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

C/S T.011

Issue 2 – Revision *2*~~1~~

November~~February~~ 2019

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

COSPAS SARSAT

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1. INTRODUCTION

1.1 Overview

The Cospas-Sarsat Space Segment consists of satellites in low earth orbit (LEO) equipped with search and rescue (SAR) instruments. The LEO satellites are complemented by satellites in geostationary earth orbit (GEO) with their respective SAR instruments. These geostationary search and rescue (GEOSAR) instruments are currently flown on USA and Indian spacecraft, and it is anticipated that they will also be flown on Russian and EUMETSAT spacecraft in the near future. The 406 MHz data received from these instruments are processed by Cospas-Sarsat Ground Segment equipment and provided to SAR agencies. This document provides a description of the GEOSAR instruments carried on board these spacecraft. The description of the Cospas-Sarsat LEO Space Segment is provided in document C/S T.003.

1.2 Purpose

The purpose of this document is to describe the functionality and performance parameters for each GEOSAR 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 geostationary local user terminal (GEOLUT) downlink. The document is not intended for use as a specification for procurement of hardware for GEOSAR satellite repeaters.

1.3 Scope

This document presents a technical description of the GEOSAR repeaters used in the Cospas-Sarsat system. Section 2 provides a general overview of the GEOSAR repeater function. Sections 3, 4, 5, and 6 provide descriptions of the repeaters on the USA, Russian, Indian, and EUMETSAT satellites.

1.4 Reference Documents

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

a) C/S T.001, Specification for Cospas-Sarsat 406 MHz Distress Beacons

b) C/S T.003, Description of the Payloads used in the Cospas-Sarsat LEOSAR System

c) C/S T.009, Cospas-Sarsat GEOLUT Specification and Design Guidelines

d) C/S T.010, Cospas-Sarsat GEOLUT Commissioning Standard

e) C/S G.003, Introduction to the Cospas-Sarsat System

f) C/S G.004, Cospas-Sarsat Glossary

- END OF SECTION 1 -

2. COSPAS-SARSAT PARAMETERS

The Cospas-Sarsat GEOSAR Space Segment consists of SAR instruments on board satellites in geostationary orbit. The SAR instruments are radio repeaters that receive distress beacon signals in the 406 - 406.1 MHz band and relay these signals to GEOLUTs 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. GEOSAR instruments are flown on the following satellites.

Spacecraft	Country/Organization	Status
GOES-13	USA	In-Orbit spare
GOES-14	USA	In-Orbit spare
GOES-15 (West)	USA	Operational
GOES-16 (East)	USA	Operational
GOES-17 (West)	*USA*	*Operational*
INSAT 3D	India	Operational
INSAT 3DR	India	Operational
GSAT-17	India	Under Test
MSG-1	EUMETSAT	Operational
MSG-2	EUMETSAT	~~Operational~~*In-Orbit Spare*
MSG-3	EUMETSAT	Operational
MSG-4	EUMETSAT	~~In-Orbit spare~~*Operational*
Electro-L#2	Russia	Under Test
Louch-5V	Russia	Under Test
Louch-5A	Russia	~~Under Test~~*Operational*

2.1 406 MHz GEOSAR Payload Functional Description

A functional diagram of SAR instruments on GEOSAR spacecraft is shown in Figure 2.1. The GEOSAR instruments were independently developed and integrated into spacecraft that have different mission requirements. This has resulted in differences in repeater designs that affect the output signal as described in Sections 3, 4, 5, and 6. These differences must be considered in developing a GEOLUT.

The GEOSAR repeater receives 406 MHz beacon signals within the field of view of the 406 MHz receive antenna beam. The beacon signals are processed by the repeater and transmitted on the downlink signal for reception by a GEOLUT. The downlink center frequency and antenna pattern characteristics vary among the different repeater implementations as described in subsequent sections of this document.

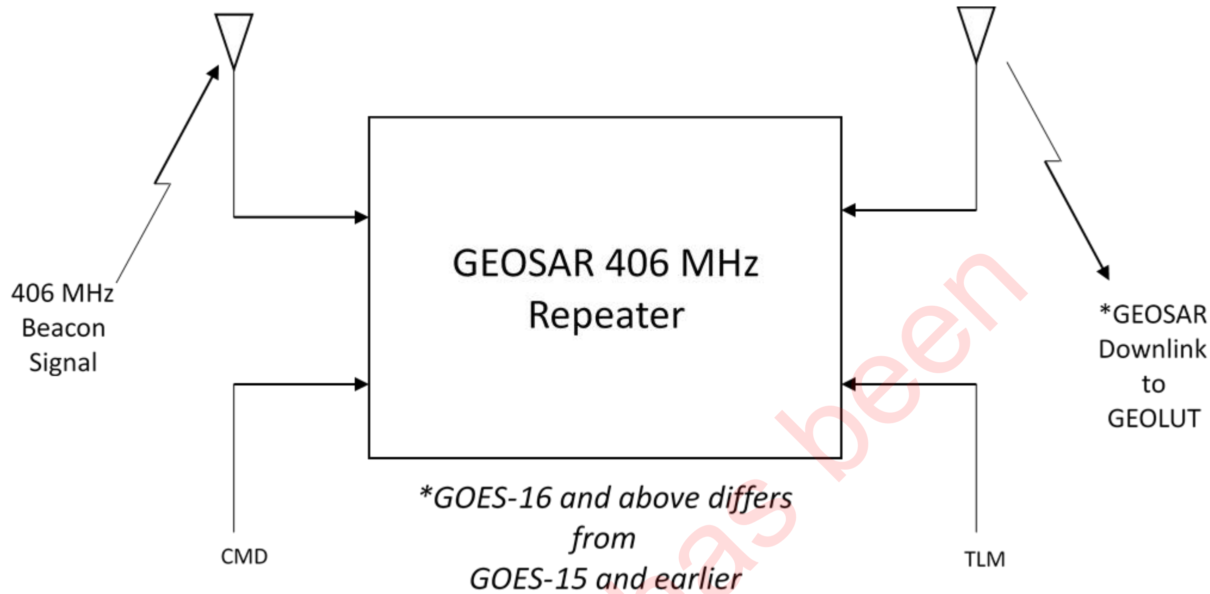


Figure 2-1~~2-12-1~~: GEOSAR Payload Functional Diagram

2.2 GEOSAR Orbit Summary

Each of the GEOSAR satellites with operational payloads in a geostationary orbit with an orbital period of 24 hours and nominal parameters as shown in Table 2.1.

