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

C/S T.016

Issue 1 – Rev.1
December 2015

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HISTORY

Issue	Revision	Date	Comments
1	-	October 2013	Approved by the Cospas-Sarsat Council (CSC-51)
1	1	December 2015	Approved by the Cospas-Sarsat Council (CSC-55)

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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 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.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 G.004	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

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 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 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/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 will 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.

2.2 MEOSAR Orbit Summary

(to be provided later)

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 have been identified in document C/S R.012 that impact MEOSAR interoperability are as follows:

- Modulation of the downlinks: frequency translation will be used by all constellations so there is no additional modulation of the downlink. This simplified MEOLUT design.

- Downlink frequency. MEOSAR satellite constellations need not have the exact same downlink frequencies to enable MEOLUTs to process their downlinks. GPS L-band and Glonass will use a 200 kHz band at 1544.9 MHz as the center frequency for the downlink while Galileo will use a 200 kHz band at 1544.1 MHz for the downlink center frequency. These frequencies were chosen to avoid the 1544.5 MHz downlink of the GEOSAR spacecraft. The 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: the design for 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 at LHCP for both the uplink and downlink.

- Repeater bandwidth: MEOSAR providers and Cospas-Sarsat have agreed that the 406 MHz 10 dB pass-band must be less than 100 kHz, centered at 406.05 MHz, and that the 1 dB pass-band must exceed 90 kHz. 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 or greater would enable the development of a fully interoperable MEOSAR system that satisfied the performance requirements for compatibility with Cospas-Sarsat.

- Repeater 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, and that the ratio of power from a relayed beacon to intermodulation products should be greater than 30 dB when the repeater is operating beyond its linear range.

- Repeater linearity: to be specified.

- 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 should be less than 10 µs with a stability within that range of 500 nanoseconds.

In addition, uplink polarization is different. GSP L-band, SAR Galileo and SAR Glonass will all use RHCP as the uplink polarization while DASS S-band uses LHCP as the uplink polarization.

- END OF SECTION 2 -

3. GPS 406 MHZ MEOSAR REPEATER

3.1 GPS-III L-Band

3.1.1 GPS III Overall Description

(to be provided later)

3.1.2 GPS III Repeater Functional Description

(to be provided later)

3.1.3 GPS III Repeater Operating Modes

(to be provided later)

3.1.4 GPS III Repeater Spectrum Characteristics

(to be provided later)

3.1.5 GPS III Repeater Coverage Area

(to be provided later)

3.1.6 GPS III Repeater Performance Parameters

(to be provided later)

3.1.6.1 GPS III SAR Receiver Parameters

(to be provided later)

3.1.6.2 GPS III SAR Transmitter Parameters

(to be provided later)

3.1.6.3 GPS III SAR Antennas

(to be provided later)

3.2 DASS S-Band

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

3.2.1 DASS S-Band Overall Description

(to be provided later)

3.2.2 DASS S-Band Repeater Functional Description

(to be provided later)

3.2.3 DASS S-Band Repeater Operating Modes

(to be provided later)

3.2.4 DASS S-Band Repeater Spectrum Characteristics

(to be provided later)

3.2.5 DASS S-Band Repeater Coverage Area

(to be provided later)

3.2.6 DASS S-Band Repeater Performance Parameters

(to be provided later)

3.2.6.1 DASS S-Band SAR Receiver Parameters

(to be provided later)

3.2.6.2 DASS S-Band SAR Transmitter Parameters

(to be provided later)

3.2.6.3 DASS S-Band 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. Of the total of four Galileo IOV satellites two are equipped with SAR repeaters. These two satellites are designated as Cospas-Sarsat 419 (GSAT0103, SVID-19) and Cospas-Sarsat 420 (GSAT0104, SVID-20). Their nominal orbital positions, represented by Keplerian elements[1] for the reference time 21 March 2010 at 00:00:00 UTC, are defined in Table 4.1.

S/C	Position		Semi-Major Axis (km)	Eccentricity	Inclination (deg)	RAAN (deg)	Arg. Perigee (deg)	True Anomaly (deg)
	Plane	Slot						
C/S 419	C	4	29599.8	0.0001	56.0	265.0	0.0	146.7
C/S 420	C	5	29599.8	0.0001	56.0	265.0	0.0	-173.3
Note: The coordinate reference frame used is CIRS[2] (true equator).								

Table 4.1: Keplerian Elements of Nominal Orbital Positions for Galileo IOV Satellites

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

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).

[1] These elements have to be used with a two-body propagator, with no perturbations. For long propagations and propagations far from the reference time, it is advisable to use an interpolation considering constant Semi-Major axis, Eccentricity, Inclination, and Perigee. In order to represent the RAAN precession, the RAAN has to be modified at a rate of 0.02764398 deg/day. The True Anomaly evolves at a rate of 613.72253566 deg/day.

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

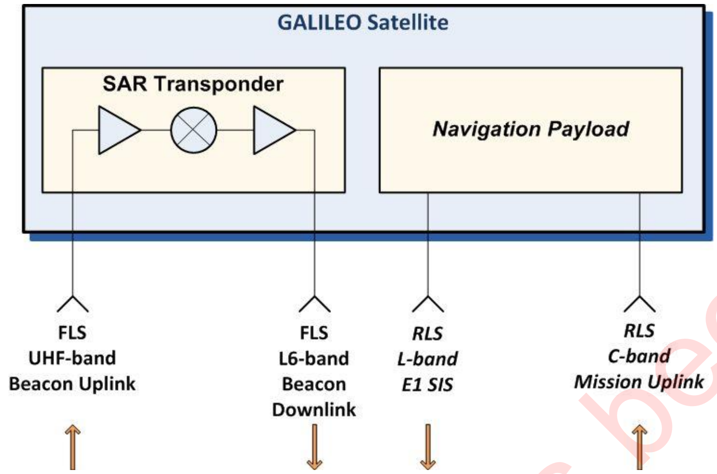

Figure 4.1: Implementation of SAR functions on the Galileo satellites

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 4.1). They are designed according to the space segment interoperability requirements[3], 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:

ON mode

- 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 dBW 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

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

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 is achieved when the gain setting is +22 dB (for CS-419) and +20 dB (for CS-420).

