COSPAS-SARSAT FREQUENCY REQUIREMENTS AND COORDINATION PROCEDURES

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1. INTRODUCTION

The Cospas-Sarsat System provides distress alert and location data for search and rescue (SAR) using space based instruments and ground facilities to detect and locate the signals of distress radiobeacons that operate at 406 MHz. The majority of the space segment instruments in the Cospas-Sarsat System operate with downlinks in the 1544 – 1545 MHz band.

The ITU Radio Regulations restrict the use of the 406.0 – 406.1 MHz band to low power satellite emergency position-indicating beacons in the mobile satellite service, and the 1544 – 1545 MHz band for distress and safety communications space-to-Earth in the mobile satellite service (MSS). Since neither band is dedicated to Cospas-Sarsat, the regulations allow the possibility for other distress and safety communications systems to operate in these bands, thereby creating the potential for harmful interference to the Cospas-Sarsat System. Furthermore, although both bands are dedicated to distress and safety communications, the regulations cannot prevent them from being used inappropriately, nor for harmful interference to be generated by emissions spilling over from other bands. Therefore, the use of these bands must be monitored by Cospas-Sarsat and procedures developed for coordinating Cospas-Sarsat actions to ensure that new systems planned to be introduced will not, under normal operating conditions, adversely affect the performance of the Cospas-Sarsat System.

1.1 Purpose

The purpose of this document is to describe the framework that guides Cospas-Sarsat actions in respect of its own use of the 406.0 – 406.1 MHz and 1544 – 1545 MHz bands, and recommend Cospas-Sarsat actions in response to the use and/or proposed use of these frequency bands by others. Specifically this document:

a. describes the international regulations that govern the use of these bands;

b. identifies the systems that have completed the ITU notification process to operate in these bands, as well as systems planned to be introduced in the future;

c. provides protection requirements in the 406.0 – 406.1 MHz and 1544.0 – 1545.0 MHz bands for Cospas-Sarsat SAR instruments; and

d. recommends the procedures to be followed by Cospas-Sarsat Participants in responding to proposals/plans to operate new or additional services in these bands.

1.2 Background

The International Telecommunication Union (ITU) has allocated the use of the bands:

a. 406.0 – 406.1 MHz to the MSS and limits its use to low power satellite emergency position-indicating radio beacons (ITU Radio Regulations, Article 5.266); and

b. 1544 - 1545 MHz to the MSS for distress and safety communications in the space-to-Earth direction (ITU Radio Regulations, Article 5.356).

In conformance with these allocations the Cospas-Sarsat System includes search and rescue instruments on low-altitude and geostationary satellites (LEOSAR and GEOSAR systems) that operate in the above-mentioned frequency bands. A description of Cospas-Sarsat's use of these bands is provided in the following Cospas-Sarsat documents:

- Description of the Payloads Used in the Cospas-Sarsat LEOSAR System, C/S T.003;
- Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System, C/S T.011; and
- Cospas-Sarsat 406 MHz Frequency Management Plan, C/S T.012.

To date Cospas-Sarsat is the only system that operates distress beacons in the 406.0 - 406.1 MHz band. With respect to the 1544 – 1545 MHz band, some administrations have indicated intentions to operate other distress and safety communications systems in this band, and it is likely that additional requests will occur in the future. In light of the possible harmful interference other systems might cause to Cospas-Sarsat, and the complicated nature of the international regulations that govern the introduction of new systems; the Cospas-Sarsat Council decided that Cospas-Sarsat Participants should coordinate their actions in respect of dealing with proposals to introduce new systems into these bands.

The international regulations that govern the assignment and use of frequency spectrum were developed to maximise its equitable and efficient use. These regulations establish a framework that allow new systems to be established, whilst providing authorised existing users a mechanism for assessing the impact that proposed new systems would have on their operation. Should such an assessment indicate the likelihood of harmful interference, the Radio Regulations include provisions for preventing the introduction of the new system until the issue of harmful interference has been resolved. Although distress and safety systems that have been notified to the ITU are provided greater protection than most systems, the responsibility remains clearly on Cospas-Sarsat Participants to:

- notify their LEOLUT's and GEOLUT's use of the 1544 – 1545 MHz band with the ITU;

- monitor the advanced publication information published by the ITU for the introduction of new systems, with a view to identifying at the earliest possible stage, those systems which might cause harmful interference to Cospas-Sarsat;

- actively participate in the formal ITU coordination process with proposed new users to assess whether proposed services would harm Cospas-Sarsat operations; and

- take appropriate action in accordance with the Radio Regulations through their designated representative to the ITU.

1.3 Communications with the ITU

This document provides guidance to Cospas-Sarsat Participants for coordinating activities concerning proposals to introduce new systems that might adversely affect Cospas-Sarsat operations. This guidance was developed to take advantage of the procedures for managing the introduction of new systems provided in the ITU Radio Regulations. A characteristic of the process is that proposed new systems would not be sanctioned by the ITU if they would generate harmful interference to systems that have been formally notified. In this regard, the procedures in the Radio Regulations call for the administrations representing proposed and existing systems to communicate with each other and the ITU to determine if the proposed system would generate harmful interference.

With respect to official correspondence with the ITU, all correspondence should be submitted through the government department or service responsible for discharging the Country's obligations in respect of the Constitution of the ITU. In most cases this government department will not be the organisation responsible for managing that Country's participation in the Cospas-Sarsat Programme. Consequently, Cospas-Sarsat Participants should coordinate their activities and forward any official correspondence through the appropriate department within their administration when communicating with the ITU, and also when officially communicating with another administration proposing to introduce new services into frequency bands used by Cospas-Sarsat.

1.4 Reference Documents

a. C/S G.003: Introduction to the Cospas-Sarsat System;

b. C/S G.004: Cospas-Sarsat Glossary;

c. C/S T.001: Specification for Cospas-Sarsat 406 MHz Distress Beacons;

d. C/S T.002: Cospas-Sarsat LEOLUT Performance Specification and Design Guidelines;

e. C/S T.003: Description of the Payloads Used in the Cospas-Sarsat LEOSAR System;

f. C/S T.005: Cospas-Sarsat LEOLUT Commissioning Standard;

g. C/S T.007: Cospas-Sarsat 406 MHz Distress Beacon Type Approval Standard;

h. C/S T.009: Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines;

i. C/S T.010: Cospas-Sarsat GEOLUT Commissioning Standard;

j. C/S T.011: Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System;

k. C/S T.012: Cospas-Sarsat 406 MHz Frequency Management Plan; and

l. C/S A.003: Cospas-Sarsat System Monitoring and Reporting.

- END OF SECTION 1 -

2. GENERAL PRINCIPLES OF FREQUENCY BAND MANAGEMENT

Administrations planning to introduce new systems are required to complete a three-phase process consisting of:

- publicising their intentions in advance,
- coordinating with existing users that might be adversely affected (if the frequency band requires coordination under the provisions of the Radio Regulations), and
- registering the new systems with the ITU using the notification procedures described in the Radio Regulations.

2.1 Spectrum Management for the 406.0 – 406.1 MHz Band

The policies that govern the international procedures for management of the 406.0 – 406.1 MHz band are summarised below.

a. Article 5 of the Radio Regulations allocates the 406.0 – 406.1 MHz band to the MSS, for low power satellite emergency position-indicating radiobeacons, and prohibits any emission capable of causing harmful interference to authorised uses of the band (Articles 5.266 and 5. 267 refer).

b. An administration planning to use this band must provide the details concerning their proposed use to the ITU for advance publication in the ITU Radio-Communication Bureau (hereafter referred to as the BR) International Frequency Information Circular (IFIC).

Since, under the provisions of the Radio Regulations, the 406.0 – 406.1 MHz band does not require formal coordination, this will probably be the only indication of an administration's intention to use this band prior to the activation of the system.

c. Currently Cospas-Sarsat is the only system that has notified its use of the 406 MHz band to the ITU. This was done by the USA and Russia when they formally notified the Cospas and Sarsat LEOSAR satellite networks. Furthermore, in the Cospas-Sarsat 406 MHz Frequency Management Plan (document C/S T.012), Cospas-Sarsat has indicated its need for the entire 406.0 – 406.1 MHz band to accommodate the expected 406 MHz beacon population.

d. Cospas-Sarsat Participants, in response to information in the IFIC proposing the introduction of a new system in the 406.0 – 406.1 MHz band, should:

i) advise the Cospas-Sarsat Secretariat of the proposed new system, citing the applicable IFIC reference, for further distribution to other Cospas-Sarsat Participants;

ii) send correspondence, through their designated national body, to the administration proposing the new service and the BR, expressing concerns that the proposed system would cause harmful interference to the Cospas-Sarsat System, citing Article 31.2 of the Radio Regulations; and

iii) submit input papers to Cospas-Sarsat Joint Committee and Council meetings, describing the status of any correspondence with other administrations and the BR in respect of the proposed use of the band.

e. In addition, Cospas-Sarsat Participants should examine all proposals for the introduction of new systems into bands near 406.0 – 406.1 MHz. Each proposal should be analysed to determine whether expected out of band emissions into the 406.0 – 406.1 MHz band might exceed the protection levels established by Cospas-Sarsat. In such circumstances Cospas-Sarsat Participants should follow the procedures described in subparagraphs i through iii above.

2.2 Spectrum Management for the 1544 – 1545 MHz Band

The policies that govern the international procedures for management of the 1544 – 1545 MHz band are summarised below. In addition, because of the complicated nature of the formal coordination procedures for this band, more detailed explanation is provided at section 3.

a. Article 5 of the Radio Regulations allocate the 1544 – 1545 MHz band to the MSS, space-to-Earth, and restricts its use to distress and safety communications (Article 5.356 refers). Under Article 5.354 the use of the band by the MSS is subject to a formal coordination process (see section 3).

b. An administration wishing to introduce a new distress and safety communication system into the band must provide the details of the proposed service to the BR for advance publication in the IFIC.

c. Existing users of the band are responsible for monitoring the contents of the IFIC, conducting analysis to determine whether the proposed service could adversely affect existing operations, and providing comments to the BR and the administration proposing the new system.

d. The administration proposing the new system can, on the basis of comments made by existing users, either amend its plans or send correspondence to the ITU to initiate the formal coordination phase of the process. The BR will publish, in a special section of the IFIC, the details of the proposed new system along with the names of the administrations that operate systems that might be affected. The BR will also inform these administrations directly.

e. Administrations that have notified their use of the band are responsible for reviewing the contents of IFIC, conducting their own interference analysis, and coordinating with the BR and the administration proposing the new system if they think that the proposed new system might generate harmful interference. If an existing user fails to provide the BR with information indicating concerns with the proposed introduction of the new system, the ITU will assume, after a defined period, that there will be no harmful interference between the existing and proposed new systems. Conversely, if the coordination process concludes that the new system would generate harmful interference, the administrations participating in the coordination process are to work together to resolve the situation, keeping the BR apprised of developments.

f. Upon successful completion of the coordination process, the administration representing the new service will "notify" their use of the spectrum, thereby becoming an authorised user of the band.

The process overviewed above implies three principles that should guide the actions and decisions of Cospas-Sarsat Participants in respect of the management of the band, namely:

- all Cospas-Sarsat Space Segment Providers (SSPs) should complete the ITU process of publication, coordination, and notification for the LEOSAR and/or GEOSAR space segment(s) they provide, thereby enabling Cospas-Sarsat GSOs to notify their LUTs to the ITU;
- all Cospas-Sarsat GSOs should notify their use of the band with the ITU (section 2.2 refers), thereby entitling them to participate in the coordination process with administrations proposing to introduce new systems into the band;
- Cospas-Sarsat should develop protection requirements that can be used by GSOs to evaluate whether proposed new systems/services would generate harmful interference; and
- all GSOs should be involved in the formal coordination process.

2.3 Notifying Use of the 1544 – 1545 MHz Band

Only administrations that have formally notified their use of the 1544 – 1545 MHz band with the BR are entitled to the protection offered by the Radio Regulations. Consequently, all SSPs and GSOs are strongly encouraged to formally notify the ITU of the use of the 1544 – 1545 MHz band by their space segment instruments, LEOLUTs and GEOLUTs. The information required by the ITU for the notification of Cospas-Sarsat ground segment equipment is identified in the Cospas-Sarsat LEOLUT and GEOLUT commissioning standards (documents C/S T.005 and C/S T.010 respectively). GSOs will not be able to notify their LUTs with the ITU until the associated satellite network (e.g. Cospas LEOSAR, Sarsat LEOSAR, GOES GEOSAR and MSG GEOSAR) has been notified. Currently none of the GEOSAR satellites in the Cospas-Sarsat System that have downlinks in the 1544 – 1545 MHz band have been notified to the ITU.

2.4 Cospas-Sarsat Protection Requirements

Each Cospas-Sarsat service, whether it is the detection and location of 406 MHz beacons using the LEOSAR Search and Rescue Processor (SARP) or Repeater (SARR) channels, or the detection of 406 MHz beacons through the GEOSAR system, can be adversely affected by interference. The impact of interference, and, therefore, the protection required for each service is determined by many factors, including:

a. the technical specifications of the SAR satellite payload(s) that support the service;

b. the technical characteristics of the LUT; and

c. the characteristics of the interfering signal.

Generic protection requirements for Cospas-Sarsat LEOSAR and GEOSAR instruments are provided at Annexes B through H. A summary of the protection criteria for each Cospas-Sarsat instrument is provided in Annex I. In determining the protection required for specific ground stations (i.e. the LUTs), the responsible GSO should amend the parameters in each analysis to reflect the technical characteristics of their own ground segment equipment.

The 406 MHz protection levels referred to above are for assessing the impact of interference from systems operating in other frequency bands. These protection levels should not be used to determine whether the 406.0-406.1 MHz band can be shared with other systems. Document C/S T.012 shows that the complete 406.0 – 406.1 MHz band is required to accommodate the projected 406 MHz beacon population. The introduction of any system into this band will generate interference that could prevent the detection of beacon signals. Therefore, all administrations that allow for the use of Cospas-Sarsat 406 MHz beacons should formally object to the ITU in respect of any proposal to introduce new systems in the 406.0 – 406.1 MHz band.

2.5 Participation in the Frequency Coordination Process

Ultimately, it is the responsibility of each administration to protect their national interests in respect of their Country’s use of the spectrum. This is accomplished by monitoring the frequency bands to identify harmful interference, and participating in the frequency coordination process with other administrations that have indicated a desire to introduce new services. Although, the Cospas-Sarsat organisation does not have the authority to participate in the formal coordination process, it provides assistance by:

- documenting generic protection requirements that can be used by individual GSOs as a foundation for developing protection requirements specific to their own ground segment equipment;
- providing a forum for sharing information between Participants in respect of interference and frequency coordination matters; and
- coordinating strategy in respect of specific frequency coordination issues.

In the matter of frequency coordination involving the 406.0 – 406.1 MHz and 1544 – 1545 MHz bands, GSOs are encouraged to cooperate with other Cospas-Sarsat Participants as described above and in Section 3.

2.6 Current and Planned Use of the Frequency Bands Used by Cospas-Sarsat

2.6.1 Systems that have Completed Notification Process to Operate in the 406 MHz Band

At present Cospas-Sarsat beacons are the only equipment authorised to operate in the 406 MHz band.

2.6.2 Current and Planned Use of the 1544 – 1545 MHz Band

Annex J provides a description of the current and planned usage of the 1544 – 1545 MHz band.

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3. COSPAS-SARSAT 1544 – 1545 MHz COORDINATION PROCEDURES

This section describes the recommended procedures to be followed by Cospas-Sarsat Participants for dealing with proposals for the introduction of new systems into the 1544 – 1545 MHz band. By coordinating efforts and working to agreed common principles and policies, Cospas-Sarsat Participants will:

- be more aware of the future intentions of other administrations in respect of their planned use of the band;
- provide consistent information to external organisations and administrations regarding the impact that proposed new services could have on Cospas-Sarsat operations; and
- capitalise on the expertise available in the Cospas-Sarsat community in respect of interference analysis and resolving international frequency coordination matters.

3.1 International Frequency Coordination Regulations for the 1544 – 1545 MHz Band

The recommended Cospas-Sarsat procedures for coordinating the actions of Cospas-Sarsat Participants in respect of the proposed introduction of new systems into the band, are consistent with, and rely upon the procedures detailed in the Radio Regulations. To place these recommended procedures in context, a summary of the relevant Radio Regulation articles dealing with the introduction of new systems into the 1544 – 1545 MHz band is provided in table 3.1 below.

Table 3.1: Overview of ITU Regulations Regarding Spectrum Management in 1544 – 1545 MHz Band

Ref	Radio Regulation	Description
Publication Phase		
1	Article 9.1	Before initiating action for frequency assignment for a satellite network or satellite system, an administration shall send to the BR a general description of the System as described in Appendix 4 of the Radio Regulations.
2	Article 9.2B	On receipt, the BR shall publish this information in a Special Section of its IFIC, within 3 months. A new IFIC is published by the BR every 2 weeks.

