



Recommendation ITU-R M.1731-2
(01/2012)

**Protection criteria for Cospas-Sarsat local
user terminals in the band 1 544-1 545 MHz**

M Series
**Mobile, radiodetermination, amateur
and related satellite services**



International
Telecommunication
Union
Documents
Document Sharing Hub

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at <http://www.itu.int/publ/R-REC/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2012

© ITU 2012

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

RECOMMENDATION ITU-R M.1731-2*

**Protection criteria for Cospas-Sarsat local user terminals
in the band 1 544-1 545 MHz**

(2005-2010-2011-2012)

Scope

This Recommendation provides protection criteria for Cospas-Sarsat local user terminals that receive 1 544-1 545 MHz downlinks from satellites in geostationary, medium-Earth and low-Earth orbits. The Cospas-Sarsat program receives and processes signals from emergency position indicating radio beacons (EPIRBs) and other distress beacons operating on 406 MHz. In some cases the signals are delivered to ground stations via a downlink operating in the 1 544-1 545 MHz band.

The ITU Radiocommunication Assembly,

considering

- a) that Recommendation ITU-R SM.1535 calls for the protection of safety services from unwanted emissions;
- b) that the Cospas-Sarsat global search and rescue satellite-aided system operates within the band 1 544-1 545 MHz which is limited by No. 5.356 of the Radio Regulations (RR) to distress and safety, space-to-Earth radiocommunications;
- c) that harmful interference to safety services can cause loss of life and property;
- d) that Cospas-Sarsat geostationary Earth orbit local user terminals (GEOLUTs) receive in the band 1 544-1 545 MHz emergency position indicating radio beacons (EPIRB) signals relayed from geostationary satellites (GOES and Electro) and Meteo-Sat second generation (MSG) satellites;
- e) that Cospas-Sarsat low-Earth orbit local user terminals (LEOLUTs) receive in the band 1 544-1 545 MHz EPIRB signals relayed from search and rescue repeaters (SARR) on Cospas and Sarsat satellites;
- f) that Cospas-Sarsat LEOLUTs receive in the band 1 544-1 545 MHz a global processed data stream (PDS) of EPIRB data processed by search and rescue processors (SARPs) on Cospas and Sarsat satellites;
- g) that Cospas-Sarsat medium-Earth orbit local user terminals (MEOLUTs) receive in the band 1 544-1 545 MHz EPIRB signals relayed from medium-Earth orbiting navigation satellites (GALILEO and GLONASS);
- h) that Annex 8 contains Cospas-Sarsat link budgets for low-Earth orbit (LEO), medium-Earth orbit (MEO) and geostationary orbit (GEO) operations using near to worst-case values referred to in this Annex as “low-level case”,

recommends

- 1** that the analysis of interference to Cospas-Sarsat GEOLUTs that operate with GOES satellites should be based on Annex 1;

* This Recommendation should be brought to the attention of Cospas-Sarsat, the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO).

- 2 that the analysis of interference to Cospas-Sarsat LEOLUTs receiving global EPIRB PDS data should be based on Annex 2;
- 3 that the analysis of interference to Cospas-Sarsat LEOLUTs receiving 406 MHz EPIRB signals relayed by Cospas and Sarsat low-Earth orbiting satellites should be based on Annex 3;
- 4 that the analysis of interference to Cospas-Sarsat GEOLUTs that operate with MSG satellites should be based on Annex 4;
- 5 that the analysis of interference to Cospas-Sarsat MEOLUTs that operate with GALILEO satellites should be based on Annex 5;
- 6 that the analysis of interference to Cospas-Sarsat GEOLUTs that operate with Electro satellites should be based on Annex 6;
- 7 that the analysis of interference to Cospas-Sarsat MEOLUTs that operate with GLONASS satellites should be based on Annex 7.

Annex 1

Protection criteria in the 1 544-1 545 MHz band for Cospas-Sarsat GEOLUTs that receive EPIRB signals relayed through GOES satellites

1.1 Introduction

Cospas-Sarsat search and rescue repeaters are onboard GOES. These repeaters receive signals from 406 MHz EPIRBs and relay the signals to Cospas-Sarsat GEOLUTs on downlink frequencies in the 1 544-1 545 MHz band. In accordance with the RR, the 1 544-1 545 MHz band is allocated to the mobile-satellite service (MSS), space-to-Earth, and is specifically limited by RR No. 5.356 to distress and safety communications. The analysis provided in this Annex establishes interference protection criteria for GEOLUTs that receive the GOES 1 544-1 545 MHz downlink.