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.

	CS-419	CS-420
Edge of coverage	182.4 dB	181.7 dB
Centre of coverage	186.4 dB	186.4 dB

Table 4.2: Overall Repeater Gain[4]

In automatic level control gain mode the operational gain is automatically adjusted to obtain a power of 7 dBW at the output of the SAR transponder.

STANDBY mode (transponder is powered up, but RF power is OFF)

OFF mode (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.

[4] The values provided refer to the center frequency of the repeater band.

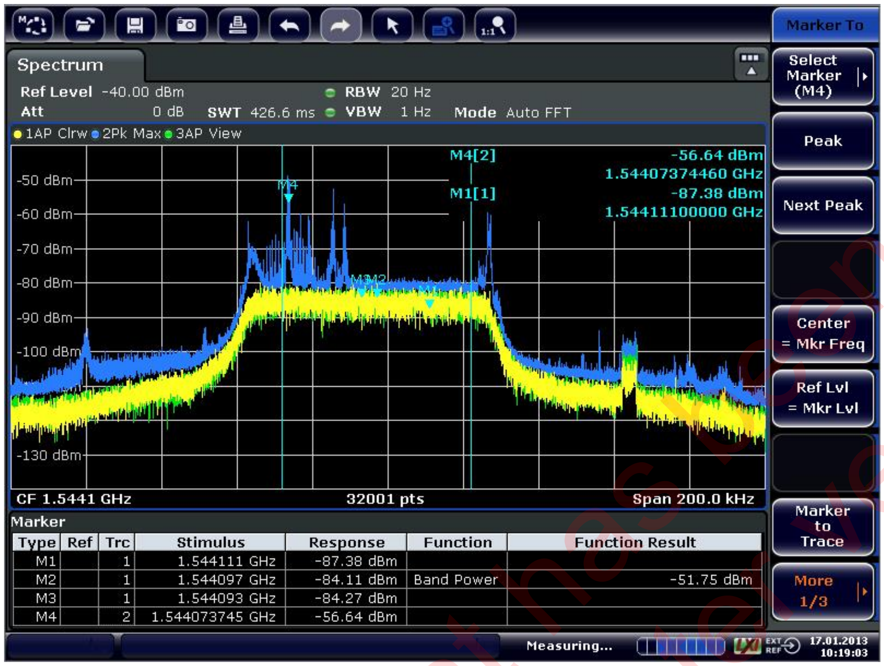

Figure 4.2: Galileo SAR Repeater L-Band Downlink Narrow-Band (50 kHz) Signal Spectrum

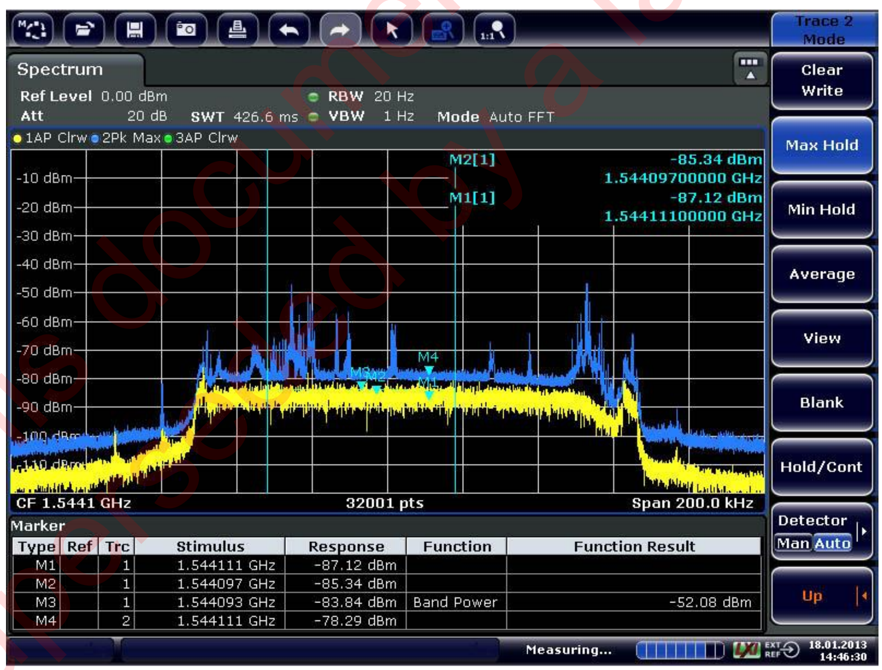

Figure 4.3: Galileo SAR Repeater L-Band Downlink Normal Band (90 kHz) Signal Spectrum

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.

The minimum and maximum achieved G/T and EIRP in the coverage area are given in Table 4.4 and Table 4.6, respectively.

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.

