COSPAS-SARSAT LEOSAR SPACE SEGMENT COMMISSIONING STANDARD

C/S T.004
Issue 2 – Revision 2
October 2012

COSPAS SARSAT

COSPAS-SARSAT LEOSAR SPACE SEGMENT COMMISSIONING STANDARD

History

Issue	Revision	Date	Comments
1	-	Nov 95	Approved (CSC-15)
1	1	Oct 96	Approved (CSC-17)
1	2	Oct 99	Approved (CSC-23)
1	3	Oct 01	Approved (CSC-27)
1	4	Oct 04	Approved (CSC-33)
1	5	Nov 07	Approved (CSC-39)
2	-	Oct 09	Approved (CSC-43)
2	1	Oct 10	Approved (CSC-45)
2	2	Oct 12	Approved (CSC-49)

TABLE OF CONTENTS

LIST OF ANNEXES

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Purpose

This document defines the recommended tests, technical measurement standards and procedures required for implementing on-orbit testing and commissioning of the Cospas-Sarsat LEOSAR Space Segment. On-orbit testing is a component of system assessment as defined in C/S G.006. Use of these measurement standards for testing the Cospas-Sarsat Space Segment will provide a standardized approach for determining the quality of space segment performance. Prior to launch, the Space Segment Provider will test the spacecraft to ensure that interoperability parameters and specifications contained in C/S T.003 are met. Commissioning is a formal declaration by the responsible Space Segment Provider that a payload is operational with or without limitations. De-commissioning is a formal declaration by the responsible Space Segment Provider that a payload is no longer operational.

An additional objective of this document is to ensure that measurements of Cospas-Sarsat LEOSAR Space Segment parameters are in accordance with a common set of test methods and definitions, so that the results may be understood and compared.

1.2 Scope

Three phases of on-orbit testing of the LEOSAR Space Segment are addressed: initial on-orbit test, periodic test, and routine monitoring. The basic responsibilities, specific tests to be performed, and test methodologies are defined.

Initial on-orbit tests are performed in order to establish that the payloads can be placed in service to support SAR operations. The tests focus on establishing that the payload will properly interface and be interoperable with the ground segments as shown in Figure 1.1. The initial on-orbit tests also confirm that values for assessment indicators are within accepted thresholds and the payload can be formally commissioned. The data from the payload can then be exchanged operationally as described in the Data Distribution Plan, C/S A.001.

Periodic tests to be performed semi-annually are defined. These tests provide measurement data used to confirm continued on-orbit performance of the LEOSAR payload.

Routine monitoring of the on-orbit payloads is conducted by the spacecraft provider. Significant changes (loss of channel, etc.) can also be detected by LEOLUT / MCC operators. Out-of-limits and other abnormal conditions are reported to the Space Segment Provider for further tests and corrective action as required. If deemed necessary the Space Segment Provider may have limitations placed on the payload or it may be de-commissioned.

The test descriptions provide sufficient detail to define the measurement method, but are not intended to be specific test procedures. It is the responsibility of the National Administrations to develop test procedures for specific tests which are traceable to the methods described in this document.

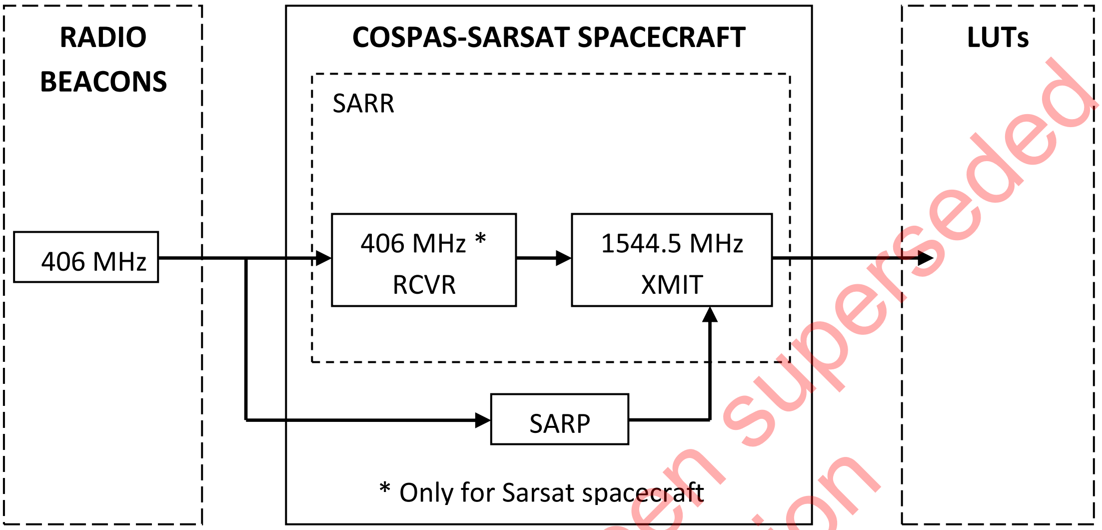

Figure 1.1: Cospas-Sarsat LEOSAR Space Segment

1.3 Reference Documents

- Cospas-Sarsat Glossary, C/S G.004
- Cospas-Sarsat System Assessment, C/S G.006
- Cospas-Sarsat Data Distribution Plan, C/S A.001
- Cospas-Sarsat System Monitoring and Reporting, C/S A.003
- Specification for Cospas-Sarsat 406 MHz Distress Beacons, C/S T.001
- Description of the Payloads Used in the Cospas-Sarsat LEOSAR System, C/S T.003
- Cospas-Sarsat LEOLUT Performance Specification and Design Guidelines, C/S T.002

1.4 Common System of Units

The units of measurement for interoperability parameters and exchanged test results will be the System International (SI).

1.5 Common List of Definitions

Interpretation of technical terms in exchanged documentation will be in accordance with the latest edition of the "IEEE Standard Dictionary of Electrical and Electronic Terms".

- END OF SECTION 1 -

2. ON-ORBIT LEOSAR SPACE SEGMENT TESTING AND COMMISSIONING

2.1 Initial On-orbit Tests

Following the launch of each new satellite, initial on-orbit tests are conducted. These tests are conducted by the spacecraft provider to confirm that the LEOSAR payload meets the interoperability requirements and is functioning within the requirements range as specified in C/S T.003.

The data from the initial on-orbit tests will be used to establish baseline values of system parameters, and to ensure Assessment Indicators are within previously established limits or to establish new limit values.

The initial on-orbit tests of elements of the Cospas-Sarsat LEOSAR Space Segment are traditionally performed by the appropriate Space Segment Providers. Each Space Segment Provider determines the extent and level of on-orbit tests performed on the elements it provides to the LEOSAR Cospas-Sarsat Space Segment.

When the initial on-orbit tests on the Cospas or Sarsat LEOSAR satellite are successfully completed, the appropriate Space Segment Provider completes the assessment report or the commissioning report and declares the payload operational. The satellite provider then supplies ephemeris data to all Ground Segment Operators.

