COSPAS-SARSAT MEOSAR REFERENCE BEACON NETWORK DESIGN GUIDELINES

C/S T.022

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This document is provided as a complement to the final clean version of the document. In case of discrepancy between this marked-up version and the clean final version, the information in the clean final version shall prevail.

COSPAS SARSAT MEOSAR REFERENCE BEACON NETWORK DESIGN GUIDELINES

HISTORY

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TABLE OF CONTENTS

Page

LIST OF ANNEXES

1. INTRODUCTION

1.1 Overview

The purpose of the Cospas-Sarsat System is to provide distress alert and location data for search and rescue (SAR), by using spacecraft and ground facilities to detect and locate distress signals and transmit the computed position and other related information to appropriate SAR authorities.

1.2 Scope

This document describes the Cospas-Sarsat MEOSAR reference beacon network and gives the specifications and design guidelines of its elements.

1.3 Reference Documents

Reference	Title
C/S A.002	Cospas-Sarsat Mission Control Centres Standard Interface Description (SID)
C/S A.003	Cospas-Sarsat System Monitoring and Reporting
C/S G.003	Introduction to the Cospas-Sarsat System
C/S T.001	Specification for Cospas-Sarsat 406 MHz Distress Beacons
C/S T.016	Description of the 406 MHz Payload Used in the Cospas-Sarsat MEOSAR System
C/S T.018	Specification for Second-Generation Cospas-Sarsat 406-MHz Distress Beacons
C/S T.019	Cospas-Sarsat MEOLUT Performance Specification and Design Guidelines

- END OF SECTION 1 -

2. COSPAS-SARSAT MEOSAR REFERENCE BEACON NETWORK

2.1 Purpose

The Cospas-Sarsat MEOSAR system is designed to provide global coverage. All MEOLUTs have the capability to detect and locate 406-MHz distress beacons within, at a minimum, their Declared Coverage Area. The location accuracy achieved is dependent on various parameters, including the accuracy of TOA and FOA measurements.

MEOSAR reference beacons are deployed with characteristics particularly suited to benefit MEOLUTs with a view towards:

- supporting the calibration of the TOA and FOA measurements by the MEOLUTs, which allow MEOLUTs (stand-alone or networked) to meet required location performance. For this purpose, MEOSAR reference beacons should have well defined and tightly controlled timing and frequency characteristics.
- being used for the monitoring of MEOSAR performance and the QMS of the MEOSAR system. The monitoring may include the continuous oversight of one or more of the following MEOLUT parameters:
    - system detection rate,
    - system localisation performance (probability and accuracy),
    - MEOLUT throughput and single satellite-MEOLUT channel throughput,
    - TOA and FOA estimation accuracy of a MEOLUT.

These beacons also provide a resource to complete the Quality Management System (QMS) objectives stated in section 7 of document C/S P.015 “Cospas-Sarsat Quality Manual”.

2.2 Characteristics

The MEOSAR reference beacon network has been developed with the view that each MEOSAR satellite has at least one MEOSAR reference beacon in its field of view, thus allowing any MEOLUT to calibrate its time and frequency measurements when tracking any MEOSAR satellite. MEOSAR reference beacons also allow the monitoring of the performance of each MEOLUT channel (satellite/MEOLUT-antenna pair), to contribute to the overall MEOSAR QMS.

2.3 Guideline for the Deployment of MEOSAR Reference Beacons

To limit adverse impact on the System, including the avoidance of unnecessary channel congestion, Participants are encouraged to:

- not install more than one MEOSAR reference beacon per MEOLUT,

- coordinate at a regional level, and at a Programme level through the Secretariat, the installation and, importantly, the transmission timing, frequency and schedule of their MEOSAR reference beacon, with a view towards limiting the number of beacon bursts to the minimum required to ensure defined MEOSAR performance.

Reference beacon providers shall provide technical characteristics of their beacons to the Secretariat, to allow this information to be published and made available on the Cospas-Sarsat website, including frequency and time characteristics, hex ID and transmission timing and schedule.

2.4 List of MEOSAR Reference Beacons in the System

The complete list of beacons, including the identification, location of each, technical characteristics and status is provided on the Cospas-Sarsat website www.cospas-sarsat.int.

