DESCRIPTION OF THE
406 MHz PAYLOADS USED IN
THE COSPAS-SARSAT MEOSAR SYSTEM

C/S T.016

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HISTORY

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1. INTRODUCTION

1.1 Overview

This document provides a description of the MEOSAR payloads carried on board these spacecraft.

1.2 Purpose

The purpose of this document is to describe the functionality and performance parameters for each MEOSAR instrument. The document is intended to be used to ensure the necessary compatibility for the 406 MHz beacon to satellite uplink and compatibility for the satellite to MEOSAR local user terminal (MEOLUT) downlink. The document is not intended for use as a specification for procurement of hardware for MEOSAR repeaters.

1.3 Scope

This document presents a technical description of the MEOSAR repeaters used in the Cospas-Sarsat system. Section 2 provides a general overview of the MEOSAR repeater function. Sections 3, 4 and 5 provide descriptions of the repeaters on the USA, European and Russian, satellites.

1.4 Reference Documents

The following documents contain useful information to the understanding of this document:

C/S R.012	Cospas-Sarsat 406 MHz MEOSAR Implementation Plan
C/S T.001	Specification for Cospas-Sarsat 406 MHz Distress Beacons
C/S T.011	Description of the Payloads used in the Cospas-Sarsat GEOSAR System
C/S T.018	Specification for Second-Generation Cospas-Sarsat 406-MHz Distress Beacons
C/S T.019	Cospas-Sarsat MEOLUT Specification and Design Guidelines
C/S T.020	Cospas-Sarsat MEOLUT Commissioning Standard
C/S G.003	Introduction to the Cospas-Sarsat System
C/S S.011	Cospas-Sarsat Glossary

- END OF SECTION 1

2. 406 MHZ MEOSAR SYSTEM DESCRIPTION

The Cospas-Sarsat MEOSAR Space Segment consists of SAR instruments on board satellites in medium-earth orbit. The SAR instruments are radio repeaters that receive distress beacon signals in the 406 - 406.1 MHz band and relay these signals to MEOLUTs for processing beacon identification and associated data. A description of the Cospas-Sarsat beacon signal parameters and data protocols is provided in reference document C/S T.001. MEOSAR instruments are flown on the following satellites:

Spacecraft	Country/Organization	Status
Galileo	Europe	In Deployment
Glonass-K	Russia	In Deployment
GPS-II/III (DASS)	USA	Non-operational; data available for operational use
GPS-III	USA/Canada	Planned
BDS-3	China (P.R. of)	Fully Deployed

Note: The DASS S-band constellation is not planned to be declared as operational, but its data may be used operationally.

2.1 406 MHz MEOSAR Payload Functional Description

The DASS S-band SAR payload is carried on some GPS spacecraft and consists of an uplink 406 MHz receive antenna, a search and rescue repeater (SARR) instrument and a transmit antenna. DASS repeaters have a S-band downlink instead of the 1544-1545 MHz band assigned by the ITU.

The SAR/GPS L-band SAR payload is carried on GPS spacecraft and consists of an uplink 406 MHz receive antenna, a search and rescue repeater (SARR) instrument and a transmit antenna. The SARR instrument consists of a 406 MHz receiver and a frequency translator feeding a 1544 MHz downlink transmitter.

The SAR/Galileo payload consists of the forward link 406 MHz receive antenna, transponder and a 1544 MHz transmit antenna, and a return link for SAR-related acknowledgements and other messages. In terms of hardware, the return link is part of the Galileo ground mission segment (GMS) and navigation payload.

The SAR/Glonass payload include a 406 MHz repeater on the K series (K-1 and K-2) of spacecraft to relay the signals transmitted by 406 MHz distress beacons. Glonass K-2 series spacecraft are expected to also include a return link capability.

The SAR/BDS payload consists of the forward link 406 MHz receive antenna, transponder and a 1544 MHz transmit antenna, and a return link for SAR-related acknowledgements and other messages via BDS B2b signal.

2.2 MEOSAR Orbit Information

Satellite positions and other information are needed for location processing and are normally available on the navigation message broadcast by each satellite. To provide redundancy, MEOSAR space segment providers are establishing servers, which can be accessed over the Internet where the orbit parameters would be available.

Annex C contains a table of what MEOLUT operators would like to see provided over the Internet with projected accuracy and, in addition, a table of what data is intended to be provided on the space segment providers' servers. For completeness, information on the navigation messages is presented as well.

2.3 MEOSAR Interoperability Parameters

Document C/S R.012 defines interoperability as follows: "the components of the MEOSAR system conform to a common architecture and comply with agreed performance standards. A set of similar satellite downlink characteristics allows MEOLUTs to track satellites and process signals from interoperable MEOSAR constellations."

Payload characteristics that had been identified in document C/S R.012 that impact MEOSAR interoperability are refined as follows:

- Modulation of the downlinks: non-inverted frequency translation will be used by all L band constellations so there is no additional modulation of the downlink, except DASS constellation, which inverts the spectrum. This simplified MEOLUT design.
- Downlink frequency: MEOSAR satellite constellations need not have the exact same downlink frequencies to enable MEOLUTs to process their downlinks. SAR/GPS L-band will operate in the 1544.740 - 1544.840 MHz band, SAR/Glonass will operate in the 1544.850 - 1545.950 MHz band, SAR/Galileo will operate in the 1544.050-1544.150 MHz band and SAR/BDS will operate in the 1544.160-1544.260 MHz band. These frequencies were chosen to avoid the 1544.5 MHz downlink of the GEOSAR spacecraft. The GPS DASS S-band satellites use S-band 2226 MHz.
- Downlink EIRP: MEOSAR providers have agreed that to ensure interoperability, MEOSAR downlink EIRPs should exceed 15 dB_W for all MEOLUT-to-satellite elevation angles above 5 degrees.
- Downlink polarization: circular. The design for SAR/GPS L-band is to operate with RHCP downlinks, whereas SAR/Galileo and SAR/Glonass plan to operate LHCP downlinks. The DASS S-band satellites operate with LHCP.
- Repeater bandwidth: MEOSAR providers and Cospas-Sarsat have agreed that the 406 MHz L band SAR repeater bandwidth should be as follows (centered on 406.05 MHz):
  - 80 kHz (1.0 dB bandwidth),
  - 90 kHz (3.0 dB bandwidth),
  - < 110 kHz (10 dB bandwidth),
  - < 170 kHz (45 dB bandwidth),
  - < 200 kHz (70 dB bandwidth).

The bandwidth of the DASS S-band repeater is about 270 kHz, wider than the nominal 100 kHz, so filtering must be done on the downlink to remove the unwanted signals.

- Repeater receiver G/T: MEOSAR providers and Cospas-Sarsat have agreed that a repeater G/T value of -17.7 dB/K (assuming an antenna noise temperature of 400 K) or greater would enable the development of a fully interoperable MEOSAR system that satisfied the performance requirements for compatibility with Cospas-Sarsat.
- System dynamic range: the repeater dynamic range and AGC characteristics determine the MEOSAR system's ability to adequately accommodate interference and varying beacon message traffic loads. MEOSAR providers have agreed that the repeater instantaneous linear range (not including AGC) should meet or exceed 30 dB.
- Repeater AGC characteristics: range >30 dB with a time constant < 80 ms.
- Repeater linearity: MEOSAR providers have agreed that the ratio of power from a relayed beacon to intermodulation products should be greater than 30 dB_c when the repeater is operating beyond its linear range.
- Repeater group delay: repeater group delay characteristics impact upon MEOLUT time-tagging accuracy and, consequently, MEOSAR independent location accuracy performance. To ensure that minimum performance requirements are satisfied regardless of the satellite constellation relaying the beacon signal, MEOSAR providers agreed that repeater group delay variation with frequency should be less than 10 µs in any 4 kHz anywhere within the 1 dB bandwidth. These variations are valid only for in-orbit nominal operational temperature ranges as determined by the respective space segment operators.
- Group delay stability: to ensure negligible impact on TOA/TDOA estimation and effective exchange of TOA data, the MEOSAR providers agreed to a group delay stability with respect to all environmental conditions and ageing with a stability within that range of 500 nanoseconds.
- Uplink polarization: SAR/GPS L-band, SAR/Galileo and SAR/Glonass will all use RHCP with an axial ratio < 2.5 dB over the Earth coverage as the uplink polarization, while DASS S-band uses LHCP as the uplink polarization.

The following satellite parameters are suggested as enhancements that can be considered by space segment providers to possibly enhance system performance:

- Repeater bandwidth: to reduce the impact of side-band interferers, the 406 MHz L-band SAR repeater bandwidth should be as follows (centered on 406.05 MHz):
    - 90 kHz (1.0 dB bandwidth),
    - < 100 kHz (10 dB bandwidth),
    - < 170 kHz (45 dB bandwidth),
    - < 200 kHz (70 dB bandwidth).
- Repeater bandpass characteristics: to ensure low distortion of the second generation beacon signals, the maximum SAR payload L-band signal amplitude ripple should be ± 0.5 dB (i.e., 1 dB peak to peak) over any 1 kHz within the 80 kHz passband, and the maximum overall amplitude ripple should be ± 1.25 dB (i.e., 2.5 dB peak to peak) within the entire 80 kHz passband.
- Repeater group delay: repeater group delay variation with frequency should be within ± 10 µs in ± 28 kHz band from the center frequency of the 1 dB bandwidth.

- Group delay stability: group delay stability with respect to environmental conditions within the 1 dB bandwidth of < 200 ns peak-to-peak in the medium term (i.e., over any 3 minutes) and < 400 ns peak-to-peak over any 24 hours (i.e., long term).

- END OF SECTION 2 -

3. GPS 406 MHZ MEOSAR REPEATER

3.1 DASS S-Band

DASS S-Band satellites have been on orbit since 2002 and have provided MEOSAR satellite functionality that has been vital to the development of the MEOSAR system, including ground system development and testing of MEOLUTs and MCCs. They were used extensively for the Proof of Concept and the Demonstration and Evaluation phases of MEOSAR system development and testing. They will be replaced as part of the normal GPS constellation replenishment with SAR/GPS MEOSAR satellites that carry a SAR/GPS payload specifically designed for Cospas-Sarsat and delivered to the GPS program from the Canadian Department of National Defence.

The DASS S-band constellation's data may be used operationally. The USA will commission DASS satellites in order to document their performance and support their use as needed. The capability to use the DASS S-band satellites is not required but the SAR payloads are available for continued support of the MEOSAR system development, operations and interference monitoring, as long as they remain in operation.

3.1.1 DASS S-Band Overall Description

DASS satellites contain a non-regenerative repeater that only amplifies, translates in frequency, and retransmits the received beacon message.

The DASS payload will transmit an RF spectrum centered at approximately 1.022 MHz below a center frequency of 2227.494 MHz. The center frequency is being very accurately derived from a phase-lock-loop that is governed by the on board GPS rubidium clock.

- Polarization: Left Hand Circular
- Center Frequency: 2227.494265 MHz
- Carrier Stability: + 0.022 Hz (1 part in 1011)
- Maximum Doppler shift: + 5.7 kHz

The DASS satellite RF spectrum is centered at approximately 1.022 MHz below the center frequency of 2227.494 MHz and is, therefore centered at 2226.472 MHz and has a double-sided -3dB bandwidth of approximately 220 kHz.

The downlink from each satellite contains a copy of the beacon message that has been translated from UHF to S-band according to the following formula.

Downlink frequency = 2226.472340 MHz + 406.05 MHz - UHF uplink frequency

The SV UHF receiver has a band pass filter with a -3 dB bandwidth of 220 kHz. The transmitted power is set at 0.6 W and is shared between all signals and in-band noise detected by the UHF receiver. The total transmitted S-band EIRP at bore sight is 10 dBw.

S-band GPS satellites, also known as DASS satellites, carrying MEOSAR repeaters acquire Cospas-Sarsat designations according to their unique two-digit Space Vehicle ID number (SVID), by preceding the SVID by the number 3.

The satellites listed in Table B-2 carry a repeater suitable for SAR use. Future GPS satellite launches will provide the DASS capability until it is replaced by the SAR/GPS capability, so the list of available satellites will continue to grow and be updated.

The GPS satellites are in six orbital planes with four satellites each. The six orbit planes have approximately 55° inclination and are separated by 60° right ascension of the ascending node (angle along the equator from a reference point to the orbit's intersection). Reference orbital positions for nominal MEOSAR GPS S-band satellites can be found in Annex A of this document.

3.1.2 DASS S-Band Repeater Functional Description

The DASS repeater can only be operated in the Automatic Gain Control (AGC) mode.

3.1.3 DASS S-Band Repeater Operating Modes

The DASS repeater can only be operated in the Automatic Gain Control (AGC) mode.

3.1.4 DASS S-Band Repeater Spectrum Characteristics

The following spectrum photographs show the downlink spectrum of a typical DASS satellite. The signals seen are other signals within the repeaters 220 kHz band, but outside of the 100 kHz SAR band. Both photographs were taken with a real time spectrum analyser.