Parameter	Interoperability Requirement[b]	Galileo IOV Performance	Unit
Uplink frequency range	406.0 to 406.1	406.0 to 406.1	MHz
Receive centre frequency Normal mode Narrowband mode	 406.050 406.043	 406.050 406.043	MHz
Nominal input power at antenna	-159.0	-	dB_W
Maximum input power at antenna	-148.0	-153.0	dB_W
System dynamic range	30	32	dB
Receive antenna polarisation	RHCP	RHCP	
Receive antenna gain at EoC [c]		11.6	dB_i
Receive antenna axial ratio	< 2.5	< 1.8	dB
Satellite G/T [d] At edge of coverage [c] At centre of coverage	-17.7	 > -12.7 > -11.0	dB/K
System noise temperature [d, e]		250	K
Bandpass characteristics Normal mode Narrowband mode	 > 80 kHz (1.0dB) > 90 kHz (3.0dB) < 110 kHz (10dB) < 170 kHz (45dB) < 200 kHz (70dB) > 50 kHz (1.0dB) < 75 kHz (10dB) < 130 kHz (45dB) < 160 kHz (70dB)	 > 80 kHz (1.9dB) > 90 kHz (2.5dB) < 110 kHz (8.5dB) < 170 kHz (64dB) < 200 kHz (67dB) > 50 kHz (1.1dB) < 75 kHz (16dB) < 130 kHz (53dB) < 160 kHz (55dB)	
Phase linearity (overall in-band) Normal mode Narrowband mode	 / /	 28 18	degree
Group delay (turn-around time) [f] Normal mode Narrowband mode	 / /	 27 38	µs

Parameter	Interoperability Requirement[b]	Galileo IOV Performance	Unit
Group delay uncertainty (95% conf.)	500	< 150	ns
Group delay over 4 kHz [g] (slope) Normal mode Narrowband mode	10	5 9	µs/4kHz
Transponder gain modes		FGM ALC	
ALC time constant	< 80	40	ms
ALC dynamic range	> 30	32	dB
Transponder gain	> 180	165 - 203	dB
Fixed gain mode adjustment range		31 (FGM: -1… +30)	dB
Transponder gain at nominal o/p power		160	dB
Transponder linearity (C/I3)	> 30	32	dB_c
Translation frequency		1,138,050,000.0	Hz
Frequency translation Accuracy Short term stability (100ms)	$\pm 2 \times 10^{-11}$ 1×10^{-11}	$< \pm 2 \times 10^{-11}$ 2×10^{-11}	[i]
Gain variation [h]		0.3	dB_{pk-pk}
Translation frequency stability		RAFS: $< 1.0 \times 10^{-11}$ PHM: $< 1.0 \times 10^{-14}$	
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	dB
Downlink EIRP	15	> 18.7 [j] < 20.3 [k]	dB_W
EIRP stability in ALC mode		0.3	dB_{pk-pk}
EIRP stability in FG mode		1.5	dB_{pk-pk}

Table 4.3: Typical SAR/Galileo IOV Repeater Characteristics[a]

(a) These are the characteristics and typical measured performance parameters of SAR repeaters on two Galileo satellites of the In-Orbit Validation (IOV) block. Characteristics of transponders on satellites of the next block (FOC-1) shall be reported separately.
(b) MEOSAR space segment interoperability requirements.
(c) The receive antenna edge of coverage (EoC) is defined at a beacon elevation angle of 5°.
(d) G/T as measured in orbit. The MEOSAR space segment interoperability requirement is defined assuming antenna external noise temperature Ta = 400 K.
(e) System temperature computed at transponder input.
(f) 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.
(g) In the 1 dB band.
(h) Gain variation in any 3 kHz within the operating band.
(i) Depending on the configuration settings of the on-board clocks may be significantly better.
(j) 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

The G/T of Galileo IOV SAR repeaters, as measured in orbit, is given in the following table.

Satellite		G/T [dB/K]
C/S-419	Centre of coverage	-11.0
	Edge of coverage	-12.7
C/S-420	Centre of coverage	-10.4
	Edge of coverage	-11.9

Table 4.4: Measured G/T

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.

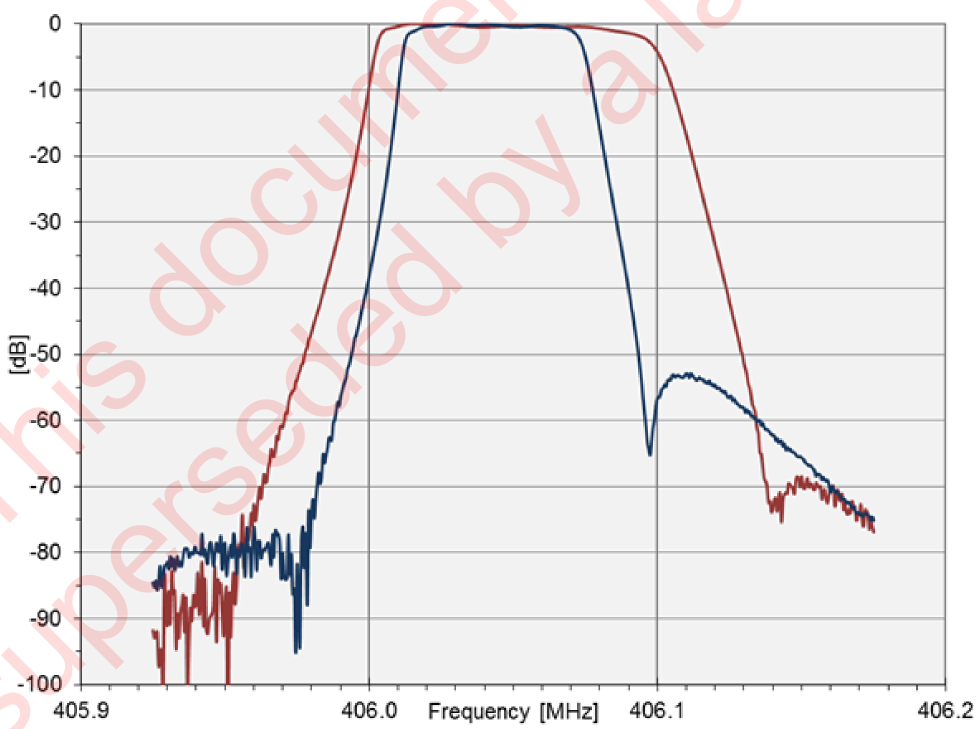

Figure 4.4: Galileo SAR Repeater Normal and Narrow Bandpass Filtering Performance