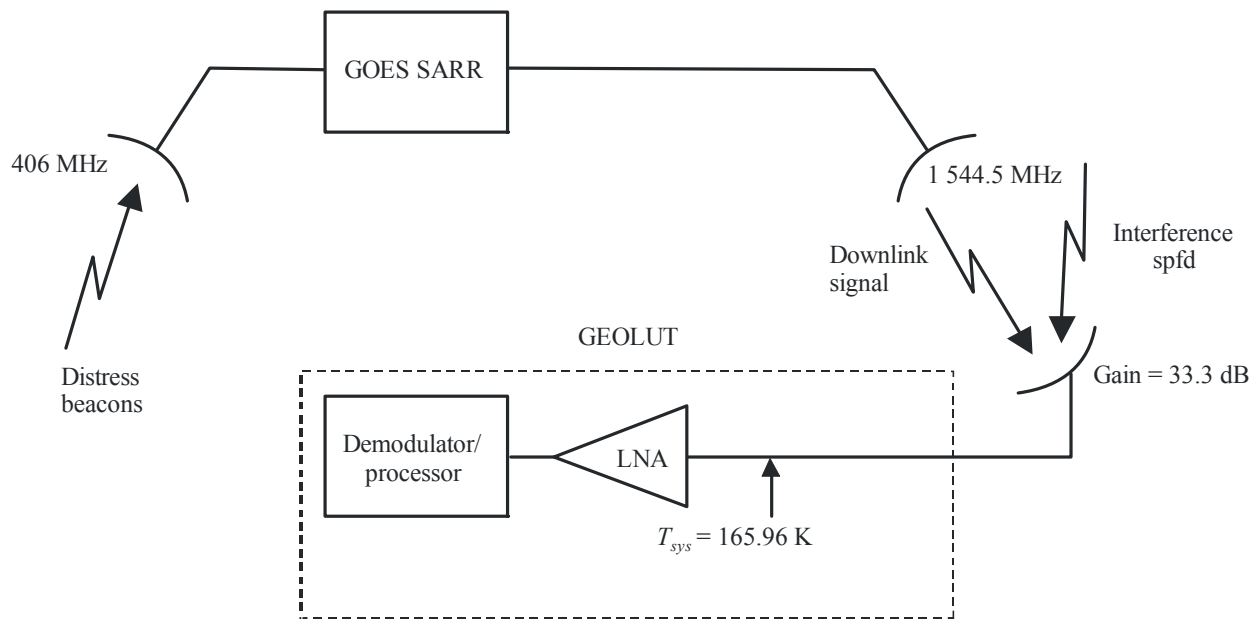
1.2 Minimum acceptable performance for detection of EPIRB signals relayed through the GOES satellite

To reliably detect 406 MHz distress beacons using GOES 406 MHz satellite repeaters, the bit-error rate (BER) of the channel must not exceed 5×10^{-5} .

1.3 Analysis of interference spectral power flux-density (spfd)

The BER of a communications channel is derived from the ratio of the energy contained in each data bit, E_b , to the noise density. The total noise density is comprised of the noise developed by Cospas-Sarsat equipment, N_0 , and noise caused by interference from other systems, I_0 . Figure 1 depicts the GOES 406 MHz SARR channel with interference on the downlink.

FIGURE 1
GOES SARR with interference on the downlink



LNA: low noise amplifier

M.1731-01

To achieve a BER of 5×10^{-5} , the ratio of the energy per bit to noise plus interference density ($E_b/(N_0 + I_0)$) at the GEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as an spfd referenced to the input to the GEOLUT antenna that could be accommodated without degrading the overall link $E_b/(N_0 + I_0)$ below 8.8 dB.