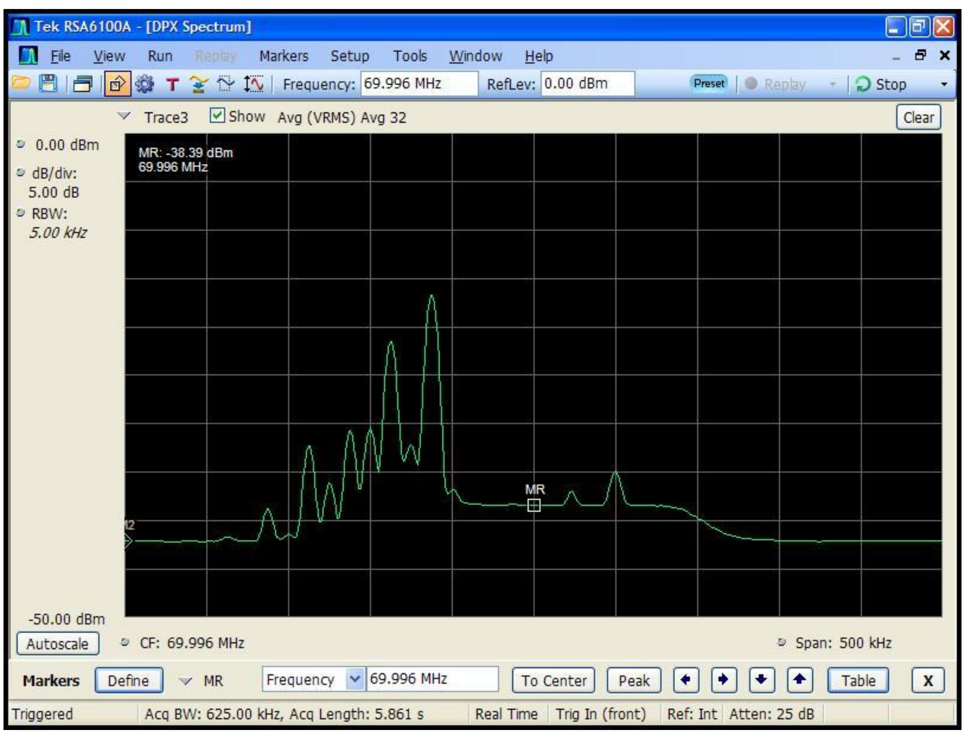

Figure 3.1: DASS S-Band Downlink Spectrum Averaged

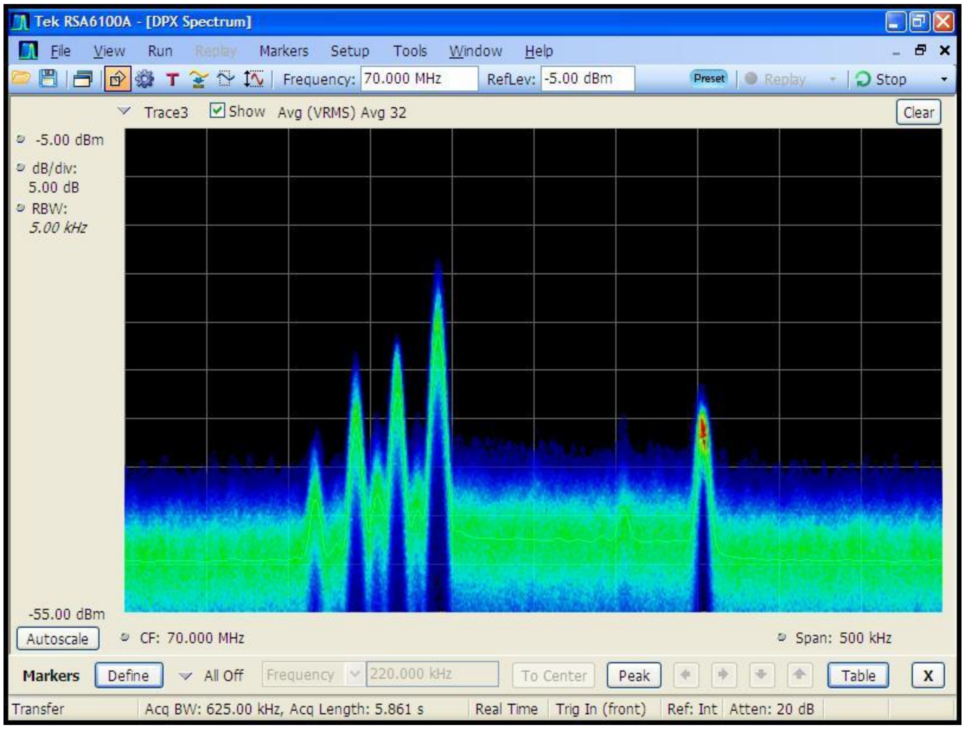

Figure 3.2: DASS S-Band Downlink Spectrum

3.1.5 DASS S-Band Repeater Coverage Area

The DASS S band repeater is designed to cover the full visible Earth's disc both in the uplink and in the downlink. The difference in the path loss between satellites seen on the horizon and those appearing in zenith is 1.9 dB.

3.1.6 DASS S-Band Repeater Performance Parameters

The following data is derived from the on-orbit DASS Commissioning Tests, conducted by the USA in 2014-2016.

A statistical analysis was performed on the data as follows:

1. When multiple measurements were made on one satellite, the results were averaged to get a single reportable result. If one measurement was done, then the reported result is that one measurement.
2. The range of the reported results for all tested satellites are given.
3. The overall average, calculated by taking the reported results for each satellite and averaging them.
4. A standard deviation calculated by taking the reported results from each satellite and finding the standard deviation.

3.1.6.1 DASS S-Band SAR Receiver Parameters

Table 3-1: DASS S-Band SAR Receiver Parameters

Parameter	Interoperability Requirement	DASS On Orbit Performance	Unit
Uplink frequency range	406.0 to 406.1	405.915 to 406.185	MHz
Receive centre frequency Normal mode	406.050	406.050	MHz
Nominal input power at antenna	-159.0	-	dB_W
Maximum input power at antenna	-148.0		dB_W
System dynamic range	30	Range: 26 to 37 Average: =30.9 Standard Deviation: =4	dB
Receive antenna polarisation	RHCP	LHCP	
Receive antenna gain at boresight and EoC		13.5 (boresight) 11.6 (EoC)	dB_i
Receive antenna axial ratio	< 2.5	Not measured on orbit	dB
Satellite G/T At edge of coverage At centre of coverage	>-17.7	Range: -29.6 to -16 Average: = -21.46 Standard Deviation: = 3.3	dB/K
System noise temperature			K
Bandpass characteristics Normal mode	> 80 kHz (1.0 dB) > 90 kHz (3.0 dB) < 110 kHz (10 dB) < 170 kHz (45 dB) < 200 kHz (70 dB)	220 kHz (3 dB)	
Phase linearity (overall in-band) Normal mode	/		degree
Group delay (turn-around time) Normal mode	/		µs
Group delay uncertainty (95% conf.)	500		ns
Group delay over 4 kHz (slope) Normal mode	10		µs/4kHz
Transponder gain modes			
ALC time constant	< 80		ms
ALC dynamic range	> 30	Range: 26 to 37 Average = 30.9 Standard deviation = 4	dB
Transponder gain (multiple measurements on each sat averaged first)	> 180	Range: 151-159.4 Average = 156.27 Standard Deviation = 1.94	dB
Fixed gain mode adjustment range			dB
Transponder gain at nominal o/p power			dB

Parameter	**Interoperability Requirement**	**DASS On Orbit Performance**	**Unit**
Transponder linearity[1]	> 30	In-Band Range: 31 to 36 Average = 33.47 Standard Deviation = 1.81 Out of band: None Seen	dB_c
Translation frequency			Hz
Frequency translation Accuracy Short term stability (100 ms)	 $\pm 2 \times 10^{-11}$ 1×10^{-11}	Accuracy $\leq 8.7 \times 10^{-9}$ Average Accuracy = 8×10^{-10} Error range=: -22 to 8 Hz Error average = 2.1 Hz Error Standard Deviation = 8.8 Hz	
Gain variation			dB_{pk-pk}
Translation frequency stability			

Table 3-2: DASS S-Band SAR Transmitter Parameters

Parameter	Interoperability Requirement	DASS Performance	Units
Downlink frequency band		2226.47229 to 2226.47239 (SAR band) 2226.472205 to 2226.472475 (repeater)	MHz
Downlink centre frequency Normal mode		 2226.47234	MHz
Downlink antenna polarisation		LHCP	
Transmit antenna axial ratio			dB
Downlink EIRP	15 dB_W	Range: 27 to 34.3 Average = 30.3 Standard Deviation = 2.1	dB_m
EIRP stability in ALC mode			dB_{pk-pk}
EIRP stability in FG mode			dB_{pk-pk}
In band Intermod Products		Range: 31 to 36 dB below two tones level Average = 33.47 Standard Deviation = 2.1	dB
Out of band Intermod products		None seen	

3.2 GPS-III L-Band

The SAR/GPS L-band payloads hosted on the GPS-IIIF Space Vehicles will replace the DASS S-band constellation as the normal GPS constellation replenishment for the Cospas-Sarsat MEOSAR system. These payloads were designed by the Canadian Department of National Defence, and the Space Vehicles hosting these payloads were built by United States Space Force, Space and Missile Systems Center.

[1] In-band measured via spectrum analyzer using two tones and comparison of the difference between the intermodulation products and the two tones.

The SAR/GPS L-band payloads are to be launched starting in 2026. The information presented in this section refers to the data presented at the Critical Design Review (CDR) of the SAR/GPS repeaters completed in 2022.

3.2.1 GPS III Overall Description

The SAR/GPS L-band repeater payloads will receive distress beacon signals in the 406-406.1 MHz band (UHF) and relay these signals at the centre frequency of 1544.79 MHz (L-band) over a 150 kHz bandwidth to the MEOLUT for processing beacon identification and location.

The GPS constellation will comprise of 22 GPS-IIIF satellites equipped with the SAR/GPS L-band repeater payloads. Once launched, these payloads will be commissioned jointly by the USA and Canada.

3.2.2 GPS III Repeater Functional Description

The SAR/GPS L-band repeater payloads will provide a near-real-time “bent-pipe” SAR function for the detection and location of both the first and second generation of compliant 406 MHz distress beacons but will not have the ability to perform a Return Link Service function. The payload will use the GPS-IIIF Space Vehicle provided uplink antenna (D1) to receive beacon signals, the L-band downlink (L6) antenna for transmission and a single 10.23 MHz sine wave reference clock signal for the generation of all local oscillators used in the frequency translation.

To ensure compatibility and interoperability across the MEOSAR system, the SAR/GPS L-band repeater payloads were designed based on the MEOSAR space segment interoperability requirements as defined in section 2.3 of this document. Its design utilizes an analog double conversion bent pipe repeater concept and applies frequency translation without frequency inversion. The repeater does not demodulate or add new modulation to the uplink signals. Being an analog system, it does not use any programmable digital components, non-volatile memory or associated software or firmware. The repeater uses a cascaded down-conversion and up-conversion to convert the cross-band UHF to L-band frequencies, by first down-converting the UHF D1 uplink to a nominal intermediate frequency (IF) and then up-converting the IF to the L-band L6 signal while providing a constant output power over the dynamic range. The repeater then uses an output L-band filter to perform the output signal filtering (i.e., rejection of amplified thermal noise and up-conversion mixing products for the protection of the radio-astronomy frequency bands) and ensures a low loss path for the downlink signal before sending it to the L6 downlink antenna.

3.2.3 GPS III Repeater Operating Modes

The SAR/GPS L-band repeater will operate in Automatic Level Control (ALC) mode but not in a Fixed Gain Mode (a feature that is only available during factory alignment and acceptance testing phases). On orbit, the repeater will therefore operate in a fixed set-point automatic gain control (AGC) mode that will preserve SNR and linearity over the input dynamic range.

The SAR/GPS L-band repeater accepts a pulse discrete ON and OFF command from the GPS-IIIF SV to turn the repeater ON or OFF. Therefore the operational modes of the SAR/GPS repeater are: ON mode and OFF mode. It also exchanges other active analog telemetry and passive temperature telemetry signals with the GPS-IIIF Space Vehicle that are downlinked to the GPS control segments for health and status monitoring by the SAR/GPS space segment providers.

The SAR/GPS L-band repeater will only operate in the normal (90 kHz) bandwidth mode as it does not have a narrow (50 kHz) bandwidth mode.

3.2.4 GPS III Repeater Spectrum Characteristics

The L-band spectrum characteristics for the SAR/GPS Engineering Qualification Model (EQM) during its CDR are shown in Figure 3.3 and Figure 3.4. These outputs were captured from the spectrum analyzer (by keeping it in maximum hold while the line-stretcher was traversed) when connected to the input and output of the EQM respectively.

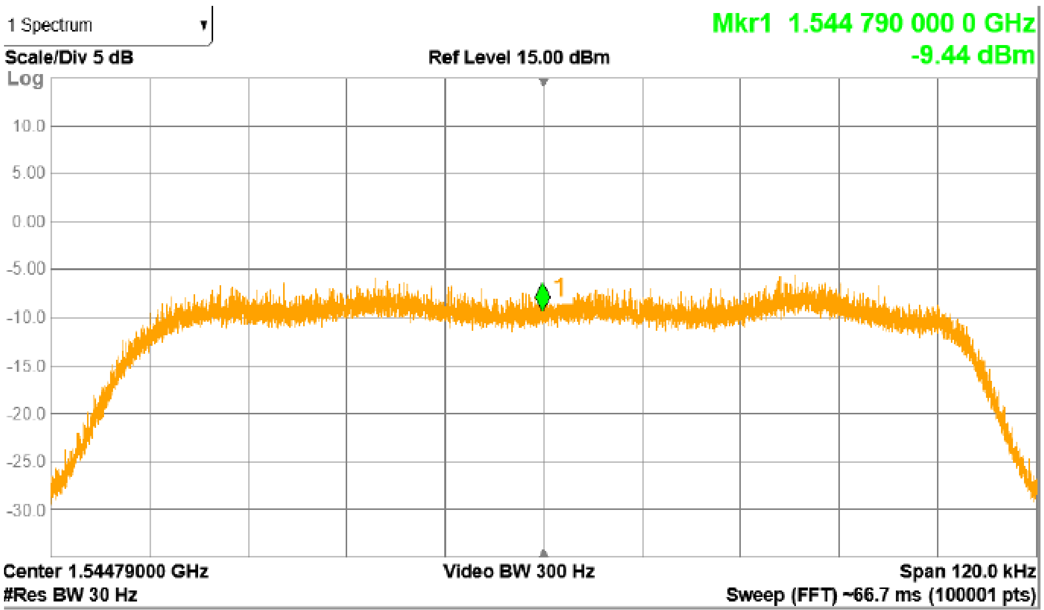

Figure 3.3: L-Band Output when Line-Stretcher was Connected to the Input of the SAR/GPS EQM.

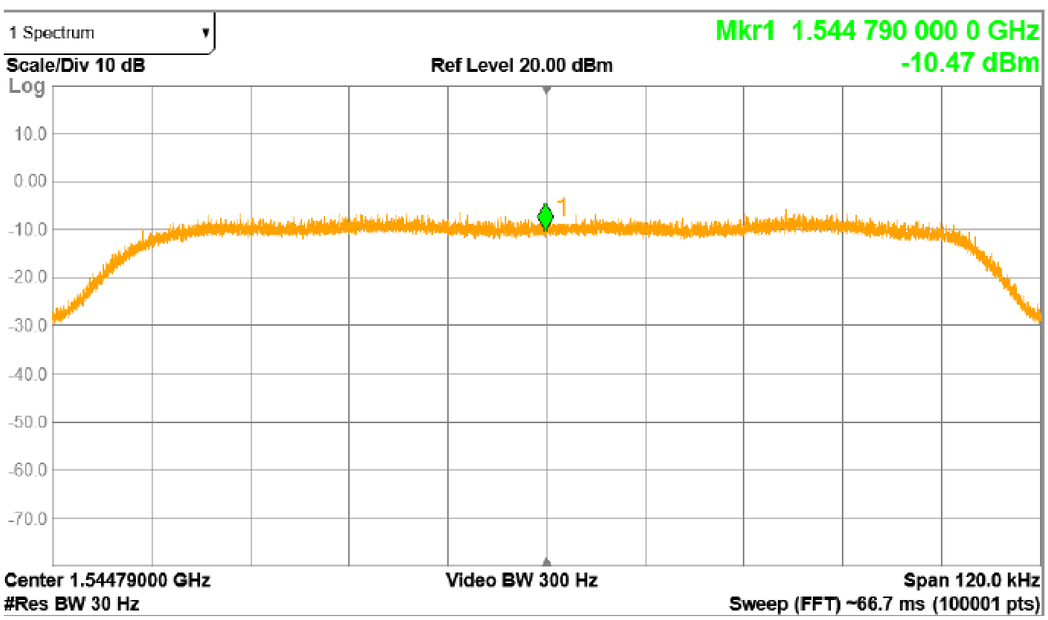

Figure 3.4: L-Band Output when Line-Stretcher was Connected to the L-Band Output of the SAR/GPS EQM (Using a Coupler).