Table 2.1: GEOSAR Space Segment Orbit Parameters*

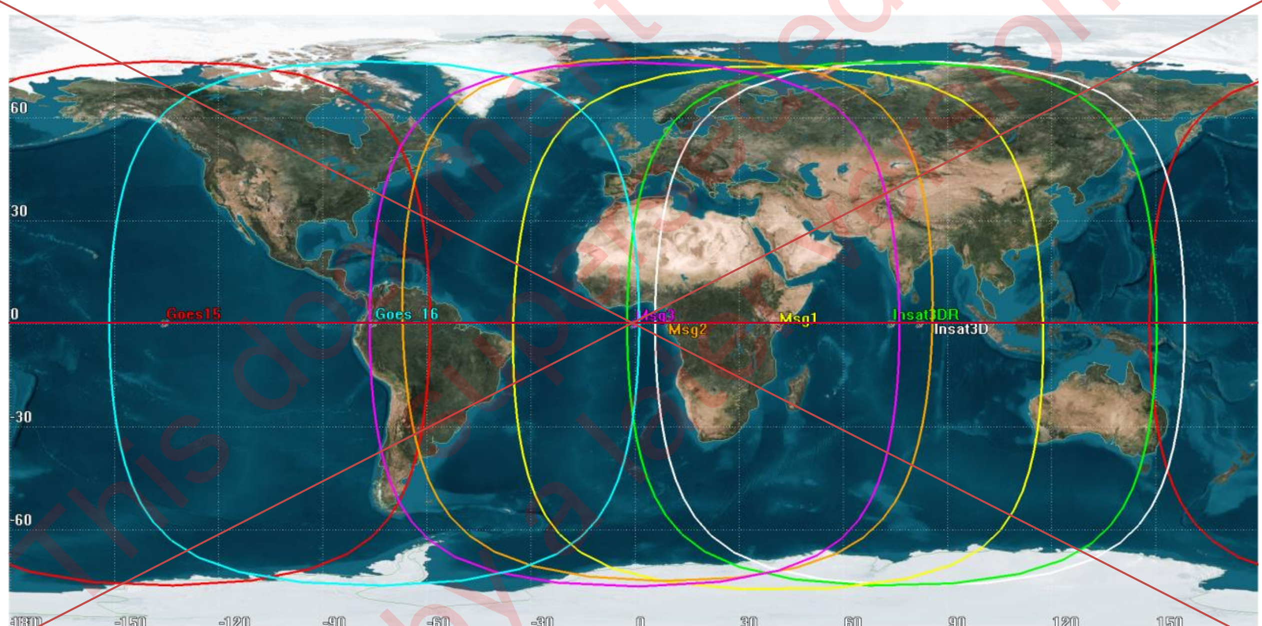
Satellite	Longitude Position	Latitude Position	Apogee and perigee radii (km)	Station Keeping
Electro-L#2	*76 ° E*	*0 °*	*42164*	*±2.0 ° long. & lat*
GOES-15 (West)	135.33° W	0°	42145-42174	±0.14° long.; ± 0.00°lat
GOES-16 (East)	75.20° W	0°	*42163 - 42169*~~42150-42159~~	±0.02~~1~~° long.; ± 0.01~~0~~°lat
GOES-17 (West)	*137.2° W*	*0°*	*42163 - 42169*	*±0.04 ° long.; ± 0.01 °lat*
*GSAT-17**	*(93.5° E)*	*0 °*		
INSAT-3D	82.08° E	0°	42163-42173	±0..02° long.; ± 0.00°lat
INSAT-3DR	73.92° E	0°	42120-42198	±0.02° long.; ± 0.00°lat

** As of December 15 2017

LOUCH-5A	*167.0º E*	*0 º*	*42164*	*±0.1° long.; ± 4°lat.*
LOUCH-5V	*95º E*	*0 º*	*42164*	*±0.1° long.; ± 4°lat.*
MSG-1	41. ~~1~~54° W	0°	42157-42162	±5.16° long.; ± 0.12°lat.
~~MSG-2~~	~~9.33°~~	~~0°~~	~~42151-42169~~	~~±2.57° long.; ± 0.03°lat.~~
MSG-3	*9.5~~0~~° E*	0°	42155-42161	±0.87° long.; ± TDB°lat.
MSG-4	*0 º*	*0 º*		

2.3 GEOSAR System Coverage

The 406 MHz coverage area for the on-orbit operational GEOSAR payloads is shown in Figure 2.2.



~~**Figure 2-2: Nominal GEOSAR 5 Degree Elevation Contour Coverage (December 2017)**~~