As seen in Fig. 1, 406 MHz distress beacon signals are received by the GOES SARR and phase modulated onto a 1 544.5 MHz downlink carrier for detection and processing by GEOLUTs. The antenna gain and system noise temperature for a GOES GEOLUT are 33.3 dB and 165.96 K, respectively.

The EPIRB signal has an elevation angle of 5° with respect to the spacecraft. When no external sources of interference are present, the overall C/N_0 is 31.1 dB-Hz, which equates to an E_b/N_0 of 5.1 dB. Accounting for implementation and beacon data demodulation losses and processing gains at the GEOLUT, results in an effective ratio of E_b/N_0 of 10.1 dB. Since the channel requires an overall $E_b/(N_0 + I_0)$ of at least 8.8 dB to reliably meet minimum performance, the accumulation of broadband interference on the downlink that reduces the overall carrier-to-noise plus interference density ratio by more than 1.3 dB cannot be accommodated.

Since the overall C/N_0 in the absence of interference equates to 31.1 dB-Hz, broadband noise-like interference on the downlink that degrades it by 1.3 dB, would result in an overall carrier-to-noise plus interference density ratio ($C/(N_0 + I_0)_{\text{overall}}$) of:

$$\begin{aligned}
 (C/(N_0 + I_0))_{\text{overall}} &= (C/N_0)_{\text{overall}} - 1.3 \text{ dB} \\
 &= 31.1 \text{ dB-Hz} - 1.3 \text{ dB} \\
 &= 29.8 \text{ dB-Hz}
 \end{aligned}$$

The $(C/(N_0 + I_0))_{\text{overall}}$ is calculated from the carrier-to-noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/(N_0 + I_0))_{\text{overall}} = ((C/(N_0 + I_0))_{\uparrow}^{-1} + (C/(N_0 + I_0))_{\downarrow}^{-1})^{-1}$$

Since this analysis only concerns downlink interference, the above equation simplifies to:

$$(C/(N_0 + I_0))_{\text{overall}} = ((C/N_0)_{\uparrow}^{-1} + (C/(N_0 + I_0))_{\downarrow}^{-1})^{-1}$$

Substituting 29.8 dB-Hz for $(C/(N_0 + I_0))_{\text{overall}}$ and 31.3 dB-Hz for $(C/N_0)_{\uparrow}$ results in a $(C/(N_0 + I_0))_{\downarrow}$ of 35.1 dB-Hz (see below):

$$C/(N_0 + I_0)_{\downarrow} = ((C/(N_0 + I_0))_{\text{overall}}^{-1} - (C/N_0)_{\uparrow}^{-1})^{-1}$$

or

$$C/(N_0 + I_0)_{\downarrow} = 10 \log ((10^{-29.8/10} - 10^{-31.3/10})^{-1})$$

then

$$C/(N_0 + I_0)_{\downarrow} = 35.1 \text{ dB-Hz}$$

The noise power spectral-density of the downlink without interference at the input to the LNA is $N_0 = k T$, where k is Boltzmann's constant. Therefore, $N_0 = -228.6 + 22.2 = -206.4 \text{ dB(W/Hz)}$.

The $(C/N_0)_{\downarrow}$ equals 43.8 dB and $(N_0)_{\downarrow}$ equals -206.4 dB(W/Hz) , so the value of $C_{\downarrow}$ is -162.6 dBW .

The maximum permissible interference power spectral-density in the downlink from the aggregate of all interfering emitters, $I_{0(\text{max})}$, measured at the input to the GEOLUT receiver LNA over the $1\,544.5 \text{ MHz} \pm 100 \text{ kHz}$ band is:

$$I_{0, \text{max}} = 10 \log (10^{(C_{\downarrow} - (C/(N_0 + I_0)_{\downarrow})/10)} - 10^{(N_0)_{\downarrow}/10})$$

or

$$I_{0, \text{max}} = 10 \log (10^{(-162.6 - 35.1)/10} - 10^{-206.4/10})$$

then

$$I_{0, \text{max}} = -198.3 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spfd interference threshold specified in $\text{dB(W/(m}^2 \cdot \text{Hz))}$ at the input to the GEOLUT antenna. The effective aperture of an antenna, A_e , having a gain of G is $A_e = G\lambda^2/4\pi$. The GEOLUT antenna has a gain of 33.3 dB, therefore, the effective aperture is 6.42 m^2 . The maximum acceptable aggregate interference specified as an spfd is:

$$\text{spfd} = I_{0, \text{max}} - L_{\text{Line}} - A_e$$

Assuming $L_{\text{Line}} = 0$.