3.2.5 GPS III Repeater Coverage Area

The SAR/GPS L-band repeater is designed to cover the full visible Earth's disc both in the uplink and in the downlink.

3.2.6 GPS III Repeater Performance Parameters

Table 3-3 presents the typical measured satellite payload (SAR/GPS EQM) performances based on ground testing at the time of SAR/GPS CDR.

Table 3-3: Typical SAR/GPS Repeater Characteristics at Design

Parameter	Interoperability Requirement[(a)]	SAR/GPS Design Performance	Unit
Uplink frequency range	406.0 to 406.1	406.0 to 406.1	MHz
Receive centre frequency	406.050	406.050	MHz
Nominal input power at antenna	-159.0	-165.0	dB_W
Maximum input power at antenna	-148.0	-135.0	dB_W
System dynamic range	30	32	dB
Receive antenna polarization	RHCP	RHCP	
Receive antenna gain		TBC[(g)]	dB_i
Receive antenna axial ratio	< 2.5	Not measured	dB
Satellite G/T [(b)] At edge of coverage [(c)] At centre of coverage	>-17.7	>-17.7[(h)]	dB/K
System noise temperature [(d)]		TBC	K
Bandpass characteristics Normal mode	> 80 kHz (1.0 dB) > 90 kHz (3.0 dB) < 110 kHz (10 dB) < 170 kHz (45 dB) < 200 kHz (70 dB)	> 80 kHz (1.0 dB) > 95 kHz (3.0 dB) < 110 kHz (10 dB) < 150 kHz (45 dB) < 200 kHz (70 dB)	
Group delay uncertainty (95% conf.)	500	107	ns
Group delay over 4 kHz [(e)] (slope)	10	< 8	μs/4 kHz
Transponder gain modes		ALC	
ALC time constant	< 80	45 - 63	ms
ALC dynamic range	> 30	32	dB
Transponder gain	> 180	> 180[(h)]	dB
Transponder linearity (C/I3)	> 30	32	dB_c
Translation frequency		1,138,733,300.0	Hz
Frequency translation Accuracy Short term stability (100 ms)	$\pm 2 \times 10^{-11}$ 1×10^{-11}	$< \pm 2 \times 10^{-11}$ 0.5×10^{-11}	
Gain variation [(f)]		TBC	dB_{pk-pk}
Translation frequency stability		TBC	
Downlink frequency band		1,544.715 to 1,544.865	MHz
Downlink centre frequency		1,544.79	MHz
Downlink antenna polarization		RHCP	
Transmit antenna axial ratio		TBC	dB

Parameter	Interoperability Requirement[(a)]	SAR/GPS Design Performance	Unit
Downlink EIRP	15	TBC	dB_W
EIRP stability in ALC mode		TBC	dB_{pk-pk}

(a) MEOSAR space segment interoperability requirements.
(b) G/T as measured in orbit. The MEOSAR space segment interoperability requirement is defined assuming antenna external noise temperature Ta = 400 K.
(c) The receive antenna edge of coverage is defined at a beacon elevation angle of 5°.
(d) System temperature computed at transponder input.
(e) In the 1 dB band.
(f) Gain variation in any 3 kHz within the operating band.
(g) Space Vehicle parameter to be provided when available.
(h) Value as determined by design.

3.2.6.1 GPS III SAR Receiver Parameters

The SAR/GPS repeater receive parameters are specified in Table 3-3.

3.2.6.2 GPS III SAR Transmitter Parameters

The SAR/GPS repeater transmit parameters are specified in Table 3-3. The bandpass characteristics and transmitter bandwidths for the SAR/GPS repeater is presented in Figure 3.5 for the normal (90 kHz) band. The typical normalized gain value was measured as 134.2 dB.

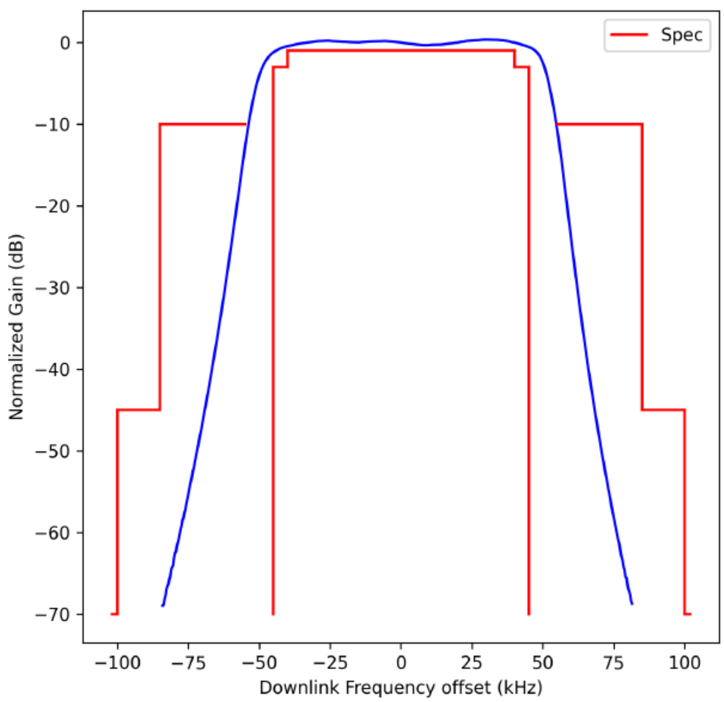

Figure 3.5: SAR/GPS Normalized Gain vs Downlink Frequency Offset

3.2.6.3 GPS III SAR Antennas

(to be provided later)

- END OF SECTION 3 -

4. GALILEO 406 MHZ MEOSAR REPEATER

4.1 Galileo Overall Description

Galileo satellites carrying MEOSAR repeaters acquire Cospas-Sarsat designations according to their unique two-digit Space Vehicle ID number (SVID), by preceding the SVID by number 4.

The information presented in this section refers to the Galileo In-Orbit Validation (IOV) satellites and to FOC (Full Operational Capability) satellites.

Only two of four Galileo IOV satellites are equipped with SAR repeaters. These two satellites are designated as Cospas-Sarsat 419 (GSAT0103, SVID-19) and Cospas-Sarsat 420 (GSAT0104, SVID 20).

SAR/Galileo FOC satellites are currently under deployment and they are all equipped with SAR Repeaters.

SAR/Galileo IOV and FOC satellites are in Walker 24/3/1 orbital configuration, with the slots separated by 45 degrees. Reference orbital positions for nominal MEOSAR Galileo satellites[2] can be found in:

http://www.gsc-europa.eu/system-status/orbital-and-technical-parameters

Note that satellites Cospas-Sarsat 418 (GSAT0201, SVID-18) and Cospas-Sarsat 414 (GSAT0202, SVID-14) are exceptionally in elliptical orbits. Their orbital positions, represented by Keplerian elements for the reference time 1 October 2010 at 00:00:00 UTC, are defined in Table 4-1.

Table 4-1: Keplerian Elements of Nominal Orbital Positions for Galileo C/S 418 and C/S 414 Satellites

Satellite			**Semi-Major Axis** (km)	**Launch date**	**Eccentricity**	**Inclination** (deg)	**RAAN** (deg)	**Arg. Perigee** (deg)	**True Anomaly** (deg)
	S VID	Slot							
GSAT0201	18	NA	27977.69	22.08.2014	1.57E-01	49.97	70.106	41.121	137.250
GSAT0202	14	NA	27977.61	22.08.2014	1.57E-01	50.03	69.080	42.294	317.263
Note: The coordinate reference frame used is CIRS[3] (true equator).									

The following sections provide information regarding the repeater configuration, modes of operation, and performance characteristics, including group delay characteristics, as recommended by CSC-47.

[2] Nominal MEOSAR Galileo satellites: SAR/Galileo Satellites for which ephemeris are available either through signal in space or through the Galileo Service Centre Server

[3] Dennis D. McCarthy and Gérard Petit (eds.), "IERS CONVENTIONS (2003)" IERS Convention Centre.

4.2 Galileo Repeater Functional Description

4.2.1 Payload Configuration

The Galileo satellite has two functional elements relevant to SAR, performing two principal functions pertaining to the SAR/Galileo system: the Navigation Function and the SAR Function. SAR/Galileo utilises both of these elements: the SAR Function for performing of the Forward Link Alert Service and the Navigation Function for performing the Return Link Service.

Figure 4.1 depicts the implementation of the two Galileo SAR functions. This section deals with the SAR Repeater, which performs the Forward Link Alert Service function, and comprises the SAR Transponder (SART) and SAR receive and transmit antennas (SARANT).

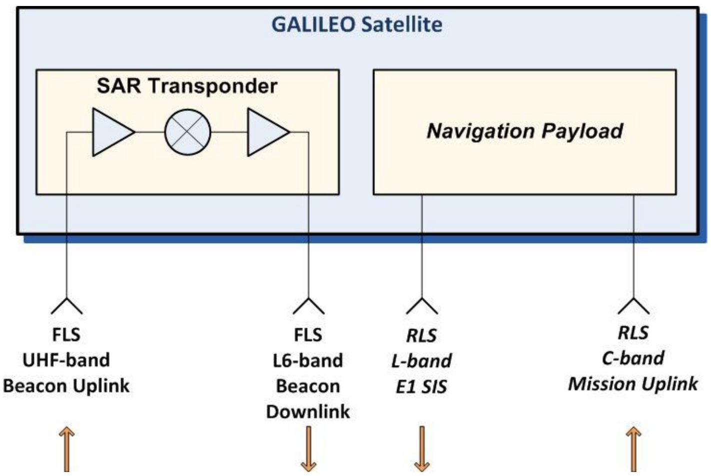

Figure 4.1: Implementation of SAR Functions on the Galileo Satellites

4.2.2 Configuration of Galileo SAR Repeaters

The Galileo SAR repeaters are based on bent pipe type transponders with no frequency inversion. They receive signals at the 406 MHz band and retransmit in the L6 band at 1.5441 GHz (see Table 4-3). They are designed according to the space segment interoperability requirements[4], ensuring MEOSAR compatibility and interoperability.

4.3 Galileo Repeater Operating Mode

The Galileo repeater can operate in two gain and two bandwidth modes. The operational modes include the normal (90 kHz) and narrow (50 kHz) bandwidth modes, as well as the possibility to operate with adjustable Fixed Gain (FGM) or Automatic Level Control (ALC) mode. The operational modes of the SAR repeater are therefore:

[4] As defined in Annex F of document C/S R.012.

<u>ON mode</u>

- ALC (transponder gain is self-regulated to ensure stable EIRP)
  - 90 kHz BW (normal bandwidth mode): ALC90 (default mode)
  - 50 kHz BW (narrowband mode): ALC50

In automatic level control gain mode the operational gain is automatically adjusted to obtain a power of 7 dB_W (IOV) or 6 dB_W (FOC) at the output of the SAR transponder.

- FGM (fixed gain, set by telecommand)
  - 90 kHz BW (normal bandwidth mode): FGM90
  - 50 kHz BW (narrowband mode): FGM50

In fixed gain mode (FGM) the operational gain is set by telecommand in a 31 dB range, with nominal step of 1 dB. The range is adjusted so that when the transponder is in the 90 kHz bandwidth mode, and at the input of the repeater there is only thermal noise, the nominal output power of 7 dB_W (IOV) or 6 dB_W (FOC) is achieved when the gain setting is set at the reference step.

The overall gain of the SAR repeater in the nominal gain setting in FGM (including the gains of the receive and transmit antennas) is given in the table below.

Table 4-2: Typical Overall Repeater Gain at Reference Gain Step in FGM

	FGM
Edge of coverage	182 dB
Centre of coverage	187 dB

<u>STANDBY mode</u> (transponder is powered up, but RF power is OFF)

<u>OFF mode</u> (transponder is not powered)

4.4 Galileo Repeater Spectrum Characteristics

The downlink spectrum of the Galileo repeaters is dominantly shaped by the intermediate-frequency crystal filters which define the pass band. Figure 4.2 and Figure 4.3 represent an example of the Galileo SAR repeater L-band downlink signal spectrum in narrow- and normal- bandwidth setting.

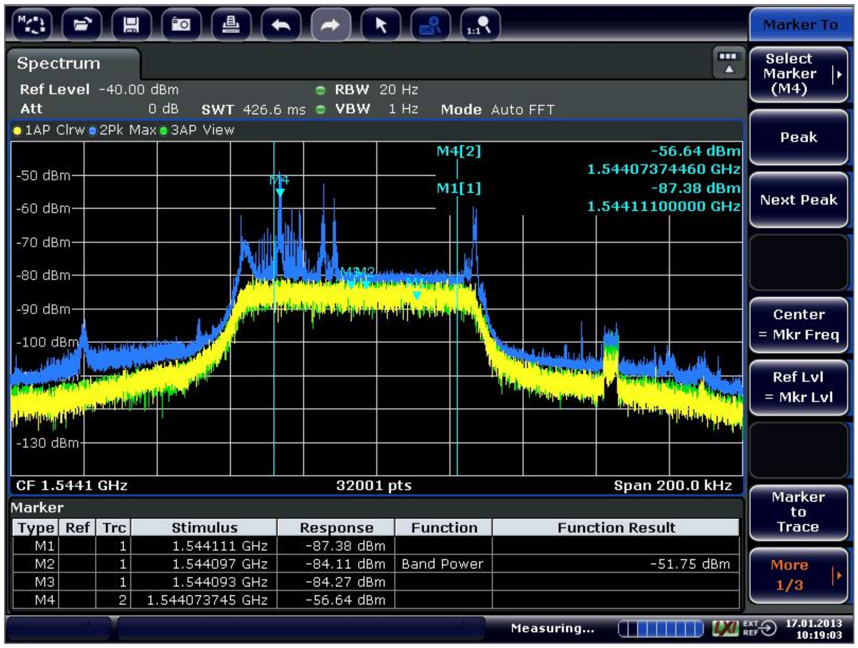

Figure 4.2: Galileo SAR Repeater L-Band Downlink Narrow-Band (50 kHz) Signal Spectrum

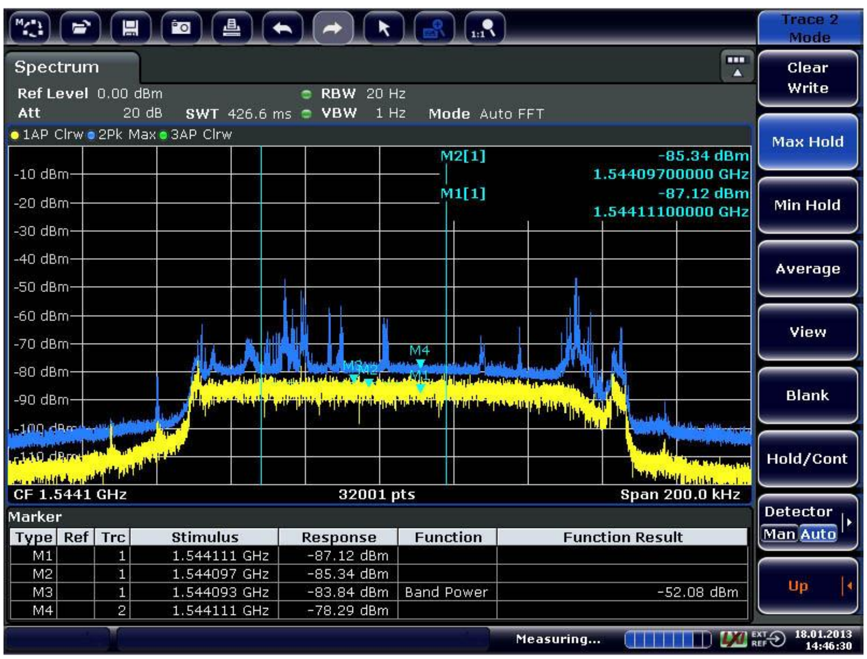

Figure 4.3: Galileo SAR Repeater L-Band Downlink Normal Band (90 kHz) Signal Spectrum

4.5 Galileo Repeater Coverage Area

The Galileo SAR repeater is designed to cover the full visible Earth's disc both in the uplink and in the downlink. From the orbital altitude of the Galileo constellation the visible Earth disc covers approximately 39.2% of Earth's surface. The difference in the path loss between satellites seen on the horizon and those appearing in zenith is 1.9 dB.