4.7.2 Galileo SAR Transmitter Parameters

Table 4.5 presents the principal downlink requirements for the IOV SAR repeaters.

Item	Design Requirement
Payload type	Direct frequency translation repeater
Downlink frequency band (used)	100 kHz: 1,544.050 – 1,544.150 MHz
Downlink EIRP	> 16.8 dB_W over the entire visible Earth > 18.0 dB_W for satellite elevation > 10°
Downlink polarisation	Left hand circular polarisation (LHCP)
Bandwidth relayed (normal mode)	406.005-406.095 MHz (3 dB bandwidth)
Bandwidth relayed (narrow mode)	406.018-406.068 MHz (1 dB bandwidth)

Table 4.5: SAR/Galileo IOV Repeater Downlink Characteristics (Requirements)

The EIRP of Galileo IOV SAR repeaters, as measured in orbit, is given in Table 4.6.

Satellite		EIRP (dB_W)
C/S-419	Centre of coverage	20.3
	Edge of coverage	19.0
CS-420	Centre of coverage	20.3
	Edge of coverage	18.8

Table 4.6: Measured EIRP

4.7.3 Galileo SAR Antennas

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.

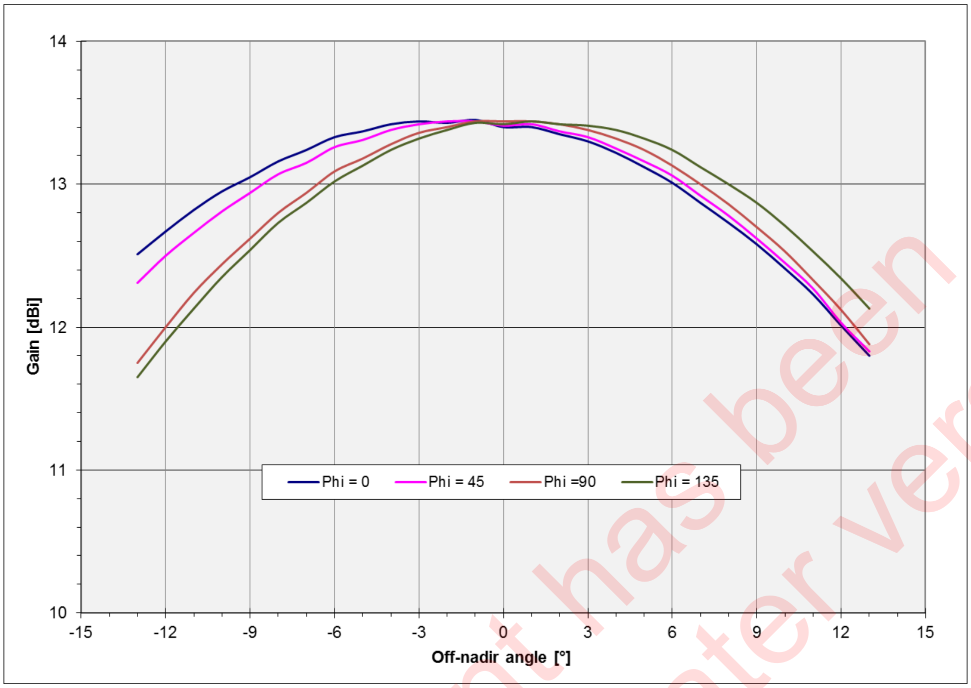

Figure 4.5: SAR Rx Antenna Gain on Galileo IOV 419 Satellite (Four Cross-Sections)

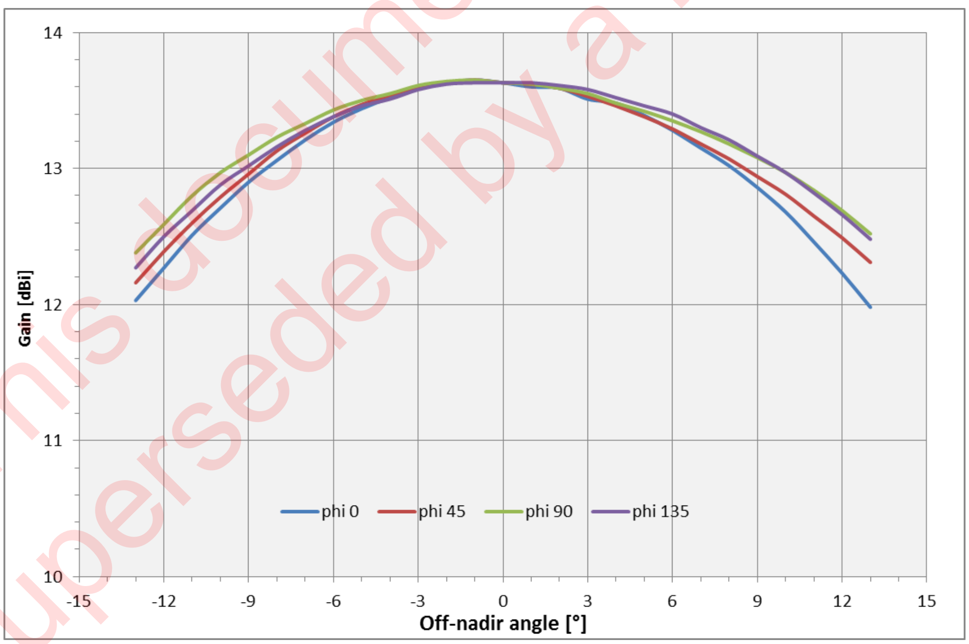

Figure 4.6: SAR Tx Antenna Gain on Galileo IOV 419 Satellite (Four Cross-Sections)

