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

C/S T.016

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COSPAS SARSAT

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

HISTORY

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

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1. INTRODUCTION

1.1 Overview

This document provides a description of the MEOSAR instruments 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 satellite 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.TBD	Cospas-Sarsat MEOLUT Specification and Design Guidelines
C/S T.TBD	Cospas-Sarsat MEOLUT Commissioning Standard
C/S G.003	Introduction to the Cospas-Sarsat System
C/S G.004	Cospas-Sarsat Glossary

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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-III	USA/Canada	Planned

2.1 406 MHz MEOSAR Payload Functional Description

(to be provided later)

2.2 MEOSAR Orbit Summary

(to be provided later)

2.3 MEOSAR Interoperability Parameters

(to be provided later)

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3. GPS III 406 MHZ MEOSAR REPEATER

3.1 GPS III Overall Description

(to be provided later)

3.2 GPS III Repeater Functional Description

(to be provided later)

3.3 GPS III Repeater Operating Modes

(to be provided later)

3.4 GPS III Repeater Spectrum Characteristics

(to be provided later)

3.5 GPS III Repeater Coverage Area

(to be provided later)

3.6 GPS III Repeater Performance Parameters

(to be provided later)

3.6.1 GPS III SAR Receiver Parameters

(to be provided later)

3.6.2 GPS III SAR Transmitter Parameters

(to be provided later)

3.6.3 GPS III SAR Antennas

(to be provided later)

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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.

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[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 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).

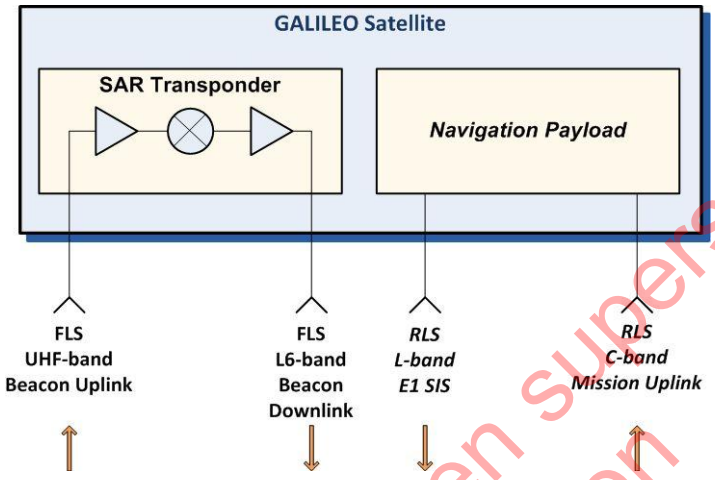

Figure 4.1: Implementation of SAR functions on the GALILEO satellites

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 4.1). 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

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

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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

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 dBW 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.

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

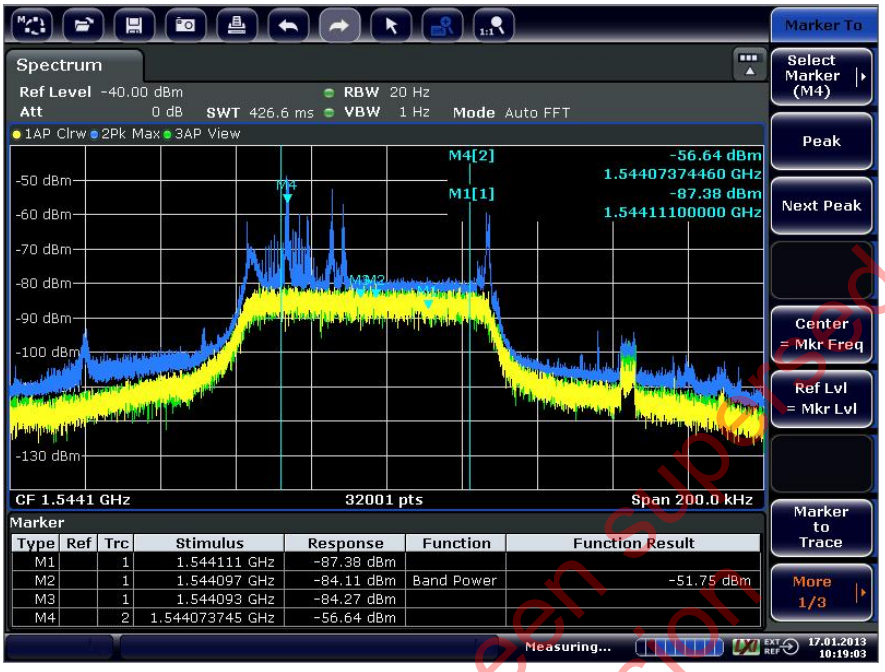

Figure 4.2: Galileo SAR Repeater L-band Downlink Narrow-Band (50 kHz) Signal Spectrum