The initial on-orbit tests to be conducted and the associated test methods are listed in Annex B. It is the responsibility of each Space Segment Provider to develop test procedures for the satellite assembly and/or unit provided by that party. Such tests shall be traceable to the methods described in this document. In addition, other states may perform LEOSAR Space Segment tests. However, these tests shall conform to the methods described herein and the test procedures shall be provided to the party responsible for the space assembly or unit that will be tested. Furthermore, all participants conducting tests shall provide appropriate coordination and ensure that there is no negative impact on Cospas-Sarsat operations. The Space Segment Provider shall still be responsible for forwarding the assessment or the commissioning reports.

The initial on-orbit tests shall provide a set of baseline values for various parameters, at the time the satellite begins operations. The baseline values can be compared with pre-launch data to determine if in-orbit operation is nominal and with results from subsequent on-orbit tests to monitor on-going performance trends.

The Space Segment Providers should conduct on-orbit tests and submit to the Secretariat the results of the tests along with a description of the tests sufficient to allow interpretation of the data. These post-launch test reports that are submitted will then be distributed in accordance with section 2.6 of this document.

2.2 Commissioning Procedure

Commissioning is a formal declaration by the responsible Space Segment Provider that the LEOSAR payload meets its assessment indicators and is declared operational as part of the Cospas-Sarsat System. Commissioning may be declared with limitations placed on the operational use if some assessment indicators are not met and limited operation is still deemed essential. Commissioning procedures for the Cospas and Sarsat LEOSAR payloads are described below.

In recognition of the fact that commissioning tests may be time consuming, and that valid operational data will normally be available from a satellite payload that is under test, a payload may be declared to be in an initial operational capability (IOC) state before the commissioning test report is completed. This may be done at the option of the spacecraft provider if there is sufficient confidence that use of its data by the Ground Segment will not cause unnecessary expenditure of SAR resources.

Once declared, IOC status shall remain in effect until commissioning is completed, which shall normally be no more than 90 days after IOC status was declared.

Payload status will be declared by the responsible Space Segment Provider with an appropriate system status message. Distribution of satellite ephemeris and TCAL data, which may precede declaration of IOC status, shall not itself be understood as a declaration of IOC status.

2.2.1 Cospas Payload

Commissioning of the COSPAS LEOSAR payload requires collection and analysis of post-launch test data to verify compliance or non-compliance with the expected values of the assessment indicators after basic health and safety of the payload is confirmed. Commissioning procedure includes 406 MHz Receivers, Transmitters and antenna subsystems testing.

Upon completion of all tests, Russia will evaluate assessment indicators and prepare, within 2.5 months of spacecraft launch, the commissioning report.

The report shall recommend that the payload be declared at full operational status, limited operational status or non-operational.

Once the COSPAS payload is declared operational, Russia will inform all Cospas-Sarsat Ground Segment Providers and begin transmission of ephemeris data.

2.2.2 Sarsat Payload

Commissioning of the Sarsat payload is the signed agreement of all Sarsat Space Segment Providers that the Sarsat payload meets its assessment indicators and is declared operational as part of the Cospas-Sarsat System. Commissioning requires the collection and analysis of post-launch test data to verify compliance or non-compliance with the expected values of the assessment indicators after basic health and safety of the payload is confirmed. The flow of the Sarsat LEOSAR payload commissioning procedure is shown in Figure 2.1. This includes payload testing by the responsible LEOSAR Space Segment Providers and submittal of assessment reports, as shown at Annex F, to the USA, which prepares the commissioning report.

The purpose of generating an assessment report is to declare the Sarsat payload operational as soon as practical. The assessment report determines whether the Sarsat payload can operate nominally and provide useful data. Canada, France and the USA will respectively evaluate the SARR, SARP and the associated antennas according to the responsibilities outlined in Annex B. Upon completion of the initial on-orbit tests each Sarsat Space Segment Provider will prepare an assessment report and forward it to the USA. The assessment reports will be prepared within 2.5 months of spacecraft launch. The assessment reports should note any anomalies or limitations on the performance or operation of the Sarsat payload.

The USA will evaluate the assessment reports for the SARR, SARP and the SAR antenna subsystems and prepare a commissioning report as shown at Annex G. This report will summarize the status of the assessment indicators and show whether they are within acceptable levels. The report shall then recommend that the payload be declared at full operational status, limited operational status or non-operational.

When the Sarsat payload is declared commissioned or at IOC status, the USA, through the USMCC, will inform all Cospas-Sarsat Ground Segment Operators and transmit ephemeris data. At this time France through the FMCC will transmit time calibration data to all MCCs. Telemetry data will also be provided by the USMCC to the CMCC and FMCC.

2.3 Periodic Tests

Periodic technical tests are performed semi-annually on each LEOSAR satellite to confirm that Assessment Indicator measurements remain within the accepted limits. The data will also be used to provide trend data for forecasting satellite operations and projecting the remaining lifetime of the search and rescue payloads.

The periodic tests are a subset of the post-launch tests as listed in Annex B.

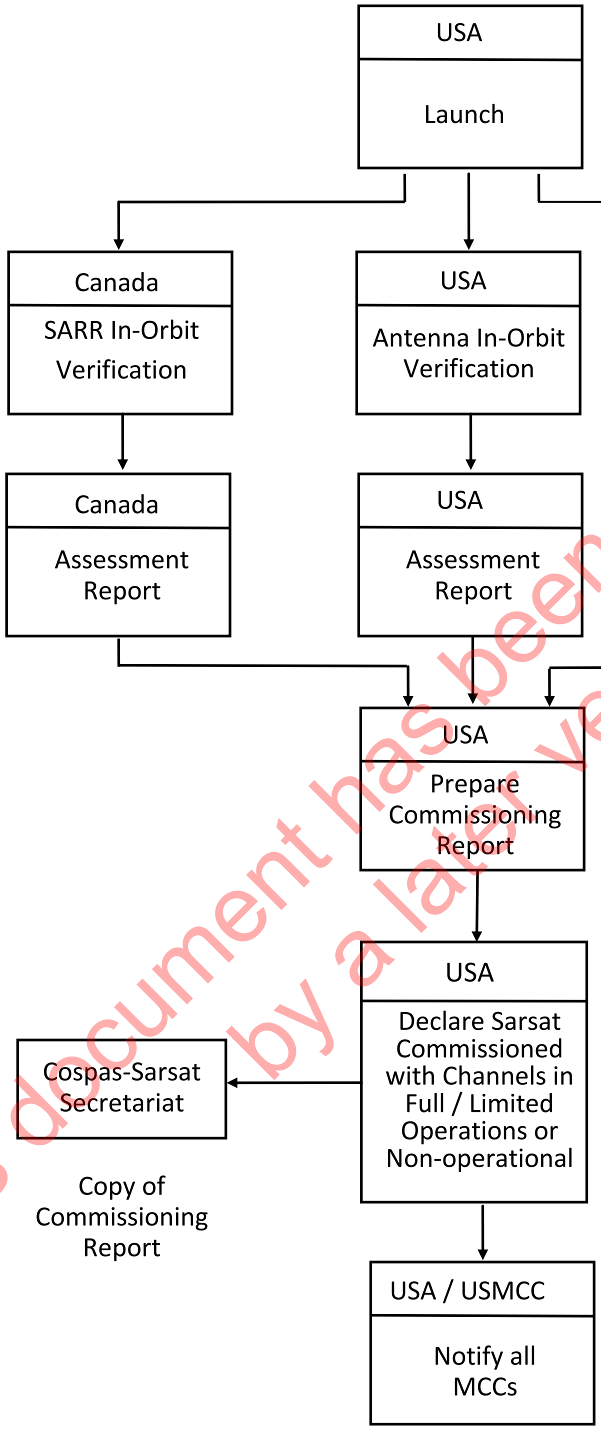

Figure 2.1: Sarsat LEOSAR Payload Commissioning Procedure

2.4 Routine Monitoring of the Space Segment

The general health of the spacecraft is routinely monitored by the spacecraft Provider, using telemetry data. Payload providers shall notify all Ground Segment Operators when their payload performance has degraded to the extent that there is an impact on SAR service.