- END OF SECTION 4 -

5. GLONASS 406 MHZ MEOSAR REPEATER

5.1 Glonass Overall Description

The information presented in this section refers to the Glonass K-series satellites. Currently two Glonass-K satellites are equipped with SAR repeater. These two satellites are designated as Cospas-Sarsat 501 and Cospas-Sarsat 502. Their nominal orbital parameters are defined in Table 5.1.

Table 5.1: Orbital Parameters of Glonass-K Satellites 501 and 502

S/C	Plane	Slot	Altitude (km)	Eccentricity	Inclination (deg)	RAAN (deg)*	Arg. Perigee (deg)	Argument of latitude (deg)**	Orbital period
502	2	09	19100	0	64.8	11° 15' 00"	0.0	160° 26' 37"	11 h. 15 m. 44 s.
501	3	20				131° 15' 00"		40° 26' 37"	

* RAAN are done according the formula:
251° 15' 00"+ 120° (i - 1)
where (i = 1, 2, 3) as of 00: 00: 00 on 1 January 1983 (UTC + 3h)

** True anomaly for circular orbit is equal to argument of latitude and is given for the epoch of 00:00:00 on 1 January 1983 (UTC+3h).

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

5.2 Glonass Repeater Functional Description

Figure 5.1 depicts the implementation of the Glonass-K SAR repeater.

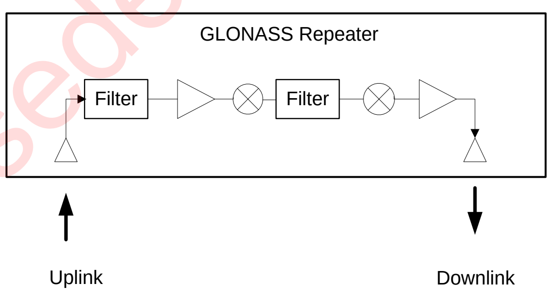

Figure 5.1: Implementation of SAR Functions on the Glonass-K Satellites

5.3 Glonass Repeater Operating Modes

The Glonass-K repeater can operate in one gain and two bandwidth modes. The operational modes include the Normal and Narrow Bandwidth modes. Repeater gain is self-regulated by Automatic Level

Control (ALC). The repeater gain is automatically adjusted to obtain a power of 7 dB_W at the output of the SAR transponder.

5.4 Glonass Repeater Spectrum Characteristics

Figure 5.2 and Figure 5.3 depict an example of the Glonass SAR repeater L-band downlink signal spectrum in narrow- and normal-bandwidth setting.

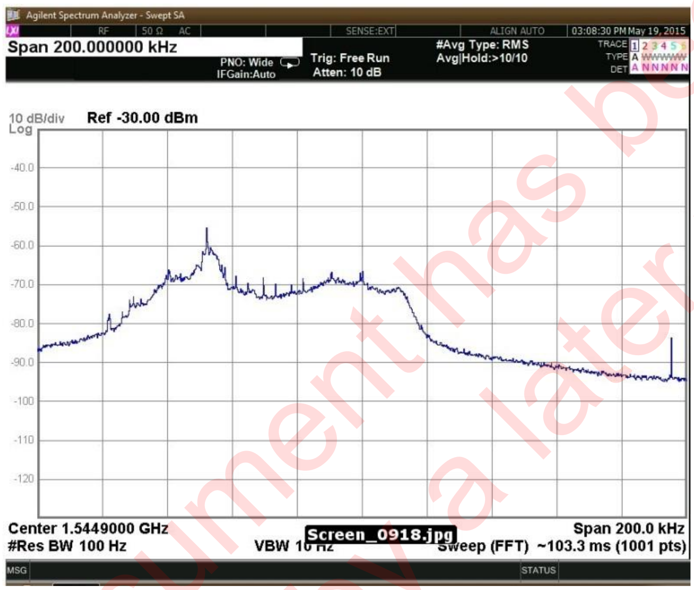

Figure 5.2: Glonass-K SAR Repeater L-Band Downlink Narrow Band Signal Spectrum

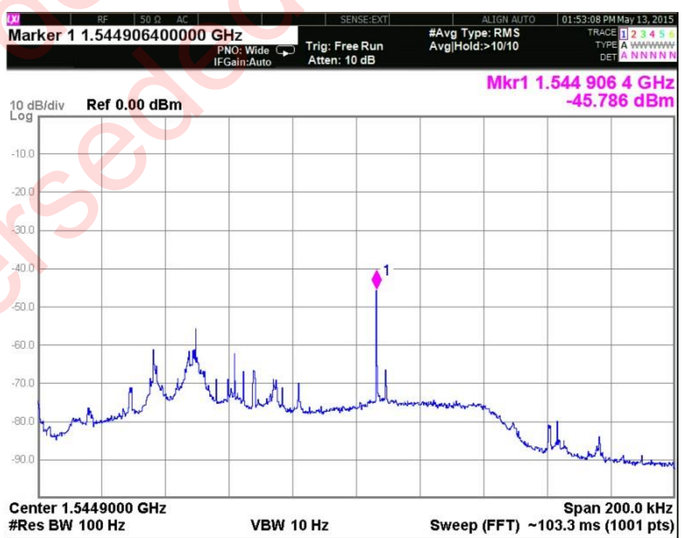

Figure 5.3: Glonass-K SAR Repeater L-Band Downlink Wide Band Signal Spectrum

5.5 Glonass Repeater Coverage Area

Figure 5.4 depicts the example of 0˚ elevation coverage area for Glonass-K.