Ref	Radio Regulation	Description
3	Article 9.5B	Under Article 5.354 the use of this band by the MSS is subject to coordination under Article 9.11A; thereby, making the provisions of Article 9.5B applicable. *It is worth noting that Article 9.11A requires that the procedures described in Appendix 5 be used for calculating interference levels, and defines the criteria for establishing whether such interference levels should be considered acceptable or unacceptable. Nevertheless, under Article 31.2 any emission causing harmful interference to distress and safety communications is prohibited. Therefore it can be argued that protection requirements for notified systems in the 1544 – 1545 MHz band are not limited to the procedures and protection levels provided in Appendix 5.* Under Article 9.5B, if upon receipt of the IFIC an administration considers its stations would be affected by any of the systems identified in the advanced publication section of the IFIC, it may send its comments to the administration proposing the new system and the BR. In any such communication it is recommended that Article 31.2 be quoted. At this point both administrations shall try to cooperate in joint efforts to resolve difficulties.
Coordination Phase		
4	Article 9.30	The administration proposing the new service shall send request for coordination to the BR, together with the appropriate information detailed in Appendix 4 of the Radio Regulations.
5	Article 9.5D	If the BR does not receive the information required under Article 9.30 within 24 months after the initial information provided under Article 9.1, the Bureau will initiate proceedings to cancel the information provided under Article 9.2B.
6	Article 9.34 Article 9.36 Article 9.37 Article 9.38	On receipt of the complete information provided under Article 9.30 the BR shall: b) using the interference criteria described in Appendix 5, identify any administration with which coordination may need to be effected; c) include the names of these administrations in the section of the IFIC which identifies the systems for which coordination are required. e) inform the administrations concerned of its actions, drawing attention to the relevant IFIC. *It should be noted that the application of the procedures for calculating harmful interference described in Appendix 5 might not be sufficient to address Cospas-Sarsat protection requirements. Therefore, it is possible that Cospas-Sarsat Ground Segment Operators may not be specifically identified in the coordination section of the IFIC. Consequently, Cospas-Sarsat Participants should review each IFIC, and make their own determination regarding whether any proposed new system undergoing coordination would generate harmful interference.*

Ref	Radio Regulation	Description
7	Article 9.50	An administration having received a request for coordination shall promptly examine the matter with regard to interference in accordance with the procedures detailed in Appendix 5. *With respect to Cospas-Sarsat Systems, the protection afforded is not limited to those specified in the procedures described in Appendix 5.*
8	Article 9.52	If pursuant to Article 9.50 an administration does not agree to coordination, it shall, within 4 months of the date of publication of the IFIC, inform the administration proposing the new system, of its disagreement and shall provide information concerning its own assignments upon which that disagreement is based. A copy of all of the above correspondence shall be sent to the BR.
9	Article 9.59	If there is a disagreement between the administration seeking coordination and an administration with which coordination is sought concerning the level of acceptable interference, either may seek the assistance of the BR; in such a case, it shall provide the necessary information to enable the BR to conduct the required analysis.
10	Article 9.63	If the disagreement cannot be resolved by the administrations participating in the coordination, the BR will seek the necessary information to enable it to assess the interference. The BR will communicate its conclusions to the administrations involved.
11	Article 9.52C	For coordination requests under Article 9.11A an administration not responding under Article 9.52 within the 4 month period shall be regarded as unaffected and, the provisions of Articles 9.48 and 9.49 apply – as summarised below: (Article 9.48) No complaint will be made in respect of any harmful interference affecting its own assignments, which may be caused by the assignment for which coordination was requested. (Article 9.49) The use of its own assignments will not cause harmful interference to the assignment for which coordination was requested.
	Notification Phase	
12	Article 11.2	Any frequency assignment to a transmitting station and to its associated receiving stations except for those mentioned in Articles 11.13 and 11.14 shall be notified to the BR.
13	Article 11.30 & Article 11.32	The BR shall examine each notice in respect of its conformity with the procedures relating to coordination with other applicable administrations.
14	Article 11.37	If, pursuant to Articles 11.30 and 11.32, the examination leads to a favourable finding, the assignment shall be recorded in the Master Register indicating the administrations with which the coordination procedure has been completed. When the finding is unfavourable, the notice shall be returned to the notifying administration, with an indication of the appropriate action.
15	Article 11.43C	Where the notifying administration resubmits the notice and the BR finds that the coordination procedures specified in Article 11.32 have been successfully completed with all affected administrations, the assignment shall be recorded in the Master Register.

3.2 Cospas-Sarsat Response to Advance Publication Information

As described at references 1 and 2 in table 3.1, on most occasions the first indication of an administration's intention to operate a new service in the 1544 – 1545 MHz band will come from information published in the advanced publication section of the IFIC. Furthermore, because the 1544 – 1545 MHz band is encompassed in the larger allocation of 1535 – 1559 MHz to MSS (space-to-Earth), many administrations may mistakenly include a reference to a service in the 1544 – 1545 MHz band in their advance publication information, even though they have no intention of operating a distress and safety communications service in the 1544 – 1545 MHz band.

3.2.1 Individual Cospas-Sarsat GSOs, in response to advance publication information provided in the IFIC, should:

a. advise the Cospas-Sarsat Secretariat of the proposed new service in the band, citing the applicable IFIC reference;

b. send correspondence, through their designated national body, to the administration proposing the new service, with an information copy to the BR, expressing concerns that the proposed service may cause harmful inference to the Cospas-Sarsat System citing Article 31.2 of the Radio Regulations (table 3.1 ref 3), and requesting a detailed description of the proposed new service, including:

- the spectral characteristics of its 1544 – 1545 MHz transmissions,
- an estimate of the amount of time that the 1544 –1545 MHz signals will be active, and
- a description of the distress and safety communications services supported by the proposed new service.

3.2.2 Further to paragraph 3.2.1.a above, upon receiving notice of relevant advance publication information, the Cospas-Sarsat Secretariat (hereafter referred to as the Secretariat) will distribute this information via Email to each GSOs' designated Representative in the Cospas-Sarsat Programme. GSOs are also encouraged to initiate similar correspondence to that described in 3.2.1.b. This will ensure that all relevant organisations and administrations are aware of the potential for the proposed service to adversely impact upon Cospas-Sarsat operations, and make the ITU aware of all administrations concerns on the matter.

3.2.3 Cospas-Sarsat Participants are also encouraged to submit input papers to Cospas-Sarsat Joint Committee and Council meetings describing the status of any discussions with other administrations in respect of proposed uses of the band, and any specific technical analysis that has been completed on the matter.

3.3 Cospas-Sarsat Participation in the Coordination Process

Article 5.354 of the Radio Regulations specifies that the use of the 1544 – 1545 MHz band is subject to coordination under Article 9.11A. Therefore, having completed the Publication Phase of the process, the administration proposing the new service should submit a request to the BR to initiate the process for formal frequency "coordination" with existing users. In response the BR will conduct analysis in accordance with Appendix 5 of the Radio Regulations to determine if the proposed new system would interfere with other systems that have been formally notified to the ITU. The BR will then publish in the coordination section of the IFIC (section CR/C to the IFIC) the details concerning the proposed new system, and based on the results of the BR's analysis, identify those administrations with which coordination may be required. The BR will also inform the affected administrations directly (Reference 6 to table 3.1).

It is important to emphasise that the BR's analysis, conducted in accordance in accordance with Appendix 5 of the Radio Regulations, may not be consistent with the protection required for Cospas-Sarsat LUTs. Consequently, Cospas-Sarsat GSOs should not rely on the BR identifying them as possibly being affected by the proposed new system. Rather, upon becoming aware that the coordination phase for a new system in the band has been initiated, each GSO should conduct their own analysis, using the generic protection criteria provided at Annexes B through H as a guide, to determine if the proposed new service might cause harmful interference to their Cospas-Sarsat operations and, therefore, formal coordination should be conducted.

Upon becoming aware that coordination will be required, each affected Cospas-Sarsat GSO should follow the procedures described below.

a. Advise the Secretariat of the requirement for coordination, the results of any analysis conducted to date, and copies of any official correspondence with the administration proposing the new service. On receipt of this information the Secretariat will distribute copies to all Cospas-Sarsat Representatives via Email. Cospas-Sarsat Participants are encouraged to review this information and provide any comments directly to the GSO that originated this information.

   If the schedule for formal coordination allows, Cospas-Sarsat Participants are also encouraged to submit papers to the Joint Committee on specific frequency coordination matters.

b. The GSO involved in the coordination process should consider the input provided by other Cospas-Sarsat Participants, update their analysis as they deem appropriate, and:

   - respond to the administration proposing the new service and the BR (see References 7 and 8 to table 3.1); and

   - provide a copy of all official correspondence to the Cospas-Sarsat Secretariat.

   The Secretariat will distribute copies of this correspondence to all Cospas-Sarsat Representatives via email.

Should the analysis conclude that the proposed new system would generate harmful interference to Cospas-Sarsat, the administrations involved in the coordination should attempt to resolve the matter. Copies of all official correspondence resulting from efforts to resolve the matter should be copied to the BR and the Cospas-Sarsat Secretariat.

If an agreement is reached for the introduction of the new system, the agreement should be fully documented by the GSO involved in the coordination process, and copies of this agreement sent to both the BR and the Cospas-Sarsat Secretariat. At this stage the Cospas-Sarsat GSO may be required to modify their "notification" for their LUT if required by agreements made during the coordination process (see section 3.4 below).

If an agreement cannot be reached between the administrations, the BR will conduct its own interference analysis and communicate its conclusions to the administrations involved. In such instances, upon receipt of information from the ITU the Cospas-Sarsat GSO should provide copies of this correspondence to the Secretariat for distribution to the other Cospas-Sarsat Participants.

3.4 Cospas-Sarsat Participation in the Notification Process

Notification is the process by which the ITU formally recognises the introduction of a system into a frequency band, thereby, entitling the system to the protection that the Radio Regulations offer. Successful notification results in an assignment being recorded in the Master International Frequency Register (often referred to simply as the Master Register). The notification actions required of Cospas-Sarsat GSOs are determined by the results of the coordination process. The four possible outcomes of the coordination process and the resulting required Cospas-Sarsat actions are described below.

3.4.1 If all the Cospas-Sarsat GSOs that participated in the coordination process agreed that the proposed new system would not generate harmful interference to the Cospas-Sarsat system, then no further action would be required of any Cospas-Sarsat GSO.

3.4.2 If all the Cospas-Sarsat GSOs that participated in the coordination process agreed that the proposed new system would be acceptable, however, one or more of the Cospas-Sarsat GSOs believed that modifications to their LUT(s) would be required, then the affected GSO(s) should determine whether such modifications necessitate a change to their existing "notification" information on file with the BR. If so, the affected GSO(s) should update the "notifications" for the LUTs concerned.

3.4.3 If at least one of the Cospas-Sarsat GSOs that participated in the coordination process could not agree with the introduction of the proposed system, and that GSO's analysis was supported by the BR's analysis, then the ITU would return any requests for notification in respect of the proposed new service to the originating administration. If after returning this information, the originating administration insisted that it be reconsidered, the BR would provisionally enter the assignment in the Master Register with an indication of those administrations for which agreement was not obtained. This entry would be changed from "provisional" to definitive in the Master Register if the Bureau was informed that the new assignment had been in use together with the Cospas-Sarsat assignment for which agreement was not obtained, for a period not less than 4 months, and that during this period no complaint of harmful interference had been made. Therefore, it is important that Cospas-Sarsat GSOs monitor the band, and report cases of interference to both the ITU and, if it could be determined, the administration responsible for the system that caused the interference.

3.4.4 If at least one of the GSOs that participated in the coordination process could not agree with the introduction of the proposed system, but, the ITU BR's analysis did not support that GSO's view, the ITU would record the assignment for the proposed system in the Master Register. In such a case the Master Register would also indicate those administrations that did not achieve agreement through the coordination process.

- END OF SECTION 3 -

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ANNEXES TO

COSPAS-SARSAT FREQUENCY REQUIREMENTS AND COORDINATION PROCEDURES

C/S T.014

ANNEX A

LIST OF ABBREVIATIONS AND ACRONYMS

BR	ITU Radiocommunication Bureau
COSPAS	COsmicheskaya Sistema Poiska Avarinykh Sudov (Satellite System for the Search of Vessels in Distress)
GEO	Geostationary Earth Orbit
GEOLUT	Local User Terminal (LUT) in the GEOSAR system
GEOSAR	Geostationary Satellite System for Search and Rescue
GSO	Cospas-Sarsat Ground Segment Operator
IFIC	International Frequency Information Circular
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
kHz	Kilohertz
LUT	Local User Terminal (Cospas-Sarsat Ground Receiving Station)
LEO	Low-altitude Earth Orbit
LEOLUT	LUT in the LEOSAR system
LEOSAR	Low-altitude Earth Orbit System for Search and Rescue
MHz	Megahertz
MCC	Mission Control Centre
PDS	Processed Data Stream Channel
SAR	Search And Rescue
SARP	Search And Rescue Processor
SARR	Search And Rescue Repeater
SARSAT	Search And Rescue Satellite Aided Tracking
SSP	Cospas-Sarsat Space Segment Provider

- END OF ANNEX A –

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ANNEX B

PROTECTION REQUIREMENTS IN THE 1544 – 1545 MHz BAND FOR COSPAS-SARSAT LEOSAR SERVICES AGAINST INTERFERENCE FROM BROADBAND EMISSIONS

B.1 Introduction

Cospas-Sarsat search and rescue (SAR) satellites in low-altitude Earth orbit (LEO) transmit using downlink frequencies in the band 1544-1545 MHz. The satellite downlinks are received and processed by Cospas-Sarsat Earth receiving stations, also referred to as local users terminals or LEOLUTs. In accordance with the ITU Radio Regulations the 1544 – 1545 MHz band is allocated to the mobile satellite service (MSS), space-to-Earth, and is specifically limited by article 5.356 to distress and safety communications. Because the 1544 – 1545 MHz band is not dedicated to Cospas-Sarsat, there is a requirement to establish protection criteria for possible use in formal frequency coordination deliberations with administrations proposing to introduce new systems into the band.

Since Cospas and Sarsat LEOSAR satellites have different technical characteristics, coupled with the fact that each LEOSAR channel (i.e. SARP, SARR) has different operating characteristics and at different portions of the 1544 – 1545 MHz spectrum, there is a requirement to establish protection requirements for each satellite/channel combination. The protection criteria for each Cospas-Sarsat LEOSAR satellite/channel combination are provided in the appendices to this annex as detailed below.

Satellite	Channel	Appendix
Cospas and Sarsat	SARP	A
Sarsat	SARR	B

B.2 Overview of Sarsat Satellite Downlinks

The detailed technical characteristics of Sarsat satellite downlinks are provided in the Cospas-Sarsat System document entitled “Description of the Payloads Used in the Cospas-Sarsat LEOSAR System, C/S T.003”. As depicted at Figures B.1 and B.2, the Sarsat SAR payload downlink contains a composite baseband signal comprised of the SARP channel 2.4 kbps processed data stream (PDS), and the SAR repeater (SARR) channel. In baseband the SARP 2.4 kbps PDS data channel is centered at 2.4 kHz, and the 406 MHz sub-band at 170 kHz for SARR-1 payloads (up to Sarsat 13) and at 88.46 kHz for SARR-2 payloads (SARSAT 14 and after). The composite baseband signal is phase modulated onto the 1544.5 MHz carrier, which results in the radiated spectrum shown in Figures B.3 and B4 respectively.