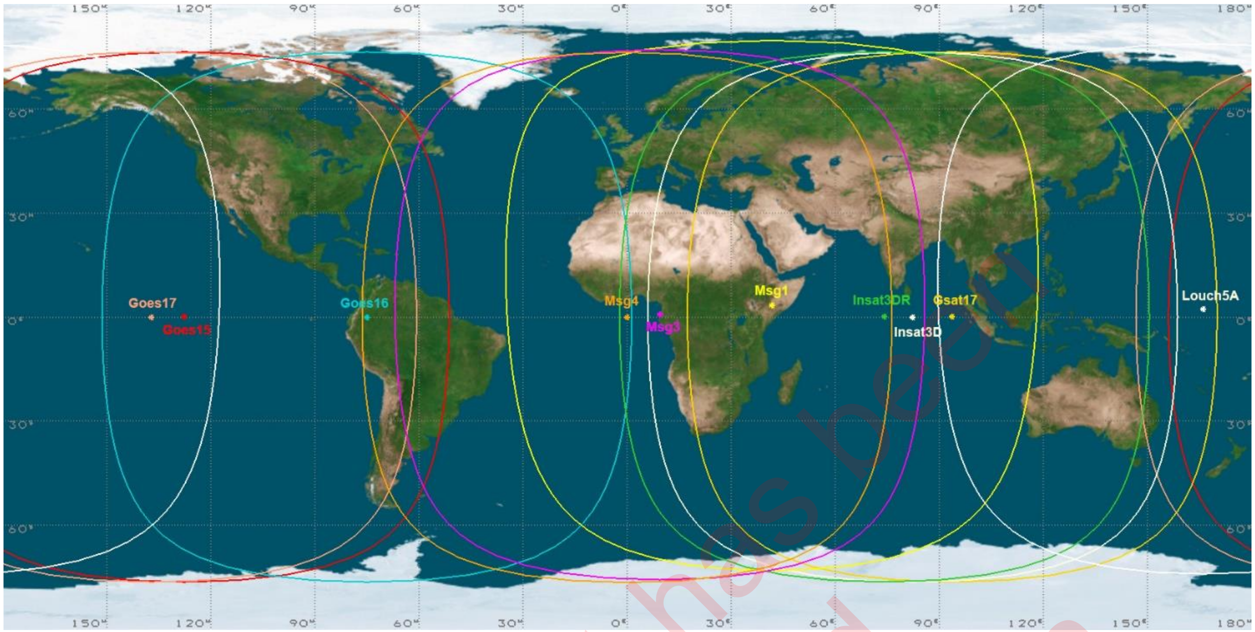


Figure* 2-2*: Nominal GEOSAR 5 Degree Elevation Contour Coverage (April 2019)

- END OF SECTION 2 -

3. COSPAS-SARSAT REPEATERS

3.1 GOES Repeater Functional Description

3.1.1 GOES 15 and before

A functional diagram of the GOES SAR repeater is shown in Figure 3.1. The repeater is redundantly configured and consists of the following units:

a) two 406 MHz low noise amplifiers (shared with another satellite subsystem);

b) two dual-conversion 406 MHz receivers;

c) two 3 watt phase modulated L-Band transmitters;

d) one 406 MHz receive antenna and one 1544.5 MHz transmit antenna; and

e) command and telemetry points interfaced with the spacecraft telemetry and command subsystem.

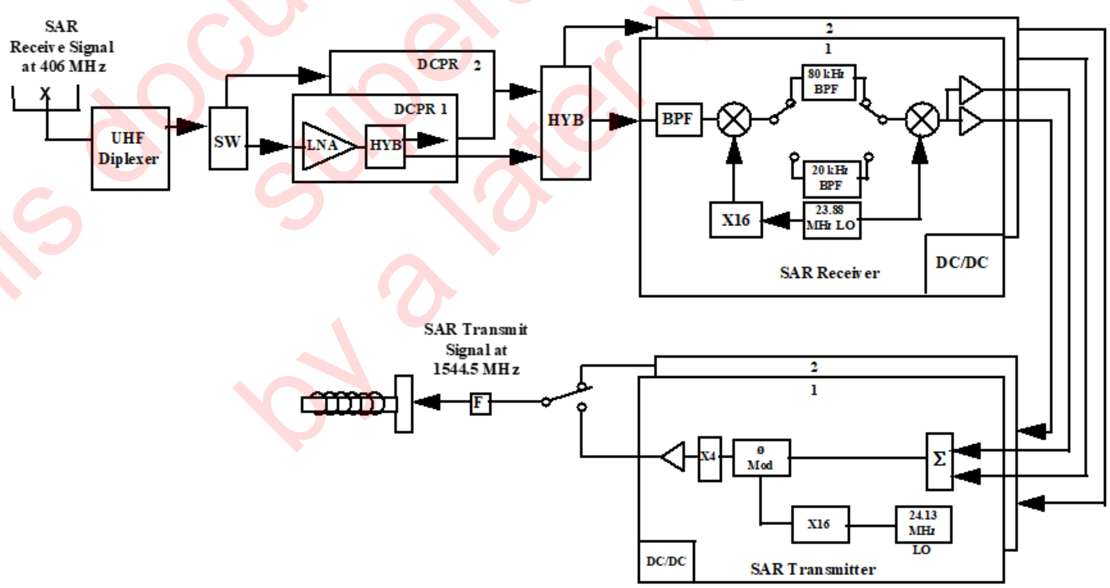


Figure 3-1~~3-1~~: GOES-15 and before Search and Rescue Repeater Functional Diagram

The 406 MHz signals from Cospas-Sarsat distress beacons are received on the UHF antenna and fed through the antenna diplexer and switch to a low noise amplifier in one of the redundant pair of Data Collection Platform Repeaters (DCPR). The DCPR low noise amplifiers are used as part of the SAR implementation to accommodate circuit efficiency on the spacecraft. The low noise amplifier outputs are connected to the redundant pair of SAR receivers. The signal applied to the selected receiver is down-converted for bandpass filtering in accordance with one of two commandable bandwidth modes; a narrow band mode of 20 kHz or a wide band mode of 80 kHz. The filtered output signal is further down-converted to near baseband and fed through amplifiers to the SAR transmitter. The overall gain of the SAR receiver can be command selected into a fixed gain or Automatic Level Control (ALC) mode.

The output of the receivers are provided to the redundant pair of SAR transmitters. The selected SAR transmitter phase modulates the signal, multiplies the signal to 1544.5 MHz, and amplifies the modulated carrier to 3 Watts. The phase modulated signal has the nominal modulation index set such that the carrier suppression is 3 dB with the receiver in the ALC mode or with the receiver in the fixed gain mode operating with two nominal beacon signals plus the noise. A baseband limiter restricts the modulation index from exceeding 2 radians. The transmitter output is applied through a 4 MHz bandwidth filter to the helical antenna and radiated with an effective radiated isotropic power (EIRP) of +15.0 dBW.

3.1.2 GOES 16 and later

The GOES-R *and GOES-S* (GOES-16 *and GOES-17* after launch) repeater is part of the SAR/DCPR system. Figure 3.2 shows a high level view of the repeater and the SAR part of the SAR/DCPR receiver.