4.6 Galileo Repeater Performance Parameters

Table 4-3 presents the typical measured satellite payload performances based on in-orbit and on ground equipment testing.

Table 4-3: Typical SAR/Galileo IOV Repeater Characteristics

<table>
<tr><th>Parameter</th><th>Interoperability Requirement[a]</th><th>Galileo IOV Performance</th><th>Galileo FOC Performance</th><th>Unit</th></tr>
<tr><td>Uplink frequency range</td><td>406.0 to 406.1</td><td colspan="2">406.0 to 406.1</td><td>MHz</td></tr>
<tr><td>Receive centre frequency
Normal mode
Narrowband mode</td><td>
406.050
406.043</td><td colspan="2">
406.050
406.043</td><td>MHz</td></tr>
<tr><td>Nominal input power at antenna</td><td>-159.0</td><td colspan="2">-</td><td>dB_W</td></tr>
<tr><td>Maximum input power at antenna</td><td>-148.0</td><td colspan="2">-153.0</td><td>dB_W</td></tr>
<tr><td>System dynamic range</td><td>30</td><td>32</td><td>30</td><td>dB</td></tr>
<tr><td>Receive antenna polarisation</td><td>RHCP</td><td colspan="2">RHCP</td><td></td></tr>
<tr><td>Receive antenna gain at EoC [b]</td><td></td><td colspan="2">11.7</td><td>dB_i</td></tr>
<tr><td>Receive antenna axial ratio</td><td>< 2.5</td><td colspan="2">< 1.8</td><td>dB</td></tr>
<tr><td>Satellite G/T [c]
At edge of coverage [a]
At centre of coverage</td><td>
>-17.7</td><td>
> -14.9
> -12.6</td><td>
> -15.3
> -13.6</td><td>dB/K</td></tr>
<tr><td>System noise temperature [c, d]</td><td></td><td>380</td><td>365</td><td>K</td></tr>
<tr><td>Bandpass characteristics
Normal mode

Narrowband mode</td><td>
> 80 kHz (1.0 dB)
> 90 kHz (3.0 dB)
< 110 kHz (10 dB)
< 170 kHz (45 dB)
< 200 kHz (70 dB)

> 50 kHz (1.0 dB)
< 75 kHz (10 dB)
< 130 kHz (45 dB)
< 160 kHz (70 dB)</td><td>
> 80 kHz (10 dB)
> 95 kHz (3 dB)
< 110 kHz (10 dB)
< 150 kHz (45 dB)
< 200 kHz (70 dB)

> 50 kHz (1.0 dB)
< 70 kHz (10 dB)
< 100 kHz (45 dB)
< 180kHz (70 dB)</td><td>
> 80 kHz (1.0 dB)
> 90 kHz (3 dB)
< 110 kHz (10 dB)
< 150 kHz (45 dB)
< 180 kHz (70 dB)

> 50 kHz (1.0 dB)
< 75 kHz (10 dB)
< 110 kHz (45 dB)
< 130 kHz (70 dB)</td><td></td></tr>
<tr><td>Phase linearity (overall in-band)
Normal mode
Narrowband mode</td><td>
/
/</td><td>
28
18</td><td>
/
/</td><td>degree</td></tr>
<tr><td>Group delay (turn-around time) [e]
Normal mode
Narrowband mode</td><td>
/
/</td><td>
27
38</td><td>
48
68</td><td>µs</td></tr>
<tr><td>Group delay uncertainty (95% conf.)</td><td>500</td><td>< 150</td><td>< 163</td><td>ns</td></tr>
<tr><td>Group delay over 4 kHz [f] (slope)
Normal mode
Narrowband mode</td><td>
10</td><td>
5
9</td><td>
2.5
3.5</td><td>µs/4kHz</td></tr>
<tr><td>Transponder gain modes</td><td></td><td colspan="2">FGM
ALC</td><td></td></tr>
<tr><td>ALC time constant</td><td>< 80</td><td>40</td><td>55</td><td>ms</td></tr>
<tr><td>ALC dynamic range</td><td>> 30</td><td colspan="2">32</td><td>dB</td></tr>
<tr><td>Transponder gain</td><td>> 180</td><td colspan="2">165 - 187</td><td>dB</td></tr>
<tr><td>Fixed gain mode adjustment range</td><td></td><td>31
(FGM: -1… +30)</td><td>31
(FGM: +1…+31)</td><td>dB</td></tr>
<tr><td>Transponder gain at nominal o/p power</td><td></td><td colspan="2">160</td><td>dB</td></tr>
<tr><td>Transponder linearity (C/I3)</td><td>> 30</td><td>32</td><td>28</td><td>dB_c</td></tr>
</table>

Parameter	Interoperability Requirement[(a)]	Galileo IOV Performance	Galileo FOC Performance	Unit
Translation frequency		1,138,050,000.0	1,138,049,997.6	Hz
Frequency translation Accuracy Short term stability (100 ms)	 ± 2 x10^{-11} 1 x10^{-11}	 < ±2 x10^{-11} 2 x10^{-11}	 < ±1 x10^{-12} 4 x10^{-12}	 (h)
Gain variation (g)		0.3		dB_{pk-pk}
Translation frequency stability		RAFS: < 1.0 x10^{-11} PHM: < 1.0 x10^{-14}		
Downlink frequency band		1,544.0 to 1,544.2		MHz
Downlink centre frequency Normal mode Narrowband mode		 1,544.100 1,544.093		MHz
Downlink antenna polarisation		LHCP		
Transmit antenna axial ratio		< 1.7	< 1.9	dB
Downlink EIRP	15	> 18.7 (i) < 20.3 (j)	> 17.8 (i) < 19.5(j)	dB_W
EIRP stability in ALC mode		0.3		dB_{pk-pk}
EIRP stability in FG mode		1.5	1.2	dB_{pk-pk}

(a) MEOSAR space segment interoperability requirements.
(b) The receive antenna edge of coverage (EoC) is defined at a beacon elevation angle of 5°.
(c) G/T as measured in orbit. The MEOSAR space segment interoperability requirement is defined assuming antenna external noise temperature Ta = 400 K.
(d) System temperature computed at transponder input.
(e) These values refer to the center frequency. The full characterization of each launched SAR payload with respect to delay is reported in accordance with the format proposed in document C/S R.018.
(f) In the 1 dB band.
(g) Gain variation in any 3 kHz within the operating band.
(h) Depending on the configuration settings of the on-board clocks may be significantly better.
(i) In ALC mode or in FGM at nominal gain setting, over full Earth disc, including pointing error.
(k) In ALC mode or in FGM at nominal gain setting, at the centre of the beam (boresight).

4.7 Galileo SAR Receiver Parameters

SAR/Galileo receiver parameters are specified in Table 4-3.

4.7.1 Galileo SAR Bandpass Parameters

Bandpass characteristics of the Galileo transponders are presented in Figure 4.4 for both the normal (90 kHz) and the narrow (50 kHz) bands. These are typical values, considering that there are small variations with temperature and from unit to unit.

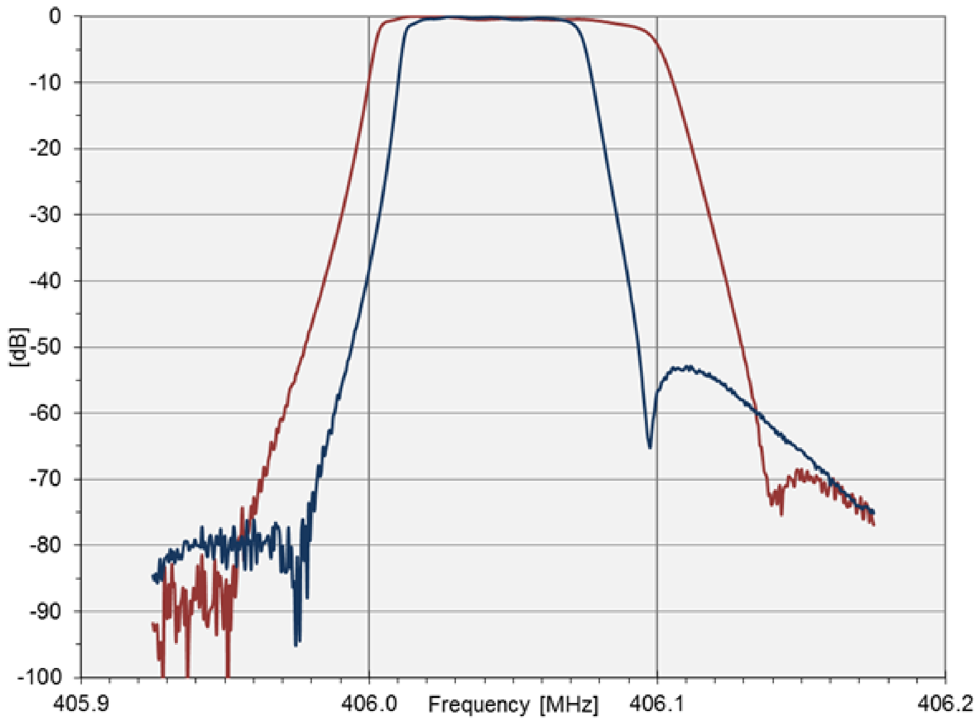

Figure 4.4: Galileo SAR Repeater Normal and Narrow Bandpass Filtering Performance

4.7.2 Galileo SAR Transmitter Parameters

SAR/Galileo transmitter parameters are specified in Table 4-3.

4.7.3 Galileo SAR Antennas

As an example of the Galileo IOV satellites, Figure 4.5 and Figure 4.6 show the SAR UHF receive and L-band transmit antenna co-polar gain plots on Galileo IOV 419 satellite in four characteristic cross-sections.

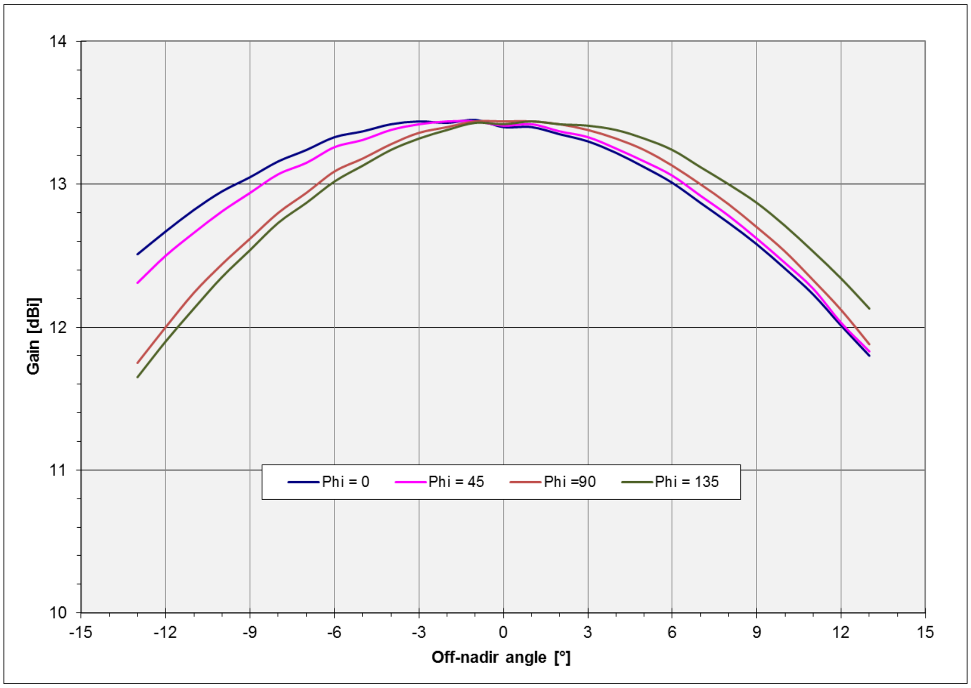

Figure 4.5: SAR Rx Antenna Gain on Galileo IOV 419 Satellite (Four Cross-Sections)

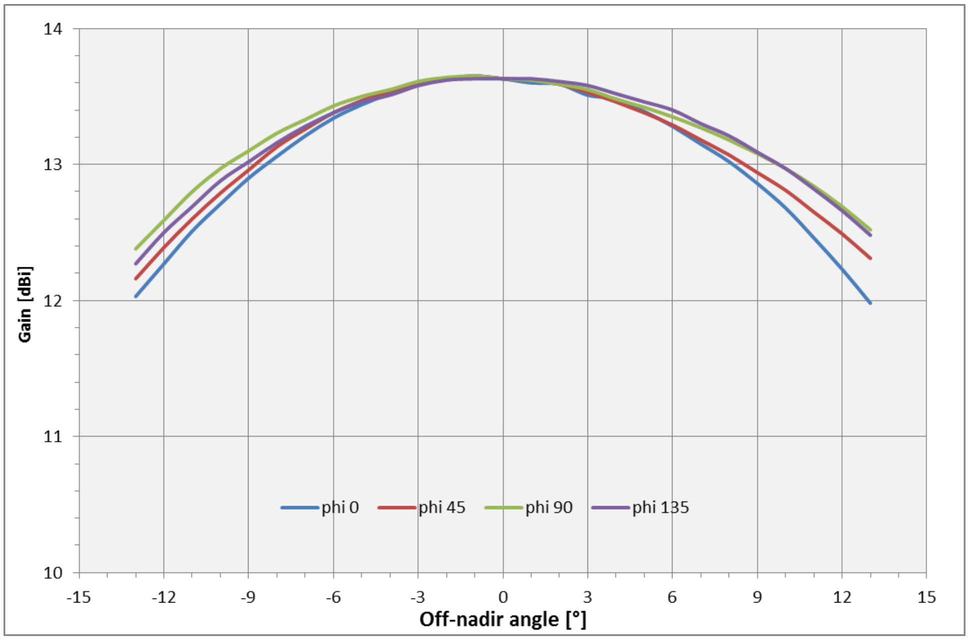

Figure 4.6: SAR Tx Antenna Gain on Galileo IOV 419 Satellite (Four Cross-Sections)

As an example of the Galileo FOC satellites Figure 4.7 and Figure 4.8 show the SAR UHF receive and L-band transmit antenna co-polar gain plots of Galileo FOC 426 satellite in four characteristic cross-sections.