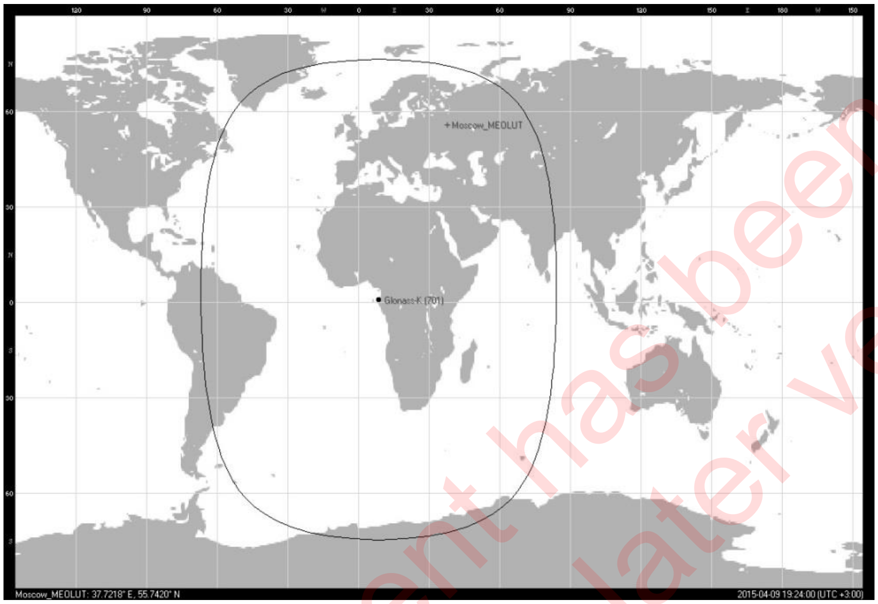

Figure 5.4: Glonass-K 0˚ Elevation Coverage Area

(an example of coverage area taken near the equator)

5.6 Glonass Repeater Performance Parameters

Table 5.2 presents the typical measured satellite payload performances based on in-orbit and on-ground equipment testing.

Table 5.2: Glonass-K SAR Repeater Characteristics

Parameter	Unit	Value
Uplink frequency range	MHz	406.0 to 406.1
Receive centre frequency Normal mode Narrowband mode	MHz	 406.050 406.043
Nominal input power at antenna	dB_W	-160
Maximum input power at antenna	dB_W	-140.0
System dynamic range	dB	30
Receive antenna polarisation		RHCP
Receive antenna gain at edge of coverage (EoC) [5]	dB_i	10.6
Receive antenna axial ratio	dB	3
Receive antenna G/T[6] At edge of coverage At centre of coverage	dB/K	 -16.3 -14.3
System noise temperature	K	490
Bandpass characteristics Normal mode Narrowband mode		 > 120 kHz (3 dB) < 150 kHz (10 dB) < 340 kHz (30 dB) < 450 kHz (40 dB) > 80 kHz (3 dB) < 95 kHz (10 dB) < 230 kHz (30 dB) < 330 kHz (40 dB
Group delay uncertainty (95% conf.)	ns	< 100
Group delay over 4 kHz (slope)	µs/4kHz	In uplink frequency range
Normal mode		< 10
Narrowband mode		< 10
Transponder gain mode		ALC
ALC time constant	ms	< 80
ALC dynamic range	dB	> 30
Transponder gain	dB	175
Transponder linearity (C/I3)	dB_c	> 30
Translation frequency	Hz	1 138 849 998.5
Frequency translation		
Accuracy	Hz	1.53
hort term stability (100 ms)		$\pm 5 \times 10^{-12}$
Gain variation (in any 3 kHz)	dB pk-pk	0.53
Downlink frequency band	MHz	1544.85-1544.95
Downlink centre frequency	MHz	
Normal mode		1544.900
Narrowband mode		1544.893
Downlink antenna polarisation		LHCP
Downlink EIRP (at edge of coverage)	dB_W	18.2

[5] The receive antenna edge of coverage (EoC) is defined at a beacon elevation angle of 5°.
[6] G/T as measured in orbit.

5.6.1 Glonass SAR Receiver Parameters

Bandpass characteristics of the Glonass-K transponder are presented in Figure 5.5 and Figure 5.6 for both narrow and normal bands respectively.