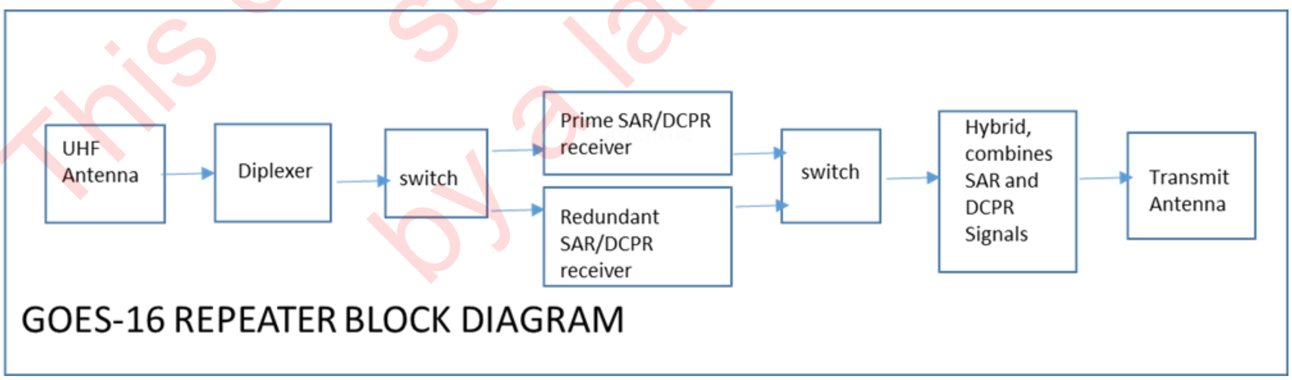


Figure 3-2~~3-2~~: GOES-16-*17* repeater block diagram

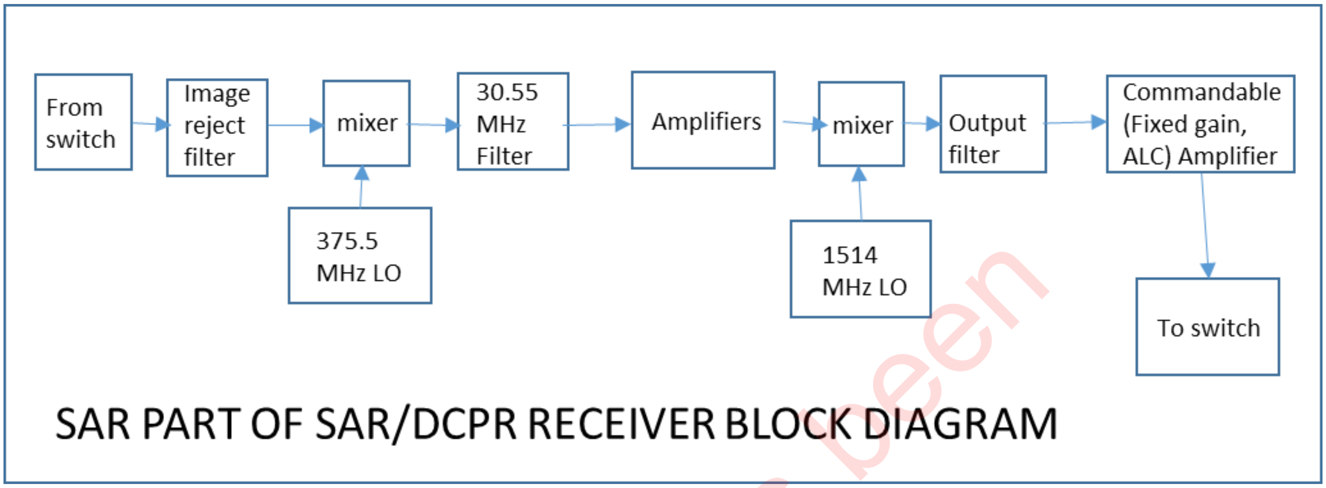


Figure 3-3~~3-3~~: SAR part of SAR/DCPR receiver block diagram

In the GOES 16-*17* series of spacecraft, the SAR repeater is shared with the data Collection platform (DCPR) as in previous GOES spacecraft. There are redundant receivers, a choice between fixed gain and ALC modes, and a frequency translation scheme. Frequency translation means that there is no modulator in the SAR receiver and the UHF input signal is first frequency translated by a mixer down to 30.55 MHz for filtering and then frequency translated via another mixer up to 1544.55 MHz by another LO. Figure 3.3 shows the 2 local oscillators with the 1514 MHz oscillator providing low side injection, so the downlink spectra is not reversed as it would be if this LO 's frequency were higher than the output frequency. Notable is a new downlink frequency, 1544.55 MHz as opposed to the usual 1544.50 M*H*~~h~~z in previous GOES, and a no narrow band mode. This was done to achieve a better G/T and a steeper filter skirt for the UHF input which will help in rejecting signals which are close to the UHF frequency. The reveiver is commandable into a fixe gain mode or an ALC mode, as in previous GOES.

3.2 GOES Repeater Operating Modes

The GOES repeater has redundant low noise amplifiers, receivers, and transmitters that can be selected to define a complete repeater configuration. A specific repeater configuration can be operated in the modes described in Table 3.1. GOES-16 and all follow on GOES will have only wide band modes.

Table 3.1: GOES Repeater Operating Modes

Mode	Band Center Frequency (MHz)	*GOES S/C up to GOES-15* Receiver 3 dB Bandwidth (kHz)	*GOES 16 and later Receiver 3 dB Bandwidth (kHz*
Narrow Band with ALC	406.025	20	*N/A*
Narrow Band Fixed Gain	406.025	20	*N/A*
Wide Band with ALC	406.050	80	*80*
Wide Band Fixed Gain	406.050	80	*80*

3.3 GOES Repeater Spectrum Characteristics

3.3.1 All GOES up to GOES-15

The spectral occupancy of the transmitted signal with the repeater in the wide band mode is shown in Figure 3.4. This output spectrum, which applies the GOES S/C up to GOES-15, therefore, represents the case of maximum spectrum occupancy. The spectrum plot was taken at a received intermediate frequency of 44.5 MHz that is equivalent to a transmitted frequency of 1544.5 MHz spectrum width. The narrow band spectrum is shown in Figure 3.3a. The wide band spectrum is shown in Figure 3.3b.