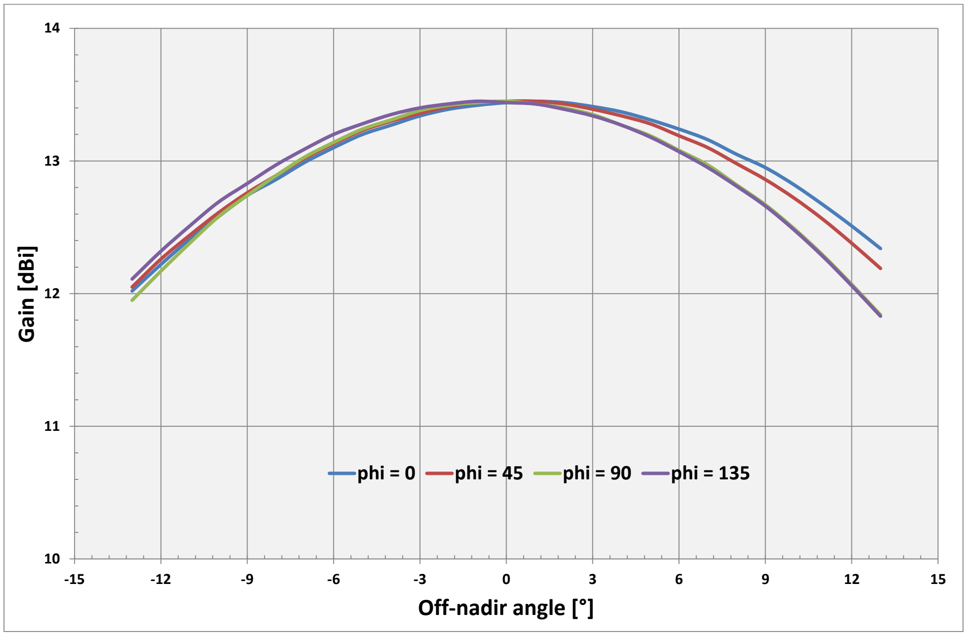

Figure 4.7: SAR Rx Antenna Gain on Galileo FOC 426 Satellite (Four Cross-Sections)

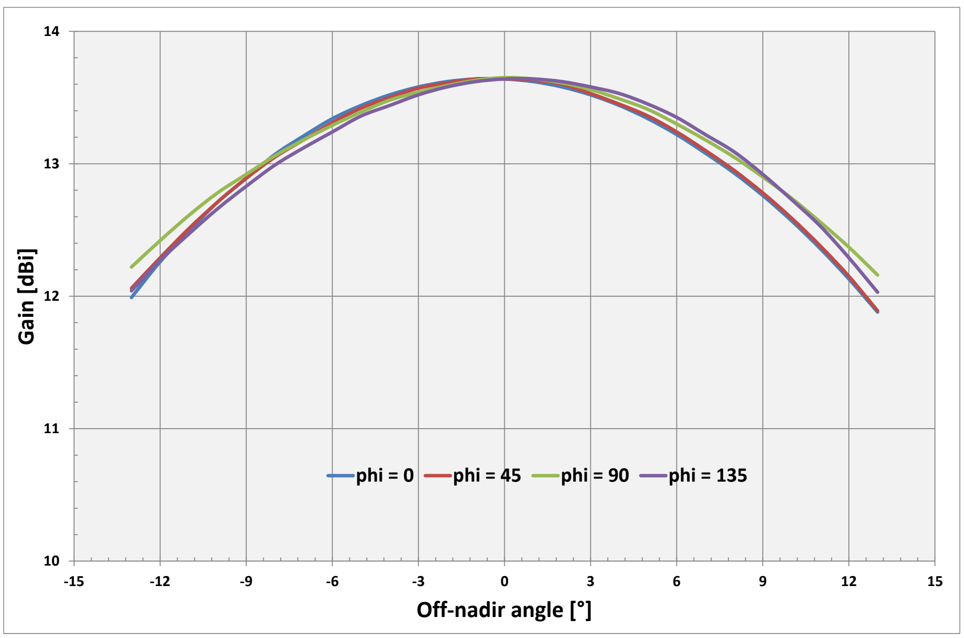

Figure 4.8: SAR Tx Antenna Gain on Galileo FOC 426 Satellite (Four Cross-Sections)

- END OF SECTION 4 -

5. GLONASS 406 MHZ MEOSAR REPEATER

5.1 Glonass Overall Description

The GLONASS satellites are located in middle circular orbit at 19,100 km altitude with a 64.8° inclination and a period of 11 hours and 15 minutes. The constellation operates in three orbital planes, with eight evenly spaced satellites on each. A fully operational constellation with global coverage consists of 24 satellites.

Installation of the search and rescue payload on a GLONASS satellite is subject to a national decision. At this time, two GLONASS spacecraft series are among those that may be equipped with a SAR payload: Glonass-K1 and Glonass-K2.

Table 5-1 details the launch dates, orbital position, other officially recognized names and additional information of the SAR/GLONASS satellites currently in orbit.

Table 5-1: Orbital Parameters of SAR/GLONASS Satellites

Cospas-Sarsat identifier	Launch date	Satellite vehicle number[5]	Satellite series	Satellite name	Other names	Norad ID	Orbital slot
501	26.02.2011	701	Glonass-K1	Cosmos-2471	Glonass-K1-11L	De-commissioned from the GLONASS constellation, cannot be used in Cospas-Sarsat	
502	01.12.2014	702		Cosmos-2501	Glonass-K1-12L	40315	2/9
503	25.10.2020	705		Cosmos-2547	Glonass-K1-15L	46805	2/11
504	07.07.2022	706		Cosmos-2557	Glonass-K1-16L	52984	3/22

In total, Glonass-K1 series will comprise six SAR/GLONASS satellites (including decommissioned 501); subsequent SAR/GLONASS satellites will be Glonass-K2 series spacecraft.

The following sections provide information regarding the repeater description, modes of operation and performance characteristics.

5.2 Glonass Repeater Functional Description

The SAR repeater is based on bent pipe type transponder with no frequency inversion. It receives signals in the 406 – 406.1 MHz band and retransmits in the L-band centered at 1,544.9 MHz. The transponder consists of two identical redundant configurations, 1st and 2nd.

The Glonass-K2 series satellites have two functional elements relevant to Cospas-Sarsat: the SAR Function, for performing of the Forward Link Alert Service, and the Return Link Service.

[5] The "satellite vehicle number" or "RF channel" value may be used to cross-reference the satellite IDs in Cospas-Sarsat and national numeration system. For further details please visit https://www.glonass-iac.ru/en/sostavOG/

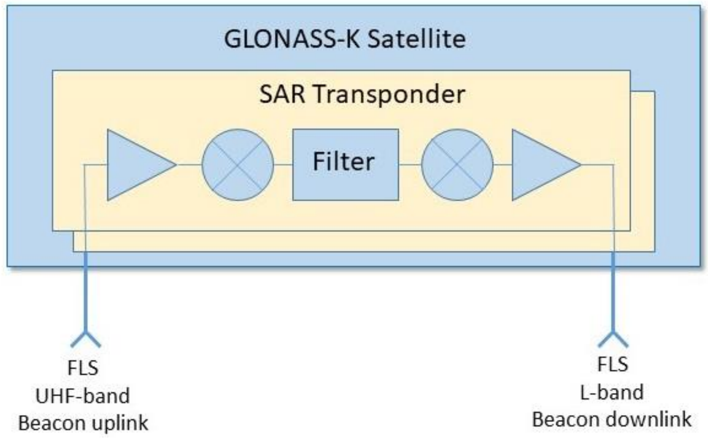

Figure 5.1: Implementation of SAR Function on GLONASS Satellites

5.3 Glonass Repeater Operating Modes

The SAR repeater can operate in one gain and two bandwidth modes. The operational modes include the Normal and Narrow Bandwidth modes, the latter not being used. The Glonass-K2 repeater can operate in one gain and one bandwidth mode (Normal). Repeater gain is self-regulated by Automatic Gain control (AGC). The repeater gain is automatically adjusted to obtain a power of 7 dBW at the output of the SAR transponder.

5.4 Glonass Repeater Spectrum Characteristics

Figure 5.2 depicts an example of the SAR repeater L-band downlink signal spectrum in normal-bandwidth setting.

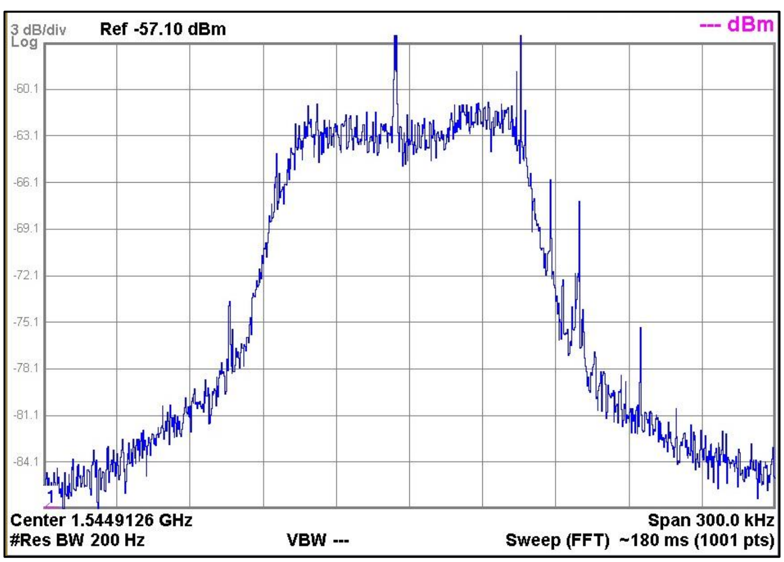

Figure 5.2: SAR Repeater L-Band Downlink Normal Band Signal Spectrum

5.5 Glonass Repeater Coverage Area

Figure 5.3 depicts the example of 0˚ elevation coverage area for SAR/GLONASS satellite C/S ID 503 crossing the equator.

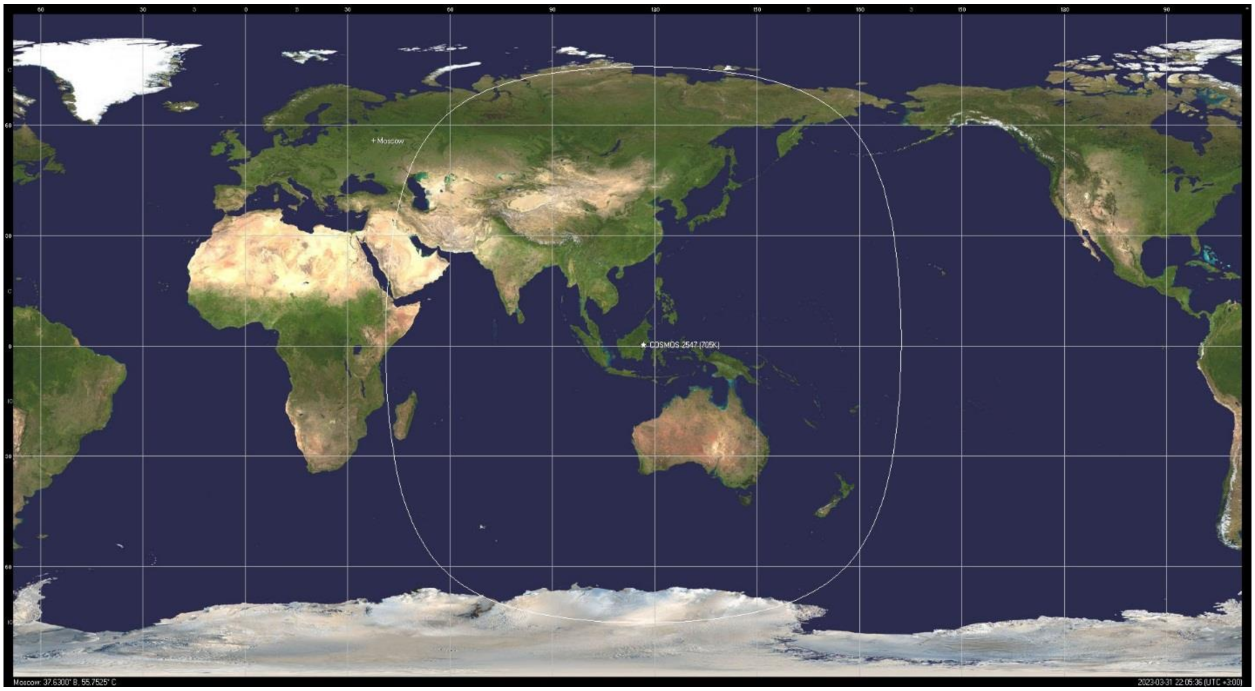

Figure 5.3: CS ID 503 Zero Degree Elevation Coverage Area

5.6 Glonass Repeater Performance Parameters

Table 5-2 details typical satellite payload performance based on in-orbit and on ground equipment testing assessments. The performance information was grouped by satellites where possible in order to better represent the variety in design and to better serve the informational needs of ground segment providers and the purposes related to space segment commissioning.