Significant changes in the basic parameters of the search and rescue payload, listed in Annex C as assessment indicators (e.g. transmitter downlink power and frequency, loss of channel, etc.) can be detected during routine system monitoring performed by LEOLUTs/MCCs as described in document C/S A.003. If degradation is detected, the LEOLUT/MCC operator shall report this information to the associated payload provider. The payload provider shall conduct tests sufficient to take corrective action or characterize the performance degradation and provide notification to Ground Segment Operators as described in section 2.6. The payload then can be declared operational with limitations or de-commissioned and the appropriate status forwarded to all Ground Segment Operators and the Cospas-Sarsat Secretariat.

2.5 De-commissioning Procedure

De-commissioning is a formal declaration by the responsible Space Segment Provider that a LEOSAR payload is no longer operational and is no longer part of the Cospas-Sarsat System. A de-commissioned payload can later be re-commissioned with or without limitations, if this is deemed essential. The decision to de-commission payloads will be based on the operational value of the SAR data versus the impact of continued operation of the payload.

2.5.1 Cospas De-commissioning Procedure

Russia will initiate an investigation as a result of unacceptable values for assessment indicators derived from COSPAS LEOSAR payload periodic tests, spacecraft operational anomalies or MCC anomaly reporting. If the results of the investigation substantiate de-commissioning, Russia will prepare a de-commissioning report.

2.5.2 Sarsat De-commissioning Procedure

As shown in Figure 2.2, the USA will initiate an investigation in conjunction with Canada and France as a result of unacceptable values for assessment indicators derived from Sarsat LEOSAR payload periodic tests, spacecraft operational anomalies or MCC anomaly reporting. If the results of the investigation substantiate de-commissioning, the USA will prepare a de-commissioning report which includes rationales, test reports and analyses to support de-commissioning.

2.6 Space Segment Status Reporting Procedures

The post-launch commissioning report on each new satellite that is prepared by the responsible Space Segment Provider shall be distributed to all Space Segment Providers. A copy of the test report shall also be sent to the Secretariat. Ground Segment operators may obtain copies by request from the Secretariat.

The Cospas-Sarsat Secretariat shall update the status of the LEOSAR Space Segment on the Cospas-Sarsat website.

The periodic test reports shall be distributed to the Cospas-Sarsat Space Segment Providers and the Secretariat. Copies may also be obtained from the Secretariat on request.

Any LEOLUT / MCC which detects anomalies of the Space Segment during routine system monitoring, shall in form the relevant Space Segment Provider so that special tests can be conducted and appropriate notification can be provided. Analysis of Space Segment anomalies shall be coordinated among the relevant Space Segment Providers and possible corrective action (e.g., switch to backup payload) shall be taken, as appropriate.

The relevant Space Segment Provider shall provide information on any anomalies which could significantly degrade system performance, to all Ground Segment Providers via the MCC network, in accordance with procedures defined in document C/S A.001. If an anomaly is confirmed by the relevant Space Segment Provider, then the relevant Space Segment Provider shall notify the Secretariat who shall then update the status of the LEOSAR Space Segment on the Cospas-Sarsat website.

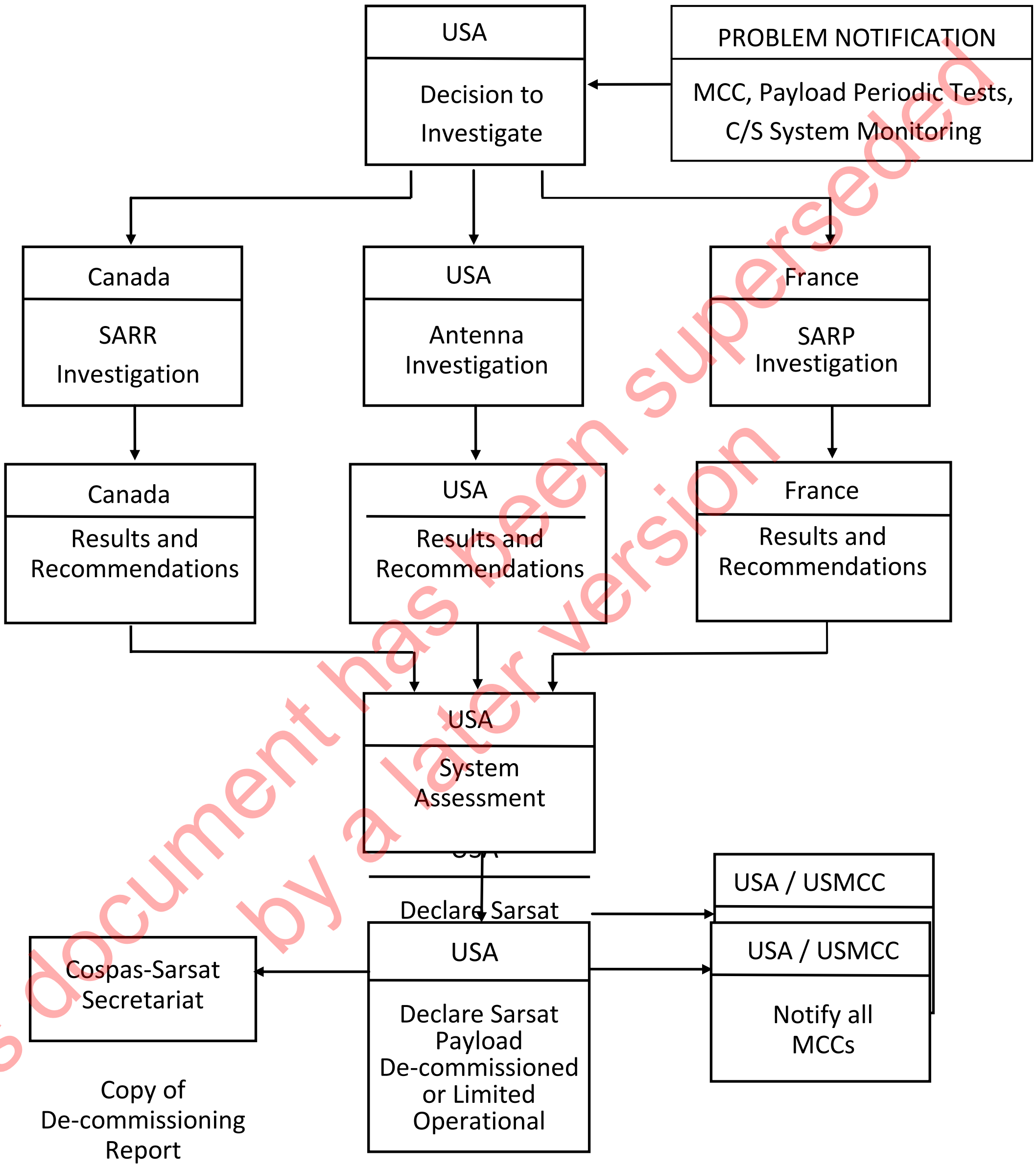

Figure 2.2: Sarsat LEOSAR Payload De-commissioning Procedure

- END OF SECTION 2 -

ANNEXES TO DOCUMENT
C/S T.004

COSPAS-SARSAT LEOSAR SPACE SEGMENT
COMMISSIONING STANDARD

ANNEX A

A. LIST OF ACRONYMS USED IN C/S T.004

AGC .... automatic gain control
AOS .... acquisition of signal

BCH .... Bose-Chaudhuri-Hocquenghem code
BW .... bandwidth

C/N_o .... carrier-to-noise density ratio

DA0.................... date and time at which the Sarsat SARP time counter resets to zero
dBHz .... decibel above one Hertz
dBm .... decibel above one milliwatt
dBW.............. decibel above one Watt