The baseband spectral characteristics are shown in Figures 3.5 and 3.6. The received 406 MHz beacon signals are filtered and translated to a baseband frequency prior to phase modulation in the transmitter. The modulation plan is such that a signal received at 406.000 MHz becomes zero Hz in the baseband spectrum. A Cospas-Sarsat beacon received at 406.025 MHz will be at 25 kHz in the baseband spectrum. The 20 kHz and 80 kHz bandpass filters control the baseband spectrum width. The narrow band spectrum is shown in Figure 3.5. The wide band spectrum is shown in Figure 6.

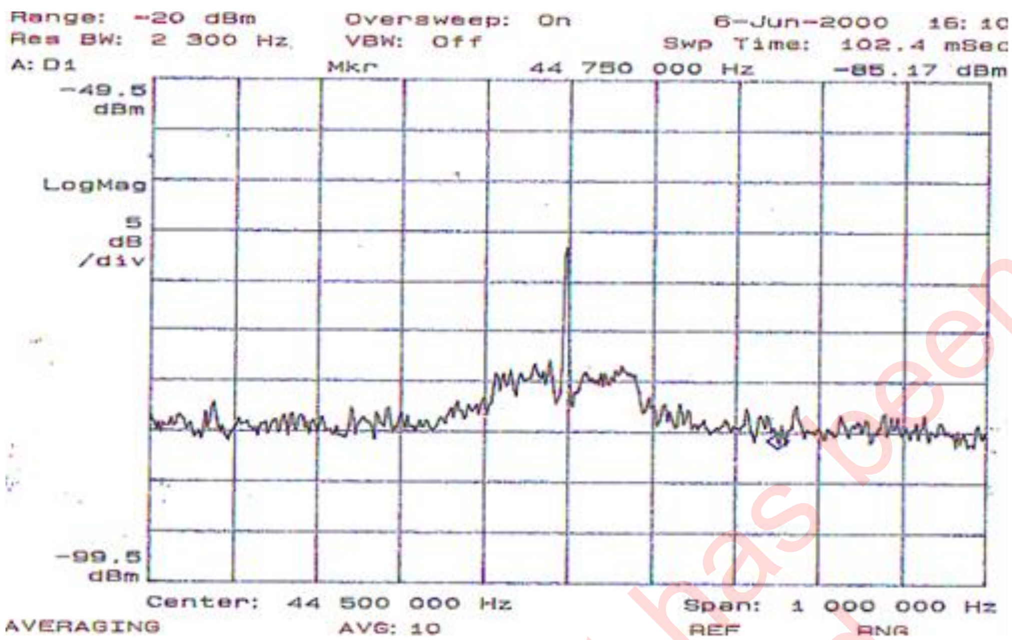


Figure 3-4~~3-4~~: GOES (15 and earlier) L-Band Transmitter Output Spectral Occupancy