Table 5-2: SAR Repeater Characteristics

Parameter	Unit	Value			
		Interoperability Requirement	Glonass-K1 (CS ID 502)	Glonass-K1 (C/S ID 503, 504)	Glonass-K2
Uplink frequency range	MHz	406.0 to 406.1	406.0 to 406.1		
Receive centre frequency: Normal mode Narrowband mode	MHz	406.050 406.043	406.05 406.043		406.05 N/A
Maximum input power at antenna	dB_W	-	-153.0		
System dynamic range	dB	> 30	30		
Receive antenna polarization		RHCP	RHCP		
Receive antenna gain at: edge of coverage (EoC)(1) centre of coverage (EoC)	dB_i	-	11.4 13.0		

Receive antenna axial ratio	dB	< 2.5	< 1.8		
Receive antenna G/T: At edge of coverage At centre of coverage	dB/K	> -17.7	> -17.7 > -16.1		
System noise temperature(2)	K	-	490		
Bandpass characteristics Normal mode Narrowband mode		> 80 kHz (1.0 dB) > 90 kHz (3.0 dB) < 110 kHz (10 dB) < 170 kHz (45 dB) < 200 kHz (70 dB) > 50 kHz (1.0 dB) < 75 kHz (10 dB) < 130 kHz (45 dB) < 160 kHz (70 dB)	> 120 kHz (1 dB) < 140 kHz (3 dB) < 170 kHz (10 dB) < 400 kHz (45 dB) Not used	> 80 kHz (1 dB) < 100 kHz (3 dB) < 125 kHz (10 dB) < 300 kHz (45 dB) Not used	> 80 kHz (1 dB) >90 kHz (3 dB) < 110 kHz (10 dB) < 200 kHz (45 dB) < 270 kHz (70 dB) N/A
Group delay uncertainty (95% conf.)	ns	< 500	< 500		
Group delay over 4 kHz (slope) Normal mode Narrowband mode	µs/4 kHz	< 10	< 10		
Transponder gain mode		-	AGC		
AGC time constant	ms	< 80	< 80		
AGC dynamic range	dB	> 30	> 30		
Transponder gain	dB	-	167…185		
Transponder linearity (C/I3)	dB_c	> 30	> 18		
Translation frequency	Hz	-	1,138,849,998.5	1,138,850,000.0	1,138,850,000.0 (Note 3)
Frequency translation: Accuracy Short term stability (100 ms)		$\pm 2 \times 10^{-11}$ $< 1 \times 10^{-11}$	$\pm 2 \times 10^{-11}$ 5×10^{-12}		
Downlink frequency band	MHz	-	1,544.85 to 1,544.95		
Downlink centre frequency Normal mode Narrowband mode	MHz	-	1,544.900 1,544.893 - not used		1,544.900 N/A
Downlink antenna polarization		circular	LHCP		
Transmit antenna axial ratio	dB	-	< 2		
Downlink EIRP	dB_W	> 15	> 18		

(1) The receive antenna edge of coverage (EoC) is defined at a beacon elevation angle of 5°.
(2) Recalculated to the input of the LNA, assuming the external noise temperature of the antenna Ta = 300 K.
(3) Translation frequency for CS IDs 507 and 508 is set to 1,138,849,998.5 and is set to 1,138,850,000.0 for CS ID 509 and onward.

5.6.1 Glonass SAR Receiver Parameters

Glonass-K1 series SAR bandpass filters characteristics are provided in
Table 5-2.

Glonass-K2 series SAR bandpass filters are deployed in 44.9 MHz intermediate frequency of SAR repeater, after frequency downconverter. Bandpass characteristics of the transponder are presented in Figure 5.4 the normal band.

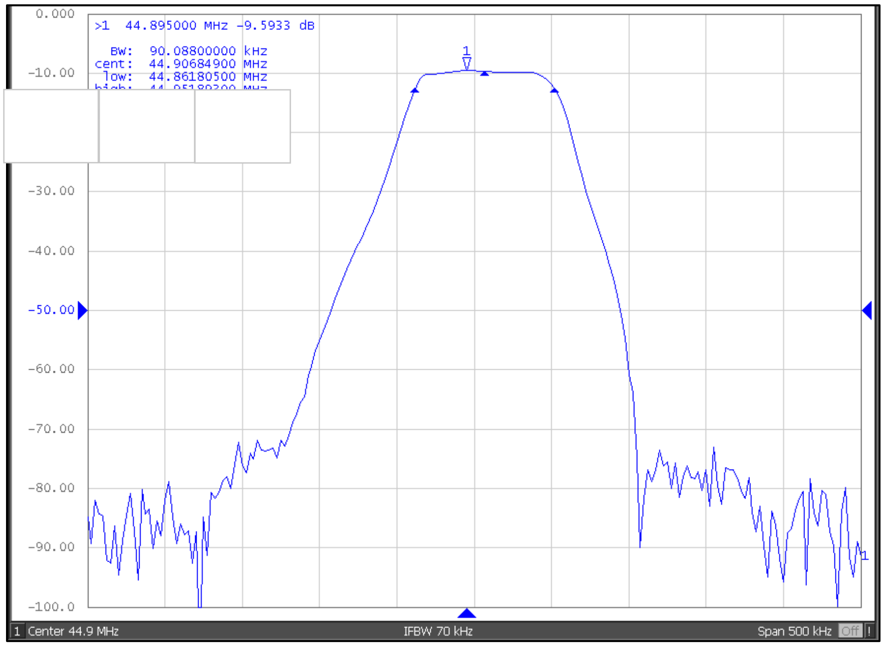

Figure 5.4: Glonass-K2 SAR Repeater Normal Bandpass Filtering Performance

5.6.2 Glonass SAR Transmitter Parameters

Glonass-K SAR transmitter parameters are specified in Table 5-2.

5.6.3 Glonass SAR Antennas

Figure 5.5 and Figure 5.6 show the SAR receive and L-band transmit antenna gain plots for Glonass K satellites in four characteristic cross-sections.

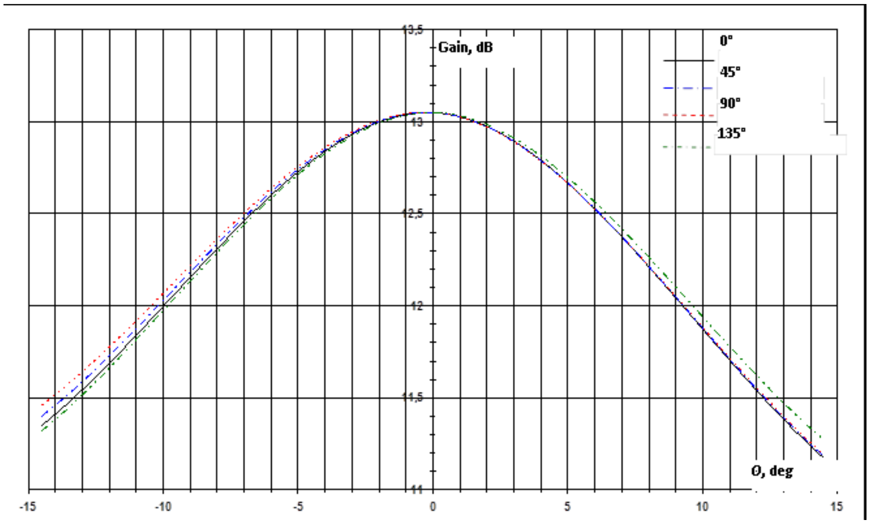

Figure 5.5: SAR Repeater Receiving Antenna Gain (Four Cross-Sections)

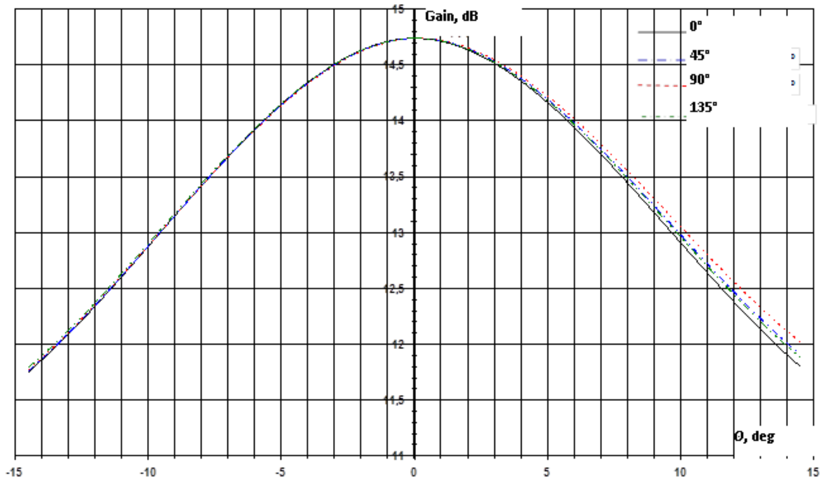

Figure 5.6: SAR Repeater Transmitting Antenna Gain (Four Cross-Sections)

- END OF SECTION 5 -

6. BDS 406 MHZ MEOSAR REPEATER

6.1 BDS MEOSAR Overall Description

The information presented in this section refers to the BD-3 MEO satellites with SARRs onboard.

The BDS MEOSAR satellites are on slots of a Walker 24/3/1 constellation, orbiting at an altitude of 21,528 km and at an inclination angle of 55°. The SAR/BDS payloads are planned to be deployed on six MEOSAR satellites as defined in Table 6-1.

Table 6-1 shows Keplerian Elements of Nominal Orbital Positions for BD-3 satellites with SAR payloads, as the epoch time is 00:00:00 on 1 October 2018 (UTC).

Table 6-1: Keplerian Elements of Nominal Orbital Positions for BDS MEO Satellites with SAR payload

Sat. No.	Slot	Launch date	Semi-Major Axis(km)	Orbit Altitude (km)	Eccen-tricity	Inclin-ation (deg)	RAAN (deg)	Arg. Perigee (deg)	Arg. f Latitude (deg)	Orbital Period (min)
BD-3 M13 (632)	B1	19 Sep. 2018	27906.1	21528.0	0	55	156.9	0.0	207.9	775
BD-3 M14 (633)	B3	19 Sep. 2018	27906.1	21528.0	0	55	156.9	0.0	297.9	775
BD-3 M23 (645)	C3	22 Sep. 2019	27906.1	21528.0	0	55	276.9	0.0	312.9	775
BD-3 M24 (646)	C5	22 Sep. 2019	27906.1	21528.0	0	55	276.9	0.0	42.9	775
BD-3 M21 (643)	A6	23 Nov. 2019	27906.1	21528.0	0	55	24.2	0.0	105.5	775
BD-3 M22 (644)	A8	23 Nov. 2019	27906.1	21528.0	0	55	24.2	0.0	195.5	775

6.2 BDS MEOSAR Functional Description

BDS MEOSAR repeaters are based on bent pipe type transponders with no frequency inversion, which receive signals in the 406.0 to 406.1 MHz band and retransmit at 1.54421 GHz. They are designed in accordance with MEOSAR space segment interoperability requirements, ensuring their compatibility and interoperability. Also, BDS will provide return link service (RLS).

Figure 6.1 shows SAR/BDS structure.

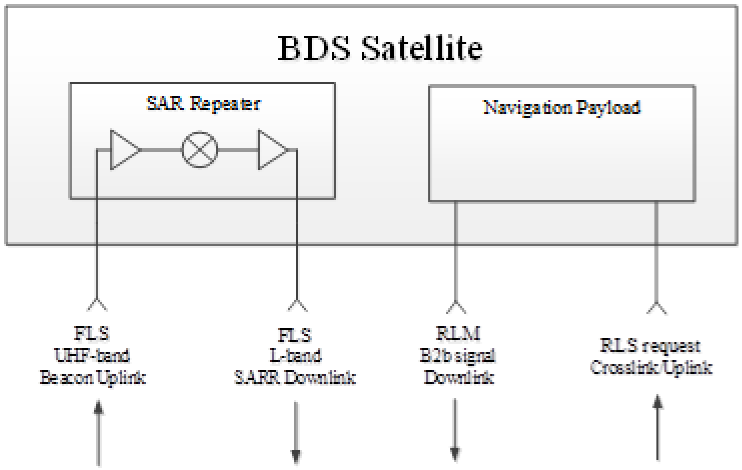

Figure 6.1: Structure of SAR Functions on the BDS Satellites

6.3 BDS Repeater Operating Modes

BDS MEOSARR can operate in single gain and two bandwidth modes.

Repeater gain is self-regulated by Automatic Level Control (ALC). The repeater gain is automatically adjusted to obtain a power of 16 dBW at the output of the SARR with antenna, neglect the input is signal or noise.

Repeater normal bandwidth mode is 90 kHz, which is designed to relay second generation beacon signal. However, narrow band mode (50 kHz) is reserved for special purpose. The bandwidth mode can be switched via TT&C.

6.4 BDS Repeater Spectrum Characteristics

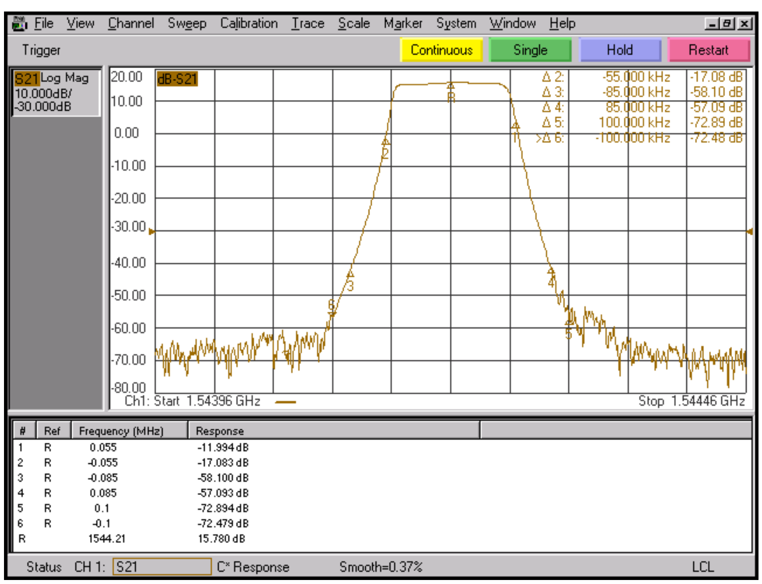

Figure 6.2: BDS MEOSARR Normal Band Spectrum Characteristics

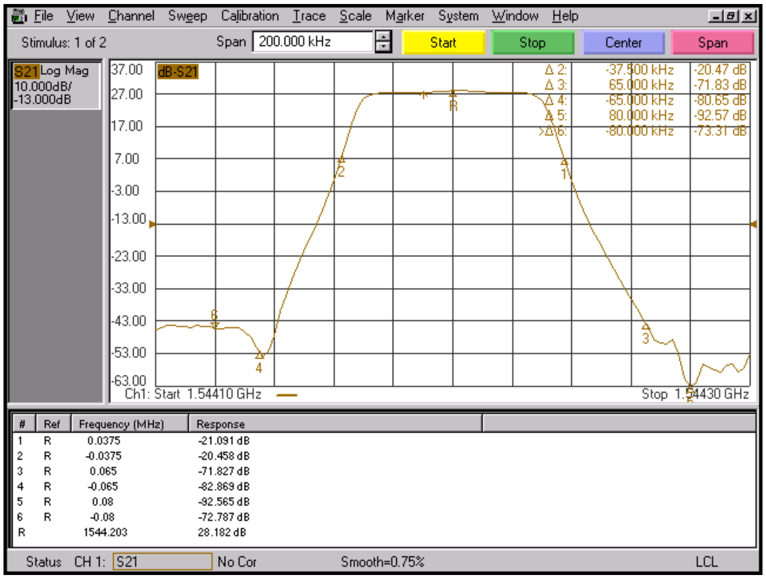

Figure 6.3: BDS MEOSARR Narrow Band Spectrum Characteristics

6.5 BDS Repeater Coverage Area

The BDS SAR repeater is designed to cover the Earth's disc both in the uplink and the downlink. From the orbital altitude of a single BDS satellite with SAR repeater, the visible Earth disc covers approximately 38.6% of Earth's surface. The difference in the path loss between satellites seen on the horizon and those appearing in zenith is 2.0 dB.

6.6 BDS MEOSAR Repeater Performance Parameters

Table 6-2 presents the typical measured satellite payload performances based on in-orbit and on-ground equipment testing.