DRU .... data recovery unit

EIRP .... equivalent isotropically radiated power

FCal.................... frequency calibration (Sarsat SARP)

G/T .... gain-to-temperature ratio

IF .... intermediate frequency

kHz .... kilohertz

LEOLUT .... local user terminal in the LEOSAR system
LEOSAR .... low-altitude Earth orbit satellite system for search and rescue
LOS .... loss of signal

MHz .... megahertz
ms .... milliseconds
mW .... milliwatt

RHCP .... right hand circular polarization

SARP .... search and rescue processor
SARR .... search and rescue repeater
S/N_o .... signal-to-noise density ratio

TCal .... time calibration (Sarsat SARP)

USO .... ultra-stable oscillator

VCO .... voltage controlled oscillator

- END OF ANNEX A-

ANNEX B

B. COSPAS-SARSAT LEOSAR SPACE SEGMENT TESTING

The following tests are performed on each satellite soon after launch. Selected tests as indicated are repeated as periodic tests.

Parameter Tested	Unit Requiring Test	See Notes
B.1 Total Received Signal Power	SARR and Antenna	1,2,3
B.2 Spectral Occupancy of the Downlink	SARR	1,2,3
B.3 Spurious Output Levels	SARR	2,3
B.4 Received Signal Power of Test Signals in the 406.05 MHz Repeater Band	SARR	2,3
B.5 Location Accuracy of 406 MHz Test Beacons	SARR	1,2
B.6 AGC Dynamic Range	SARR	2,3
B.7 Modulation Index of the Repeater	SARR	1,2,3
B.8 Translation and Transmitter Frequencies	SARR	2,3
B.9 Channel Bandwidth and Amplitude Ripple	SARR	2,3
B.10 Intermodulation and Harmonic Levels	SARR	2,3
B.11 SARR Receive Antenna Pattern	Antenna	2,3
B.12 SARP Receive Antenna Pattern	Antenna	3,4
B.13 SARP Calibration and Characteristics	SARP	1,2,3
B.14 SARP Processing and Localisation Performance	SARP	1,2,3
B.15 SARP Performance with Variable Emission Power	SARP	1,2,3

Note 1: This test is also performed as a periodic test.

Note 2: The responsible parties for testing the Sarsat Spacecraft are Canada for the SARR, France for the SARP and the USA for the antennas.

Note 3: Commissioning tests.

Note 4: COSPAS only.

B.1: Total Received Signal Power

Objective

The objective of this test is to measure the satellite L-band downlink EIRP contour and compute the total power emitted by the satellite transponder at 1544.5 MHz as a function of the nadir angle, to compare the results with the level specified in the Description of the Cospas-Sarsat LEOSAR Space Segment, C/S T.003 and to identify any degradation of satellite performance.

Procedure

The received carrier power is a measured parameter. This is measured using the calibrated AGC voltage of the receiver. This voltage is read by digital voltmeter and stored for subsequent analysis. After a particular satellite pass is completed, a graph of satellite EIRP versus nadir angle is obtained for comparison with the specified levels. An alternate procedure is to use a calibrated spectrum analyser to measure the down link signal's carrier power levels. The EIRP is then calculated from these measurements, and an EIRP versus nadir angle graph is produced.

B.2: Spectral Occupancy of the Downlink

Objective

The objective of this test is to measure the spectral occupancy of the downlink in order to identify the presence of out-of-band spurious signals or any other anomalous spectral characteristics.

Procedure

The downlink spectra of the 1 MHz band centred on the carrier are measured several times during a satellite pass and stored for subsequent analysis. The average of these spectra is calculated and plotted and used to identify the signals received directly from ground based interferers. By studying the frequencies relative to the carrier it is possible to distinguish between spacecraft based interferers and signals originating from the ground in the 406 MHz band and which are being retransmitted by the spacecraft transponder. The procedure is repeated for the 5 MHz band centred on the carrier.

B.3: Spurious Output Levels

Objective

This test has two objectives:

a) To check for any out-of-band signals from the satellite which are within the range of frequency covered by the LEOLUT antenna feed and receiver subsystem.

b) To check for any spurious signals within the repeater bandwidth.

Procedure

A spectrum analyzer is used to check repeatedly for out-of-band spurious signals in an 8 MHz band centred on the downlink carrier during a satellite pass. A comparison between spectra received from the spacecraft with reference spectra for the ground receiving system is used to discriminate between potential spacecraft generated spurious signals and locally generated signals. The receiving system reference spectrum must be taken with the ground station antenna not pointing at a spacecraft.

Spurious signals within the repeater bandwidth can be detected in the LEOLUT Doppler frequency/time "dot" plot and the frequency established. Any spurious signal originating in the spacecraft will not have an associated Doppler frequency and will therefore be seen as a strait line in the dot plot. The frequency can be scaled from the dot plot. Once the spurious signal has been identified, more accurate frequency measurements may be obtained by using a spectrum analyzer to monitor the channel baseband and make frequency measurements

The levels of spurious signals referred to the SARR receiver input can be determined by making the measurements with the SARR channel tested in the fixed gain mode. In fixed gain mode, the SARR is a linear repeater with a preset gain, G_r, and receiver output level of -8.5 dBm for nominal modulation index. The ground receiver/demodulator is calibrated to read S_{nom} when receiving a signal modulated at the nominal modulation index. The SARR receiver channel output is then given by:

$$P_o = -8.5 \text{ dBm} + (S_m - S_{nom})$$

and

$$P_i = P_o - G_r = -8.5 \text{ dBm} - G_r + (S_m - S_{nom})$$

where:

P_o = SARR channel output power
P_i = SARR channel input power
G_r = SARR channel receiver gain (available from prelaunch data)
S_{nom} = Ground receiver/demodulator output for nominal SARR channel mod index
S_m = measured value of spurious signal at ground receiver/demodulator output.