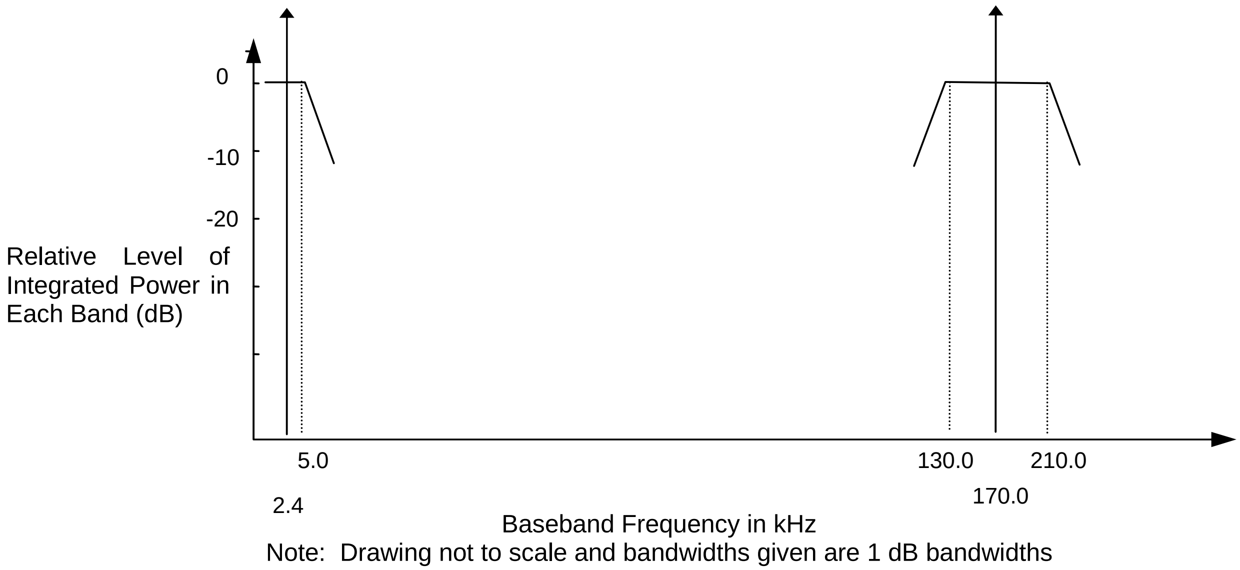

Figure B.1: Sarsat SARR-1 Baseband Frequency Spectrum

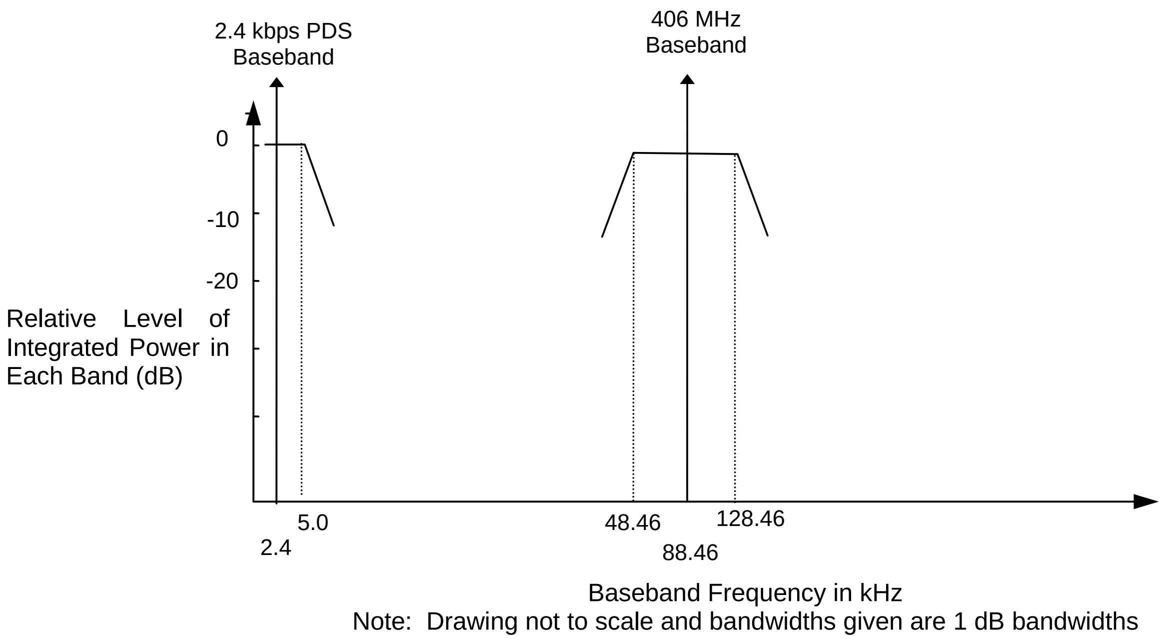

Figure B.2: Sarsat SARR-2 Baseband Frequency Spectrum

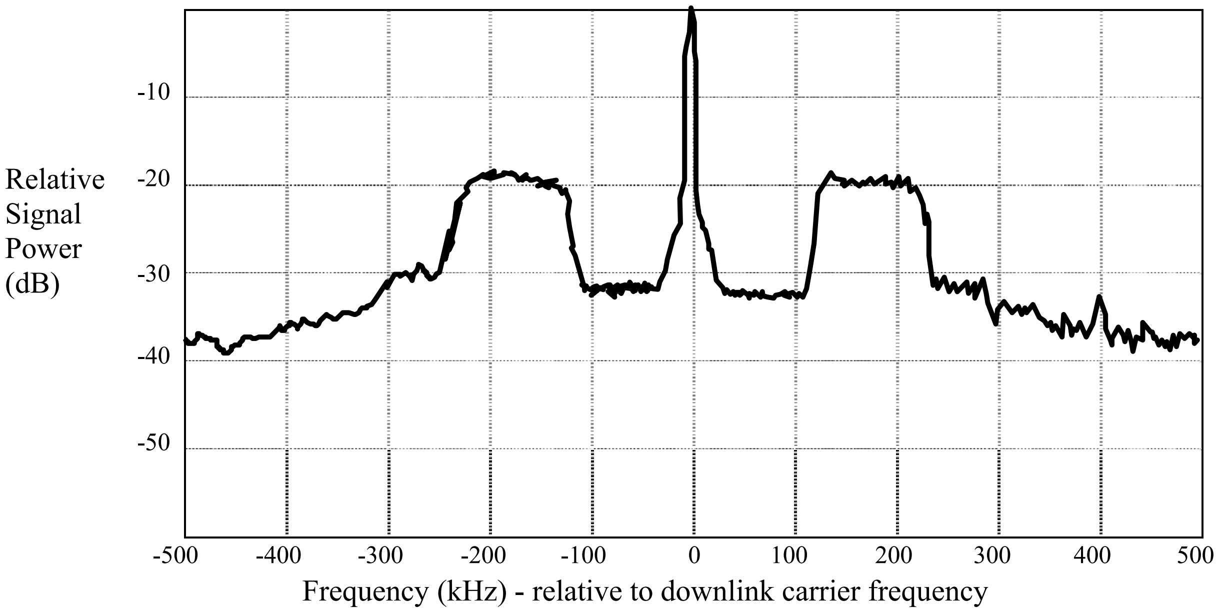

Figure B.3: Typical Sarsat SARR-1 1544.5 MHz Observed Downlink Signal

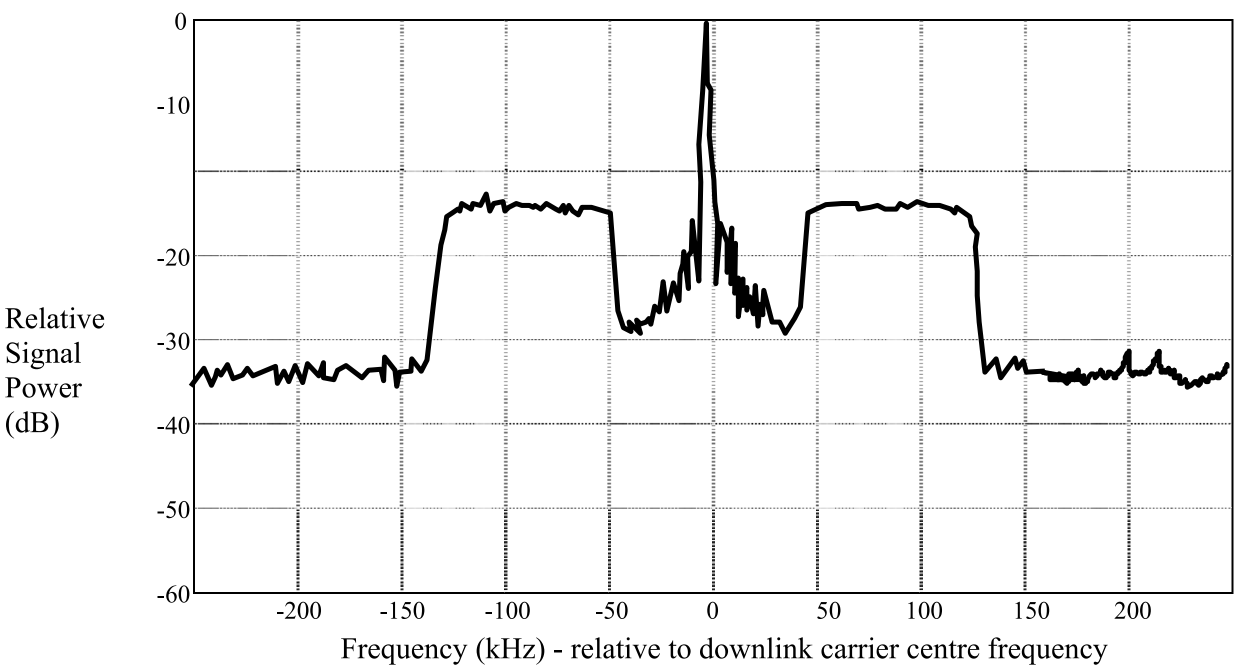

Figure B.4: Typical Sarsat SARR-2 1544.5 MHz Observed Downlink Signal

B.3 Overview of Cospas Satellite Downlinks

The detailed technical characteristics of Cospas satellite downlinks are provided in the Cospas-Sarsat System document C/S T.003. Cospas SAR payload downlinks contain a composite baseband signal comprised of the SARP channel 2.4 kbps PDS. In baseband the SARP 2.4 kbps PDS data channel is centered at 2.4 kHz. The composite baseband signal is phase modulated onto the 1544.5 MHz carrier, which results in the radiated spectrum shown in Figure B.5.

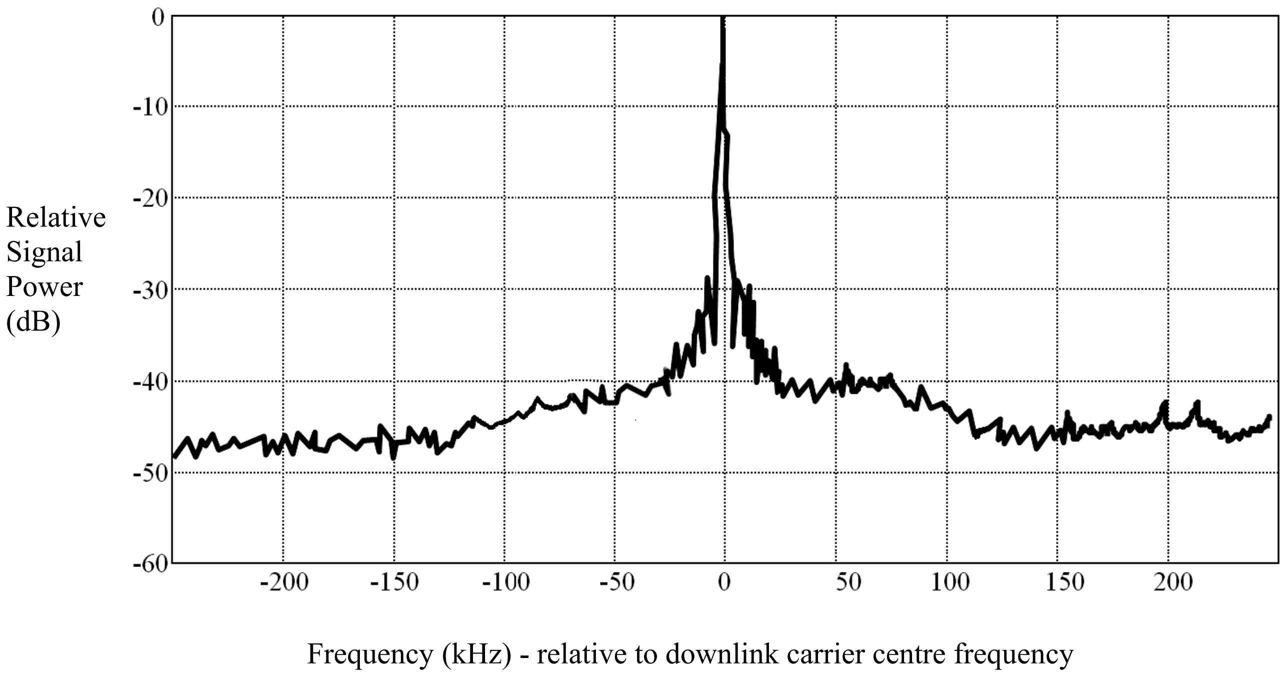

Figure B.5: Cospas 1544.5 MHz Downlink Signal Spectrum

APPENDIX A to ANNEX B

PROTECTION REQUIREMENTS IN THE 1544 – 1545 MHz BAND FOR COSPAS AND SARSAT SARP SERVICES AGAINST INTERFERENCE FROM BROADBAND EMISSIONS

B-A.1 General

Cospas and Sarsat SARP 2.4 kbps channels are located at 1544.5 MHz ± 5 kHz on the LEOSAR payload downlinks (note that due to the resolution of Figures B.2 and B.4 it is difficult to see the SARP channels). Because of the frequency spreading caused by the modulation process and the Doppler shift resulting from the movement of the satellite, the 2.4 kbps SARP channel is received at LEOLUTs over a frequency range of 1544.5 MHz ± 50 kHz.

Table B-A.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 (C/S T.002 refers). 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.

B-A.2 Criteria for Establishing Harmful Level of Interference to the SARP Channel (2.4 kbps PDS)

In order to reliably detect and locate 406 MHz distress beacons the bit error rate (BER) of the SARP channel downlink must not exceed $1x10^{-6}$ (reference Cospas-Sarsat document C/S T.002).

B-A.3 Analysis of Spectral Power Flux Density 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 (No) and noise caused by interference from other systems (Io).

This analysis will establish the level of interference, expressed as a spectral power flux density (spfd) at the LEOLUT antenna, that would degrade the BER of the SARP channel downlink to one bit error in every million ($1x10^{-6}$).

Table B-A.1 shows the recommended downlink power budget for the SARP channel (reference C/S T.002). The link budget has been completed using typical LEOLUT parameters. The link budget shows that the required BER of $1x10^{-6}$ 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. In other words, 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 (Io) at the LEOLUT receiver is given by the following equation (numeric quantities).

$$No + Io \leq 10^{(2.4/10)} \text{ x } No$$

or

$$Io/No \leq (10^{(2.4/10)} - 1) = .738 \text{ (numeric)}$$

then

$$Io/No = -1.3 \text{ dB}$$

The cumulative effect of all interferers, therefore, must not exceed an Io/No = -1.3 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 low noise amplifier (LNA). The noise power spectral density without interference (No) is the product of Boltzmann's constant (k) and the noise temperature T, or No = kT.

$$No = -228.6 +22.4 = -206.2 \text{ dB(W/Hz)}$$

Therefore, the maximum interference power spectral density from all interfering emitters, Io(max), at the LEOLUT low noise amplifier within the 1544.5 MHz ± 50 kHz band must not exceed the following:

$$Io(max) \leq No – 1.3 = -207.5 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB(W/m^2 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 or $10^{(0.1x26.7)} = 467.74$ results in $A_e = 467.74\lambda^2/4\pi = 1.4 \text{ m}^2$. Therefore, the maximum level of all interference on the downlink expressed as a spfd is:

$$spfd = Io/A_e = -207.5 – 10\log(1.4) = -209.0 \text{ dB(W/m}^2 \text{ Hz)}$$

The maximum level of broadband noise-like interference in the 1544.5 MHz ± 50 kHz band channel should not exceed –209.0 dB(W/m^2 Hz).

B-A.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-Earth allocations.

The emission bandwidth must be examined to determine if energy is transmitted in the frequency range 1544.5 MHz ± 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 dB(W/m^2 Hz) in any portion of the 1544.5 MHz ± 50 kHz.

The link budget associated with this analysis is summarised in tabular format at Annex H.

Table B-A.1: Downlink Power Budget Parameters for the Cospas and Sarsat Processed Data Stream (PDS) of the SARP

Parameter	Units	Cospas Nominal	Sarsat Nominal	Source
Carrier frequency	(MHz)	1544.5	1544.5	C/S T.003
Polarization (Left Hand Circular)		LCHP	LHCP	C/S T.003
Elevation angle	(degrees)	5	5	C/S T.002
Satellite altitude	(km)	1000	850	C/S T.003
Satellite e.i.r.p*	(dBW)	6.2	7.1	C/S T.003
Slant range @ 5 degrees	(km)	3200	2900	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	10	
Other losses (L_o)	(dB)	3.6**	3.6**	LUT-design & site-dependent
Antenna (G/T)***	(dBK^{-1})	4.3	4.3	G = 26.7 dB, T = 22.4 dB(K)
Boltzmann constant (k)	($dBWK^{-1}Hz^{-1}$)	-228.6	-228.6	physical constant
Data rate factor @ 2.4 kbps (r)	(dBHz)	33.8	33.8	C/S T.003
Modulation loss (P_{PDS}/P_T)	(dB)	-12.1	-14.1	
Desired maximum Bit Error Rate	(BER)	10^{-6}	10^{-6}	C/S T.002
Calculated $(E_b/N_0)_c$	(dB)	13.3	13.0	using above parameters
Theoretical $(E_b/N_0)_{th}$ for BER of 10^{-6}	(dB)	10.6	10.6	E_b/No for required BER
PDS Link Margin	(dB)	2.7	2.4	

----

* Equivalent Isotropically Radiated Power

** Polarization mismatch, antenna pointing and demodulator implementation losses

*** Antenna Gain-to-Noise Temperature Ratio, to include radome, if applicable, and cable losses. USA LUTs G/T = 4.3 dB.

APPENDIX B to ANNEX B

PROTECTION REQUIREMENTS IN THE 1544 – 1545 MHz BAND FOR SARSAT 406 MHz REPEATER (SARR) SERVICES AGAINST INTERFERENCE FROM BROADBAND EMISSIONS

B-B.1 General

The Sarsat 406 MHz SARR channel occupies approximately 100 kHz of spectrum starting 120 kHz above and below the 1544.5 MHz carrier. However, due to the allowable frequency drift caused by the aging of the satellite transmitter, the Doppler shift caused by the movement of the Sarsat satellite, a minimum guard band and the spreading of the signal caused by the modulation process, LEOLUTs require 220 kHz of spectrum beginning 80 kHz above and below the 1544.5 MHz carrier to process the 406 MHz SARR channel.

The frequency occupied by the SARR channel is depicted at Figure B-B.1.

[New Figure to be provided]

Figure B-B.1: Sarsat 1544.5 MHz Downlink Signal Spectrum

B-B.2 Criteria for Establishing Harmful Level of Interference to the Sarsat 406 MHz SARR Channel

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

B-B.3 Analysis of Interference Spectral Power Flux Density

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 (No) and noise caused by interference from other systems (Io). Figure B-B.2 depicts the SARR channel with interference on the downlink.

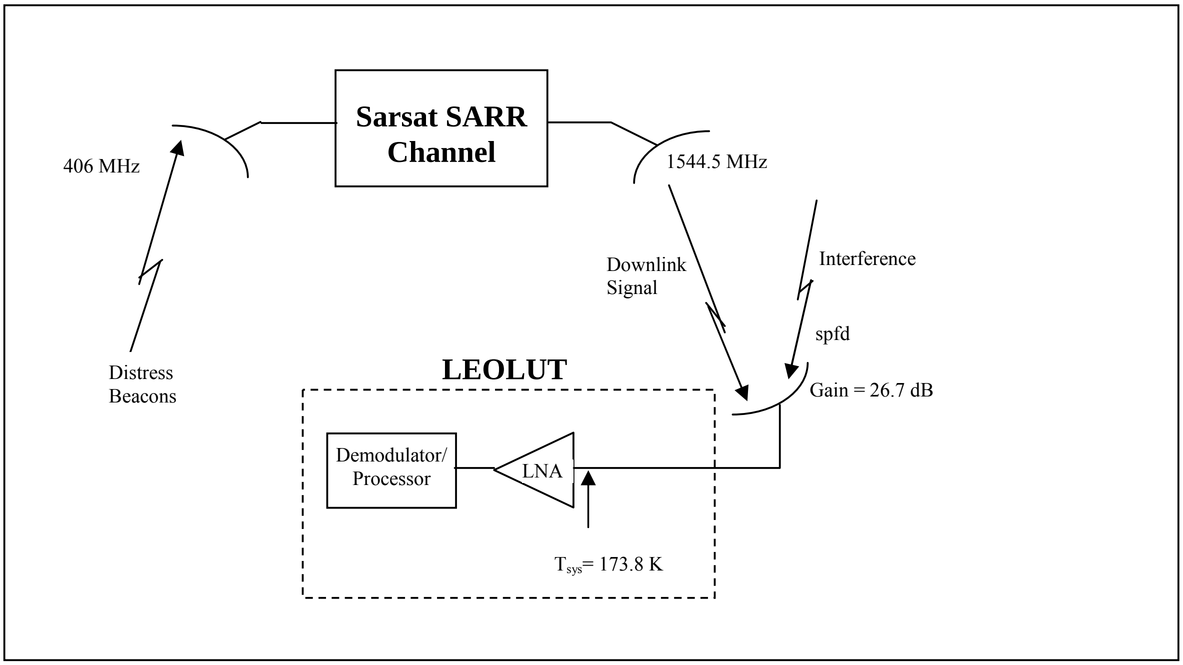

Figure B-B.2: Sarsat SARR with Interference on the Downlink

To achieve a BER of $5x10^{-5}$, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the LEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the LEOLUT antenna that could be accommodated without degrading the overall link Eb/(No+Io) below 8.8 dB.

As depicted in Figure B-B.2, the composite baseband, comprised of the Sarsat SARP, SARR channels, are phase modulated onto a 1544.5 MHz downlink carrier for detection and processing by LEOLUTs. The antenna gain and system noise temperature for a typical LEOLUT is 26.7 dB and 173.8 K, respectively.

This analysis assumes three simultaneously active beacons transmitting at the exact same time on three different frequencies in the 406.0 – 406.1 MHz band. The "Low-Level" beacon, which is the subject of the analysis, has an elevation angle of 5 degrees with respect to the spacecraft. The two other beacons transmit at 'Nominal-Levels' and at elevation angles of 40 degrees with respect to the spacecraft. The two "Nominal Level" beacons are included in the analysis because they share the available satellite repeater power, and, therefore, affect the link budget. This manifests itself in the link budget as a 15.3 dB sharing loss on the downlink (Annex H refers).