- END OF SECTION 2 -

3. GUIDELINES FOR MEOSAR REFERENCE BEACON REQUIREMENTS AND SPECIFICATIONS

3.1 Guidelines for Supplying a MEOSAR Reference Beacon

Supplying a MEOSAR Reference Beacon

A MEOSAR reference beacon is supplied by a country accepting the commitment stated in Annex A.

Availability

Once a MEOSAR reference beacon has been installed, its availability should be greater than 95%.

Antenna Blockage

The MEOSAR reference beacon antenna should provide the widest possible horizon.

Location Data

The beacon antenna location (longitude, latitude, altitude) should be provided with a three dimensional accuracy better than 1 m. This location should be given with respect to the Bureau International de l'Heure (BIH) Conventional Terrestrial System, having a reference ellipsoid defined as follows [or expressed in WGS84]:

Semi-major axis = 6,378,137 m
Flattening (ellipticity) = 1/298.2572

The location of all MEOSAR reference beacons is given on the Cospas-Sarsat website www.cospas-sarsat.int.

3.2 Specifications Unique to a MEOSAR Reference Beacon

MEOSAR reference beacons should conform to the signal specifications defined in document C/S T.001 (FGB) or C/S T.018 (SGB), except for the following.

Reference beacons should transmit one or several of the transmission type described as calibration FGB bursts, calibration SGB bursts, FGB QMS bursts and SGB QMS bursts.

Repetition period

Four types of bursts can be transmitted:

- FGB calibration bursts, with a period between burst transmissions of 180 seconds continuously transmitting,
- SGB calibration bursts, with a period between burst transmissions of 180 seconds continuously transmitting,
- FGB QMS bursts, with a repetition period of 50 seconds, transmitting per 10-minute slots,
- SGB QMS bursts, with a repetition period of 30 seconds, transmitting per 5-minute slots.

Beacon activation should be co-ordinated with other providers of MEOSAR reference beacons to prevent repeated transmission collisions.
It should be possible to interrupt the beacon activation for some periods of time to meet the need for coordination of transmissions with other reference beacons.

Transmitted Frequency

Initial frequency:

For FGB:

The transmitted frequency can be 406.034 MHz ± [10 Hz] or one of the frequency channels designated as "Reserved, not to be assigned" in Table H.2 of document C/S T.012 up to channel K (406.052 MHz) (note that channels L (406.055 MHz) and above should not be used).

The transmitted frequency might be configurable to any frequency channel identified in Table H.2 of document C/S T.012 (i.e., including operational and "Reserved, not to be assigned" channels), in order to accommodate future evolution.

For SGB:

The transmitted frequency should be 406.049 MHz ± [10 Hz] or 406.051 MHz ± [10 Hz].

The exact transmitted frequency should be provided to the Secretariat by the reference beacon operator for publication.

Short term frequency stability:

For calibration bursts, the transmitted frequency should not vary more than 1 part in 10^{10} in 100 ms.

Frequency accuracy[1]:

For FGB reference beacons used for calibration purpose, the frequency of transmission of each burst should be between [-0.014] Hz and [+0.014] Hz from the declared transmission frequency.
For SGB reference beacons used for calibration purpose, the frequency of transmission of each burst should be between [-0.014] Hz and [+0.014] Hz from the declared transmission frequency.

Modulation symmetry

For FGB calibration bursts, the modulation symmetry, as defined in document C/S T.001, should be less than 0.02.

[1] The frequency accuracy values were derived from section 5.8.1 in document C/S T.019. Considering that a MEOLUT may use two calibration beacons to calibrate its FOA measurements, and that the FOA measurement bias is required to be below 0.02 Hz, a maximum value of $0.02/\sqrt{2} = 0.014$ Hz is proposed.

Rise and fall times of the modulated waveform

For FGB calibration bursts, the modulation rise and fall times should be in the range 50-150 µs and maintained within ± 1 µs of the selected value.

The modulation rise and fall times should be provided by the calibration beacon operator.

Digital Message

For FGB calibration bursts, the final 360 ms ± 1 percent of the transmitted signal should contain a 144-bit message at a bit rate of 400 bps ± 0.1%.