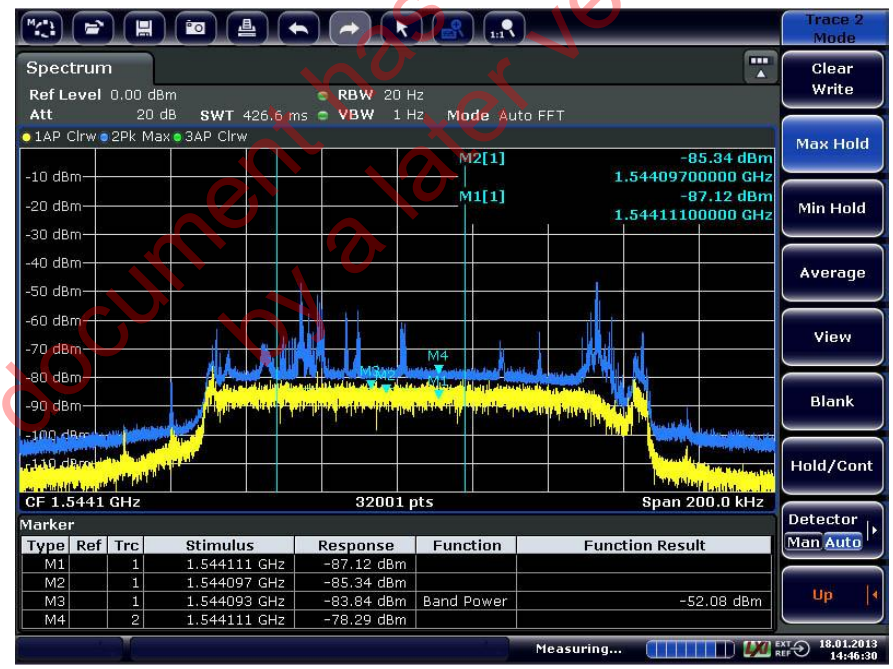

Figure 4.3: Galileo SAR Repeater L-band Downlink Normal Band (90 kHz) Signal Spectrum

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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

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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	dBc
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 [i] < 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).

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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.

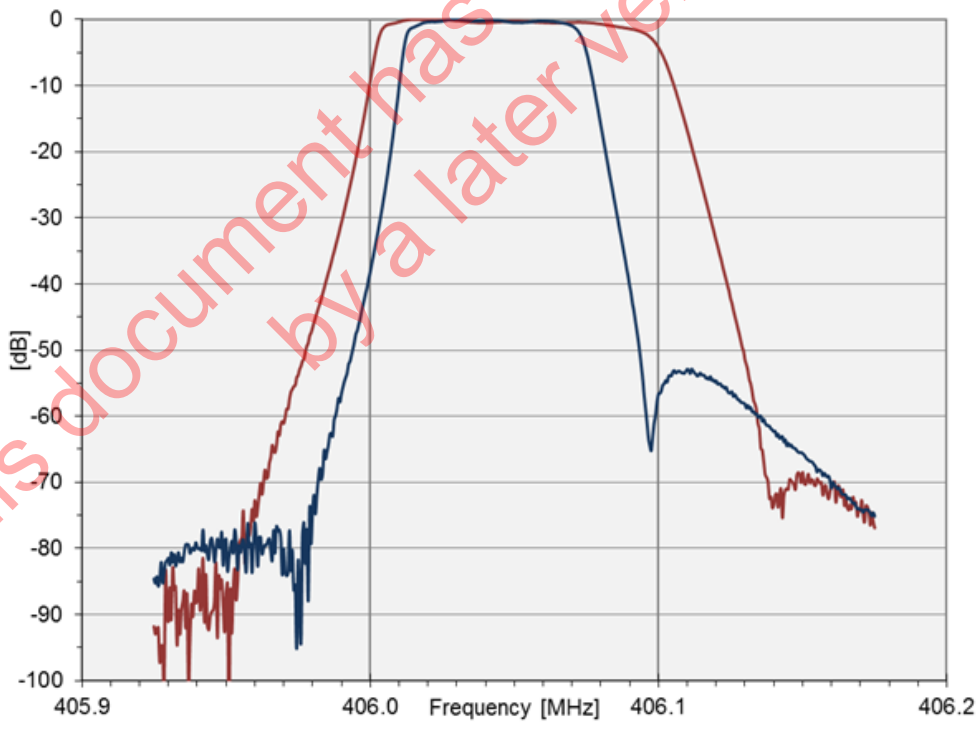

Figure 4.4: Galileo SAR Repeater Normal and Narrow Bandpass Filtering Performance

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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.