B.4: Received Signal Power of Test Signals in the 406.05 MHz Repeater Band

Objective

The objective of this test is to check the end-to-end performance of the 406.05 MHz repeater link

Procedure

The test consists of measuring the signal-to-noise density ratio (S/N_o) of the test signal in the demodulated baseband and of measuring the carrier-to-beacon ratio in the predetected IF.

a) The calibrated uplink facility is used to provide an unmodulated test signal to the input of the onboard 406.05 MHz repeater at a nominal level of -120 dBm, correcting for range and the variation of antenna gain with angle-off-nadir. The signal frequency is compensated for the uplink Doppler frequency shift and is located 7 kHz above the band centre. A spectrum analyzer is used to measure the signal strength (S) in the baseband and the noise level (N) is obtained from the trace by inspection. Thus:

$$\text{Noise Density, } N_o = N - 10 \log(\text{Resolution BW}) = N - 10 \log(100) = N - 20 \text{ dBHz}$$

$$S/N_o = S - N_o = S - N + 20 \text{ dBHz}$$

These measurements are taken as frequently as possible during a single pass.

b) In a separate pass the uplink signal is set up as previously but this time the predetected IF is used and the signal levels of the carrier and the beacon are measured using the spectrum analyzer to obtain the carrier-to-beacon ratio. This is carried out as many times as possible during the pass.

B.5: Location Accuracy of Test Beacons

Objective

The objective of this test is to determine the accuracy of the location data produced by the tracking computer from test signals and to compare it with the previous system performance and with the specifications.

Procedure

A 406 MHz ELT or beacon simulator is used to produce the test signal for the 406 MHz band. The location estimates are produced by the tracking computer. All test signals are transmitted from a predetermined position.

Only passes with durations over ten minutes are used. Shorter passes are not used in practice and so would be unrepresentative. All such testing must be coordinated with the MCC so that the signals will not be treated as genuine alarms and to avoid interference with any ongoing search operation. The tests can be run unattended subject to MCC approval.

B.6: AGC Dynamic Range

Objective

The objective of this test is to measure the AGC dynamic range curve of the SARR 406.05 MHz receivers.

Procedure

In this test, a carrier is transmitted to the SARR 406.06 MHz receiver in the form of a power staircase. The uplink is increased in 2 dB steps such that the input power to the receiver is varied from -130 to -90 dBm (21 steps). The test time interval for each step is three seconds, during which time the downlink baseband signal level at 170 kHz and the respective baseband N_o level (at 3 kHz away from the signal) are measured. The duration of the test for the 21 steps is 63 seconds, so that the run can be repeated a number of times during the pass under dynamic background noise and interference conditions.

The test ground station receiver is calibrated in terms of phase demodulator baseband output level versus the downlink modulation index. Therefore, the test data plots may be either relative downlink baseband level or actual downlink modulation index versus the input to the SARR receiver.

The equivalent noise temperature, T_e, of the total discrete and noise-like interference power in the receiver may be computed as follows. Note the spacecraft receiver test input where the AGC curve is 3 dB below the maximum. At this point, the test uplink power (P_1) and total other power (P_2) in the channel bandwidth are equal ($P_1/P_2 = 0$ dB). Therefore, the equivalent noise temperature (T_e) of the total power in the channel other than the test signal may be computed from the following:

$$P_1 = P_2 = KT_eB$$

where:

K = Boltzmann's constant

T_e = Equivalent noise temperature

B = Noise bandwidth of the spacecraft receiver being tested

P_2 = Total other power in the receiver bandwidth which is equal to the receiver test input power at the 3 dB down point of the AGC curve. The other power consists of noise-like interference plus discrete interference plus the inherent SARR receiving system noise, including 290 K for the earth's temperature.

It follows that:

$$T_e\ (\text{dB-K}) = P_1 / KB$$

or

$$T_e\ (\text{dB-K}) = P_1\ (\text{dBm}) - 10 \log K - 10 \log B$$
$$= P_1\ (\text{dBm}) + 198.6\ \text{dBm} - 10 \log B$$

B.7: Modulation Index of the Repeater

Objective

The purpose of this test is to measure the modulation index of the 406.05MHz repeater and of the 2.4 kbps data channel.

Procedure

Under computer control, a signal generator is used to provide an unmodulated test signal to the input of the satellite receiver at a level which will saturate the AGC in the spacecraft receiver, in the 406 MHz uplink frequency band. (The 406 MHz band applies only to Sarsat LEOSAR satellites, and not to Cospas LEOSAR satellites.)

The uplink test signal frequency is compensated for the Doppler shift and is set 7 kHz above the centre frequency of each receiver band. The amplitude is also compensated for free space path loss and the effect of nadir angle on the Cospas-Sarsat antenna gain. A spectrum analyzer is used to measure the carrier-to-beacon ratio of each test signal in the 10 MHz IF signal. The data is stored and subsequently used to calculate the RMS modulation index.

B.8: Translation and Transmitter Frequencies

Objective

The objective of this test is to measure the in-orbit SARR translation and transmitter frequencies.

Procedure

A strong uplink carrier at the channel centre frequencies is transmitted from the Test ground station to the 406.05 MHz spacecraft repeater channel. Frequency measurements of the downlink 1544.5 MHz carrier and the downlink baseband are performed every six seconds during the pass. The frequencies are measured with a spectrum analyzer operating in the counter mode with a 1 Hz resolution.

The nominal downlink and baseband frequencies are 1544.5 MHz for the downlink carrier, 170 kHz for the 406.05 MHz repeater on SARR-1 and [88.462] KHz on SARR-2.

All frequencies for the test equipment in this test are derived from the test ground station 10 MHz ultra-stable frequency standard. This includes the frequency source for the synthesizers generating the uplink test signals, the spectrum analyzer, and all downconversions in the test ground station receiver. Thus, the spacecraft frequencies are being compared with the test ground station ultra-stable standard.

It is necessary to subtract the Doppler frequency shift from the frequency measurements at the test ground station to obtain a measure of the frequencies referred to the spacecraft. The Doppler frequency shift to be subtracted is computed from the spacecraft orbit parameters obtained during the test pass. Quality of the current orbit parameters is monitored.

B.9: Channel Bandwidth and Amplitude Ripple

Objective

The objective of this test is to measure the bandwidth and the amplitude ripple in the SARR 406 MHz repeater channel.

Procedure

This measurement is performed by frequency sweeping the uplink test signal to a spacecraft receiver and tracking the downlink baseband frequency while measuring the baseband signal amplitude. The desired arrangement can be achieved using a standard spectrum analyzer tracking generator setup.

It is desirable to perform the test for both the AGC and fixed gain mode configuration.

B.10: Intermodulation and Harmonic Levels

Objective

The objectives of this test are to detect and measure any intermodulation products produced by two large in-band test signals in the 406 MHz SARR channel and to detect and measure any harmonic products produced by an uplink test signal in one SARR channel and falling in another SARR channel.

Procedure

For testing intermodulation products, two strong uplink carriers are simultaneously transmitted from the test ground station to the 406 MHz SARR receiver. All tests are performed with the receivers in the AGC mode. The in-band uplink frequencies are as follows:

f_1 = Nominal channel frequency - 1 kHz
f_2 = Nominal channel frequency + 1 kHz

The uplink frequencies are automatically Doppler compensated so that the frequencies at the SARR receiver input are constant throughout the test pass. It follows that the downlink signal baseband frequencies are constant. This enables the prediction of exactly where the intermodulation products would occur in frequency, if present.