Table 6-2: Typical SAR/BDS Repeater Design Characteristics

Parameter		Interoperability Requirement	Design Result of BDS MEOSARR	Unit
Uplink frequency range		406.0 to 406.1	406.0 to 406.1	MHz
Receive centre frequency	Normal mode	406.050	406.050	MHz
	Narrow band mode	406.043	406.043	
Nominal input power at antenna		-159	-159	dB_W
Maximum input power at antenna		-148	-148	dB_W
System dynamic range		30	31	dB
Receive antenna polarisation		RHCP	RHCP	
Receive antenna gain at EoC[(a)]		/	> 11.5	dB_i

Parameter		Interoperability Requirement	Design Result of BDS MEOSARR	Unit
Receive antenna axial ratio		< 2.5	< 2	dB
Satellite G/T		> -17.7	> -15.3	dB/K
System noise temperature[b]		/	< 480	K
Bandpass characteristics	Normal mode	1 dB >80 kHz	1 dB >80 kHz	
		3 dB >90 kHz	3 dB >90 kHz	
		10 dB <110 kHz	10 dB <110 kHz	
		45 dB <170 kHz	45 dB <170 kHz	
		70 dB <200kHz	70 dB <200 kHz	
	Narrow band mode	1 dB >50 kHz	1 dB >50 kHz	
		10 dB <75 kHz	10 dB <75 kHz	
		45 dB <130 kHz	45 dB <130 kHz	
		70 dB <160 kHz	70 dB <160 kHz	
Group delay uncertainty (95% conf.)		500	< 500	ns
Group delay over 4 kHz (slope)[c]	Normal mode	≤ 10	≤ 9	μ s/4kHz
	Narrow band mode		≤ 9	
Transponder gain modes		/	ALC	
ALC time constant		< 80	< 60	ms
ALC dynamic range		> 30	> 32	
Transponder gain		> 180	> 180	dB
Transponder linearity		> 30	> 30.5	dB$_c$
Frequency translation accuracy		±2e-11	±2e-11	
Frequency translation Short term stability (100 ms)		≤ 1e-11	≤ 1e-11	
Translation frequency stability		/	< 3e-12/1s < 1e-12/10s < 3e-13/100s	
Downlink frequency band		/	1544.16~1544.26	MHz
Downlink centre frequency	Normal mode	/	1544.210	MHz
	Narrow band mode	/	1544.203	MHz
Downlink antenna polarisation		/	RHCP	
Transmit antenna axial ratio		/	< 1.5	dB
Downlink EIRP		> 15	> 18.0	dB$_W$
EIRP stability in ALC mode		/	< 1.0	dB$_{PK-PK}$

a) The receive antenna edge of coverage (EoC) is defined at a beacon elevation angle of 5°.
b) System noise temperature computed at transponder input.
c) In the 1 dB band.

6.7 BDS SAR Repeater Receiver Parameters

6.7.1 BDS SAR Repeater Bandpass Parameters

Bandpass filters are deployed in 63.5 MHz intermediate frequency of SAR/BDS repeater, after frequency down converter. Bandpass characteristics of the filter are presented in Figure 6.4 for both the normal (90 kHz) and the narrow (50 kHz) bands. These are typical values, considering that there are small variations with temperature and from unit to unit.

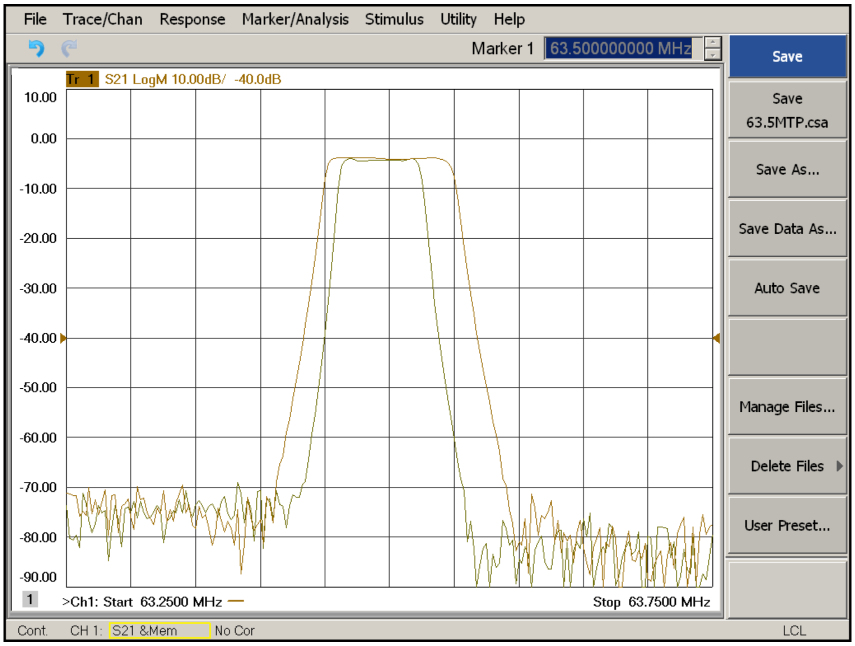

Figure 6.4: BDS MEOSARR Normal and Narrow Bandpass Filtering Performance

6.7.2 BDS MEOSAR Repeater Receive Antenna Pattern

Receive antenna gain is shown in Figure 6.5.

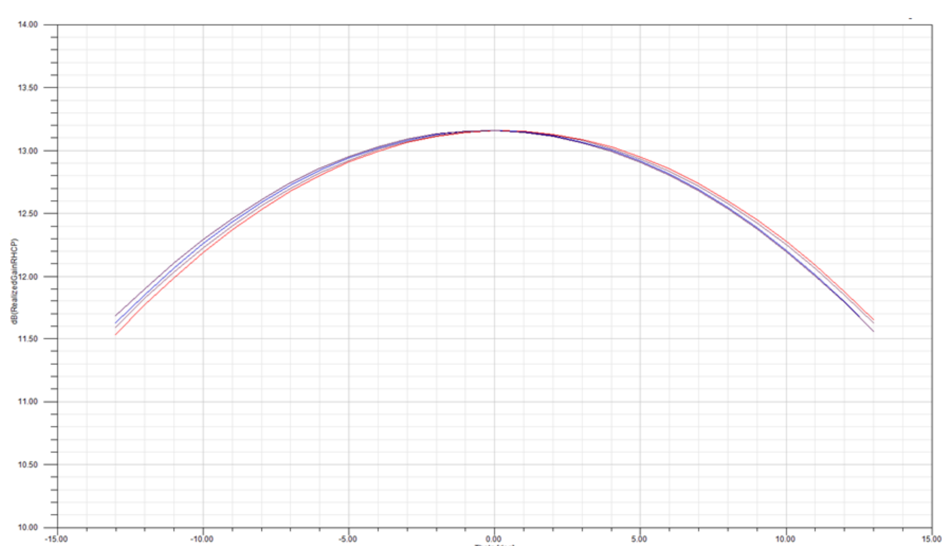

Figure 6.5: SAR/BDS Rx Antenna Gain (Four Cross-Sections)

6.7.3 BDS MEOSAR Repeater Transmit Antenna Pattern

Transmit antenna gain is shown in Figure 6.6.

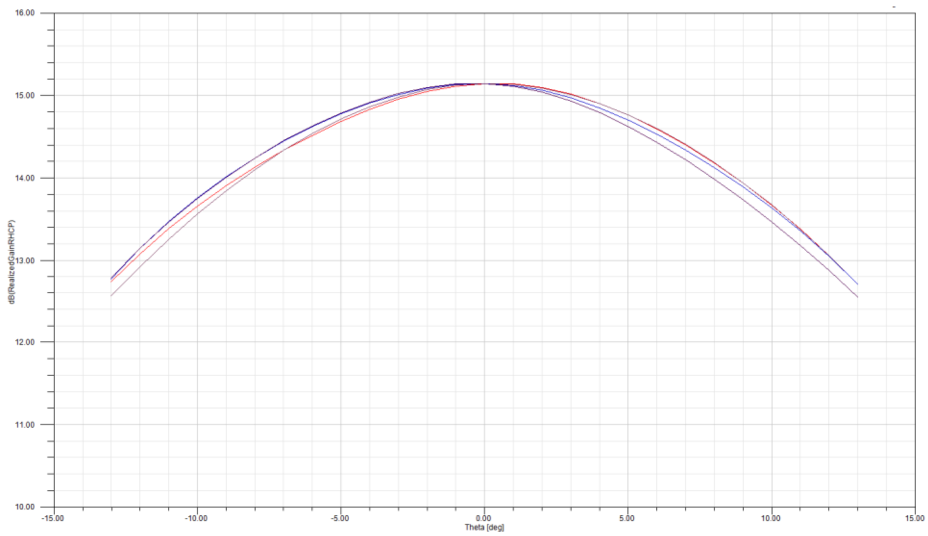

Figure 6.6: SAR/BDS Tx Antenna Gain (Four Cross-Sections)

- END OF SECTION 6 -

ANNEX A: INFORMATION FOR MEOLUT OPERATORS

The complete list of all operational satellites in each constellation with current status as of publication date is provided in **Error! Reference source not found.**. A dynamic list is maintained on the Cospas-S arsat website.

Additional sources regarding the current status of MEOSAR satellites are available on the following websites:

- for Galileo satellites:
  - http://www.gsc-europa.eu/system-status/Constellation-Information
- for Glonass satellites:
  - http://glonass-iac.ru/en/GLONASS/
- for GPS satellites:
  - http://www.navcen.uscg.gov/?Do=constellationStatus
  - http://en.wikipedia.org/wiki/List_of_GPS_satellites
- for BDS satellites:
  - http://www.csno-tarc.cn/en/system/constellation

Information regarding the orbital parameters of MEOSAR satellites is available from:

- the navigation signals broadcasted from MEOSAR satellites, or
- http://www.celestrak.com/NORAD/elements/sarsat.txt (data are retrieved from JSpOC via www.space-track.org) The orbit data are providing using the two-line format, which is defined at:
  - http://spaceflight.nasa.gov/realdata/sightings/SSapplications/Post/JavaSSOP/SSOP_Help/tle_def.html
  - http://celestrak.com/NORAD/documentation/tle-fmt.asp
- the laser-ranging community in CPF format (a derivative of SP3) for Galileo and Glonass satellites, at:
  - ftp://cddis.gsfc.nasa.gov/pub/slr/cpf_predicts/
  - ftp://edc.dgfi.badw.de/pub/slr/cpf_predicts/

- END OF ANNEX A -

ANNEX B: MEOSAR SATELLITE TECHNICAL PARAMETERS

B.1 MEOSAR Satellite Identification Parameters

Table B-1: MEOSAR Satellite Identification Parameters

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

	Cospas-Sarsat Satellite ID code (note 1)	NORAD ID (NASA Catalogue Number) (note 2)	International Designator (note 3)	Satellite Name (note 4)	Space Vehicle Number (SVN) (note 5)	Other Names	Other Names	Other Names	PRN Number (note 6)	Launch Date
DASS S-Band										
Galileo										
Glonass										
BDS										

Notes:

1. Cospas-Sarsat Satellite ID Code number is a unique 3-digit number allocated by Cospas-Sarsat for each operating, SAR-equipped satellite (as defined in document C/S R.012, page M-2), based on PRN or SVN, so PRNs would get re-assigned to future replacement satellites.
2. A unique 5-digit ID number for each satellite, permanently assigned to that object in orbit.
3. 5-digit designator comprising the last 2 digits of the launch year and 3 digits of the launch number in that year plus one letter for each piece of the launch (A, B, C...).
4. Satellites have various names and designations by different users in different databases, as shown in the ¨Other Names¨ columns. DASS refers to an experimental S-band payload on some GPS Block 2 satellites.
5. SVN is a unique satellite or space vehicle number assigned by the satellite constellation owner or operator.
6. PRN is a pseudo-random noise code number assigned by the satellite owner or operator to identify the code for GNSS receivers to decode the navigation signal. As there is a limited supply of PRN numbers, they get gets reassigned to new satellites that replace older, decommissioned satellites. Final PRN numbers are not yet assigned to the initial Galileo and Glonass satellites.
7. Galileo 411 and 412 should not be tracked by MEOLUTs as they are not equipped with a SAR repeater. However, Galileo 411 and 412 will be used for the return link service provided by Galileo.

B.2 RF Configuration of the MEOSAR satellites

Table B-2: Current RF Configuration of the MEOSAR Satellites

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

	Cospas-Sarsat Satellite ID code (note 1)	Downlink Frequency Band (note 2)	Nominal Downlink Centre Freq (MHz) (notes 3 & 4)	Repeater Frequency Translation (note 5)	Uplink Antenna Polarization (note 6)	Downlink Antenna Polarization (note 6)	Current BW (kHz) @Centre Frequency (MHz) (note 7)	Current mode (note 8)	Comments
DASS S-Band									
Galileo									
Glonass									
BDS									

Notes:

1 Cospas-Sarsat Satellite ID Code number is a unique 3-digit number allocated by Cospas-Sarsat for each operating, SAR-equipped satellite (as defined in document C/S R.012, page M-2), based on PRN or SVN, so PRNs would get re-assigned to future replacement satellites.

2 The S-band downlink is in a band normally used for telemetry, whereas the L-band is in the 1 MHz bandwidth allocated by ITU for Distress and Safety, space-to-Earth, so has protection from harmful interference.

3 The nominal downlink centre frequency corresponds to the 406.050 MHz received frequency, which is the centre of the 100 kHz SAR band allocated for distress beacons. The exact centre frequency can be derived from information provided in the tables providing the SAR Receiver Parameters in section 4.6, Table 4.3.

4 The repeater bandwidth of the S-band satellites is about 270 kHz; Galileo is about 80 kHz, or else 50 kHz in narrowband mode (with centre frequency shifted 7 kHz lower) and Glonass is about 100 kHz, or else 60 kHz in narrowband mode (with centre frequency shifted 7 kHz lower).

5 The S-band payloads on the Block 2 GPS satellites have "inverted" frequency translation of the relayed 406 MHz frequencies, whereas the L-band satellites, including the future SAR/GPS, are designed for SAR purposes, and do not invert the relayed band.

6 Future SAR/GPS L-band satellites will have an RHCP downlink, and transmit on the same downlink frequency as Glonass, but with opposite polarization.

7 Downlink frequency is that frequency referenced to 406.05 MHz. Downlink frequency may not be exact. It is to be noted that any satellite may have a nominal offset of [± 100 Hz]. However, once this value is set for each repeater, the frequency translation accuracy requirement applies. The format is [1544.xxxxxxx MHz] (8 decimal places) (TBC).