The complete link budget for the 406 MHz SARR channel is summarised in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 38.8 dBHz, which equates to an E_b/No of 12.8 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the LEOLUT, this results in an effective ratio of E_b/No at the LEOLUT demodulator of 10.8 dB. Since the channel requires an overall $E_b/(No+Io)$ of at least 8.8 dB to operate effectively, any broadband interference on the downlink that reduces the overall carrier to noise plus interference density ratio by more than 2.0 dB cannot be accommodated.

Since the C/No in the absence of interference equates to 38.8 dBHz, broadband noise-like interference on the downlink that degrades the overall link by 2.0 dB, would result in a $(C/No+Io)_{overall}$ of:

$$
\begin{aligned}
(C/No+Io)_{overall} &= (C/No)_{overall} - 2.0 \text{ dB} \\
&= 38.8 \text{ dBHz} - 2.0 \text{ dB} \\
&= 36.8 \text{ dBHz}
\end{aligned}
$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No+Io)_{overall}=[(C/No+Io)^{-1}{}_{up} + (C/No+Io)^{-1}{}_{down}]^{-1}$$

Because this analysis only concerns interference on the downlink, it is assumed that there is no interference on the uplink, therefore, the equation simplifies to:

$$(C/No+Io)_{overall}=[(C/No)^{-1}{}_{up} + (C/No+Io)^{-1}{}_{down}]^{-1}$$

Substituting the values for $(C/No+Io)_{overall}$ (36.8 dBHz, see above) and $(C/No)_{up}$ (41.3 dBHz, see Annex H), the value of the downlink carrier to noise plus interference density ratio $[(C/No+Io)_{down}]$ equals 38.7 dBHz (see below):

$$C/(No+Io)_{down} = ((C/No+Io)_{overall}{}^{-1} - (C/No)_{up}{}^{-1})^{-1}$$

or

$$C/(No+Io)_{down} = 10\log((10^{-36.8/10} - 10^{-41.3/10})^{-1})$$

then

$$C/(No+Io)_{down} = 38.7 \text{ dBHz}$$

The noise power spectral density of the downlink without interference at the input to the LNA is No=kT, where k is Boltzmann's constant. Therefore, No=-228.6+22.4 = -206.2 dB (W/Hz).

Knowing that $(C/No)_{down}$ equals 42.5 dB (see Annex H), and $(No)_{down}$ equals -206.2 dBW/Hz, the value of C_{down} is -163.7 dBW.

The maximum permissible interference power spectral density in the downlink from the aggregate of all interfering emitters, Io(max), measured at the input to the LEOLUT receiver LNA in the 1544 – 1545 MHz band used for the downlink of the 406 MHz SARR channel:

$$Io(max) \leq 10\log(10^{(Cdown-(C/(No+Io)down)/10} - 10^{(No)down/10})$$

or

$$Io(max) \leq 10\log(10^{(-163.7-38.7)/10} - 10^{-206.2/10})$$

then

$$Io(max) \leq -204.7 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB(W/m^2 Hz) at the input to the LEOLUT antenna. The effective aperture of an antenna (A_e) having a gain of G is $A_e = G\lambda^2/4\pi$. For LEOLUT antennas with a gain of 26.7 dB the effective aperture is 1.4 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io(max) - L_{Line} - A_e$$

assuming no line losses ($L_{Line} = 0$)

$$spfd = -204.7 - 0 - 10\log(1.4) = -206.2 \text{ dB(W/m}^2\text{ Hz)}$$

The maximum level of broadband noise-like interference in the bands processed by LEOLUTs for the 406 MHz SARR channel shall not exceed -206.2 dB(W/m^2 Hz).

B-B.4 Procedure for Computing Level of Interference to the LEOSAR SARR 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-Earth allocations.

The emission bandwidth must be examined to determine if energy is transmitted in the frequency ranges processed by LEOLUTs for 406 MHz SARR channel (i.e.,1544.58 – 1544.80 MHz and 1544.42 – 1544.20 MHz). Particular care must be taken when analysing the impact of mobile systems (e.g. non-geostationary satellites and airborne transmitters) to take into account 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 a spfd level at the LEOLUT antenna. The aggregate level for all interfering sources must not exceed -206.2 dB(W/m^2 Hz) anywhere in this range.

ANNEX C

PROTECTION REQUIREMENTS IN THE 1544 – 1545 MHz BAND FOR GOES GEOSAR SERVICES

C.1 Introduction

GOES geostationary search and rescue satellites (GEOSAR) operate using downlink frequencies in the 1544 - 1545 MHz band. The satellite downlinks are received and processed by Cospas-Sarsat Earth receiving stations, also referred to as local user terminals for geostationary satellites or GEOLUTs. In accordance with the ITU Radio Regulations the 1544 – 1545 MHz band is allocated to the mobile satellite service (MSS), space-to-Earth, and is specifically limited by article 5.356 to distress and safety communications. The analysis provided in this Annex establishes protection criteria for GOES GEOLUTs from interference in the 1544 - 1545 MHz band. This protection criterion could be used by the administrations that operate Cospas-Sarsat equipment in any formal frequency coordination deliberations with administrations proposing to introduce new systems that would also use this frequency band.

C.2 Criteria for Establishing Harmful Level of Interference to the GOES 406 MHz SARR Channel Downlink

To reliably detect 406 MHz distress beacons using GOES satellite repeaters the bit error rate (BER) of the channel must not exceed $5x10^{-5}$.

C.3 Analysis of Interference Spectral Power Flux Density

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 (No) and noise caused by interference from other systems (Io). Figure C.1 depicts the GOES SARR channel with interference on the downlink.

To achieve a BER of $5x10^{-5}$, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the GEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the GEOLUT antenna that could be accommodated without degrading the overall link Eb/(No+Io) below 8.8 dB.

As seen in Figure C.1, 406 MHz distress beacon signals are received by the GOES search and rescue repeater and phase modulated onto a 1544.5 MHz downlink carrier for detection and processing by GEOLUTs. The antenna gain and system noise temperature for a typical GOES GEOLUT are 33.3 dB and 165.96 K, respectively. By using sophisticated digital signal processing and burst integration techniques, when there is no interference the overall carrier to noise density ratio (C/No) equals 31.1 dBHz.

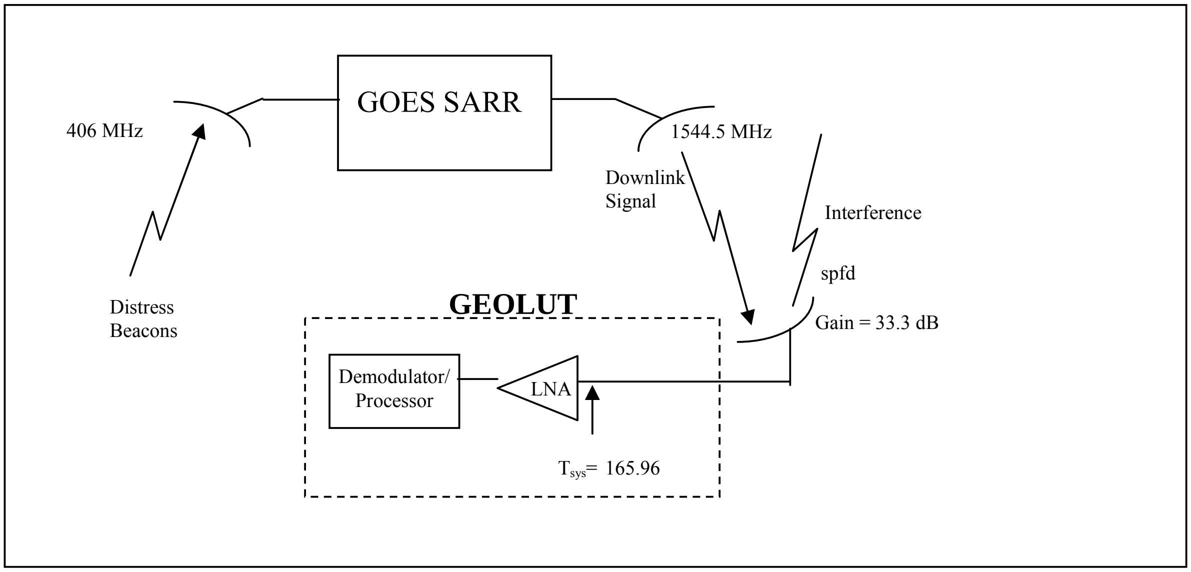

Figure C.1: GOES SAR Repeater with Interference on the Downlink

This analysis assumes three simultaneously active beacons transmitting at the exact same time on three different frequencies in the 406.0 – 406.1 MHz band. The "Low-Level" beacon, which is the subject of the analysis, has an elevation angle of 5 degrees with respect to the spacecraft. The two other beacons transmit at 'Nominal-Levels' and at elevation angles of 40 degrees with respect to the spacecraft. The two "Nominal Level" beacons are included in the analysis because they share the available satellite repeater power, and, therefore, affect the link budget. This manifests itself in the link budget as a 18.3 dB sharing loss in the downlink (Annex H refers).

The complete link budget for the GOES SARR channel is summarised in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 31.1 dBHz, which equates to an E_b/No of 5.1 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the GEOLUT as well as GEOLUT processing gain, this results in an effective ratio of E_b/No at the GEOLUT demodulator of 10.1 dB. Since the channel requires an overall E_b/(No+Io) of at least 8.8 dB to operate effectively, any 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 C/No in the absence of interference equates to 31.1 dBHz, broadband noise-like interference on the downlink that degrades the overall link by 1.3 dB, would result in a $(C/No+Io)_{overall}$ of:

$$\begin{aligned}(C/No+Io)_{overall} &= (C/No)_{overall} - 1.3\text{ dB} \\ &= 31.1\text{ dBHz} - 1.3\text{ dB} \\ &= 29.8\text{ dBHz}\end{aligned}$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No+Io)_{overall}=[(C/No+Io)^{-1}{}_{up} + (C/No+Io)^{-1}{}_{down}]^{-1}$$

Since this analysis only concerns interference on the downlink, it is assumed that there is no interference on the uplink, therefore, the equation simplifies to:

$$(C/No+Io)_{overall}=[(C/No)^{-1}{}_{up} + (C/No+Io)^{-1}{}_{down}]^{-1}$$

Substituting the values for $(C/No+Io)_{overall}$ (29.8 dBHz, see above) and $(C/No)_{up}$ (31.3 dBHz, see Annex H), the value of the downlink carrier to noise plus interference density ratio $[(C/No+Io)_{down}]$ equals 35.1 dBHz (see below):

$$C/(No + Io)_{down} = ((C/No +Io)_{overall}{}^{-1} - (C/No)_{up}{}^{-1})^{-1}$$

or

$$C/(No + Io)_{down} = 10\log((10^{-29.8/10} - 10^{-31.3/10})^{-1})$$

then

$$C/(No + Io)_{down} = 35.1 \text{ dBHz}$$

The noise power spectral density of the downlink without interference at the input to the LNA is No=kT, where k is Boltzmann's constant. Therefore, No=-228.6+22.2 = -206.4 dB(W/Hz).

Knowing that $(C/No)_{down}$ equals 43.8 dB (see Annex H), and $(No)_{down}$ equals -206.4 dBW/Hz, the value of C_{down} is –162.6 dBW.

The maximum permissible interference power spectral density in the downlink from the aggregate of all interfering emitters, Io(max), measured at the input to the GEOLUT receiver LNA over the 1544.5 MHz ± 100 kHz band is:

$$Io(max) \leq 10\log(10^{(Cdown-(C/(No+Io)down)/10} - 10^{(No)down/10})$$

or

$$Io(max) \leq 10\log(10^{(-162.6-35.1)/10} - 10^{-206.4/10})$$

then

$$Io(max) \leq -198.3 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB(W/m^2 Hz) at the input to the GEOLUT antenna. The effective aperture of an antenna (A_e) having a gain of G is $A_e = G\lambda^2/4\pi$. For GEOLUT antennas with a gain of 33.3 dB the effective aperture is 6.42 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io(max) - L_{Line} - A_e$$

assuming no line losses (L_{Line} = 0)

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

The maximum level of broadband noise-like interference in the 1544.5 MHz ± 100 kHz GEOLUT channel shall not exceed -206.4 dB(W/m^2 Hz).

C.4 Procedure for Computing Level of Interference to the GOES 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-Earth allocations.

The emission bandwidth must be examined to determine if energy is transmitted in the frequency range 1544.5 MHz ± 100 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 a spfd level at the GEOLUT antenna. The aggregate level for all interfering sources must not exceed -206.4 dB(W/m^2 Hz) anywhere in this range.

- END OF ANNEX C -

ANNEX D

PROTECTION REQUIREMENTS IN THE 1544 – 1545 MHz BAND FOR MSG GEOSAR SERVICES

D.1 Introduction

MSG geostationary search and rescue satellites (GEOSAR) operate using downlink frequencies in the 1544 - 1545 MHz band. The satellite downlinks are received and processed by Cospas-Sarsat Earth receiving stations, also referred to as local user terminals for geostationary satellites or GEOLUTs. In accordance with the ITU Radio Regulations the 1544 – 1545 MHz band is allocated for mobile satellite service (MSS), space-to-Earth, and is specifically limited by article 5.356 to distress and safety communications. The analysis provided in this Annex establishes protection criteria for MSG GEOLUTs from interference in the 1544 - 1545 MHz band. This protection criterion could be used by administrations that operate Cospas-Sarsat equipment in any formal frequency coordination deliberations with other administrations proposing to introduce new systems that would also use the frequency band.

D.2 Criteria for Establishing Harmful Level of Interference to the MSG SARR Channel Downlink

To reliably detect 406 MHz distress beacons using MSG 406 MHz satellite repeaters the bit error rate (BER) of the channel must not exceed $5x10^{-5}$.

D.3 Analysis of Interference Spectral Power Flux Density

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 (No) and caused by interference from other systems (Io).

To achieve a BER of $5x10^{-5}$, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the GEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the GEOLUT antenna that could be accommodated without degrading the overall link Eb/(No+Io) below 8.8 dB.

406 MHz distress beacon signals are received by the MSG search and rescue repeater (SARR) and are directly translated to a frequency band centred at 1544.5 MHz for detection and processing by GEOLUTs. The gain and system noise temperature for a typical MSG GEOLUT are 35.7 dB and 105 K, respectively. By using sophisticated digital signal processing and burst integration techniques, when there is no interference the overall carrier to noise density ratio (C/No) equals 27.4 dBHz.

The complete link budget for the MSG 406 MHz SARR channel is summarised in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 27.4 dBHz, which equates to an E_b/No of 1.4 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the GEOLUT as well as GEOLUT processing and coding gain, this results in an effective ratio of E_b/No at the GEOLUT demodulator of 8.9 dB. Since the channel requires an overall E_b/(No+Io) of at least 8.8 dB to operate effectively, any broadband interference on the downlink that reduces the overall carrier to noise plus interference density ratio by more than 0.1 dB cannot be accommodated.

Since the C/No in the absence of interference equates to 27.4 dBHz, broadband noise-like interference on the downlink that degrades the overall link by 0.1 dB, would result in a $(C/No+Io)_{overall}$ of:

$$\begin{aligned}(C/No+Io)_{overall} &= (C/No)_{overall} - 0.1 \text{ dB}\\ &= 27.4 \text{ dBHz} - 0.1 \text{ dB}\\ &= 27.3 \text{ dBHz}\end{aligned}$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No+Io)_{overall}=[(C/No+Io)^{-1}_{up} + (C/No+Io)^{-1}_{down}]^{-1}$$

Since this analysis only concerns interference on the downlink, it is assumed that there is no interference on the uplink, the equation simplifies to:

$$(C/No+Io)_{overall}=[(C/No)^{-1}_{up} + (C/No+Io)^{-1}_{down}]^{-1}$$

Substituting the values for $(C/No+Io)_{overall}$ (27.3 dBHz, see above) and $(C/No)_{up}$ (28.1 dBHz, see Annex H), the value of the downlink carrier to noise plus interference density ratio $[(C/No+Io)_{down}]$ equals 35.0 dBHz (see below):

$$C/(No+Io)_{down} = ((C/No+Io)_{overall}^{-1} - (C/No)_{up}^{-1})^{-1}$$

or

$$C/(No+Io)_{down} = 10\log((10^{-27.3/10} - 10^{-28.1/10})^{-1})$$

then

$$C/(No+Io)_{down} = 35.0 \text{ dBHz}$$

The noise power spectral density of the downlink without interference at the input to the LNA is No=kT, where k is Boltzmann's constant. Therefore, No=-228.6+20.2 = -208.4 dB(W/Hz).

Knowing that $(C/No)_{down}$ equals 35.5 dB (see Annex H), and $(No)_{down}$ equals -206.5 dBW/Hz, the value of $(C)_{down}$ is –171.0 dBW.

The maximum permissible interference power spectral density in the downlink from the aggregate of all interfering emitters, Io(max), measured at the input to the GEOLUT receiver LNA over the 1544.5 MHz ± 100 kHz band is:

$$Io(max) \leq 10\log(10^{(C)down-(C/(No+Io)down)/10}-10^{(No)down/10})$$

or

$$Io(max) \leq 10\log(10^{(-171.0-35.0)/10}-10^{-208.4/10})$$

then

$$Io(max) \leq -209.7 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB(W/m^2 Hz) at the input to the GEOLUT antenna. The effective aperture of an antenna (A_e) having a gain of G is $A_e = G\lambda^2/4\pi$. For GEOLUT antennas with a gain of 35.7 dB the effective aperture is 12.0 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io(max) - L_{Line} - A_e$$

assuming no line losses ($L_{Line} = 0$)

$$spfd = -209.7 - 0 - 10\log(12.0) = -220.5 \text{ dB(W/m}^2\text{ Hz)}$$

The maximum level of broadband noise-like interference in the 1544.5 MHz ± 100 kHz GEOLUT channel shall not exceed -220.5 dB(W/m^2 Hz).

D.4 Procedure for Computing Level of Interference to the MSG 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-Earth allocations.

The emission bandwidth must be examined to determine if energy is transmitted in the frequency range 1544.5 MHz ± 100 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 a spfd level at the GEOLUT antenna. The aggregate level for all interfering sources must not exceed -220.5 dB(W/m^2 Hz) anywhere in this range.