Timing accuracy of transmitted beacon bursts[2]

For FGB reference beacons used for calibration, the time of transmission of each burst should be between- [-1.77] µs and [+1.77] µs from the declared transmission time.

For SGB reference beacons used for purpose, the time of transmission of each burst should be between [-0.14] µs and [+0.14] µs from the declared transmission time.

The definition of the time reference point (anchor) of the transmitted bursts is identical to the uplink TOA time reference, as defined for MF#67 in document C/S A.002.
The time reference point should be provided by the calibration beacon operator.

A round second is preferred for the time reference point of calibration beacons.

Output power

37 dBm ± 1dB

The transmitted power should be configurable from 25 dBm to 37 dBm with 1 dB steps (note: this requirement is needed for possible mitigation of interference in the future, as deemed necessary).

Antenna Characteristics

The MEOSAR reference beacon antenna should be located to provide visibility to the lowest possible elevation angles at all azimuths (i.e., least obstructed horizon).

For calibration beacons, the antenna polarization should be either right-hand circular polarization (RHCP), left-hand circular polarization (LHCP) or linear polarisation (note: RHCP polarization is most suitable for L-band MEOSAR satellites, LHCP polarization for DASS S-band satellites, and linear polarization for both S-band and L-band satellites, although with attendant polarization losses). For LHCP and RHCP antennas, the radiation pattern should be omni-directional in azimuth and elevation. If selected, linear-polarized

[2] The time accuracy values were derived from section 5.8.1 in document C/S T.019. Considering that a MEOLUT may use two calibration beacons to calibrate its TOA measurements, and that the TOA measurement bias is required to be below 2.5 µs for C/S T.001 beacons and [0.2] µs for C/S T.018 beacons, $2.5/\sqrt{2} = 1.77$ µs is proposed for C/S T.001 beacons measurements and a maximum value of $0.2/\sqrt{2} = 0.14$ µs is proposed for C/S T.018 beacons measurements.

antennas should offer the widest coverage (radiation pattern) possible, in particular for high elevation angles.

For QMS beacons, the antenna polarization should be linear.

Wideband Interference

If collocated with a MEOLUT, a MEOSAR reference beacon should not produce a power flux spectral density above -211 dB (W/m^{2}Hz) in the 1544.0 MHz – 1545.0 MHz frequency band.

Narrowband Interference

If collocated with a MEOLUT, a MEOSAR reference beacon should not produce a power flux density above -168 dBW/m^2 within 1 Hz of the 1544.0 MHz – 1545.0 MHz frequency band.

Environmental and Operational Requirements

The MEOSAR reference beacon is designed to be operated within a controlled environment consistent with the ranges below and, therefore, is not subject to the stricter thermal or other operational requirements specified in document C/S T.001 for distress beacons.

Temperature requirements

Operating temperature range:	+15 ^{o} C to +40^o C
Storage temperature range:	-20^o C to +60^o C

Built in GNSS Receiver

A MEOSAR reference beacon may incorporate a GNSS receiver to receive return link messages (RLM) and for UTC time and frequency synchronization of calibration bursts.

Calibration Protocol (for FGB calibration bursts)

The orbitography user protocol should be used. This protocol, defined in document C/S T.001, is as follows:

Bits	Usage
1-15	bit synchronization
16-24	frame synchronization
25	format flag ("0" for short message and "1" for long message)
26	protocol flag (set bit to "1")
27-36	country code (MID)
37-39	orbitography protocol ("000")
40-81	seven character orbitography beacon clear text identifier using the modified Baudot code (see document C/S T.001). The seven characters shall be right justified. Characters not used shall be filled with the "space" character (100100).
82-85	four binary zeros ("0000")
107	national use (set bit to "0")
108-112	national use
113-144	optional long message. National use.

The 15 hexadecimal character identification used by the MCCs describes bits 26 through 85 (i.e., 60 bits).

[A protected PDF2 field might be used.]