When intermodulation products are generated, the third order intermods are generally the strongest and occur at $2f_1$-f_2 and $2f_2$-f_1. If f_1 equals nominal frequency minus 1 kHz and f_2 equals nominal frequency plus 1 kHz, then the third order intermodulation products would be at the nominal frequency -3 kHz and at the nominal frequency +3 kHz. Therefore, the baseband frequencies to search for detecting any third order intermods are as follows:

Channel	Nominal Channel Frequency (kHz)	Lower Intermod Frequency (kHz)	Upper Intermod Frequency (kHz)
406.05 MHz (SARR-1)	170	167	173
406.05 MHz (SARR-2)	[88.462]	[85.462]	[91.462]

The uplink EIRP of each test signal is +28 dBW. This produces the following range of test signal strengths at the spacecraft referred to isotropic, where the minimum is at AOS and the maximum is at overhead:

406.05 MHz Channel: -126 to -115 dBW

In order to avoid intermodulation products from the test ground station test system itself, separate transmitters are used for the two uplinks. One transmitter is connected to the horizontal elements of the test ground station uplink antenna and the other to the vertical elements.

To test for the possible generation of harmonic products, one or two Doppler compensated uplink carriers are transmitted to the 406 MHz SARR channel. The downlink baseband is swept with the spectrum analyzer to detect and measure any harmonic products.

B.11: SARR 406 MHz Receive Antenna Patterns

Objective

The objective of this test is to measure the in-orbit antenna pattern of the SARR 406 MHz receiver.

Procedure

The antenna pattern of the SARR 406 MHz receiver is measured with the receiver in the Fixed Gain Mode. In an automated test, the test uplink EIRP and the test uplink frequency are updated every three seconds to maintain the input power and frequency at the SARR receiver constant throughout the pass. The input power requirement is to establish a sufficient downlink S/N ratio for the measurements, and to stay within the linear dynamic range of the receiver in the Fixed Gain Mode.

During the test interval of 3 seconds, a power and frequency updated RHCP uplink is transmitted to the 406 MHz SARR receiver. The downlink baseband output level (S_R) at the test ground station, and the baseband noise level (N_o) in a frequency slot away from the signal frequency, are measured in each 3 second interval.

From the test ground station's EIRP and the known path loss obtained from orbit data, the input power to the SARR receiver referred to isotropic (P_{io}) is computed. Also, the nadir angle is known from orbit data. By combining the above data with the measured downlink baseband data, the antenna pattern shape is computed throughout the pass as a function of the nadir angle.

The actual on-orbit antenna gain is computed using the measured data and pre-launch values for the SARR receiver gains in the Fixed Gain Mode. The specific gain values are available from prelaunch test results.

The test ground station receiver gain is set such that the demodulated baseband output is +13.0 dBm when the downlink is at nominal modulation index. Therefore, the SARR receiver output (P_O) to the SARR modulator is equal to

$$P_O = -8.5 \text{ dBm} + (S_R - 13.0 \text{ dBm})$$

where S_R is the measured test ground station's baseband output level in dBm. For example, when S_R equals 13.0 dBm, the SARR receiver is known from the prelaunch setting to be producing an output equal to -8.5 dBm.

The receiver absolute antenna gain G_A is given by:

$$G_A = P_O - G_r \text{ dB} - P_{io}$$

where P_{io} is the input to the SARR receive antenna referred to isotropic. The values of P_{io} are set throughout the test pass by adjusting the uplink test signal EIRP as required to compensate for variation in the path loss to the spacecraft.

The antenna G/T can be measured absolutely in orbit and needs no calibration parameters from pre-launch data, which is necessary for the absolute antenna gain. However, the G/T is a function of the instantaneous background noise, which affects the T in the denominator. One must, therefore, monitor the channel activity during the tests and not use data from passes which were corrupted with interference signals that impact the noise temperature measurement.

The antenna G/T is computed from the measured downlink baseband level (S_R) and the measured downlink baseband noise level (N_o dBm per Hz). The data reduction formula is as follows:

$$G/T = S_R/N_o - P_{io} - 198.6 \text{ dBm}$$

where for a strong downlink path it can be assumed that the baseband S/N_o is equal to the uplink S/N_o at the spacecraft receiver input.

B.12: SARP 406 MHz Receive Antenna Pattern

Objective

The objective of this test is to measure the in-orbit SARP antenna pattern.

Procedure

The SARP instrument contains a power detector which measures P_i, the received signal level at the input to the SARP receiver. The precision of the measurement is ±2.5 dB and must be considered in interpretation of results. This may result in being able to determine only the pattern shape and not the absolute gain of the antenna. The SARP received signal level, P_i, can be obtained by decoding the SARP PDS data and processing in accordance with the algorithms in C/S T.003.

The general approach for making the antenna pattern measurement is as follows. Test transmissions from a 406.025 MHz beacon will be uplinked at a 3 second rate via a programmed tracked yagi antenna. Each beacon transmission received by the SARP is processed at the ground measurement station and the beacon ID, time, and value of P_i derived from the SARP data. A point on the antenna pattern can be computed for each SARP message correlated with the uplink transmission. Computation of the antenna gain points are given by the following equations.

$$G(\prod_n) = P_{ij} + L_r - P_{ioj}$$

where:

P_{ioj}	=	$EIRP_{uj} - L(j) - P_{ol}$ Input power (dBm at SARP receiver at time j referred to isotropic)
L_r	=	1.5 dB SARP Receiver line loss.
Pol	=	0.5 dB estimated polarization loss for RHCP uplink to RHCP antenna on spacecraft.
L(j)	=	Path loss from Test ground station to spacecraft at time j.
$EIRP_{uj}$	=	$P_u - L_t + G_a(\prod_e)$ Equivalent Isotropically Radiated Power at time j.
L_t	=	Loss from beacon output to uplink test antenna (dB).
$G_A(\prod_e)$	=	Gain of uplink test antenna. G_A is a fixed value (on axis gain) for case where yagi is used in the program track mode. If a fixed antenna is used, G_A is described by the antenna pattern.

The data output will consist of tables and graphic presentations of SARP antenna gain (dB) versus angle off spacecraft nadir in degrees. The data processing software should have the capability of merging data from pass to pass to construct a cumulative pattern. Test passes should be selected to include minimum angles off nadir of at least 10 degrees.

B.13: SARSAT-SARP Calibration and Characteristics

B.13.1: USO Mean Frequency

Objective

The objective is to characterise the mean frequency of the on-board Ultra-Stable Oscillator, and to compare it to the instrument specification (10.000000 MHz +/- 5 Hz for SARP-3 and 5.203205 MHz +/- 2.5 Hz for SARP-2).

Procedure

The USO mean frequency is calculated as the average value of the USO frequency measurements provided by the LEOLUT over a 2-month period.

B.13.2: USO Frequency Drift/Day

Objective

The objective is to characterise the drift of the USO frequency on a one-day duration. The USO frequency drift/day, calculated with the below procedure, cannot be directly compared to the instrument specification (Drift/day less than 1 mHz for SARP-3 and 0.5 mHz for SARP-2) due to ground segment contribution, but is expected to be lower than 15 mHz.

Procedure

The USO frequency drift/day is calculated using the USO frequency measurements provided by the LEOLUT over a 2-month period. It is the standard deviation of the observed drifts, reduced to a one-day duration.