- END OF ANNEX D -

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ANNEX E

PROTECTION REQUIREMENTS IN THE 406.0 – 406.1 MHz BAND FOR COSPAS-SARSAT LEOSAR SERVICES

Introduction

The Cospas-Sarsat LEOSAR system includes SAR instruments on board Cospas and Sarsat satellites in low-altitude Earth orbit. In the case of the Sarsat sub-system, each satellite includes both SARP and SARR instruments, whereas Cospas satellite distress alert services are provided by SARP instruments only.

Article 5.266 of the ITU Radio Regulations limit the use of the band 406.0-406.1 MHz to low power satellite EPIRBs. Furthermore, article 5.267 states that "any emission capable of causing harmful interference to the authorized use of the band 406.0-406.1 MHz is prohibited". The protection criteria for each Cospas-Sarsat satellite/channel combination in the 406.0 – 406.1 MHz band are provided in the appendices to this annex as detailed below.

Satellite	Channel	Appendix
Sarsat	SARP	A
Cospas	SARP	B
Sarsat	SARR	C

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APPENDIX A TO ANNEX E

PROTECTION CRITERIA IN THE 406.0 – 406.1 MHz BAND FOR SARSAT SARP INSTRUMENTS

E-A General

This appendix identifies the protection requirements for Sarsat SARP instruments against broadband and narrow band interference in the 406.0 – 406.1 MHz band. The protection criteria are also included in ITU Recommendation ITU-R M.1478.

E-A.1 Broadband Interference

E-A.1.1 Criteria for Establishing Harmful Level of Interference to the SARP Channel from Broadband Interference

In order to reliably detect and locate 406 MHz distress beacons the bit error rate (BER) of the uplink of the Sarsat SARP channel must not exceed 5 x 10^{-5}.

E-A.1.2 Analysis of Spectral Power Flux Density In Respect of Broadband 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 noise density being comprised of the noise developed by Cospas-Sarsat equipment (No) and the noise caused by interference from other systems (Io).

To achieve a BER of 5 x 10^{-5}, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the satellite SARP must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the Sarsat 406 MHz SARP satellite antenna that could be accommodated without degrading the Sarsat SARP uplink Eb/(No+Io) below 8.8 dB.

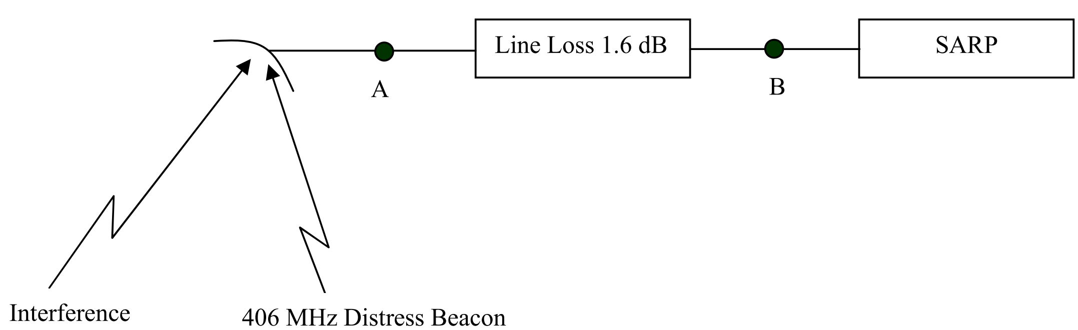

Figure E-A.1: Sarsat SARP with Uplink Interference

The system noise temperature without uplink interference measured at the input of the SARP receiver (point B) is 1010K, which equates to a spectral noise density No of -198.6 dB(W/Hz).

The SARP processor is designed to operate effectively for uplink signals equal or greater than C= -161 dBW at the input of the receiver. When interference is not present, such a signal provides an E_b/No of 9.1 dB, which provides a BER of 2.6 x 10^{-5}.

Since the uplink requires an E_b/(No+Io) of at least 8.8 dB for the SARP channel to provide the required BER, any broadband interference on the uplink that reduces the uplink carrier to noise plus interference density ratio by more than 0.3 dB cannot be accommodated.

Consequently the maximum allowable noise density interference (Io) at point B is -210.1 dB(W/Hz).

Converting this value to a spfd at the SARP satellite receive antenna by applying the line losses and the maximum satellite antenna gain, the maximum aggregate level of broadband interference in the 406.0 – 406.1 MHz band should not exceed –198.6 dB(W/m^2Hz).

E-A.2 Sarsat Narrow Band Interference

E-A.2.1 Criteria for Establishing Harmful Level of Interference to the Sarsat SARP Channel from Narrow Band Interference

Sarsat SARP instruments include, depending upon the model, either 2 or three data recover units (DRUs). Narrow band signals 21 dB(Hz) above the noise floor are assigned to a DRU to demodulate the distress beacon message and to measure the parameters required for Doppler processing. Any interfering signal that satisfies this criterion would cause the SARP to allocate a DRU to process it, which would render that DRU unavailable to process signals from real distress beacons.

E-A.2.2 Analysis of Power Flux Density In Respect of Narrow Band Interference

As identified at section E-A.1.2 the system noise temperature without uplink interference measured at the input of the SARP receiver (point B) is 1010K, which equates to a spectral noise density No of –198.6 dB(W/Hz). Any interfering signal 21 dB above this level, C_{min} = -177.6 dBW, would cause a DRU to be assigned for its processing.

Converting this value to a power flux density (pfd) at the SARP satellite receive antenna by applying the line losses and the maximum satellite antenna gain, the maximum narrow band signal that could be accommodated is:

$$\begin{aligned} pfd(max) &= -177.6 - L_{line} - Ae \\ &= -177.6 + 1.6 - 10 \log (0.105) = -166.2 \text{ dB(W/m}^2\text{)} \end{aligned}$$

APPENDIX B TO ANNEX E

PROTECTION CRITERIA IN THE 406.0 – 406.1 MHz BAND FOR COSPAS SARP INSTRUMENTS

E-B General

This appendix identifies the protection requirements for Cospas SARP instruments against broadband and narrow band interference in the 406.0 – 406.1 MHz band. The protection criteria are also included in ITU Recommendation ITU-R M.1478.

E-B.1 Broadband Interference to Cospas SARP Channel

E-B.1.1 Criteria for Establishing Harmful Level of Interference to the Cospas SARP Channel from Broadband Interference

In order to reliably detect and locate 406 MHz distress beacons the bit error rate (BER) of the uplink of the Cospas SARP channel must not exceed 5 x 10^{-5}.

E-B.1.2 Analysis of Spectral Power Flux Density In Respect of Broadband 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 noise density being comprised of the noise developed by Cospas-Sarsat equipment (No) and the noise caused by interference from other systems (Io).

To achieve a BER of 5x10^{-5}, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the satellite SARP must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the Cospas 406 MHz SARP satellite antenna that could be accommodated without degrading the Cospas SARP uplink Eb/(No+Io) below 8.8 dB.

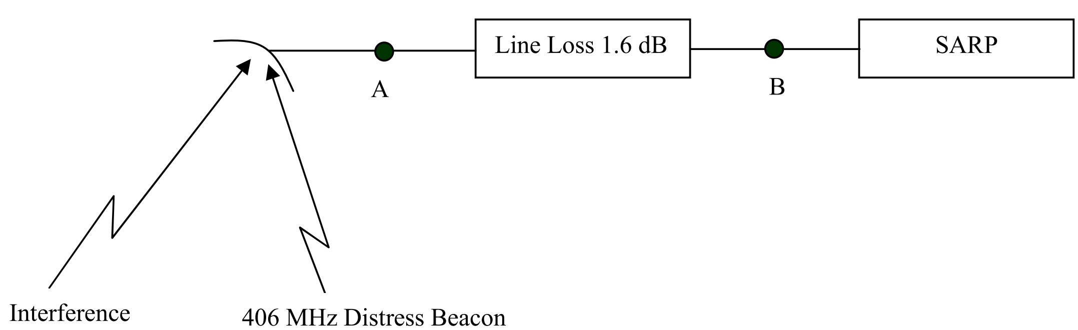

Figure E-B.1: Cospas SARP with Uplink Interference

The system noise temperature without uplink interference measured at the input of the Cospas SARP receiver (point B) is 600K, resulting in a spectral noise density No of -200.8 dB(W/Hz).

When interference is not present the E_b/No is 9.6 dB. Since the uplink requires an E_b/(No+Io) of at least 8.8 dB for the SARP channel to provide the required BER, any broadband interference on the downlink that reduces the uplink carrier to noise plus interference density ratio by more than 0.8 dB cannot be accommodated.

Consequently the maximum allowable noise density interference (Io) at point B is -207.8 dB(W/Hz).

Converting this value to a spfd at the SARP satellite receive antenna by applying the line losses and the maximum satellite antenna gain, the maximum aggregate level of broadband interference in the 406.0 –406.1 MHz band should not exceed -198.6 dB(W/m^{2}Hz).

E-B.2 Narrow Band Interference to the Cospas SARP Channel

E-B.2.1 Criteria for Establishing Harmful Level of Interference to the Cospas SARP Channel from Narrow Band Interference

Cospas SARP instruments include, depending upon the model, either 2 or three data recover units (DRUs). Narrow band signals 21 dB(Hz) above the noise floor are assigned to a DRU to demodulate the distress beacon message and to measure the parameters required for Doppler processing. Any interfering signal that satisfies this criterion would cause the SARP to allocate a DRU to process it, which would render that DRU unavailable to process signals from real distress beacons.

E-B.2.2 Analysis of Power Flux Density In Respect of Narrow Band Interference

As identified at section E-B.1.2 the system noise temperature without uplink interference measured at the input of the SARP receiver (point B) is 600K, which equates to a spectral noise density No of –200.8 dB(W/Hz). Any interfering signal 21 dB above this level, C_{min} = -179.8 dBW, would cause a DRU to be assigned for its processing.

Converting this value to a power flux density (pfd) at the SARP satellite receive antenna by applying the line losses and the maximum satellite antenna gain, the maximum narrow band signal that could be accommodated is:

$$\text{pfdmax} = -179.8 - L_{line} - Ae$$

$$= -179.8 + 1.6 - 10 \log (0.174) = -170.6 \text{ dB(W/m}^2\text{)}$$

APPENDIX C TO ANNEX E

PROTECTION CRITERIA IN THE 406.0 – 406.1 MHz BAND FOR SARSAT SARR INSTRUMENTS

E-C.1 General

The appendix identifies the protection requirements for Sarsat SARR instruments against broadband interference in the 406.0 – 406.1 MHz band.

E-C.2 Criteria for Establishing Harmful Level of Interference to the SARR channel from Broadband Interference

To reliably detect distress beacons using the Sarsat LEO 406 MHz satellite repeaters the bit error rate (BER) of the channel must not exceed $5x10^{-5}$.

E-C.3 Analysis of Spectral Power Flux Density 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 noise density being comprised of the noise developed by Cospas-Sarsat equipment (No) and the noise caused by interference from other systems (Io). Figure E-C.1 depicts the LEO SARR channel with interference on the uplink.

To achieve a BER of 5×10^{-5}, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the LEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the Sarsat LEO 406 MHz satellite antenna that could be accommodated without degrading the overall link E_b/(No+Io) below 8.8 dB.

As depicted in Figure E-C.1, distress beacon signals are received by the LEO search and rescue repeater and phase modulated onto a 1544.5 MHz downlink carrier for detection and processing by LEOLUTs. The gain and system noise temperature for the satellite repeater is -4 dB and 1000 K at point B (Figure E-C.1).

This analysis assumes three simultaneously active beacons transmitting at the exact same time on three different frequencies in the 406.0 – 406.1 MHz band. The “Low-Level” beacon, which is the subject of the analysis, has an elevation angle of 5 degrees with respect to the spacecraft. The two other beacons transmit at ‘Nominal-Levels’ and at elevation angles of 40 degrees with respect to the spacecraft. The two “Nominal Level” beacons are included in the analysis because they share the available satellite repeater power, and, therefore, affect the link budget.

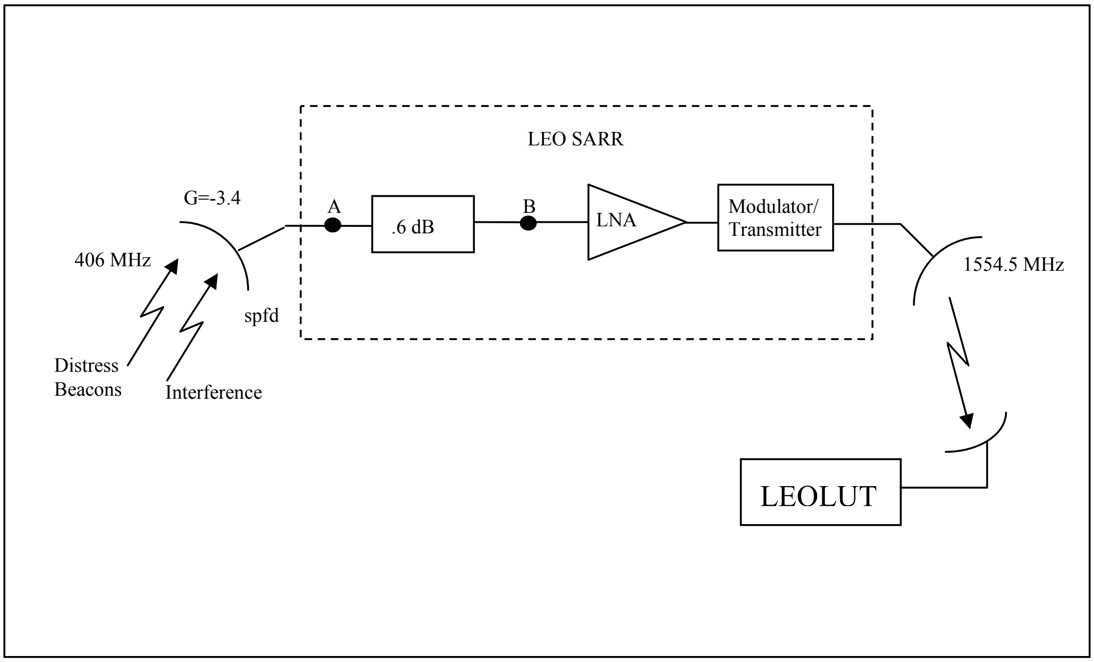

Figure E-C.1: Sarsat SARR with Uplink Interference

This manifests itself in the link budget as a 15.3 dB sharing loss in the downlink (Annex H refers).

The complete link budget for the LEOSAR 406 MHz repeater channel is summarized in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 38.8 dBHz, which equates to an E_b/No of 12.8 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the LEOLUT, this results in an effective ratio of E_b/No at the LEOLUT demodulator of 10.8 dB. Since the channel requires an overall E_b/(No+Io) of at least 8.8 dB to operate effectively, any broadband interference on the uplink that reduces the overall carrier to noise plus interference density ratio by more than 2.0 dB cannot be accommodated.

Since the C/No overall in the absence of interference equates to 38.8 dBHz, broadband noise-like interference on the uplink that degrades the overall link by 2.0 dB, would result in an $(C/No)_{Overall}$ of:

$$(C/No)_{Overall\ with\ Interference} = (C/No)_{OI} = (C/No)_{Overall} - 2.0\ dB$$
$$(C/No)_{OI} = 38.8\ dBHz - 2.0\ dB$$
$$(C/No)_{OI} = 36.8\ dBHz \quad (1)$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No)_{OI} = [(C/No)^{-1}_{up\ with\ interference} + (C/No)^{-1}_{down\ with\ interference}]^{-1} \ \text{(numeric)} \quad (2)$$

Since this analysis concerns interference on the uplink, $(C/No)_{up\ with\ interference}$ in equation 2 becomes:

$$(C/No)_{up\ with\ interference} = (C_{U/L}/(No+Io)) \quad \text{(numeric)} \qquad (3)$$

The interferer also affects the downlink carrier to noise density ratio by increasing the total power shared within the SAR bandwidth. The power sharing loss is the ratio of the beacon signal power (subject of the analysis) to the total available band power. This increased total power decreases the power sharing loss and affects the downlink carrier to noise power density as follows:

$$(C/No)_{down\ with\ interference} = (C/No)_{D/L} \times (Lpsi/Lps) \quad \text{(numeric)} \qquad (4)$$

Where Lps is the power sharing loss without interference and Lpsi is the power sharing loss with interference. Lpsi is calculated as follows:

$$Lpsi = C_{U/L}/(C_{U/L} + 2 \times C2 + N_{U/L} + IoB) \quad \text{(numeric)} \qquad (5)$$

Where C2 is the power level from one of the two ‘Other Beacon’ simultaneously received by the LEOSAR repeater.

Substituting equation 5 into equation 4 and then substituting equations 3 and 4 into equation 2 and solving for Io results in the following formula:

$$Io = (C_{U/L}((C/No)_{OI}^{-1} - (C/No)_{D/L}^{-1}) - No_{U/L})/(1 + Lps(C/N)_{D/L}^{-1}) \quad \text{(numeric)} \qquad (6)$$

Given equation 1 where $(C/No)_{OI}$ is 36.8 dBHz and Annex H, Cospas-Sarsat Link Budget, where $C_{U/L}$ is –157.3 dB, $(C/No)_{D/L}$ is 42.5 dBHz, $No_{U/L}$ is –198.6, Lps is –15.3 and $(C/N)_{D/L}$ is 42.5 dBHz minus 10log(80k) or –6.5 dB, and substituting their numeric into equation 6 yields:

$$Io = -198.9 \text{ dBW/Hz}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB (W/m^2Hz) at the input to the satellite 406 MHz receive antenna. The effective aperture of an antenna (A_e) having a gain of G is $A_e = G\lambda^2/4\pi$. For a LEO receive antenna with the gain of –3.4 dB, the effective aperture is .02 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io - L_{Line} - A_e$$

Assuming line losses of 0.6 dB (see Figure E-C.1):

$$spfd = -198.9 + .6 - 10\log(.02) = -181.3 \text{ dB } (W/m^2Hz)$$

The maximum level of broadband noise-like interference in the 406.0 – 406.1 MHz band measured at the LEO satellite antenna shall not exceed –181.3 dB (W/m^2Hz).

E-C.4 Procedure for Computing Level of Interference to the LEOSAR Repeater Channel

Interference to Cospas-Sarsat is most often a result of out-of-band emissions from services in adjacent or near adjacent bands.

The emission bandwidth must be examined to determine if energy is transmitted in the 406.0 – 406.1 MHz band. Particular care must be taken when analyzing 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 406-406.1 MHz expressed as a spfd level at the satellite antenna. The aggregate level for all interfering sources must not exceed –181.3 dB (W/m^2Hz) anywhere in this range.