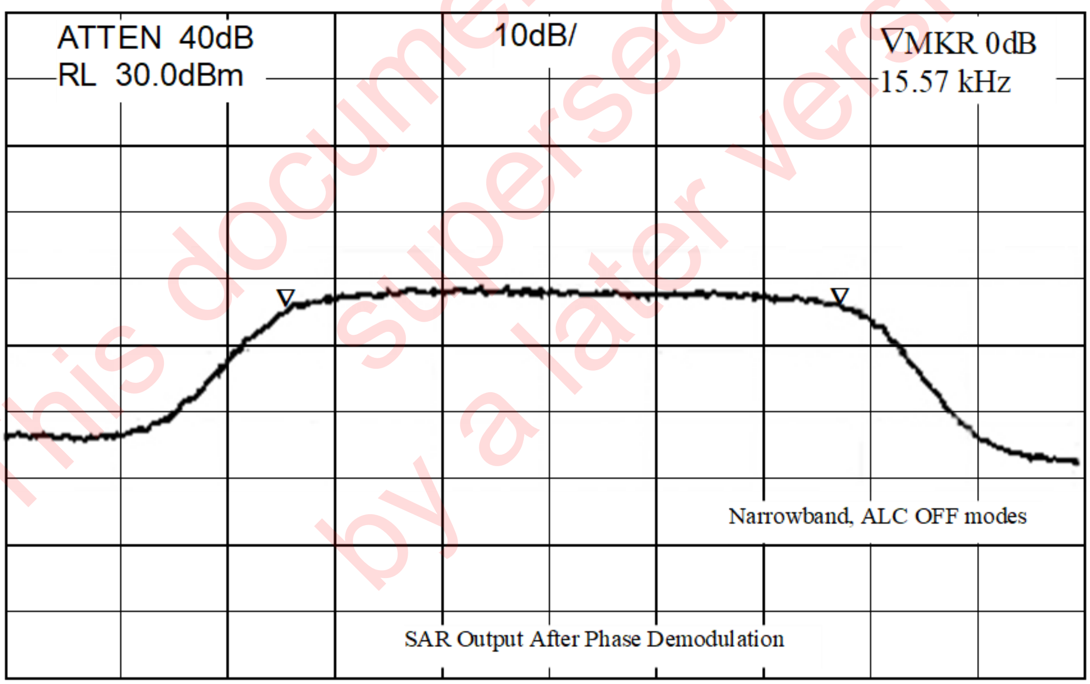


Figure 3-5~~3-5~~: For all GOES up to GOES-15: Narrow Band Baseband Spectrum

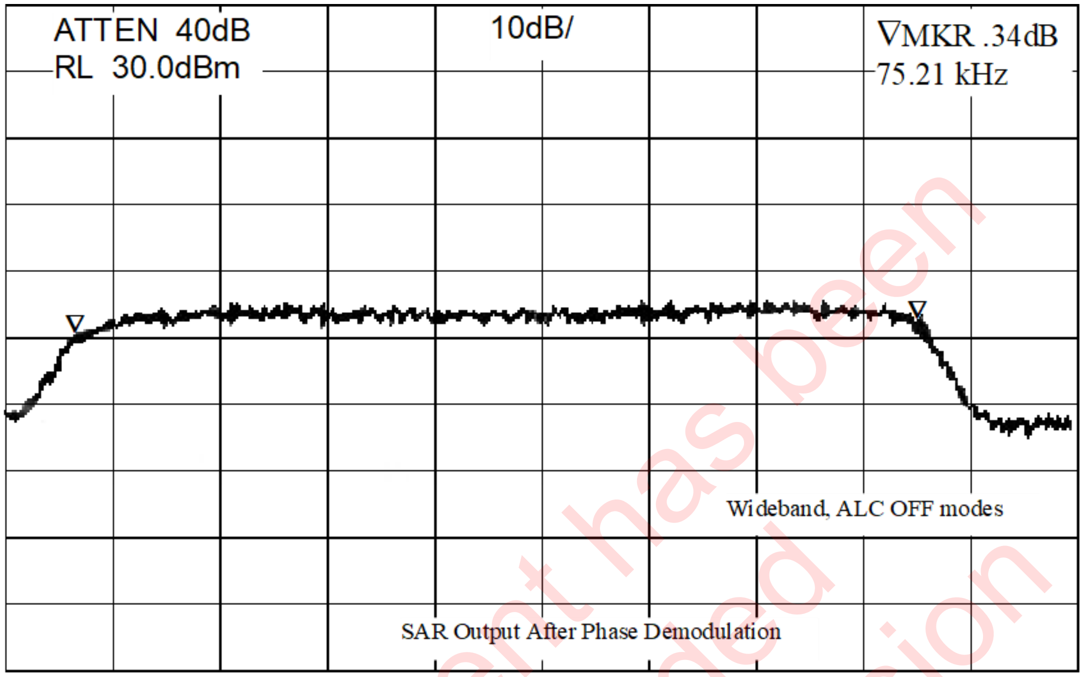


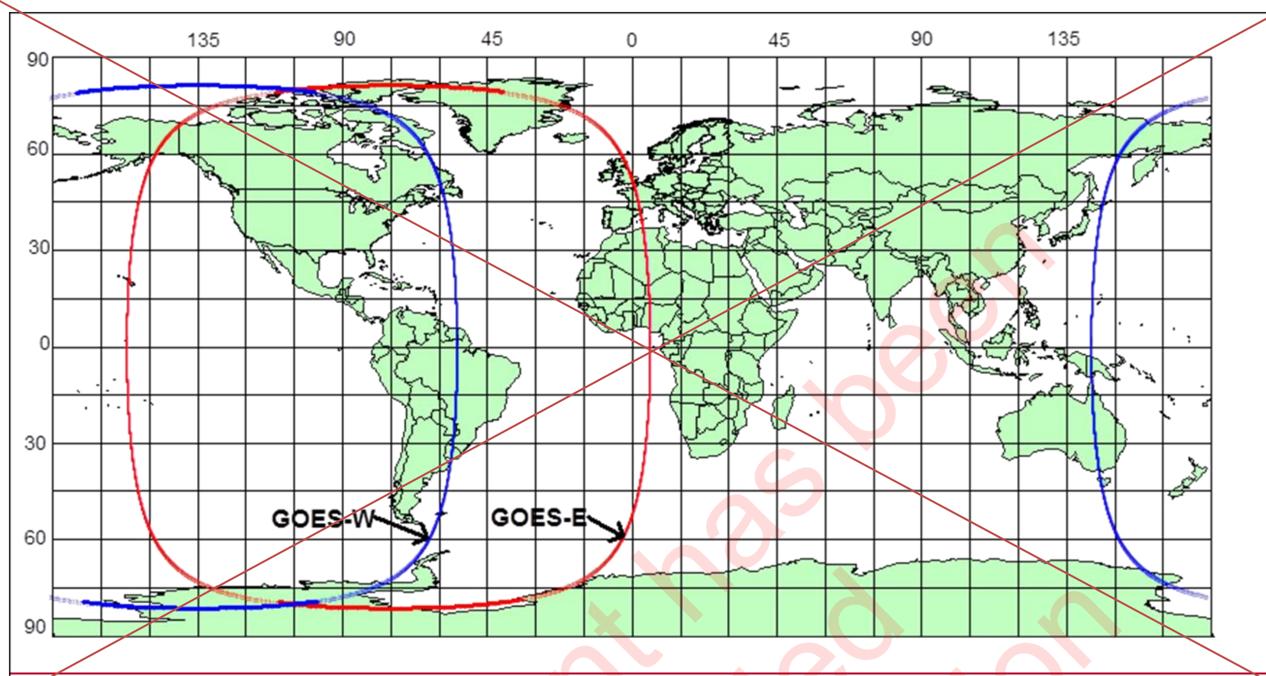
Figure 3-6~~3-6~~: GOES (ALL) Wide Band Baseband Spectrum

3.3.2 GOES 16 and later

Figure 3-7~~3-7~~: GOES-16 Downlink Spectrum

3.4 GOES Repeater Coverage Area

The zero degree elevation angle coverage contour for the GOES-E and *two* GOES-W satellites is shown in Figure 3.4. The receive and transmit antennas are broad beam earth coverage types. Therefore, the coverage patterns in Figure 3.8 apply to both the receive and transmit functions.