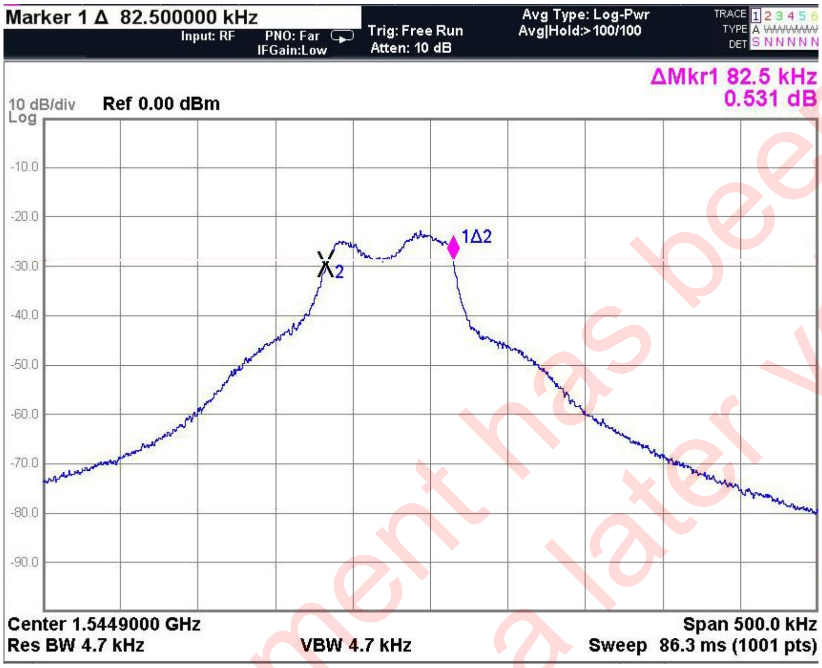

Figure 5.5: Glonass-K SAR Repeater Narrow Bandpass Filtering Performance

Figure 5.6: Glonass 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 5.7 and Figure 5.8 show the SAR receive and L-band transmit antenna gain plots for Glonass-K satellites in four characteristic cross-sections.

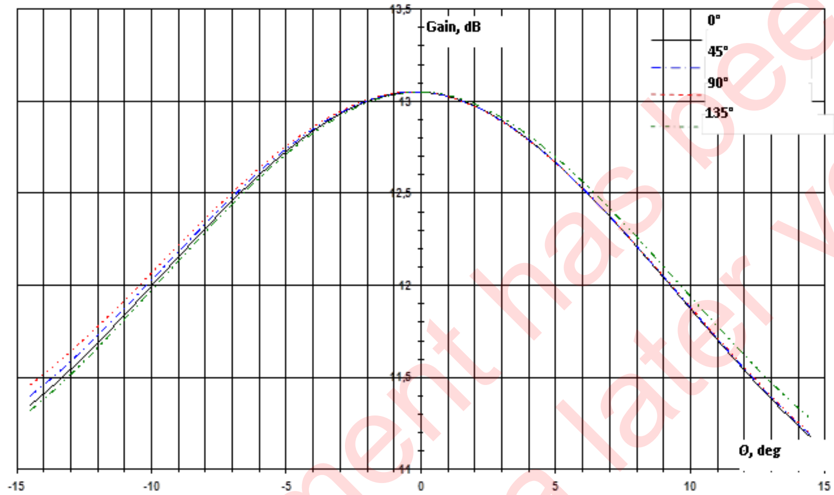

Figure 5.7: Glonass-K SAR Repeater Receiving Antenna Gain (Four Cross-Sections)

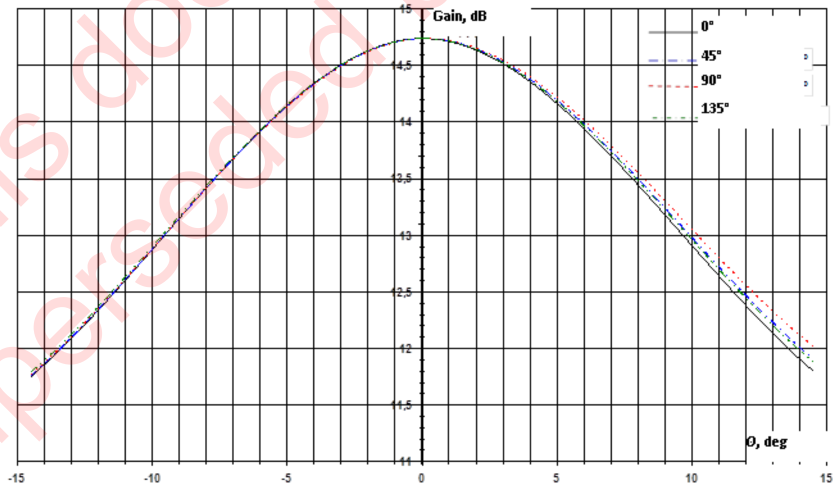

Figure 5.8: SAR Repeater Transmitting Antenna Gain (Four Cross-Sections)

- END OF SECTION 5 -

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 Table B-1. A dynamic list is maintained on the Cospas-Sarsat 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