8 Current mode:

- WA = Wideband filter and ALC

- NA = Narrowband filter and ALC
- WF = Wideband filter and fixed gain
- NF = Narrowband filter and fixed gain
- UT = under test
- OFF

Table B-3: DASS S-Band Filter Settings

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

1	2	3	4	5	6a	6b	6c	6d	6e	7	8	9	10a	10b	10c	10d	11
SAT_ID	MODE_ID	BW (kHz)	Centre Frequency (MHz)	Group Delay @ Centre Frequency Coeff. a0 (µs)	Group Delay Data Curve Fit Coeff.					Group Delay Uncertainty (ns)	FG Setting (dB)	Short Term Stability	Pre-Filter Characteristics				Historical
					a1	a2	a3	a4	a5				3 dB BW (kHz)	10 dB BW (kHz)	45 dB BW (kHz)	BWn (kHz)	

Table B-4: Galileo Filter Settings

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

1	2	3	4	5	6a	6b	6c	6d	6e	7	8	9	10a	10b	10c	10d	11
SAT_ID	MODE_ID	BW (kHz)	Centre Frequency (MHz)	Group Delay @ Centre Frequency Coeff. a0 (µs)	Group Delay Data Curve Fit Coeff.					Group Delay Uncertainty (ns)	FG Setting (dB)	Short Term Stability	Pre-Filter Characteristics				Historical
					a1	a2	a3	a4	a5				3 dB BW (kHz)	10 dB BW (kHz)	45 dB BW (kHz)	BWn (kHz)	

Table B-5: GPS L-Band Filter Settings (To Be Completed)

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

1	2	3	4	5	6a	6b	6c	6d	6e	7	8	9	10a	10b	10c	10d	11
SAT_ID	MODE_ID	BW (kHz)	Centre Frequency (MHz)	Group Delay @ Centre Frequency Coeff. a0 (µs)	Group Delay Data Curve Fit Coeff.					Group Delay Uncertainty (ns)	FG Setting (dB)	Short Term Stability	Pre-Filter Characteristics				Historical
					a1	a2	a3	a4	a5				3 dB BW (kHz)	10 dB BW (kHz)	45 dB BW (kHz)	BWn (kHz)	

Table B-6: Glonass L-Band Filter Settings

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

1	2	3	4	5	6a	6b	6c	6d	6e	7	8	9	10a	10b	10c	10d	11
SAT_ID	MODE_ID				Group Delay Data Curve Fit Coeff								Pre-Filter Characteristics				Historical

		BW (kHz)	Centre Frequency (MHz)	Group Delay @ Centre Frequency Coeff. a0 (µs)	a1	a2	a3	a4	a5	Group Delay Uncertainty (ns)	FG Setting (dB)	Short Term Stability	3 dB BW (kHz)	10 dB BW (kHz)	45 dB BW (kHz)	BWn (kHz)	

Table B-7: BDS L-Band Filter Settings

The up-to-date version of this table is available on the Cospas-Sarsat website www.cospas-sarsat.int.

1	2	3	4	5	6a	6b	6c	6d	6e	7	8	9	10a	10b	10c	10d	11
SAT_ID	MODE_ID	BW (kHz)	Centre Frequency (MHz)	Group Delay @ Centre Frequency Coeff. a0 (µs)	Group Delay Data Curve Fit Coeff.					Group Delay Uncertainty (ns)	FG Setting (dB)	Short Term Stability	Pre-Filter Characteristics				Historical
					a1	a2	a3	a4	a5				3 dB BW (kHz)	10 dB BW (kHz)	45 dB BW (kHz)	BWn (kHz)	

As group delay data curve fit coefficients is calculated by using script polyfit (Frequency, Group_Delay, 5) in Octave or Matlab, as unit of Frequency is Herz, of Group_Delay is second, and a1 to a5 are first to fifth coefficients of the 6-term polynomial.

Additional information on the columns:

1 SAT_ID is the unique identifier format that is the same as defined for MEOSAR satellite identification. There are a maximum of four modes per satellite but only one will be in selected at any time. Therefore, any satellite ID will have data populated in rows equal to the number of satellite modes as defined by column 3.

2 MODE_ID is a single unique identifier defining the specific single satellite mode. All data contained in the row are the space segment parameter values for the unique combination of SAT_ID and MODE_ID. The four unique identifiers are:

- WA = Wideband filter and ALC,
- NA = Narrowband filter and ALC,
- WF = Wideband filter and Fixed Gain,
- NF = Narrowband filter and Fixed Gain.

3 BW is the bandwidth associated with the MODE_ID.

4 Centre frequency associated with the MODE_ID.

5 Group delay is a single value that defines the actual group delay at 406.05 MHz for wideband filter and 406.43 MHz for narrowband. The format is xx.y in microseconds. This value is coefficient a0 derived from the group curve fit data defined in column 5 at the associated downlink frequency (see Table B-4) for wideband and narrowband filters.

6 The group delay curve fit data defines the coefficients of the group delay variation curve as a function of frequency over the respective filter's 1 dB bandwidth. This data represents a single best fit curve of the filter's group delay performance as a function of a variety of environmental conditions. Coefficient a0 is the group delay at the associated downlink frequency (see Table B-4) for wideband and narrowband filters. Note this value is populated in column 4.

7 Group delay uncertainty is single value defining the maximum error of the actual group delay due to any satellite environmental condition from the best fit curve (columns 5 and 6) and quantifies the uncertainty of the delay through the satellite at any time. The format is a single integer number in nanoseconds.

8 The FG gain setting is a single value that sets the gain of the transponder/repeater for the nominal output power. This value only applies to MODE_ID WF and NF. Format is xx.

9 Short term frequency stability is a value quantifying the actual performance of the satellite for any 100 ms per document C/S R.012 ($< 1 \times 10^{-11}$). The method to assess the short term frequency stability is still to be confirmed.

10 Pre-Filter Characteristics provides the BW range in kHz (yyy) for 3 dB, 10 dB, 45 dB rejection points, and noise bandwidth. MEOSAR payload providers should provide within future technical documents rejection characteristics of any repeater filtering. The bandwidth at rejection points of 3 dB, 10 dB, and 45 dB should be provided at a minimum within this Annex. Final rejection values (i.e., 60 dB or 70 dB) and its respective BW should be provided in future technical documents. In addition, to quantify the impacts of the general background interfering noise signals, the knowledge of the equivalent Gaussian noise bandwidth, BWn in kHz (xxxxx) of any repeater input filtering if used would be beneficial for definition of ITU protection requirement and should be provided in future technical documents . This is fourth sub-column (10d).

11 Column 11 is intended to provide a means whereby historical data can be accessed. For the current mode selected, the start date and UTC time of when this current mode was in use is provided at the top of its cell (i.e., since 1 September 2011). The date should be specified in the format dd/mm/yyyy, where dd is the day of the month, mm is the month (as a number), and yyyy is the year. The time should be specified as hh:mm:ss, where hh is hour, mm is minutes, and ss is seconds.

- END OF ANNEX B -

ANNEX C: MEOSAR ORBITAL DATA DESCRIPTION

C.1 Introduction

Precise satellite position vectors and velocity vectors are essential for location processing as they directly impact the achievable accuracy of beacon locations (satellite position and velocity vector errors are part of the location error budget). These vectors can be computed from the ephemeris broadcasted in the navigation message by GNSS satellites. However the ephemeris data may not be available for the following reasons:

- if the navigation signal is not available (e.g., no navigation signal broadcasted by the satellite, navigation signal not processed by the GNSS receiver, etc.), or
- if the station GNSS receiver has failed.

A MEOLUT may acquire satellite position vectors and velocity vectors by other means, such as from an on-line source.

C.2 Summary of available MEOSAR Satellite Orbital Data and Associated Accuracy Performance

The following table represents values of the parameters that the service providers are intending to provide (url to be specified later for ground server).

Table C-1: Parameters that Service Providers Are Intending to Provide

MEOSAR Constellation	Orbital Data Type	Duration of Data Validity (days)	Update Rate (hours)	Latency (hours)	Position Accuracy (meters)	Data Source
Galileo	Sp3	7	12v	< 2	50	Ground server
	Rinex 3.0	7 [6]	1	< 2	50	Ground server
	Ephemerids	0.167 (4 hours)	1	< 2	50	Ground server
	Almanac	TBD	24	< 2	TBD	Ground server
	Broadcasted ephemerids	100 min	TBC	0 (real time)	< 1	Satellite
	Broadcasted almanac	TBC	TBC	TBC	TBC	Satellite
GPS DASS	Sp3	7	24	< 2	< 1	Ground server
	Rinex 2.1	0.083 (2 hours)	1	< 1	< 1	Ground server
	Broadcasted ephemerids	0.167 (4 hours)	2	0 (real time)	< 1	Satellite
	Broadcasted almanac	30	24	0 (real time)	< 1,000	Satellite

[6] Each file contains several blocks of data. The whole file covers 7 days prediction, each block is valid for 4 hours.

MEOSAR Constellation	Orbital Data Type	Duration of Data Validity (days)	Update Rate (hours)	Latency (hours)	Position Accuracy (meters)	Data Source
GPS L-Band	Sp3	7	24	< 2	< 1	Ground server
	Rinex 2.1	0.083 (2 hours)	1	< 1	< 1	Ground server
	Broadcasted ephemerids	0.167 (4 hours)	2	0 (real time)	< 1	Satellite
	Broadcasted almanac	30	24	0 (real time)	< 1,000	Satellite
Glonass	Rinex	0.021 (30 min)	1	< 1	< 1 over 30 min < 15 over 1 hour	Ground server
	Sp3 – ultra rapid	1	6	< 4	< 2	Ground server
	SP3 - rapid	2	24	< 15	< 4	Ground server
	Broadcasted ephemerids	0.021 (30 min)	0.5	0 (real time)	< 1	Satellite
	Broadcasted almanac	1	24	0 (real time)	< 1,000	Satellite
BDS	Sp3 (final)	1	24	24	< 1	Ground server
	Ephemerids	0.083 (2 hours)	24	2	< 2.5	Ground server
	Almanac	< 7	24	1	< 1,000	Ground server
	Broadcasted ephemerids	0.083 (2 hours)	24	0	< 2.5	Satellite
	Broadcasted almanac	< 7	1	0	< 1,000	Satellite

Note: characteristics regarding broadcasted almanacs are provided for information only.

Galileo notes:

GSC (Galileo Service Center) data are linked to GST (Galileo System Time). In order to use Galileo orbital data the following information are needed:

- the clock corrections,
- the GST-UTC differences.

Furthermore GST-GPS time differences may also be helpful. This information is contained in Rinex 3.0 only (SP3 do not contain it).

GPS DASS notes: to be supplied

GPS L-band notes: to be supplied

BDS notes:

sp3 is gizp compressed, and can be obtained from

- http://en.igmas.org/Product/TreePage/tree/nav_id/36/cate_id/37.html ; and
- ftp://cospas:cospas-sarsat@ftp.csno-tarc.cn/eph.

Ephemerids can be obtained from: ftp://cospas:cospas-sarsat@ftp.csno-tarc.cn/brdc.
Almanac can be obtained from: ftp://cospas:cospas-sarsat@ftp.csno-tarc.cn/almanac.

Glonass notes: applies to commissioned Glonass-M series only, will include Glonass-K when commissioned into the Glonass system.

C.3 Definitions

Orbit data product
Set of satellite orbit data information allowing to determine future satellite locations and/or velocity vectors. Orbit data products can be provided in different formats (SP3, Rinex, ephemerids, almanac, xml, etc.)

Standard Product 3 (SP3) format
The Standard Product #3 (SP3) format is used to exchange orbital information in the form of tabular ephemerides of satellite positions every 15 min expressed. Associated consistent estimates for the satellite clocks are also provided at 15-min intervals.

Ephemeris Data
Ephemeris data is a set of parameters that can be used to accurately calculate the location of a GNSS satellite at a particular point in time. It describes the path that the satellite is following as it orbits Earth. Ephemeris data are valid for a certain period of time, typically 4 hours for GPS and Galileo.

Almanac Data
The GPS almanac is a set of data that every GNSS satellite transmits, and it includes information about the state (health) of the entire GPS satellite constellation, and coarse data on every satellite's orbit. When a GNSS receiver has *current* almanac data in memory, it can acquire satellite signals and determine initial position more quickly.

RINEX
Receiver Independent Exchange Format (RINEX) is a data interchange format for raw satellite navigation system data. This allows the user to post-process the received data to produce a more accurate result. RINEX is the standard format that allows the management and disposal of the measures generated by a receiver, as well as their off-line processing by a multitude of applications. The RINEX format is designed to evolve over time, adapting to new types of measurements and new satellite navigation systems.
There is basically two types of RINEX data:

- Observation Data which contains receiver measurements (pseudoranges, Doppler, C/N_0, etc…)
- Navigation Data which contain the ephemeris parameters as read by the receiver from the navigation message

Definitions related to the timeline for making orbit data products available through ground servers:

- t_{obs}: observation time, i.e., time at which satellite orbits are ultimately observed to produce the orbit data products

- t_{FTP}: time at which the orbit data product are made available to users on the FTP server
- latency: duration required to produce the orbit data products (i.e., time elapsed between t_{obs} and the time when the data are made available to users on the FTP server). Latency may vary based on conditions.
- validity: duration during which the orbit data product are valid (i.e., duration for which the orbit data products are within accuracy values guaranteed by the space segment provider)
- update rate (expressed in hours): duration between two successive orbital data products be made available on the FTP server (i.e., refresh rate of the files on the FTP server).

Latency and validity timeline
An illustration of the definitions above is provided in the schematic below (latency and update rate may vary based on conditions).

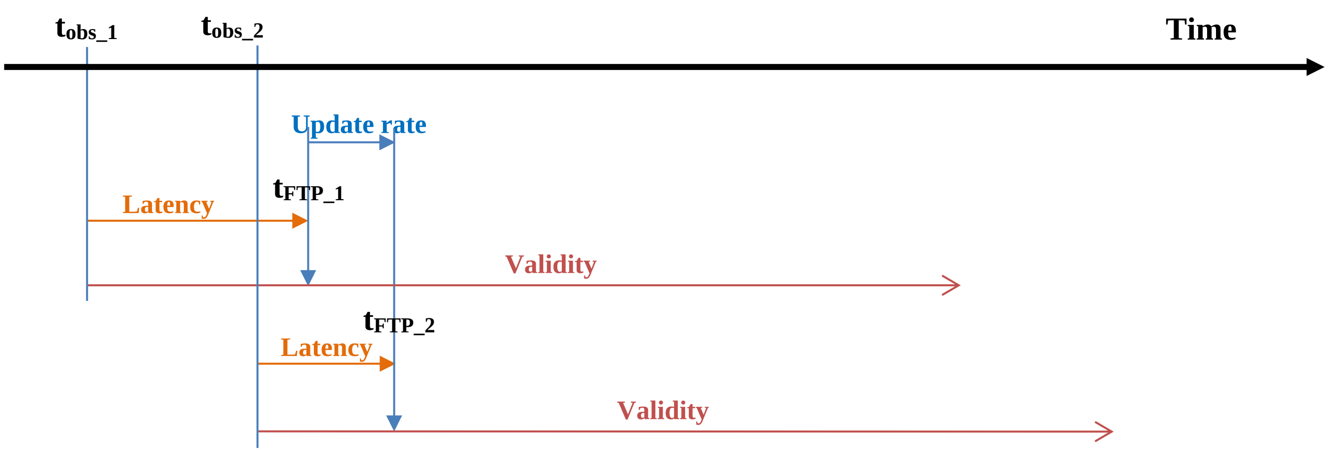

Figure C.1: Latency and Validity Timeline

- END OF ANNEX C -

- END OF DOCUMENT -

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