APPENDIX D TO ANNEX E

PROTECTION CRITERIA IN THE 406.0 - 406.1 MHz BAND FOR COSPAS SARR INSTRUMENTS

E-D.1 General

The appendix identifies the protection requirements for Cospas SARR instruments against broadband interference in the 406.0 - 406.1 MHz band.

E-D.2 Criteria for Establishing Harmful Level of Interference to the SARR channel from Broadband Interference

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

E-D.3 Analysis of Spectral Power Flux Density 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 noise density being comprised of the noise developed by Cospas-Sarsat equipment (No) and the noise caused by interference from other systems (Io). Figure E-D.1 depicts the LEO SARR channel with interference on the uplink.

To achieve a BER of 5 x 10^{-5}, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the LEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the Cospas LEO 406 MHz satellite antenna that could be accommodated without degrading the overall link E_b/(No+Io) below 8.8 dB.

As depicted in Figure E-D.1, 406 MHz distress beacon signals are received by the LEO search and rescue repeater and phase modulated onto a 1544.5 MHz downlink carrier for detection and processing by LEOLUTs. The gain and system noise temperature for the satellite repeater is -4 dB and 1000 K at point B (Figure E-D.1).

This analysis assumes three simultaneously active beacons transmitting at the exact same time on three different frequencies in the 406.0 - 406.1 MHz band. The “Low-Level” beacon, which is the subject of the analysis, has an elevation angle of 5 degrees with respect to the spacecraft. The two other beacons transmit at ‘Nominal-Levels’ and at elevation angles of 40 degrees with respect to the spacecraft. The two “Nominal Level” beacons are included in the analysis because they share the available satellite repeater power, and, therefore, affect the link budget.

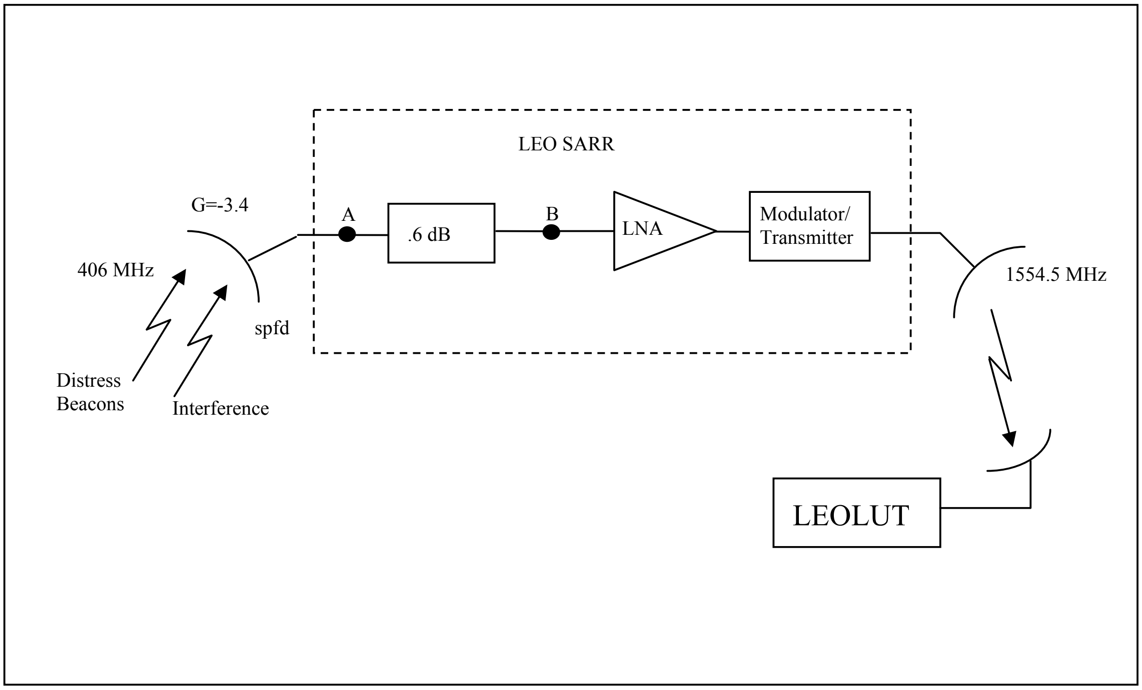

Figure E-D.1: Cospas SARR with Uplink Interference

This manifests itself in the link budget as a 15.5 dB sharing loss in the downlink (Annex H refers).

The complete link budget for the LEOSAR 406 MHz repeater channel is summarized in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 39.8 dBHz, which equates to an E_b/No of 13.8 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the LEOLUT, this results in an effective ratio of E_b/No at the LEOLUT demodulator of 13.8 dB. Since the channel requires an overall E_b/(No+Io) of at least 8.8 dB to operate effectively, any broadband interference on the uplink that reduces the overall carrier to noise plus interference density ratio by 3.0 dB cannot be accommodated.

Since the C/No overall in the absence of interference equates to 39.8 dBHz, broadband noise-like interference on the uplink that degrades the overall link by 3.0 dB, would result in an $(C/No)_{Overall}$ of:

$$(C/No)_{Overall\ with\ Interference} = (C/No)_{OI} = (C/No)_{Overall} - 3.0\ dB$$
$$(C/No)_{OI} = 39.8\ dBHz - 3.0\ dB$$
$$(C/No)_{OI} = 36.8\ dBHz \quad (1)$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No)_{OI} = [(C/No)^{-1}_{up\ with\ interference} + (C/No)^{-1}_{down\ with\ interference}]^{-1} \ \text{(numeric)} \quad (2)$$

Since this analysis concerns interference on the uplink, $(C/No)_{up\ with\ interference}$ in equation 2 becomes:

$$(C/No)_{up\ with\ interference} = (C_{U/L}/(No+Io)) \quad \text{(numeric)} \qquad (3)$$

The interferer also affects the downlink carrier to noise density ratio by increasing the total power shared within the SAR bandwidth. The power sharing loss is the ratio of the beacon signal power (subject of the analysis) to the total available band power. This increased total power decreases the power sharing loss and affects the downlink carrier to noise power density as follows:

$$(C/No)_{down\ with\ interference} = (C/No)_{D/L} \times (Lpsi/Lps) \quad \text{(numeric)} \qquad (4)$$

Where Lps is the power sharing loss without interference and Lpsi is the power sharing loss with interference. Lpsi is calculated as follows:

$$Lpsi = C_{U/L}/(C_{U/L} + 2 \times C2 + N_{U/L} + IoB) \quad \text{(numeric)} \qquad (5)$$

Where C2 is the power level from one of the two ‘Other Beacon’ simultaneously received by the LEOSAR repeater.

Substituting equation 5 into equation 4 and then substituting equations 3 and 4 into equation 2 and solving for Io results in the following formula:

$$Io = (C_{U/L}((C/No)_{OI}^{-1} - (C/No)_{D/L}^{-1}) - No_{U/L})/(1 + Lps(C/N)_{D/L}^{-1}) \quad \text{(numeric)} \qquad (6)$$

Given equation 1 where $(C/No)_{OI}$ is 36.8 dBHz and Annex H, Cospas-Sarsat Link Budget, where $C_{U/L}$ is -158.2 dB, $(C/No)_{D/L}$ is 48.6 dBHz, $No_{U/L}$ is -198.6, Lps is -15.5 and $(C/N)_{D/L}$ is 48.6 dBHz minus 10log(80k) or –0.4 dB, and substituting their numeric into equation 6 yields:

$$Io = -198.2 \text{ dBW/Hz}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB (W/m^{2}Hz) at the input to the satellite 406 MHz receive antenna. The effective aperture of an antenna (A_e) having a gain of G is A_e=Gλ^2/4π. For a LEO receive antenna with the gain of –3.4 dB, the effective aperture is .02 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io - L_{Line} - A_e$$

Assuming line losses of 0.6 dB (see Figure E-D.1):

$$spfd = -198.2 + .6 - 10\log(.02) = -180.6 \text{ dB (W/m}^2\text{Hz)}$$

The maximum level of broadband noise-like interference in the 406.0 – 406.1 MHz band measured at the LEO satellite antenna shall not exceed –180.6 dB (W/m^{2}Hz).

-END OF ANNEX E-

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ANNEX F

PROTECTION REQUIREMENTS IN THE 406.0 – 406.1 MHz BAND FOR GOES GEOSAR SERVICES

F.1 Introduction

The Cospas-Sarsat GOES GEOSAR system consists of SAR instruments on board satellites in geostationary orbit. The SAR instruments are radio repeaters that receive distress beacon signals in the 406 - 406.1 MHz band and relay these signals to GEOLUTs for processing.

Article 5.266 of the ITU Radio Regulations limit the use of the band 406-406.1 MHz to low power satellite EPIRBs. Furthermore, article 5.267 states that "any emission capable of causing harmful interference to the authorized use of the band 406-406.1 MHz is prohibited". The analysis provided in this Annex establishes protection criteria for the GOES GEOSAR system from interference in the 406 MHz band that could be used in formal frequency coordination deliberations.

F.2 Criteria for Establishing Harmful Level of Interference to the GOES 406 MHz GEOSAR SARR Channel Uplink

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}.

F.3 Analysis of Spectral Power Flux Density 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 noise density being comprised of the noise developed by Cospas-Sarsat equipment (No) and the noise caused by interference from other systems (Io). Figure F.1 depicts the GOES SARR channel with interference on the uplink.

To achieve a BER of 5×10^{-5}, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the GEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the GOES 406 MHz satellite antenna that could be accommodated without degrading the overall link Eb/(No+Io) below 8.8 dB.

As depicted in Figure F.1, distress beacon signals are received by the GOES search and rescue repeater and phase modulated onto a 1544.5 MHz downlink carrier for detection and processing by GEOLUTs. The gain and system noise temperature for the satellite repeater is 7.05 dB and 359 K at point B (Figure F.1). By using sophisticated digital signal processing and burst integration techniques, when there is no interference the overall carrier to noise density ratio (C/No) equals 31.1 dBHz.

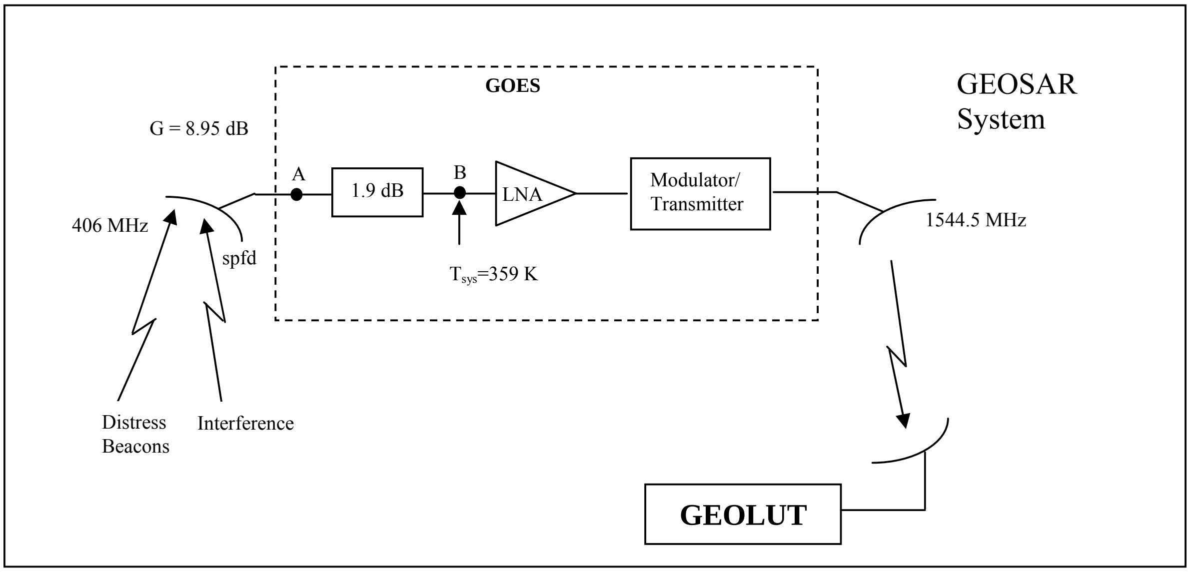

Figure F.1: GOES Repeater with Uplink Interference

This analysis assumes three simultaneously active beacons transmitting at the exact same time on three different frequencies in the 406.0 – 406.1 MHz band. The "Low-Level" beacon, which is the subject of the analysis, has an elevation angle of 5 degrees with respect to the spacecraft. The two other beacons transmit at 'Nominal-Levels' and at elevation angles of 40 degrees with respect to the spacecraft. The two "Nominal Level" beacons are included in the analysis because they share the available satellite repeater power, and, therefore, affect the link budget. This manifests itself in the link budget as a 18.3 dB sharing loss in the downlink (Annex H refers).

The complete link budget for the GOES 406 MHz SARR channel is summarised in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 31.1 dBHz, which equates to an E_b/No of 5.1 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the GEOLUT as well as GEOLUT processing gain, this results in an effective ratio of E_b/No at the GEOLUT demodulator of 10.1 dB. Since the channel requires an overall E_b/(No+Io) of at least 8.8 dB to operate effectively, any broadband interference on the uplink that reduces the overall carrier to noise plus interference density ratio by more than 1.3 dB cannot be accommodated.

Since the C/No overall in the absence of interference equates to 31.1 dBHz, broadband noise-like interference on the uplink that degrades the overall link by 1.3 dB, would result in an $(C/No)_{\text{Overall with Interference}}$ of:

$$(C/No)_{\text{Overall with Interference}} = (C/No)_{OI} = (C/No)_{\text{Overall}} - 1.3 \text{ dB}$$
$$(C/No)_{OI} = 31.1 \text{ dBHz} - 1.3 \text{ dB}$$
$$(C/No)_{OI} = 29.8 \text{ dBHz} \quad (1)$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No)_{OI} = [(C/No)^{-1}_{\text{up with interference}} + (C/No)^{-1}_{\text{down with interference}}]^{-1} \text{ (numeric)} \quad (2)$$

Since this analysis concerns interference on the uplink, $(C/No)_{up\ with\ interference}$ in equation 2 becomes:

$$(C/No)_{up\ with\ interference} = (C_{U/L}/(No_{U/L}+Io)) \quad \text{(numeric)} \tag{3}$$

The interferer also affects the downlink carrier to noise density ratio by increasing the total power shared within the SAR bandwidth. The power sharing loss is the ratio of the beacon signal power (subject of the analysis) to the total available band power. This increased total power decreases the power sharing loss and affects the downlink carrier to noise power density as follows:

$$(C/No)_{down\ with\ interference} = (C/No)_{D/L} \times (Lpsi/Lps) \quad \text{(numeric)} \tag{4}$$

Where Lps is the power sharing loss without interference and Lpsi is the power sharing loss with interference. Lpsi is calculated as follows:

$$Lpsi = C_{U/L}/(C_{U/L} + 2 \times C2 + N_{U/L} + IoB) \quad \text{(numeric)} \tag{5}$$

Where C2 is the power level from one of the two ‘Other Beacon’ simultaneously received by the GOES SARR and B is the bandwidth of the GOES receiver.

Substituting equation 5 into equation 4 and then substituting equations 3 and 4 into equation 2 and solving for Io results in the following formula:

$$Io = (C_{U/L}[(C/No)_{OI}^{-1} - (C/No)_{D/L}^{-1}] - No_{U/L})/(1 + Lps(C/N)_{D/L}^{-1}) \quad \text{(numeric)} \tag{6}$$

Given equation 1 where $(C/No)_{OI}$ is 29.8 dBHz and Annex H, Cospas-Sarsat Link Budget, where $C_{U/L}$ is –171.7 dBW, $(C/No)_{D/L}$ is 43.8 dBHz, $No_{U/L}$ is –203.0 dB(W/Hz), Lps is –18.3 dB and $(C/N)_{D/L}$ is 43.8 dBHz minus 10log(80k) or –5.2 dB, and substituting their numeric into equation 6 yields:

$$Io = (10^{-171.7/10}\,[10^{-29.8/10} - 10^{-43.8/10}] - 10^{-203/10})/(1 + 10^{-18.3/10} \times 10^{5.2/10})$$

or

$$Io = -207.7 \text{ dBW/Hz}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB (W/m^2HZ) at the input to the satellite 406 MHz receive antenna. The effective aperture of an antenna (A_e) having a gain of G is $A_e = G\lambda^2/4\pi$. For a GOES receive antenna with the gain of 8.95 dB, the effective aperture is 0.341 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io - L_{Line} - A_e$$

Assuming line losses of 1.9 dB (see Figure F.1):

$$spfd = -207.7 + 1.9 - 10\log(.341) = -201.1 \text{ dB } (W/m^2Hz)$$

The maximum level of broadband noise-like interference in the 406.0 – 406.1 MHz band measured at the GOES satellite antenna shall not exceed –201.1 dB (W/m^2Hz).

F.4 Procedure for Computing Level of Interference to the GOES SARR Channel

Interference to Cospas-Sarsat is most often a result of out-of-band emissions from services in adjacent or near adjacent bands.

The emission bandwidth must be examined to determine if energy is transmitted in the 406.0 – 406.1 MHz band. 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 a spfd level at the satellite antenna. The aggregate level for all interfering sources must not exceed -201.1 dB(W/m^2 Hz) anywhere in this range.

- END OF ANNEX F -

ANNEX G

PROTECTION REQUIREMENTS IN THE 406.0 – 406.1 MHz BAND FOR MSG GEOSAR SERVICES

G.1 Introduction

The Cospas-Sarsat MSG GEOSAR system consists of SAR instruments on board satellites in geostationary orbit. The SAR instruments are radio repeaters that receive distress beacon signals in the 406 - 406.1 MHz band and relay these signals to GEOLUTs for processing beacon identification and associated data.

Article 5.266 of the ITU Radio Regulations limit the use of the band 406-406.1 MHz to low power satellite EPIRBs. Furthermore, article 5.267 states that "any emission capable of causing harmful interference to the authorized use of the band 406-406.1 MHz is prohibited". The analysis provided in this Annex establishes protection criteria for the MSG GEOSAR system from interference in the 406 MHz band that could be used in formal frequency coordination deliberations.

G.2 Criteria for Establishing Harmful Level of Interference to the MSG GEOSAR SARR Channel Uplink

To reliably detect 406 MHz distress beacons using MSG 406 MHz satellite repeaters the bit error rate (BER) of the channel must not exceed $5x10^{-5}$.

G.3 Analysis of Spectral Power Flux Density 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 noise density being comprised of the noise developed by Cospas-Sarsat equipment (No) and interference noise generated from other systems (Io). Figure G.1 depicts the MSG SARR channel with interference on the downlink.