~~Calibration Protocol (for SGB calibration bursts)~~*Reference SGB Message Definition*

~~The calibration protocol should be used. This protocol, defined in document C/S T.018, is as follows:~~*Using the SGB message definition from document C/S T.018, the following message parameters should be used:*

Bits	Usage
1 - 16	~~TAC~~ specific TAC ~~TBD~~ indicating a System beacon *as follows:* • *65,535 for calibration beacons,* • *65,534 for QMS beacons,* • *65,533 for reference beacons (other than QMS beacons),* • *65,532 for beacon simulators,*
17 - 30	pre-assign serial number
31 - 40	country code
41	status of homing device: shall be set to "0" (no homing device or homing device disabled)
42	RLS function: shall be set to ~~“0” (no RLS capability or RLS capability disabled)~~*“0” if RLS is not enabled and set to "1" if RLS is enabled (e.g., RLS system testing)*
43	test protocol: shall be set to “1” (test protocol)
44 - 90	encoded GNSS location
91 - 93	vessel ID protocol identifier: shall be set to "111" (reserved for System testing)
94 - 137	vessel ID: all bits defaulted to “0” or user defined (fixed)
138 - 140	beacon type: ~~“000” for ELT~~*“111” for System beacons*
141 - 154	spare bits: all bits set to “1”

And use Rotating Field #0 with all fields with valid values

Lifetime

MEOSAR reference beacons should be designed for a lifetime of at least 20 years.

- END OF SECTION 3 -

4. GUIDELINES FOR BEACON SIMULATOR REQUIREMENTS AND SPECIFICATIONS

4.1 Guidelines for Supplying a Beacon Simulator

Antenna Blockage

The beacon simulator antenna should provide the widest possible horizon.

Location Data

The beacon antenna location (longitude, latitude, altitude) should be provided with a three-dimensional accuracy better than 1 m. This location should be given with respect to the Bureau International de l'Heure (BIH) Conventional Terrestrial System, having a reference ellipsoid defined as follows [or expressed in WGS84]:
Semi-major axis = 6,378,137 m
Flattening (ellipticity) = 1/298.2572

4.2 Guidelines Unique to a Beacon Simulator

Guidelines for Functional Specifications

A beacon simulator should:

a) Be able to simulate the burst transmissions of both C/S T.001 and C/S T.018 beacons in accordance with those specifications;

b) Be able to execute all test scripts for both C/S T.001 and C/S T.018 beacons as defined in documents C/S T.005, C/S T.010 and C/S T.020;

c) Be able to transmit C/S T.001 and C/S T.018 beacon bursts over the average burst power range 25 dB_m to 39 dB_m in 1 dB steps by pre-configuration;

d) Be able to transmit bursts at fixed invariant power and variable power levels per burst following a pre-configured profile over time;

e) Have transmission antenna patterns with associated EIRP values consistent with C/S T.001 and C/S T.018 beacons for the particular beacon types being simulated;

f) Be able to implement burst schedules including time randomization as defined in document C/S T.001 and C/S T.018, and also transmit bursts at time-invariant rates as defined by the pre-configuration;

g) Be able to simultaneously transmit at least [10] beacon bursts of any combination of C/S T.001 and C/S T.018 beacon types, with both partial and complete bursts overlapping in time;

h) Be able to synchronize burst transmission schedules with UTC time (see timing accuracy specification below);

i) Be able to simulate up to 200 C/S T.001 and up to 200 C/S T.018 simultaneous active beacons;

j) Be able to vary message content (e.g., GNSS encoded position) from burst to burst for any given simulated beacon event;

k) Be configurable in all beacon transmission parameters (e.g., by script or operator interface) within allowed ranges in documents C/S T.001 and C/S T.018 (e.g., modulation index, rise time, bit rate, chip rate, chip rate variation, etc.);

l) Be able to record, store and export to a file in a standard format (e.g., csv, xml) all beacon transmission parameters for each burst transmission, including transmission time stamps; and

m) Be able to generate various pulse shapes (i.e., waveform) for C/S T.018 beacons (e.g., half-sine, cosine, rectangular).

These functional requirements are useful for both MEOLUT commissioning tests and system-level tests (e.g., Demonstration and Evaluation (D&E)). Items (a), (b) and (c) are particularly useful for commissioning tests. Item (g) through (i) are particularly useful for system capacity testing. Item (j) could be useful for evaluating message processing of moving beacons.