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

	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	301	37753	11036A	GPS BIIF-2	63	GPS 2F-2	Navstar 66	USA 232	1	2011-07-16
	302	28474	04045A	GPS BIIR-13	61	GPS 2R-13	Navstar 56	USA 180	2	2004-11-06
	303	40294	14068A	GPS-BIIF-8	69	GPS 2F-8	Navstar 72	USA 258	3	2014-10-29
	306	39741	14026A	GPS BIIF-6	67	GPS 2F-6	Navstar 70	USA 251	6	2014-05-17
	308	40730	15033A	GPS IIF-10	72	GPS 2F-10	Navstar 74	USA 262	8	2015-07-15
	309	40105	14045A	GPS BIIF-7	68	GPS 2F-7	Navstar 71	USA 256	9	2014-08-02
	312	29601	06052A	GPS BIIRM-3	58	GPS 2R-16	Navstar 59	USA 192	12	2006-11-17
	315	32260	07047A	GPS BIIRM-4	55	GPS 2R-17	Navstar 60	USA 196	15	2007-10-17
	316	27663	03005A	GPS BIIR-8	56	GPS 2-R-8	Navstar 51	USA 166	16	2003-01-29
	317	28874	05038A	GPS BIIRM-1	53	GPS 2R-14	Navstar 57	USA 183	17	2005-09-26
	318	26690	01004A	GPS BIIR-7	54	GPS 2-28	Navstar 50	USA 156	18	2001-01-30
	319	28190	04009A	GPS BIIR-11	59	GPS 2R-11	Navstar 54	USA 177	19	2004-03-20
	323	28361	04023A	GPS BIIR-12	60	GPS 2R-12	Navstar 55	USA 178	23	2004-06-23
	324	38833	12053A	GPS BIIF-3	65	GPS 2F-3	Navstar 67	USA 239	24	2012-10-04
	326	40534	15013A	GPS IIF-9	71	GPS 2F-9	Navstar 73	USA 260	26	2015-03-25
	327	39166	13023A	GPS-BIIF-4	66	GPS 2F-4	Navstar 68	USA 242	27	2013-05-15
	329	32384	07062A	GPS BIIRM-5	57	GPS 2R-M	Navstar 61	USA 199	29	2007-12-20
	330	39533	14008A	GPS BIIF-5	64	GPS 2F-5	Navstar 69	USA 248	30	2014-02-21
Galileo	411 (note 7)	37846	11060A	GSAT0101	11	Galileo-IOV PFM	IOV-1	Thijs	-	2011-10-21

	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
	412 (note 7)	37847	11060B	GSAT0102	12	Galileo-IOV FM2	IOV-2	Natalia	-	2011-10-21
	414	40129	14050B	GSAT0202	14	Galileo-FOC FM2	Galileo 6	Milena	-	2014-08-22
	418	40128	14050A	GSAT0201	18	Galileo-FOC FM1	Galileo 5	Doresa	-	2014-08-22
	419	38857	12055A	GSAT0103	19	Galileo-IOV FM3	IOV-3	David	-	2012-10-12
	420	38858	12055B	GSAT0104	20	Galileo-IOV FM4	IOV-4	Sif	-	2012-10-12
	422	40545	15017B	GSAT0204	22	Galileo-FOC FM4	Galileo 8	Anastasia	-	2015-03-27
	426	40544	15017A	GSAT0203	26	Galileo-FOC FM3	Galileo 7	Adam	-	2015-03-27
Glonass	501	37372	11009A	Glonass-K1	701	Cosmos 2471	Glonass-K1-#11L	Uragan-K1 11L	-	2011-02-26
	502	40315	14075A	Glonass-K1-#2	702	Cosmos 2501	Glonass-K1-#12L	Uragan-K1 12L	-	2014-11-30

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.

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

	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	301	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	302	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	303	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	306	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	308	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	309	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	312	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	315	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	316	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	317	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	318	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	319	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	323	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	326	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	324	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	327	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	329	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
	330	S-band	2226.47234	Inverted	LHCP	LHCP	270 @ 406.050		
Galileo	414	L-band	1544.1	Not inverted	RHCP	LHCP	90 @ 406.050	UT	Elliptical orbit, all navigation signals with dummy navigation message
	418	L-band	1544.1	Not inverted	RHCP	LHCP	90 @ 406.050	UT	Elliptical orbit, all navigation signals with dummy navigation message
	419	L-band	1544.1	Not inverted	RHCP	LHCP	90 @ 406.050	WA	
	420	L-band	1544.1	Not inverted	RHCP	LHCP	90 @ 406.050	WA	Only the E1 navigation signal with dummy navigation message
	422	L-band	1544.1	Not inverted	RHCP	LHCP	90 @ 406.050	-	Under test
	426	L-band	1545.1	Not inverted	RHCP	LHCP	90 @ 406.050	-	Under test
Glonass	501	L-band	1544.9	Not inverted	RHCP	LHCP	100 @ 406.050	OFF	Repeater turned off
	502	L-band	1544.9	Not inverted	RHCP	LHCP	100 @ 406.050	UT	

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.

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.

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

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.3: DASS S-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)	
419	WA	90	406.05	26.9	-54.85	4583.28	162823.18	838747.67	-141170213.84	100	N/A	1.30E-11	95	106	145	85	TBD
419	NA	50	406.043	38.6	1.21	1111.39	-45298.19	16934072.10	-88037351.72	100	N/A	1.30E-11	62	68	94	58	TBD
419	WF	90	406.05	26.9	-54.85	4583.28	162823.18	838747.67	-141170213.84	100	155	1.30E-11	95	106	145	85	TBD
419	NF	50	406.043	38.6	1.21	1111.39	-45298.19	16934072.10	-88037351.72	100	N/A	1.30E-11	62	68	94	58	TBD
420	WA	90	406.05	27.2	34.03	5168.09	63330.85	167315.61	-53564418.98	100	N/A	1.10E-11	95	106	146	87	TBD
420	NA	50	406.043	38.5	-128.71	12624.37	441313.62	18817793.16	-589936952.92	150	N/A	1.10E-11	61	68	95	57	TBD
420	WF	90	406.05	27.2	34.03	5168.09	63330.85	167315.61	-53564418.98	100	156	1.10E-11	94	106	146	87	TBD
420	NF	50	406.043	38.5	-128.71	12624.37	441313.62	18817793.16	-589936952.92	150	156	1.10E-11	61	68	95	57	TBD

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)	
501		60	406.043														
501		100	406.050														
502		60	406.043														
502		100	406.050														

Table B.6: Glonass 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.

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 x 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 –

- END OF DOCUMENT -

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