To achieve a BER of $5x10^{-5}$, the ratio of the energy per bit to noise plus interference density E_b/(No+Io) at the GEOLUT demodulator must equal or exceed 8.8 dB. This analysis determines the maximum amount of broadband noise-like interference specified as a spectral power flux density (spfd) referenced to the input to the MSG 406 MHz satellite antenna that could be accommodated without degrading the overall link Eb/(No+Io) below 8.8 dB.

As seen in Figure G.1, 406 MHz distress beacon signals are received by the MSG search and rescue repeater (SARR) and are translated in frequency to a frequency band centred on 1544.5 MHz for detection and processing by GEOLUTs. The gain and system noise temperature for the satellite repeater are 3.0 dB and 326K at point A (Figure G.1). By using sophisticated digital signal processing and burst integration techniques, when there is no interference the overall carrier to noise density ratio (C/No) equals 27.4 dBHz.

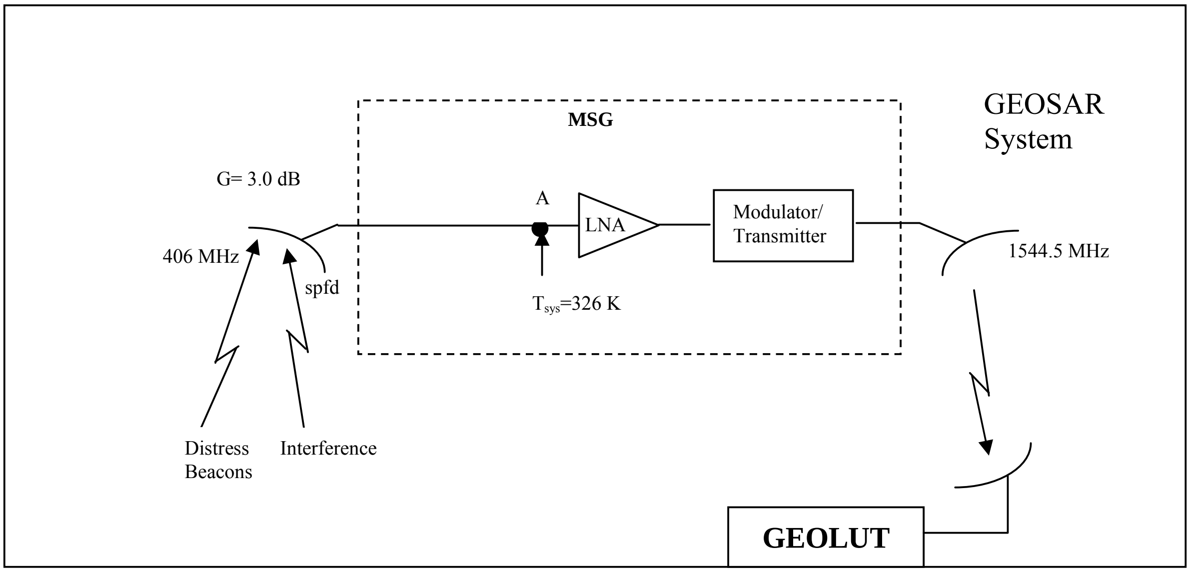

Figure G.1: MSG Repeater with Uplink Interference

The complete link budget for the MSG 406 MHz SARR channel is summarised in tabular format at Annex H. When no external sources of interference are present the overall C/No of the link is 27.4 dBHz, which equates to an E_b/No of 1.4 dB. Under such conditions, and accounting for implementation and beacon data demodulation losses at the GEOLUT as well as GEOLUT processing gain, this results in an effective ratio of E_b/No at the GEOLUT demodulator of 8.9 dB. Since the channel requires an overall E_b/(No+Io) of at least 8.8 dB to operate effectively, any broadband interference on the downlink that reduces the overall carrier to noise plus interference density ratio by more than 0.1 dB cannot be accommodated.

Since the C/No in the absence of interference equates to 27.4 dBHz, broadband noise-like interference on the downlink that degrades the overall link by 0.1 dB, would result in a $(C/No+Io)_{overall}$ of:

$$\begin{aligned}(C/No+Io)_{overall} &= (C/No)_{overall} - 0.1 \text{ dB}\\ &= 27.4 \text{ dBHz} - 0.1 \text{ dB}\\ &= 27.3 \text{ dBHz}\end{aligned}$$

The overall carrier to noise plus interference density ratio can be calculated from the carrier to noise plus interference density ratios of the uplink and downlink as indicated below:

$$(C/No+Io)_{overall}=[(C/No+Io)^{-1}_{up} + (C/No+Io)^{-1}_{down}]^{-1}$$

Since this analysis only concerns interference on the uplink, it is assumed that there is no interference on the downlink, the equation simplifies to:

$$(C/No+Io)_{overall}=[(C/No+Io)^{-1}_{up} + (C/No)^{-1}_{down}]^{-1}$$

Substituting the values for $(C/No+Io)_{overall}$ (27.3 dBHz, see above) and $(C/No)_{down}$ (35.5 dBHz, see Annex H), the value of the worst-case acceptable carrier to noise plus interference density ratio $[(C/No+Io)_{up}]$ is 28.0 dBHz (see below):

$$C/(No + Io)_{up} = ((C/No + Io)_{overall}{}^{-1} - (C/No)_{down}{}^{-1})^{-1}$$

or

$$C/(No + Io)_{up} = 10\log((10^{-27.3/10} - 10^{-35.5/10})^{-1})$$

then

$$C/(No + Io)_{up} = 28.0 \text{ dBHz}$$

Solving for Io yields:

$$Io = 10*\log[10^{(Cup-(C/(No+Io)up)/10} - 10^{(No(up)/10)}]$$

The noise power spectral density of the uplink without interference at point A is No=kT, where k is Boltzmann's constant and T is the repeater noise temperature referenced to point A. Therefore, No(up) = -228.6+25.1 = -203.5 dB(W/Hz). The uplink carrier power is Cup = -175.7 dBW. Therefore, the maximum acceptable value for the noise density in the uplink $(Io)_{up}$ is:

$$(Io)_{up} = 10*\log[10^{(-175.7-28.0)/10} - 10^{(-203.5/10)}]$$

or

$$(Io)_{up} = -217.0 \text{ dB(W/Hz)}$$

It is desirable to characterize the protection criteria in terms of the spectral power flux density (spfd) interference threshold specified in dB(W/m^2 Hz) at the input to the satellite 406 MHz receive antenna. The effective aperture of an antenna (A_e) having a gain of G is $A_e = G\lambda^2/4\pi$. For MSG receive antennas with gains of 3.0 dB the effective aperture is 0.087 m^2. Therefore, the maximum acceptable aggregate interference specified as a spfd is:

$$spfd = Io(max) - A_e$$

$$spfd = -217.0 - 10\log(0.087) = -206.4 \text{ dB(W/m}^2\text{ Hz)}$$

The maximum level of broadband noise-like interference in the 406.0 – 406.1 MHz band measured at the MSG satellite antenna shall not exceed –206.4 dB(W/m^2 Hz).

G.4 Procedure for Computing Level of Interference to the MSG SARR Channel

Interference to Cospas-Sarsat is most often a result of out-of-band emissions from services in adjacent or near adjacent bands.

The emission bandwidth must be examined to determine if energy is transmitted in the 406.0 – 406.1 MHz band. 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 a spfd level at the satellite antenna. The aggregate level for all interfering sources must not exceed –206.4 dB(W/m^2 Hz) anywhere in this range.

- END OF ANNEX G -

ANNEX H

COSPAS-SARSAT LINK BUDGETS

			LEOSAR		GEOSAR				MEOSAR	
			Sarsat PDS	Sarsat SARR	Cospas SARR	GOES SARR	MSG SARR	Electro SARR	Galileo SARR	Glonass SARR
					EPIRB to Spacecraft Uplink					
Parameter	Units	See Note	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case
SAR bandwidth	kHz	1		80.0	80.0	80.0	100.0	80.0	50.0 / 80.0	80.0
Data Rate, Rb	b/s			400.0	400.0	400.0	400.0	400.0	400.0	400.0
Frequency	MHz	2		406.05	406.05	406.05	406.05	406.05	406.05	406.05
Transmit power	dBW	3		5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tx Antenna Gain	dB	4		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
EIRP	dBWi			3.0	3.0	3.0	3.0	3.0	3.0	3.0
Elevation Angle	Deg	5		5.0	5.0	5.0	5.0	5.0	5.0	5.0
Path Distance	km			2900.0	3200.0	41126.3	41126.3	41126.3	28354.4	24158.0
Path Loss	dB			153.8	154.7	176.9	176.9	176.9	173.7	172.3
Polarization Loss	dB	6				4.9	4.5	4.9	4.0	4.0
Fading Loss	dB			2.5	2.5			-	2.5	2.5
G/T of Satellite Rx Antenna	dB/K	7		-34.0	-34.0	-18.5	-22.1	-17.5	-15.7	-17.0
Boltzmann's Constant	dB (J/K)			-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
Uplink C/No	dBHz			41.3	40.4	31.3	28.1	32.3	35.7	35.8
					Space to Earth Downlink					
Parameter	Units	See Note	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case	Low Level Case
Downlink Frequency	MHz	8	1544.5	1544.5	1544.5	1544.5	1544.5	1544.5	1544.1	1544.8
Transmit EIRP	dBW	9	7.1	7.1	6.2	15.0	-18.9	18.0	1.6	15.0
Power Sharing Loss	dB	10		15.3	15.5	18.3		-17.4	/	14.8
Modulation Loss	dB	11	14.1	14.1	6.0	3.54		3.54	/	/
Elevation Angle	Deg	12	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Path Distance	km		2900.0	2900.0	3200.0	41126.3	41126.3	41,126.3	28354.4	24158.0
Path Loss	dB		165.5	165.5	166.4	188.46	188.46	188.49	185.3	183.9
G/T of LUT Rx Antenna	dB/K	13	4.3	4.3	4.3	11.0	15.5	11.9	3.0	4.0
Polarization Loss	dB	14				0.35	0.2	0.35	0.2	0.35
Other Losses	dB		2.6	2.6	2.6			-	1.0	1.0
Pointing Loss		15				0.20	1.0	0.2	0.1	0.2
Short Term Fading Loss	dB	16	10.0					-		-
Downlink C/No	dBHz		47.8	42.5	48.6	43.8	35.5	48.5	46.7	47.6
Overall C/No	dBHz			38.8	39.8	31.1	27.4	32.2	35.4	35.5
Data Rate, Rb	dB	17	33.8	26.0	26.0	26.0	26.0	26.0	26.0	26.0
Eb/No	dB		14.0	12.8	13.8	5.1	1.4	6.18	9.4	9.5
Implementation Loss	dB		1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0
Bcn Data Modulation Loss, b=1.1 rad	dB	18		1.0	1.0	1.0	1.0	1.0	1.0	1.0
Coding Gain	dB		0.0	0.0	0.0	0.0	2.0	0.0	2.0	2.0
Processing Gain (5 bursts)	dB	19				7.0	7.0	7.0	0.0	0.0
Available Eb/No	dB		13.0	10.8	11.8	10.1	8.9	11.2	9.9	9.5
Theoretical Eb/No for 1E-6 and 5E-05 BERs	dB	20	10.6	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Margin	dB	21	2.40	2.04	3.0	1.3	0.1	2.4	1.10	0.7

Notes to Cospas-Sarsat Link Budget (used for System Protection Criteria)

1. Nominal 1 dB bandwidth of satellite receiver, centred at 406.05 MHz. For MEOSAR the normal (wide) bandwidth is considered in the link budget.

2. Beacon frequencies are within the range 406.022 to 406.079 MHz.

3. A beacon transmitter can range from 5 to 9 dBW, so this weak beacon (5dBW) beacon is used for the link budget calculation, while two additional nominal 406 MHz beacons are also assumed to be transmitting bursts simultaneously, each at 40 degree elevation to the satellite, with 7 dBW, 0 dB antenna gain, 1 dB emission loss, so 6 dBW EIRP uplink (this additional beacon loading affects the power sharing value of the satellite transmitter).

4. Transmit antenna is linearly polarised.

5. The 5-degree elevation from the beacon to the satellite is the nominal edge of coverage, and the nominal altitude of the GEOSAR satellites is 35,786 km, 850km for Sarsat satellites (ranges from 830 to 870km) and 1,000 km for Cospas satellites. For the Glonass satellites, the nominal altitude is 19,140 km and a 5° elevation from the beacon to the Glonass satellites is assumed (see C/S R.012 (MIP), Annex J).

6. Polarization loss due to linear polarisation of the beacon antenna and fading of the uplink signal. The polarization loss of the LEOSAR link is included in the antenna gain, and is therefore reflected in the G/T of the satellite Rx antenna.

6a. Allowance of 2.5dB for fading of the signal (dominated by scintillation) is provided for the link, as per MIP Annex J.7. G/T of the satellite 406 MHz receiver referenced to the LNA input, where nominal gain and noise temperatures are:

GOES: G= 7.05 dB and Noise Temp = 359K;

MSG: G= 3.0 dB and Noise Temp= 326K;

Sarsat: G= -4.0 dB and Noise Temp=1000K;

Cospas: G= -4.0 dB and Noise Temp=1000K;

Glonass: G=11.5 dB and Noise Temp=700K;

Electro-L: G=12.0 dB and Noise Temp=891K.

8. Downlink frequency band allocated for distress and safety is 1544 – 1545 MHz.

9. EIRP based on satellite transmitter power and transmit antenna gain. In the cases of MSG and Galileo the EIRP for the observed beacon is given (hence all power sharing with other beacons and thermal noise is included).

10. Power sharing loss is the fraction of the transmit EIRP allocated for this one distress beacon signal. The “Power sharing loss” has been included in the item “Transmit EIRP” in cases of MSG and GALIELO. The power sharing loss for the LEOSAR and GEOSAR are calculated below.

    a. The power sharing loss for the LEOSAR Repeater (Sarsat) is calculated as follows:

C1 = ‘Low Level’ beacon. Power received at the spacecraft due to C1 is –157.3 dB.

C2 = ‘Other Beacon’. Power received at the spacecraft due to C2 is –146 dB.

kTB = The noise power at the spacecraft in the bandwidth of interest.

kTB= 10Log(Bandwidth) + 10Log(degrees K) + 10Log(Boltzman’s constant).

kTB = 10Log(80000 Hz) + 10Log(1000 K) + 10Log($1.38x10^{-23}$) = -149.6

Pt = Total power in the spacecraft receiver.

Pt = $10^{C1/10} + 2 \times 10^{C2/10} + 10^{kTB/10} + 10^{IoB/10}$, Pt =$10^{-15.73} + 2 \times 10^{-14.6} + 10^{-14.96}$
= -142.0 dB (No interference included in this calculation).

The power sharing loss without interference is C1/Pt. C1/Pt = -157.3 dB – (-142 dB)
=-15.3 dB.

b. The power sharing loss for the LEOSAR Repeater (Cospas) is calculated as follows:

C1 = 'Low Level' beacon. Power received at the spacecraft due to C1 is -158.2 dB.

C2 = 'Other Beacon'. Power received at the spacecraft due to C2 is -146.9 dB.

kTB = The noise power at the spacecraft in the bandwidth of interest.

kTB= 10Log(Bandwidth) + 10Log(degrees K) + 10Log(Boltzman's constant).

kTB = 10Log(80000 Hz) + 10Log(1000 K) + 10Log($1.38x10^{-23}$) = -149.6

Pt = Total power in the spacecraft receiver.

Pt = $10^{C1/10} + 2 \times 10^{C2/10} + 10^{kTB/10} + 10^{IoB/10}$, Pt =$10^{-15.82} + 2 \times 10^{-14.69} + 10^{-14.96}$
= -142.7 dB (No interference included in this calculation).

The power sharing loss without interference is C1/Pt. C1/Pt = -158.2 dB – (-142.7 dB)
=-15.5 dB.

c. The power sharing loss for the GOES Repeater is calculated as follows:

C1 = 'Low Level' beacon. Power received at the spacecraft due to C1 is -171.7 dB.

C2 = 'Other Beacon'. Power received at the spacecraft due to C2 is -166.0 dB.

kTB = The noise power at the spacecraft in the bandwidth of interest.

kTB= 10Log(Bandwidth) + 10Log(degrees K) + 10Log(Boltzman's constant).

kTB = 10Log(80000 Hz) + 10Log(359K) + 10Log($1.38x10^{-23}$) = -154.0 dB.

Pt = Total power in the spacecraft receiver.

Pt = $10^{C1/10} + 2 \times 10^{C2/10} + 10^{KTB/10} + 10^{IoB/10}$, Pt = $10^{-17.17} + 2 \times 10^{-16.60} + 10^{-15.4}$
=-153.4 dB (No interference included in this calculation).

The power sharing loss without interference is C1/Pt. C1/Pt = -171.7 dB – (-153.4 dB)
= -18.3 dB.

d. The power sharing loss for the Glonass Repeater is calculated as follows:

C1 = 'Low Level' beacon. Power received at the spacecraft due to C1 is -164.35 dB.

C2 = 'Other Beacon'. Power received at the spacecraft due to C2 is -158.5 dB.

kTB= The noise power at the spacecraft in the bandwidth of interest.

kTB = 10Log(Bandwidth) + 10Log(degrees K) + 10Log(Boltzman's constant)

kTB = 10Log(80000 Hz) + 10Log(700K) + 10Log($1.38x10^{-23}$) = -151.1 dB

Pt = Total power in the spacecraft receiver.

Pt = $10^{C1/10} + 2 \times 10^{C2/10} + 10^{kTB/10}$, Pt = $10^{-16.43} + 2 \times 10^{-15.85} + 10^{-15.1}$ = -149.6 dB

(No interference included in this calculation).

The power sharing loss without interference is C1/Pt.

C1/Pt = -164.35 dB – (-149.6 dB) = -14.8 dB.

e. The power sharing loss for the ELECTRO-L Repeater is calculated as follows:

C1 = 'Low Level' beacon. Power received at the spacecraft due to C1 is -166.8 dB.
C2 = 'Other Beacon'. Power received at the spacecraft due to C2 is -161.1 dB.
kTB = The noise power at the spacecraft in the bandwidth of interest.
kTB= 10Log(Bandwidth) + 10Log(degrees K) + 10Log (Boltzman's constant).
kTB = 10Log(80000 Hz) + 10Log(891K) + 10Log(1.38×10^{-23}) = -150.1 dB
Pt = Total power in the spacecraft receiver.
Pt = $10^{C1/10} + 2 \times 10^{C2/10} + 10^{kTB/10}$
Pt = $10^{-16.68} + 2 \times 10^{-16.11} + 10^{-15.01}$= -149.4 dB
(No interference included in this calculation).