Transmitted Frequency

Initial frequency:

For FGB:

The transmitted frequency can be from 406.0 MHz to 406.1 MHz.

For SGB:

The transmitted frequency should be from 406.048 MHz to 406.052 MHz.

Short term frequency stability:

For simulated bursts, the transmitted frequency should not vary more than 1 part in 10^{10} in 100 ms.

Frequency accuracy[3]For FGB simulator, the frequency of transmission of each burst should be between [-0.014] Hz and [+0.014] Hz from the declared transmission frequency.

For SGB simulator, the frequency of transmission of each burst should be between [-0.014] Hz and [+0.014] Hz from the declared transmission frequency.

[3] The frequency accuracy values were derived from section 5.8.1 in document C/S T.019. Considering that a MEOLUT may use two calibration beacons to calibrate its FOA measurements, and that the FOA measurement bias is required to be below 0.02 Hz, a maximum value of $0.02/\sqrt{2} = 0.014$ Hz is proposed

Timing Accuracy of Transmitted Beacon Bursts[4]

For FGB simulator, the time of transmission of each burst should be [-1.77] µs and [+1.77] µs from the declared transmission time.

For SGB simulator, the time of transmission of each burst should be [-0.14] µs and [+0.14] µs from the declared transmission time.

The definition of the time reference point (anchor) of the transmitted bursts is identical to the uplink TOA time reference, as defined for MF#67 in document C/S A.002.

Wideband Interference

If collocated with a MEOLUT, a beacon simulator should not produce a power flux spectral density above -211 dB ($W/m^2/Hz$) in the 1544.0 MHz – 1545.0 MHz frequency band.

Narrowband Interference

If collocated with a MEOLUT, a beacon simulator should not produce a power flux density above -168 dB_W/m^2 within 1 Hz of the 1544.0 MHz – 1545.0 MHz frequency band.

Environmental and Operational Requirements

The beacon simulator should be designed to be operated within a controlled environment and, therefore, is not subject to the stricter thermal or other operational requirements specified in documents C/S T.001 and C/S T.018 for distress beacons.

Built in GNSS Receiver

A beacon simulator should incorporate a GNSS receiver to receive return link messages (RLM) and for UTC time and frequency synchronization of bursts. This GNSS receiver should be compatible with RLS providers.

- END OF SECTION 4 -

[4] The time accuracy values were derived from section 5.8.1 in document C/S T.019. Considering that a MEOLUT may use two calibration beacons to calibrate its TOA measurements, and that the TOA measurement bias is required to be below 2.5 µs for C/S T.001 beacons and [0.2] µs for C/S T.018 beacons, $2.5/\sqrt{2} = 1.77$ µs is proposed for C/S T.001 beacons measurements and a maximum value of $0.2/\sqrt{2} = 0.14$ µs is proposed for C/S T.018 beacons measurements.

ANNEX A
COMMITMENT OF THE MEOSAR REFERENCE BEACON PROVIDER

The installation and operation of a MEOSAR reference beacon is based upon a mutual agreement between Cospas-Sarsat and the country providing such a beacon, whereby the Cospas-Sarsat Council accepts the proposed provision of the MEOSAR reference beacon and the providing country agrees to abide with the following principles:

- the host country will assume all costs of providing, operating and maintaining the beacon in service,
- in taking the decision where to place an orbitography or MEOSAR reference beacon, both Cospas Sarsat system requirements and the supplying country's requirements should be taken into account,
- the supplying country will inform Cospas-Sarsat of the precise location of the MEOSAR reference beacon,
- information on the MEOSAR reference beacon must be provided by the beacon operator as described in document C/S T.022,
- the MEOSAR reference beacon should meet the Cospas-Sarsat specifications defined in document C/S T.022,
- Cospas-Sarsat may request and/or the country supplying the beacon may decide to terminate the operation of the MEOSAR reference beacon,
- a decision to terminate operation will be subject to coordination among Cospas-Sarsat Participants and will not take effect until 12 months after the request/decision has been made by one of the parties involved,
- in case of a failure of a beacon that would be cost-prohibitive to remedy, the supplying country will not be obliged to supply a new beacon.

- END OF ANNEX A -

- END OF DOCUMENT -

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