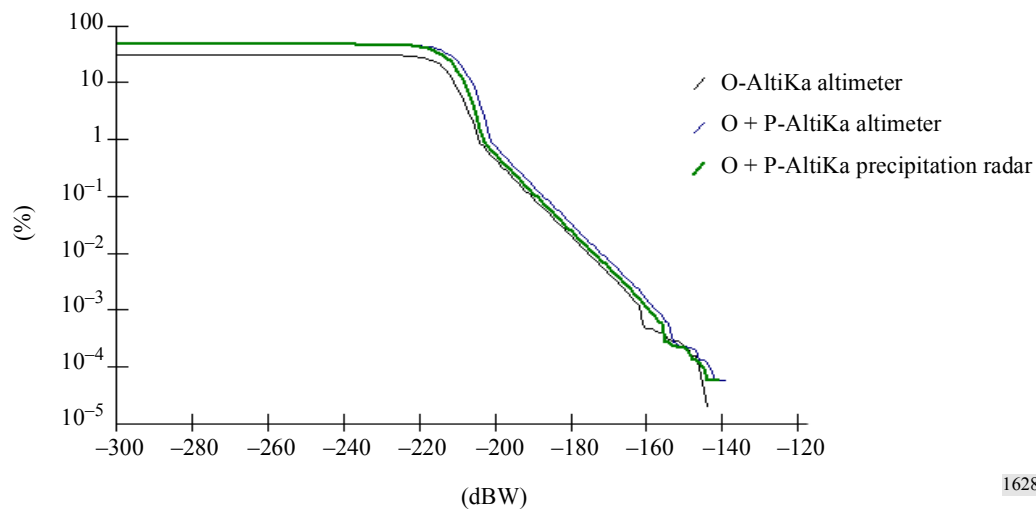
Interference CDF for GPM precipitation radars into south-pointing metric Radar 1



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FIGURE 6

Interference CDF for AltiKa altimeters and precipitation radar into south-pointing metric Radar 1



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