B.13.3: Time Tagging Accuracy

Objective

The objective is to characterise the time tagging accuracy, and to compare it to the system specification (10 ms, as per document C/S T.003).

Procedure

The time tagging accuracy is calculated using the dates of the Toulouse orbitography beacon bursts provided by the LEOLUT. It is the standard deviation of the time tagging error observed for all the bursts of the Toulouse beacon over a 2- month period.

B.13.4: Instrument Sensitivity

Objective

The objective is to characterise the sensitivity of the instrument, and to compare it to the instrument specification (-134 dBm for SARP-3 and -131 dBm for SARP-2).

Procedure

The sensitivity of the instrument is derived from the histogram of the levels (in dBm) received on-board the instrument for all the beacons (operational + test beacons) over a 5-day period. The sensitivity is the lower level plotted on the histogram.

B.13.5: Dynamic Range

Objective
The objective is to characterise the dynamic range of the instrument, and to compare it to the instrument specification (29 dB for SARP-3 and 23 dB for SARP-2).

Procedure

The dynamic range is derived from the histogram of the levels (in dBm) received on-board the instrument for all the beacons (operational + test beacons) over a 5-day period. The dynamic range is the difference between the higher and the lower levels plotted on the histogram.

B.13.6: Frequency Bandwidth

Objective

The objective is to characterise the frequency bandwidth of the instrument, and to compare it to the specification (80 kHz [406.010 – 406.090 MHz] for SARP-3 and 40 kHz [406.010 – 406.050 MHz] (Mode 2) for SARP-2).

Procedure

The frequency bandwidth is derived from the histogram of the frequencies measured for all beacons (operational + test beacons) over a 5-day period.

B.14: SARSAT-SARP Processing and Localisation Performance

B.14.1: Probability to provide a valid solution

Objective

The objective is to characterise the probability to provide a valid solution, and to compare it to the specification (probability better than 95% to provide a valid solution (15 hexa identification provided) for a beacon transmitting with a 37 dBm output power (with a whip antenna) and for satellites passes with elevation above 5°).

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator over a 5-day period.

B.14.2: Access probability or throughput

Objective

The objective is to characterise the access probability or throughput, i.e. the probability to retrieve a valid message for each single transmitted message in the same conditions as above. The specification is 75 % at 37 dBm and the target is a value higher than 90%.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator over a 5-day period.

B.14.3: Probability to retrieve a complete message

Objective

The objective is to characterise the probability to retrieve a complete message for each transmitted message in the same conditions as above. There are no specifications for this parameter.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator over a 5-day period.

B.14.4: Probability of Doppler processing

Objective

The objective is to characterise the probability to retrieve at least 4 beacon bursts per pass, in the same conditions as above. The specification is 95 % at 37 dBm.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator over a 5-day period.

B.14.5: Probability of Doppler location better than 5 km

Objective

The objective is to characterise the probability to provide a Doppler location with an accuracy better than 5 km. The specification is a probability better than 95% to provide a Doppler location with an accuracy better than 5 km for a beacon transmitting with a 37 dBm output power (with a whip antenna) and for satellites passes with elevation above 5°.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator over a 5-day period.

B.14.6: Accuracy of Doppler location

Objective

The objective is to characterise the accuracy of Doppler location, i.e. the average value of the error made when processing the location. There is no specification for this parameter.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator, and also for the Toulouse orbitography beacon over a 5-day period.

B.14.7: Ellipse error mean radius

Objective

The objective is to characterise the average value of the ellipse error radius parameter provided by the LEOLUT. There are no specifications for this parameter.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator over a 5-day period.

B.15: SARSAT-SARP Performance with Variable Emission Power

For assessing these performances, the power will be varied from 20 dBm to 37 dBm with a 2 dBm or 3 dBm step.

B.15.1: Probability to provide a valid solution

Objective

The objective is to characterise the probability to provide a valid solution (15 hexa identification provided) as a function of beacon emission power.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator with variable power over a 3-day period.

B.15.2: Access probability or throughput

Objective

The objective is to characterise the access probability or throughput, i.e. the probability to retrieve a valid message for each single transmitted message, as a function of beacon emission power.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator with variable power over a 3-day period.

B.15.3: Probability to retrieve a complete message

Objective

The objective is to characterise the probability to retrieve a complete message as a function of beacon emission power.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator with variable power over a 3-day period.

B.15.4: Probability of Doppler processing

Objective

The objective is to characterise the probability of Doppler processing, i.e. the probability to retrieve at least 4 beacon bursts per pass, as a function of beacon emission power.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator with variable power over a 3-day period.

B.15.5: Accuracy of Doppler processing

Objective

The objective is to characterise the accuracy of Doppler location, i.e. the average value of the error made when processing the location, as a function of beacon emission power.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator with variable power over a 3-day period.

B.15.6: Threshold for a 75% access probability

Objective

The objective is to characterise the threshold for a 75% access probability, i.e. the value of beacon power for which the LEOLUT is able to provide a valid message for each beacon event 75% of the time. The target is a value about 23 dBm.

Procedure

The statistical analysis is done through beacon messages transmitted with the Toulouse beacon simulator with variable power over a 3-day period.

- END OF ANNEX B -

ANNEX C

C. LIST OF LEOSAR SPACE SEGMENT ASSESSMENT INDICATORS / COMPLIANCE LEVELS

Table C.1: Sarsat LEOSAR Space Segment Assessment Indicators/Compliance Levels

Assessment Indicator	Compliance Level
L-band EIRP	As per Section 5 of C/S T.003, the EIRP is calculated by combining the transmitter output power 8.6 dBW (7.2 W) for SARR-1 and 6 dBW (4.0 W) for SARR-2 with the SLA Gain Pattern for the corresponding antenna used on the specific spacecraft. EIRP values vary over the range of nadir angles depicted in document C/S T.003.
Spectral occupancy (of downlink)	As per C/S T.003 Figure 3.9 “Typical Sarsat SARR-1 1544.5 MHz Observed Downlink Signal” and Figure 3.14 “Typical Sarsat SARR-2 1544.5 MHz Observed Downlink Signal”.
Signal levels (out-of-band)	As per C/S T.003 Figure 3.10 “Sarsat SARR Transmitter Spurious Emission Limits”
Signal levels (spacecraft generated)	-145 dBm referred to SARR receiver input
Signal-to-noise density ratio	As per C/S T.004 test B.4
Carrier-to-beacon ratio	As per C/S T.004 test B.4
Location accuracy (test signals)	406 MHz 5 km 2.4 kb/s 5 km
AGC dynamic range	As per C/S T.003 Table 3.2 “Sarsat SARR Receiver Parameters”. 406 MHz > 50dB
Modulation index	As per C/S T.003 Table 2.4 “Cospas and Sarsat Output Parameters” For SARR-1: 406 MHz [.58] ± 10% radians rms 2.4 kb/s [.39] ± 10% radians rms overall [.70] ± 10% radians rms For SARR-2: 406 MHz [.35] ± 10% radians rms 2.4 kb/s [.35] ± 10% radians rms overall [.50] ± 10% radians rms
SARR translation and transmitter frequencies	As per C/S T.003 Table 3.2 “Sarsat SARR Receiver Parameters”, Table 3.3 “Sarsat SARR-1 1544.5 MHz Transmitter Parameters” and Table 3.5 Sarsat SARR-2 1544.5 MHz Transmitter Parameters”. 406 MHz ± 406 Hz 1544.5 MHz ± 3.2 kHz