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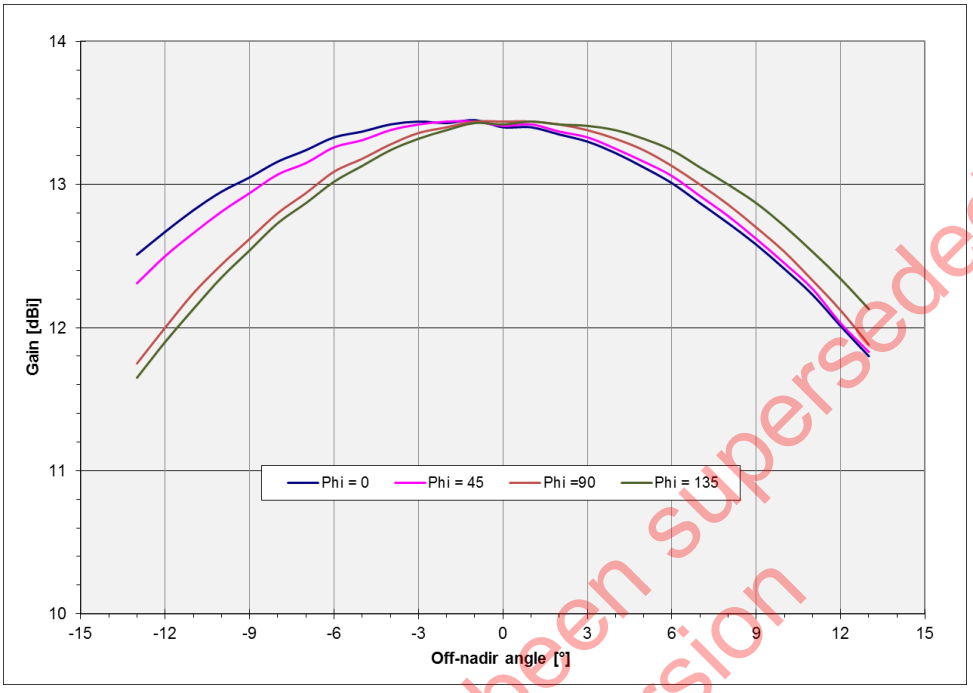

Figure 4.5: SAR Rx Antenna Gain on Galileo IOV 419 Satellite (Four Cross-Sections)

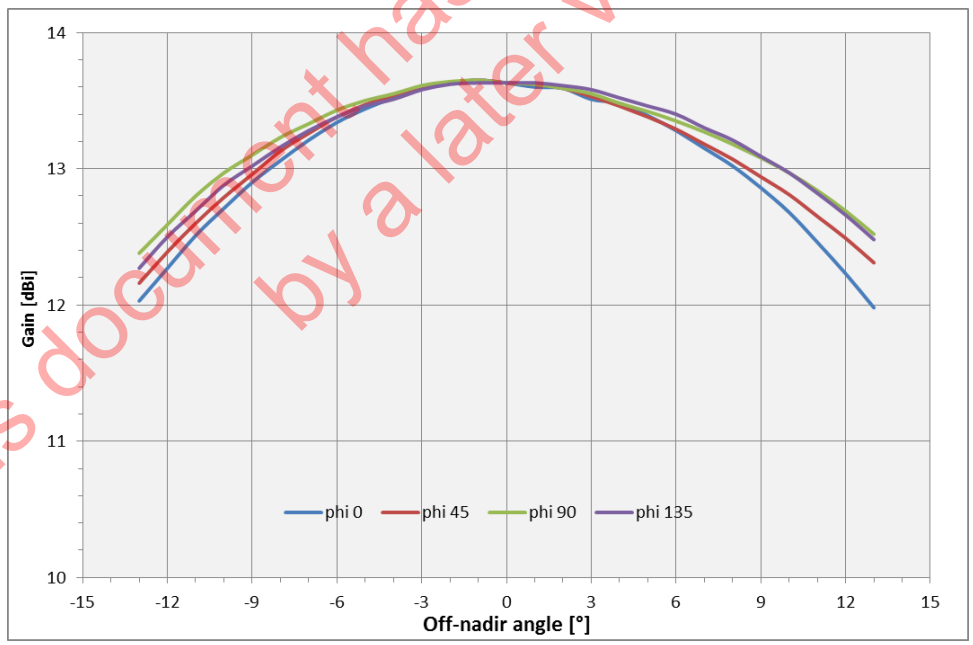

Figure 4.6: SAR Tx Antenna Gain on Galileo IOV 419 Satellite (Four Cross-Sections)

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5. GLONASS 406 MHZ MEOSAR REPEATER

5.1 Glonass Overall Description

(to be provided later)

5.2 Glonass Repeater Functional Description

(to be provided later)

5.3 Glonass Repeater Operating Modes

(to be provided later)

5.4 Glonass Repeater Spectrum Characteristics

(to be provided later)

5.5 Glonass Repeater Coverage Area

(to be provided later)

5.6 Glonass Repeater Performance Parameters

(to be provided later)

5.6.1 Glonass SAR Receiver Parameters

(to be provided later)

5.6.2 Glonass SAR Transmitter Parameters

(to be provided later)

5.6.3 Glonass SAR Antennas

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