$$\begin{aligned} \text{spfd} &= -198.3 - 0 - 10 \log (6.42) \\ &= -206.4 \text{ dB(W/(m}^2 \cdot \text{Hz))} \end{aligned}$$

The maximum level of broadband noise-like interference in the $1\,544.5 \text{ MHz} \pm 100 \text{ kHz}$ GEOLUT channel shall not exceed $-206.4 \text{ dB(W/(m}^2 \cdot \text{Hz))}$.

1.4 Procedure for computing level of interference to the GOES 406 MHz SARR channel downlink

Interference to Cospas-Sarsat is most often a result of out-of-band emissions from services in adjacent or near adjacent bands such as MSS space-to-Earth allocations.

The emission bandwidth must be examined to determine if energy is transmitted in the frequency range $1\,544.5\text{ MHz} \pm 100\text{ kHz}$. Particular care must be taken when analysing the impact of mobile systems (e.g. non-geostationary satellites and airborne transmitters) to take into account the effects of the Doppler shift generated by their movement.

Compute the level of interference from all sources that transmit energy in the band expressed as an spfd level at the GEOLUT antenna. The aggregate level for all interfering sources must not exceed $-206.4\text{ dB(W/(m}^2 \cdot \text{Hz))}$ anywhere in this range.

The above level is based on a GEOLUT antenna on-axis gain of 33.3 dBi. Depending upon the systems, involved antenna discrimination, polarization, and other engineering considerations should be used in establishing the impact of the interference.

Annex 2

Interference protection criteria in the 1 544-1 545 MHz band for LEOLUTs that receive SARP 2.4 kbit/s processed data from Cospas and Sarsat satellites

1 General

The Cospas and Sarsat SARP 2.4 kbit/s channel is located at $1\,544.5\text{ MHz} \pm 5\text{ kHz}$ on the LEOSAR payload downlinks. Because of the frequency spreading caused by the modulation process and the Doppler shift resulting from the movement of the satellite, the 2.4 kbit/s SARP channel is received at LEOLUTs over a frequency range of $1\,544.5\text{ MHz} \pm 50\text{ kHz}$.

Table 1 provides recommended downlink power budgets for Cospas and Sarsat SARP channels that were developed to assist administrations design LEOLUTs for use in the Cospas-Sarsat system. The link budget shows that the Cospas SARP channel has a more robust communications link than the Sarsat SARP service; therefore, protection requirements suitable for the Sarsat SARP channel would also provide adequate protection for the Cospas SARP service.

2 Minimum acceptable performance for 2.4 kbit/s PDS data in the SARP channel

In order to reliably detect and locate 406 MHz distress beacons, the BER of the SARP channel downlink must not exceed 1×10^{-6} (see Table 1).

3 Analysis of spfd that causes interference

The BER of a communications channel is derived from the ratio of the energy contained in each data bit, E_b , to the noise density. The total noise density is comprised of the noise developed by Cospas-Sarsat equipment, N_0 , and noise caused by interference from other systems, I_0 .

This analysis will establish the level of interference, expressed as an spfd at the LEOLUT antenna, that would degrade the BER of the SARP channel downlink to one bit error in every million (1×10^{-6}).