The power sharing loss without interference is C1/Pt.

C1/Pt = -166.8 dB – (-149.4 dB) = -17.4 dB.

11. Modulation loss is the fraction of the transmit EIRP allocated to the 406 MHz repeater band on the satellite, as set by the phase modulation index (not applicable for MSG and MEOSAR satellites, which have direct frequency translation).

12. 5 degree elevation angle from the LUT to the satellite is the nominal edge of coverage.

13. G/T uses nominal values for each type of LUT.

14. Polarization loss for each type of LUT antenna.

15. Pointing Loss due to LUT antenna pointing.

16. Short duration 10dB drops in the carrier level due to high modulation in other channels before the AGC responds.

17. Data rate is 400 bps for the beacon emission and 2400 bps for the PDS.

18. Beacon data modulation loss, since some power is intentionally retained in the carrier, as the modulation index is set to 1.1 ± 0.1 radians.

19. Processing gain due to the integration of several beacon bursts at the LUT. For MEOSAR single burst demodulation is assumed (MIP, Annex J). Single burst demodulation is assumed for MEOSAR (MIP, Annex J).

20. Bit Error Rate (BER) for repeater band is 5.0×10^{-5}, as stated in Recommendation ITU-R M.1478, whereas for the PDS channel it is 1.0×10^{-6}.

21. Margin is the extra signal remaining that might be taken when there is interference.

- END OF ANNEX H -

ANNEX I

SUMMARY OF COSPAS-SARSAT 406 MHz BEACON DATA PROTECTION CRITERIA AGAINST BROADBAND INTERFERENCE

Channel	C/(No+Io) dBHz	No dB(W/Hz)	Io(max) dB(W/Hz)	spfd dB(W/m^{2}Hz)	Frequency Range MHz
Cospas SARP Uplink	39	-200.8	-207.8	-198.6	406.0 - 406.1
Sarsat SARP Uplink	37.3	-198.6	-210.1	-198.6	406.0 - 406.1
Cospas and Sarsat PDS Downlink	N/A	-206.2	-207.5	-209.0	1544.45 - 1544.55
Sarsat SARR Uplink	36.8	-198.6	-198.9	-181.3	406.0 - 406.1
Sarsat SARR Downlink	36.8	-206.2	-204.7	-206.2	1544.2 - 1544.8
GOES SARR Uplink	29.8	-203.0	-207.7	-201.1	406.0 - 406.1
GOES SARR Downlink	29.8	-206.4	-198.3	-206.4	1544.4 - 1544.6
MSG SARR Uplink	27.3	-203.5	-217.0	-206.4	406.0 - 406.1
MSG SARR Downlink	27.3	-208.4	-209.7	-220.5	1544.4 - 1544.6

- END OF ANNEX I -

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ANNEX J

EXISTING AND PLANNED SYSTEMS OPERATING IN THE 1544 – 1545 MHz BAND

J.1 Introduction

Cospas-Sarsat became the initial user of the 1544 – 1545 MHz distress and safety frequency band with the launch of the first Cospas LEO satellite in June of 1982. The Cospas-Sarsat space segment has continued to evolve and includes payloads on satellites in LEO and GEO orbit, with plans in place to further augment the System to include SAR payloads on satellites in medium-altitude Earth orbit (MEOSAR).

The existing and planned use of the 1544 – 1545 MHz band is graphically depicted at Figure J.1and J.2. Analyses of the spectral occupancy requirements for Cospas-Sarsat instruments and other systems that are planned to be operated in the band are provided in the following sections of this Annex.

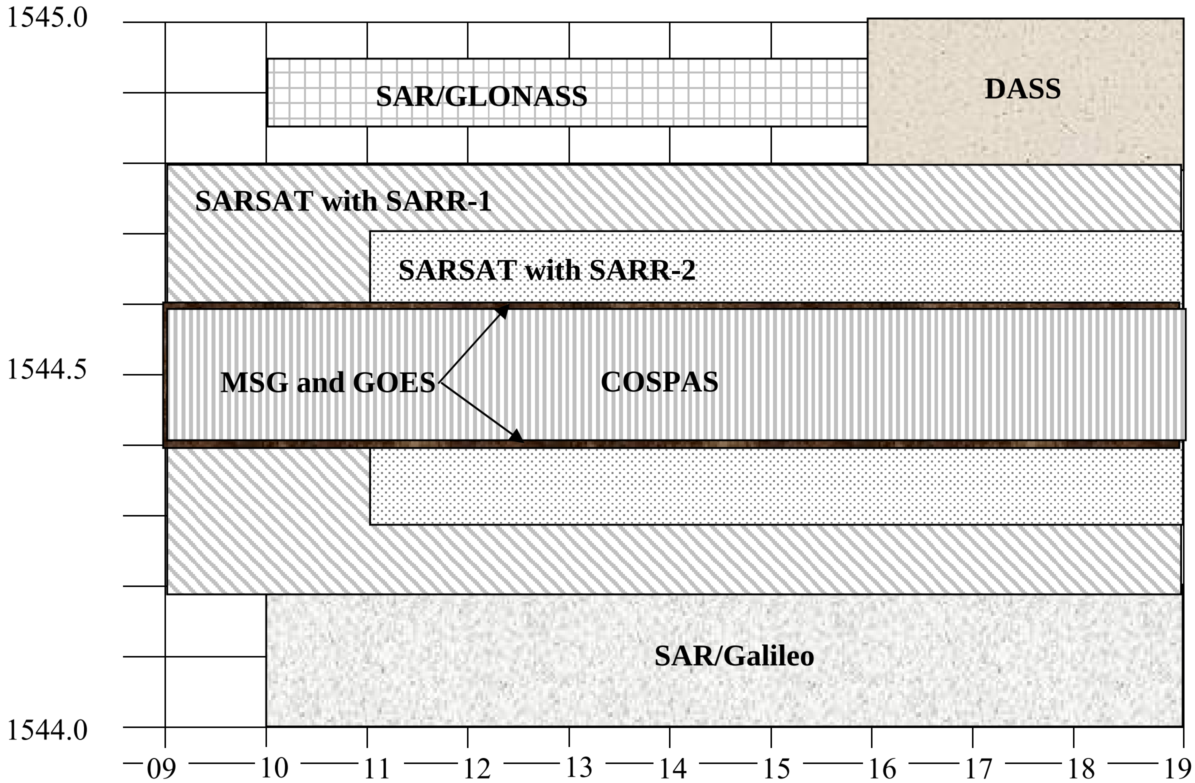

Figure J.1: Existing and Planned Use of the 1544 – 1545 MHz Band (2009 – 2019)

Note: SAR/Galileo will occupy approximately 100 kHz.

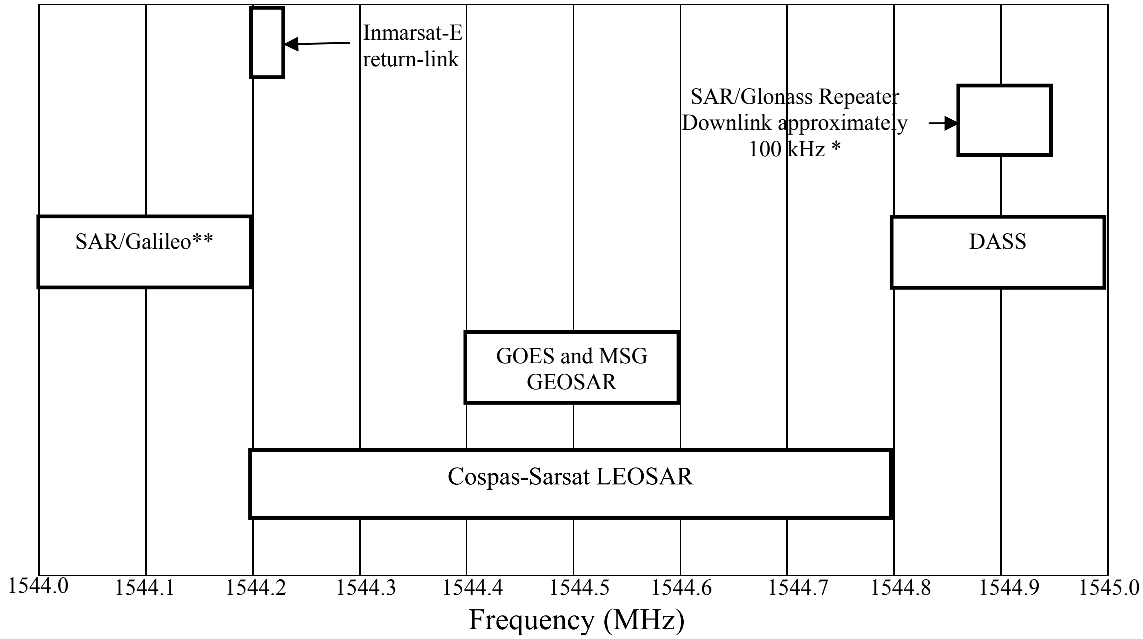

Figure J.2: Existing and Planned Use of the 1544 – 1545 MHz Band

Notes:. * exact location of SAR/Glonass processor and repeater downlinks have yet to be determined; and
** SAR/Galileo will occupy approximately 100 kHz.

J.2 1544 – 1545 MHz Bandwidth Requirements for Sarsat SARR-1 Payloads

Sarsat SARR-1 Payload Downlink Characteristics	
Downlink emission polarity	LHCP
Downlink centre frequency	1544.5 MHz
Long-term frequency stability (C/S T.003, Table 3.4)	± 3.2 kHz
Doppler frequency range	± 36 kHz
Guard band (each edge of spectrum)	20 kHz

The SARP and SARR channels are phase modulated onto the 1544.5 MHz downlink with a composite phase modulation index of 0.7 radians rms. The maximum modulating frequency is at the upper edge of the 406 MHz channel. The 406 MHz channel 3 dB bandwidth is approximately 90 kHz centred at 170 kHz in the baseband. This results in a baseband maximum modulating frequency of 170 + 45 = 215 kHz. The spurious emissions from Sarsat SARR transmitters must be considered by other systems planning to operate in the 1544 – 1545 MHz band. The maximum spurious emission limits are described in document C/S T.003 (description of LEOSAR payloads), and a spectral plot from an actual SARR transmitter is provided at Appendix A.

Due to the relatively narrow band phase modulation and ground station filtering, LEOLUTs tracking these satellites can adequately process the SAR data when receiving the carrier and first order spectral sidebands. Without accounting for long-term frequency offsets and Doppler frequency, the necessary bandwidth is 1544.5 MHz ± 215 kHz or 1544.2850 MHz to 1544.7150 MHz.

By adding the effects of long-term frequency stability, Doppler frequency, and guard band, the "necessary bandwidth" required for reliable LEOLUT processing is 1544.2258 MHz to 1544.7742 MHz.

The necessary bandwidth for LEOLUT processing of SAR downlink signals from Sarsat satellites that have a SARR - 1 service, is:

1544.2 MHz to 1544.8 MHz

J.3 1544 – 1545 MHz Bandwidth Requirements for Sarsat SARR-2 Payloads

Sarsat SARR-2 Payload Downlink Characteristics	
Downlink emission polarity	LHCP
Downlink centre frequency	1544.5 MHz
Long-term frequency stability (C/S T.003, Table 3.4)	± 3.2 kHz
Doppler frequency range	± 36 kHz
Guard band (each edge of spectrum)	20 kHz

The SARP channel and 406 MHz SARR channel are phase modulated onto the 1544.5 MHz downlink with a composite phase modulation index of 0.5 radians rms. The maximum modulating frequency is at the upper edge of the 406 MHz channel. The 406 MHz channel 3 dB bandwidth is approximately 90 kHz centred at 88.46 kHz in the baseband. This results in a baseband maximum modulating frequency of 88.46 +45 = 133.46 kHz.

Due to the narrow band phase modulation and ground station filtering, LEOLUTs tracking these satellites can adequately process the SAR data when receiving the carrier and first order spectral sidebands. Without accounting for long-term frequency offsets and Doppler frequency, the necessary bandwidth is 1544.5 MHz ± 133.46 kHz or 1544.36654 MHz to 1544.63346 MHz.

By adding the effects of long-term frequency stability, Doppler frequency, and guard band, the "necessary bandwidth" required for reliable LEOLUT processing is 1544.30734 MHz to1544.69266 MHz.

The necessary bandwidth for LEOLUT processing of SAR downlink signals from Sarsat satellites that have a SARR- 2 service is:

1544.3 MHz to 1544.7 MHz

J.2 1544 – 1545 MHz Bandwidth Requirements for Cospas Payloads

Cospas Payload Downlink Characteristics	
Downlink emission polarity	LHCP
Downlink centre frequency	1544.5 MHz
Long-term frequency stability (C/S T.003, Table 3.4)	± 1.5 kHz
Doppler frequency range	± 36 kHz
Guard band (each edge of spectrum)	20 kHz

The SARP channel is phase modulated onto the 1544.5 MHz downlink with a composite phase modulation index of 0.6 radians rms. In baseband the SARP [2.4] kbps PDS data channel is centered at [2.4] kHz. This results in a baseband maximum modulating frequency of [2.4] +[1.2] = [3.6] kHz.

Due to the narrow band phase modulation and ground station filtering, LEOLUTs tracking Cospas satellites can adequately process the SAR data when receiving the carrier and first order spectral sidebands. Without accounting for long-term frequency offsets and Doppler frequency the necessary bandwidth is 1544.5 MHz ± [3.6] kHz or [1544.4494] MHz to 1544.5036 MHz.

By adding the effects of long-term frequency stability, Doppler frequency, and guard band the "necessary bandwidth" required for reliable LEOLUT processing is [1544.4389] MHz to [1544.5611] MHz.

The necessary bandwidth for LEOLUT processing of SAR downlink signals from Cospas satellites is:

[1544.43] MHz to [1544.57] MHz

J.3 1544 – 1545 MHz Bandwidth Requirements for GOES Payloads

GOES Payload Downlink Characteristics	
Downlink emission polarity	RHCP
Downlink centre frequency	1544.5 MHz
Long-term frequency stability (C/S T.011)	± 3.9 kHz
Doppler frequency range	negligible
Guard band (each edge of spectrum)	10 kHz

The 406 MHz channel is phase modulated onto the 1544.5 MHz downlink with a phase modulation index of 1.1 radians rms. The maximum modulating frequency at the upper edge of the 406 MHz channel baseband occurs in the wideband mode and is approximately 90 kHz.

GEOLUTs tracking these satellites can adequately process the SAR data when receiving the carrier and first order spectral sidebands. Without accounting for long-term frequency offsets, the necessary bandwidth is 1544.5 MHz ± 90 kHz or 1544.41 MHz to 1544.59 MHz.

By adding the effects of long-term frequency stability and guard band, the "necessary bandwidth" required for reliable GEOLUT processing is 1544.3961 MHz to 1544.6039 MHz.

The necessary bandwidth for GEOLUT processing of SAR downlink signals from GOES satellites is:

1544.4 MHz to 1544.6 MHz

J.4 1544 – 1545 MHz Bandwidth Requirements for MSG Payloads

MSG Payload Downlink Characteristics	
Downlink emission polarity	linear
Downlink centre frequency	1544.5 MHz
Long-term frequency stability (C/S T.011)	± 13.9 kHz
Doppler frequency range	negligible
Guard band (each edge of spectrum)	10 kHz

The MSG spacecraft directly translates the 406 MHz band to the L-band downlink centred at 1544.5 MHz. The on-board 406 MHz channel filter 0.5 dB bandwidth is 100 kHz. This results in a useable downlink transmission ranging from 1544.45 MHz to 1544.55 MHz.

By adding the effects of long-term frequency stability and guard band, the necessary bandwidth needed for reliable GEOLUT processing is 1544.4261 MHz to 1544.5739 MHz.

The necessary bandwidth for GEOLUT processing of SAR downlink signals from MSG satellites is:

1544.42 MHz to 1544.58 MHz

J.5 1544 – 1545 MHz Bandwidth Requirements for DASS Payloads

The Distress Alerting Satellite System (DASS) currently being considered as a potential enhancement to the Cospas-Sarsat system would be comprised of 406 MHz SAR instruments to be flown on USA Global Positioning System satellites. A full constellation of DASS instruments would include SAR payloads on at least 24 satellites.

Operating DASS downlinks in the 1544-1545 MHz band is desirable since this band is allocated strictly for distress and safety use. However, caution must be used in development of a 1544-1545 MHz DASS downlink to assure non-interference with existing Cospas-Sarsat systems and other planned systems such as SAR/Galileo and SAR/Glonass.

A potential design for DASS is to use direct frequency translation of the 406 MHz uplink band to L-band. It is estimated that DASS would require 200 kHz of spectrum and could be placed at:

1544.8 MHz – 1545.0 MHz.

J.6 1544 – 1545 MHz Bandwidth Requirements for SAR/Galileo Payloads

The SAR/Galileo system currently being considered as a potential enhancement to the Cospas-Sarsat system would be comprised of 406 MHz SAR instruments to be flown on the Galileo GNSS satellites. A full constellation of SAR/Galileo instruments would include SAR payloads on at least 27 satellites.

SAR/Galileo is planning to operate with downlinks in the 1544-1545 MHz band. Caution must be used in development of the downlink to assure non-interference with existing Cospas-Sarsat systems and other planned systems such as DASS and SAR/Glonass.

A potential design for SAR/Galileo is to use direct frequency translation of the 406 MHz uplink band to L-band. It is estimated that SAR/Galileo would require 100 kHz of spectrum and could be placed at:

1544.0 – 1544.2 MHz (the exact location has yet to be determined).

J.7 1544 – 1545 MHz Bandwidth Requirements for SAR/Glonass Payloads

The SAR/Glonass system currently being considered as a potential enhancement to the Cospas-Sarsat systems would be comprised of 406 MHz SAR instruments to be flown on the Glonass GNSS satellites. The planned SAR/Glonass payloads would include a 406 MHz direct frequency translation. The two onboard instruments would have separate downlinks.

The repeater downlink would require approximately 100 kHz of spectrum and is tentatively planned to be located in the band:

1544.8 – 1545.0 MHz (the exact location has yet to be determined).

Analysis is underway to design SAR/Glonass downlinks that would not generate harmful interference to existing Cospas-Sarsat systems, nor to the DASS and SAR/Galileo systems.

APPENDIX A TO ANNEX J

SARSAT SARR TRANSMITTER EMISSION TEST RESULTS

[New Figure to be provided]

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