~~Figure 3-8: GOES-E and GOES-W 0° Elevation Coverage Contours~~

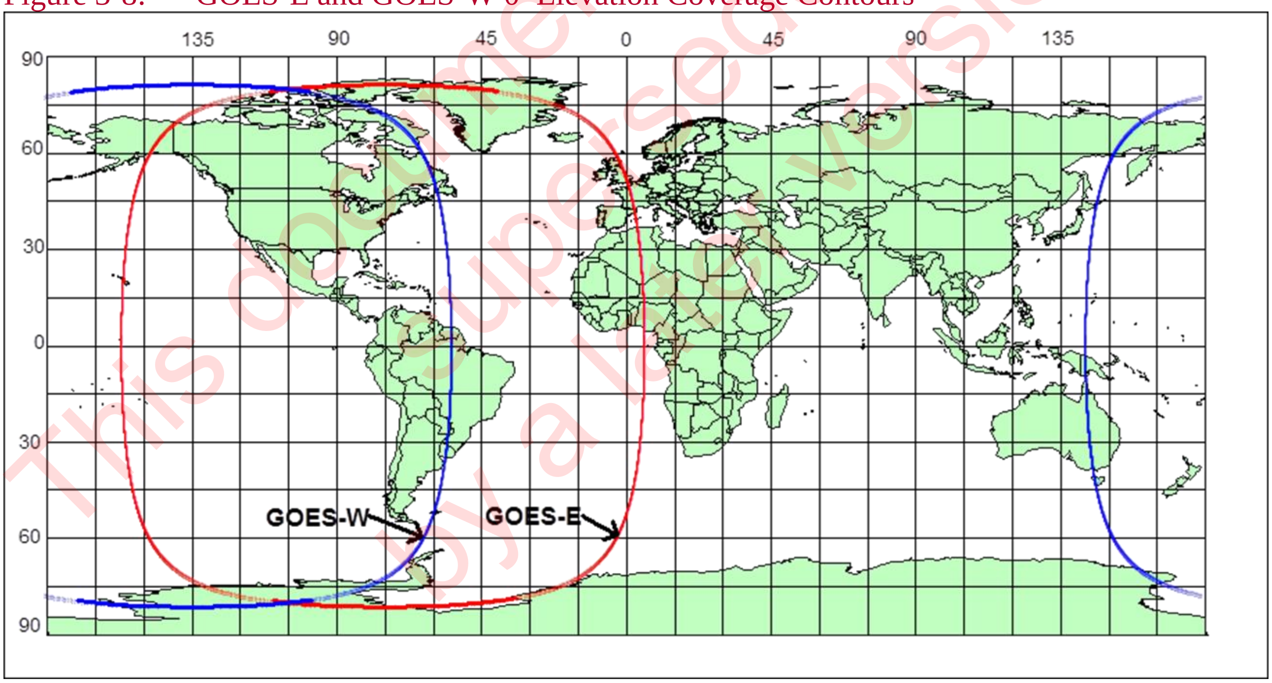


Figure* 3-8~~3-8~~*:* *GOES-E and GOES-W 0^{o} Elevation Coverage Contours

3.5 GOES Repeater Performance Parameters

3.5.1 GOES SAR Receiver Parameters

The receiver parameters are shown in Table 3.2.

Table 3.2: GOES SAR Receiver Parameters

Parameter	Unit	All GOES up to GOES-15 Values	GOES-16 and later Values
Nominal Input Level at Antenna	dBW	-173.1	-173.1
System Noise Temperature (referred to preamp input)	K	359	*530*
G/T	dB/K	-18.5	>-15.5 (-13.3 for GOES-16)
Receiver Bandpass Characteristic Narrow Band Mode (relative to 406.025 MHz) Wide Band Mode (relative to 406.05 MHz)	kHz kHz	± 6.0 (1 dB BW) ± 10.0 (3 dB BW) ± 20.0 (20 dB BW) ± 30.0 (1 dB BW) ± 40.0 (3 dB BW) ± 50.0 (20 dB BW)	No narrow band mode >80 (1 dB BW) <100 (3 dB BW) <130 (20 dB BW) <180 (40 dB BW) <230 (50 dB BW)
Dynamic Range	dB	≤ 15	15
Group Delay (over 4 kHz)	µs/kHz	≤ 13	
Image Rejection	dB	60	70 @ ±21.4 MHz
AGC Time Constant	ms	≤ 40	<40
Frequency Stability Frequency Conversion Oscillators (over 0.25 s)	N/A	$\pm 1 \times 10^{-9}$	

Note 1: Nominal input level at antenna from 5 Watt beacon located at 45° elevation angle to the satellite. Includes 4.1 dB polarization loss.

3.5.2 GOES SAR Transmitter Parameters

The transmitter parameters are shown in Table 3.3.

Table 3.3: GOES SAR Transmitter Parameters

Parameter	Unit	All GOES up to GOES-15 Values	GOES-16 and later Values
Centre Frequency	MHz	1544.5	*1544.55*
Output Power of Transmitter	W	3.0	*7.0*
Repeater EIRP	dBW	+ 15.0	*+15.0 (+17.3 for GOES-16)*
Phase Jitter (in 50 Hz bandwidth)	deg. (rms)	≤ 10	
Modulation Type	type	Linear Phase	*None: frequency translation*
Transmitter Nominal Modulation Index	radians peak	1.0 2.0	*N/A*
Frequency Stability of downlink	N/A	$\pm 2.5 \times 10^{-6}$	
Amplitude Ripple (over any 24 hour period)	dB	± 1	*± 1*
Linearity	*dB*	see note 1	30 dB below desired signal levels

Note 1: <u>Fixed Gain Mode</u> - Two equal test tones each at 2 dB above the receiver noise applied to the receiver input will not produce intermodulation products within the transponder bandwidth greater than 20 dB below the test tone output level.

<u>ALC Mode</u> - Two equal test tones each at 7 dB above the receiver noise applied to the receiver input will not produce intermodulation products within the transponder bandwidth greater than 30 dB below the test tone output level.

3.5.3 GOES SAR Antennas

The relative gain pattern for the GOES SAR receive antenna is shown in Figure 3.9 for GOES up to GOES-15 and in Figure 3.11 for GOES-16 and later. The antenna is right hand circular polarized (RHCP) with an on-axis gain of 10 dB for GOES spacecraft up to GOES-15 and about 14 dB for GOES-16.

For GOES spacecraft up to GOES-15, the receive line loss between the antenna terminal and the low noise preamplifier is 1.9 dB. Therefore, the effective gain relative to the preamplifer input is 8.1 dB. The receive antenna has a maximum axial ratio of 3 dB.