TABLE 1

Downlink power budget parameters for the Cospas and Sarsat PDS of the SARP

Parameter	Cospas nominal	Sarsat nominal	Source
Carrier frequency (MHz)	1 544.5		
Polarization (left hand circular)	LHCP		
Elevation angle (degrees)	5		
Satellite altitude (km)	1 000	850	
Satellite e.i.r.p. ⁽¹⁾ (dBW)	6.2	7.1	
Slant range @ 5° (km)	3 200	2 900	Calculated from geometry
Free-space path loss (L_p) (dB)	166.3	165.5	Calculated standard formula
Short-term fading loss (L_f) (dB)	10		
Other losses (L_o) (dB)	3.6 ⁽²⁾		LUT-design and site-dependent
Antenna (G/T) ⁽³⁾ (dB/K)	4.3		$G = 26.7$ dB, $T = 22.4$ dB(K)
Boltzmann's constant, k (dB(W/(K · Hz)))	−228.6		Physical constant
Data rate factor @ 2.4 kbit/s, r (dB-Hz)	33.8		
Modulation loss (dB)	−12.1	−14.1	
Desired maximum BER	10 ^{−6}		
Calculated (E_b/N_0) (dB)	13.3	13.0	Using above parameters
Theoretical (E_b/N_0)-th for BER of 10 ^{−6} (dB)	10.6		E_b/N_0 for required BER
PDS link margin (dB)	2.7	2.4	

LUT: local user terminal

⁽¹⁾ Equivalent isotropically radiated power.

⁽²⁾ Polarization mismatch, antenna pointing and demodulator implementation losses.

⁽³⁾ Antenna gain-to-noise temperature ratio, to include radome, if applicable, and cable losses. United States of America LUTs $G/T = 4.3$ dB.

Table 1 shows the recommended downlink power budget for the SARP channel. The link budget has been completed using typical LEOLUT parameters. The link budget shows that the required BER of 1×10^{-6} is achieved with a 2.4 dB margin for tracking Sarsat satellites. The link must maintain a positive margin in order to sustain the required BER. Therefore, the total of all interference cannot be allowed to degrade the link by more than 2.4 dB. In this case, the cumulative interference power spectral-density, I_0 at the LEOLUT receiver is given by the following equation (numeric quantities):

$$N_0 + I_0 \leq 10^{(2.4/10)} \times N_0$$

or

$$I_0/N_0 \leq (10^{(2.4/10)} - 1) = 0.738 \text{ (numeric)}$$

then

$$I_0/N_0 = -1.3 \text{ dB}$$

The cumulative effect of all interferers, therefore, must not exceed an $I_0/N_0 = -1.3 \text{ dB}$.

For LEOLUTs with an antenna gain G of 26.7 dB and a system noise temperature, T , of 22.4 dBK at the LEOLUT LNA, the noise power spectral-density without interference, N_0 , is the product of Boltzmann's constant, k , and the noise temperature T , or $N_0 = k T$, and is given in dB form as follows:

$$N_0 = -228.6 + 22.4 = -206.2 \text{ dB(W/Hz)}$$

Therefore, the maximum interference power spectral-density from all interfering emitters, $I_0(\text{max})$, at the LEOLUT LNA within the 1 544.5 MHz $\pm$ 50 kHz band must not exceed the following:

$$I_{0, \text{max}} = N_0 - 1.3 = -207.5 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spfd interference threshold specified in dB(W/m² · Hz) at the input to the LEOLUT antenna. The effective aperture of an antenna having a gain G is $A_e = G\lambda^2/4\pi$. The LEOLUT antenna gain of 26.7 dB results in $A_e = 1.4 \text{ m}^2$. Therefore, the maximum level of all interference on the downlink is:

$$\begin{aligned} \text{spfd} &= I_0/A_e = -207.5 - 10 \log(1.4) \\ &= -209.0 \text{ dB(W/(m}^2 \cdot \text{Hz))} \end{aligned}$$

The maximum level of broadband noise-like interference in the 1 544.5 MHz $\pm$ 50 kHz band channel should not exceed $-209.0 \text{ dB(W/(m}^2 \cdot \text{Hz))}$.

4 Procedure for computing level of interference to the LEOSAR SARP channel

Interference to Cospas-Sarsat is most often a result of out-of-band emissions from services in adjacent or near adjacent bands such as MSS space-to-Earth allocations.

The emission bandwidth must be examined to determine if energy is transmitted in the frequency range 1 544.5 MHz $\pm$ 50 kHz. Particular care must be taken when analysing the impact of mobile systems (e.g. non-geostationary satellites and airborne transmitters) to take into account their Doppler effect generated by their movement.

Compute the spfd level at the LEOLUT antenna. The aggregate level of all sources of interference must not exceed $-209.0 \text{ dB(W/(m}^2 \cdot \text{Hz))}$ in any portion of the 1 544.5 MHz $\pm$ 50 kHz range.