Assessment Indicator	Compliance Level
SARR Channel bandwidth (1 dB)	As per C/S T.003 Figure 3.8 “Sarsat SARR-1 Baseband Frequency Spectrum”, Figure 3.13 “Sarsat SARR-2 Baseband Frequency Spectrum”, and Table 2.3, “Cospas and Sarsat Input Parameters”. 406 MHz 80 kHz
Amplitude ripple of passbands	As per C/S T.003 Table 3.3 “Sarsat SARR-1 1544.5 MHz Transmitter Parameters” and Table 3.5 “Sarsat SARR-2 1544.5 MHz Transmitter Parameters”. 406 MHz < 2.5 dB
Intermodulation products (2 test signals)	As per C/S T.003 Table 3.2 “Sarsat SARR-1 Receiver Parameters”. 406 MHz < 170 dBW As per C/S T.003 Table 3.4 “Sarsat SARR-2 Receiver Parameters” [TBD].
Harmonic products in downlink baseband (from Doppler compensated uplink carriers)	As per C/S T.003 Table 3.2 “Sarsat SARR-1 Receiver Parameters”. 406 MHz < 170 dBW As per C/S T.003 Table 3.4 “Sarsat SARR-2 Receiver Parameters” [TBD].
Antenna patterns of SARP receivers	As per C/S T.003 Figure 5.6 “Sarsat-TIROS SARP Receive Antenna (UDA) Gain Pattern”.
Antenna patterns of SARR receivers	As per C/S T.003 Figure 5.5 “Sarsat-TIROS 406 MHz Receive Antenna (SRA) Gain Pattern”.
Antenna pattern of SARP/SARR receivers (SARSAT-METOP)	As per C/S T.003 Section 5.3 “SARSAT-MetOp 406 MHz SARR and SARP Receive antenna (CRA)”, Figure 5. 9.

Table C.2: Cospas LEOSAR Space Segment Assessment Indicators / Compliance Levels

Assessment Indicator	Compliance Level
L-band EIRP	EIRP values vary from approx 4 dBW to 6 dBW over the range of nadir angles depicted in document C/S T.003
Spectral occupancy (of downlink)	As per C/S T.003 Figure 3.3 "Typical Cospas 1544.5 MHz Observed Downlink Signal"
Signal levels (out-of-band)	As per C/S T.003 Table 3.1 "Cospas 1544.5 MHz Transmitter Parameters" Spurious Output Level ≤-60 dBW
Signal levels (spacecraft generated)	- 150 dBm referred to Cospas Repeater input
Signal–to–noise density ratio	TBD
Carrier–to–beacon ratio	TBD
Location accuracy (test signals)	2.4 kb/s 5 km
AGC dynamic range	60 dB
Modulation index	As per C/S T.003 Table 2.4 "Cospas and Sarsat Output Parameters" 2.4 kb/s 0.27 ± 10% radians rms overall [0.27] ± 10% radians rms
SARR translation and transmitter frequencies	As per C/S T.003 Table 3.1 "Cospas 1544.5 Transmitter Parameters" 1544.5 MHz $\pm 2 \cdot 10^{-6}$ for small Cospas satellites
Antenna pattern of SARP receiver	As per C/S T.003 Figure 5.2 "Cospas (SARP-2) 406 MHz Receive Antenna (SPA) Gain Pattern"
SARP processor message access (stressed conditions)	TBD
SARP processor receiver sensitivity	As per C/S T.003 Table 4.2 "Cospas SARP-2 Parameters" -161 dBW
SARP processor throughput (normal conditions)	[99%]

- END OF ANNEX C -

ANNEX D

D. SARSAT LEOSAR ASSESSMENT REPORT (SARR)

SARSAT - _______			
Test	**Result**	**Pass / Fail**	**Comments**
B.1 Total Received Signal Power			
B.2 Spectral Occupancy of the Downlink			
B.3 Spurious Output Levels			
B.4 Received Signal Power of Test Signals in the 406 MHz Repeater Band			
B.5 Location Accuracy of 406 MHz Test Beacons			
B. 6 AGC Dynamic Range			
B. 7 Modulation Index of the Repeater			
B. 8 Translation and Transmitter Frequencies			
B. 9 Channel Bandwidth and Amplitude Ripple			
B.10 Intermodulation and Harmonic Levels			

Note: Required graphics and/or data should be provided as attachments to this report.

SARR: Operational _______ Not Operational _______

Limitations:

Remarks:

- END OF ANNEX D -

ANNEX E

E. SARSAT LEOSAR ASSESSMENT REPORT (SARP_3)

SARSAT - _______			
Test	**Result**	**Pass/Fail**	**Comments**
B.13 SARP Calibration USO Mean Frequency		10 MHz +/-5Hz	
B.13 SARP Calibration Dating Accuracy		≤ 10 ms	
B.13 SARP Calibration Sensitivity/Dynamic Range		-134dBm/29dB	
B.13 SARP Calibration Frequency Bandwidth		[406.01-406.09MHz]	
B.14 SARP Performance Throughput		≥ 75%	Expected value ≥ 90%
B.14 SARP Performance Prob. of Location ≥ 5 km		≥ 95%	
B.15 SARP Variable Power Threshold for a 75% Access Probability		≤ 37 dBm	Expected value about 23 dBm

Note: Required graphics and/or data should be provided as attachments to this report.

SARP: Operational _______ Not Operational _______

Limitations:

Remarks:

- END OF ANNEX E -

ANNEX F

F. SARSAT LEOSAR ASSESSMENT REPORT (ANTENNAS)

SARSAT - _______			
Test	**Result**	**Pass/Fail**	**Comments**
B.1 Total Received Signal Power			
B.12 SARP 406 MHz Antenna Receive Pattern			
B.11 SARR 406 MHz Receive Antenna Pattern			

Note: Required graphics and/or data should be provided as attachments to this report.

Antennas: Operational _______ Not Operational _______

Limitations:

Remarks:

- END OF ANNEX F -

ANNEX G

G. LEOSAR COMMISSIONING REPORT

Satellite: __________			
Unit	**Pass/Fail**	**Operational, Limited Operation, Not Operational**	**Comments**
SRA Antenna			
SPA Antenna[1]			
UDA Antenna[2]			
SLA Antenna			
406 MHz SARR[2]			
406 MHz SARP – Global			
406 MHz SARP – Local			

(1) Cospas payloads only
(2) Sarsat payloads only

Notes: Required graphics and/or data should be provided as attachments to this report.
SARR - Search and Rescue Repeater
SARP - Search and Rescue Processor
SRA - SARR Receive Antenna
SPA - SARP Receive Antenna
UDA - UHF data collection system antenna
SLA - SARR L-band transmit antenna

Limitations:

Remarks:

- END OF ANNEX G –

- END OF DOCUMENT -

Cospas-Sarsat Secretariat
700 de la Gauchetière West, Suite 2450, Montreal (Quebec) H3B 5M2 Canada
Telephone: +1 514 954 6761 / Fax: +1 514 954 6750
Email: mail@cospas-sarsat.int
Website: www.cospas-sarsat.org