The relative gain pattern for the GOES through GOES-15 SAR transmit antenna is shown in Figure 3.10. The antenna is RHCP with an on-axis gain of 12.3 dB. The transmit line loss between the power amplifier and the antenna terminal is 1.7 dB. Therefore, the effective gain relative to the power amplifier output is 10.6 dB. The transmit antenna has a maximum axial ratio of 3 dB.

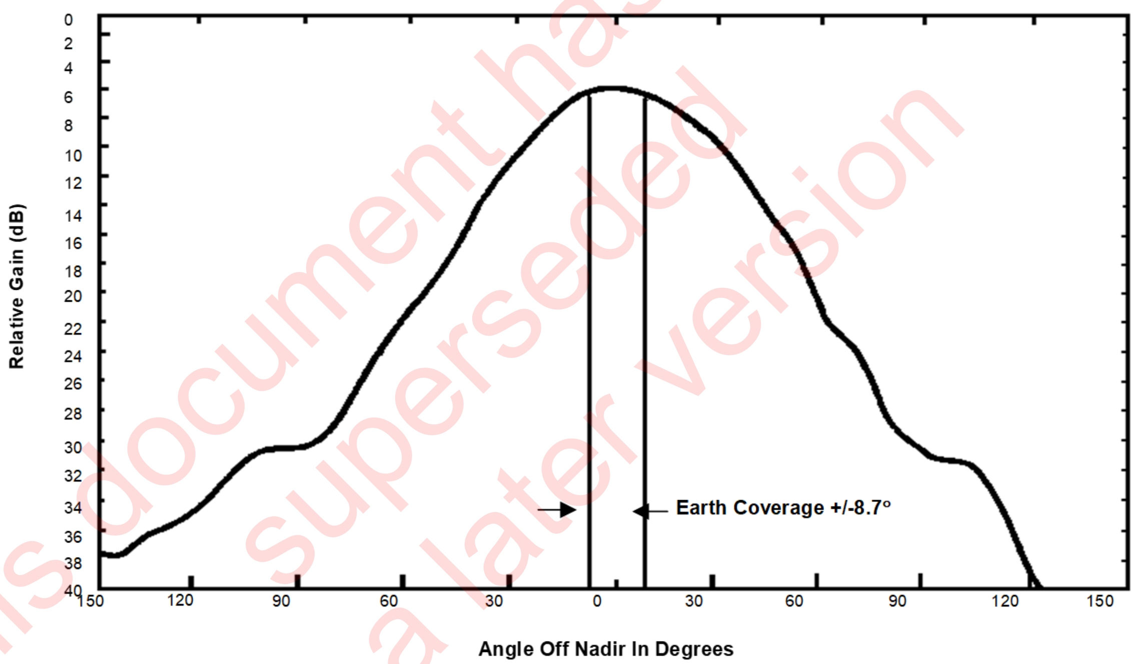


Figure 3-93-9: GOES through GOES-15 Receive Antenna Pattern at 406.05 MHz

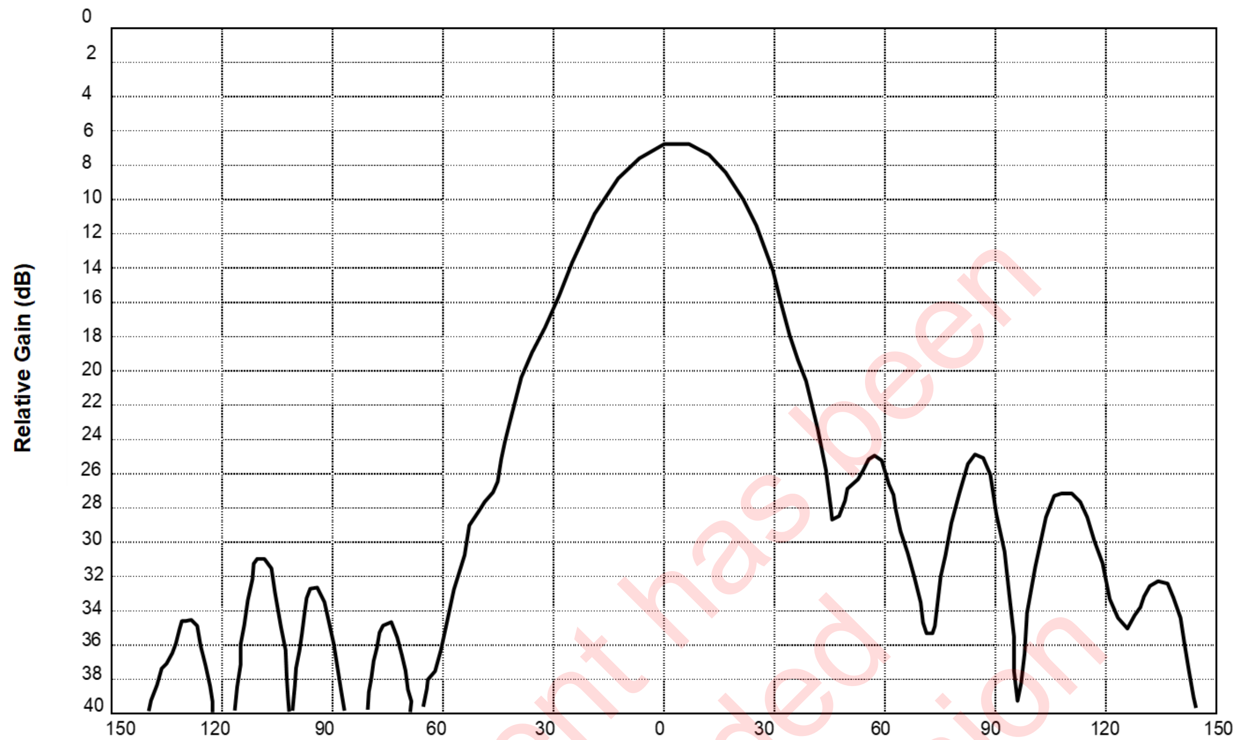


Figure 3-103~~-10~~: GOES through GOES-15 Transmit Antenna Pattern at 1544.5 MHz

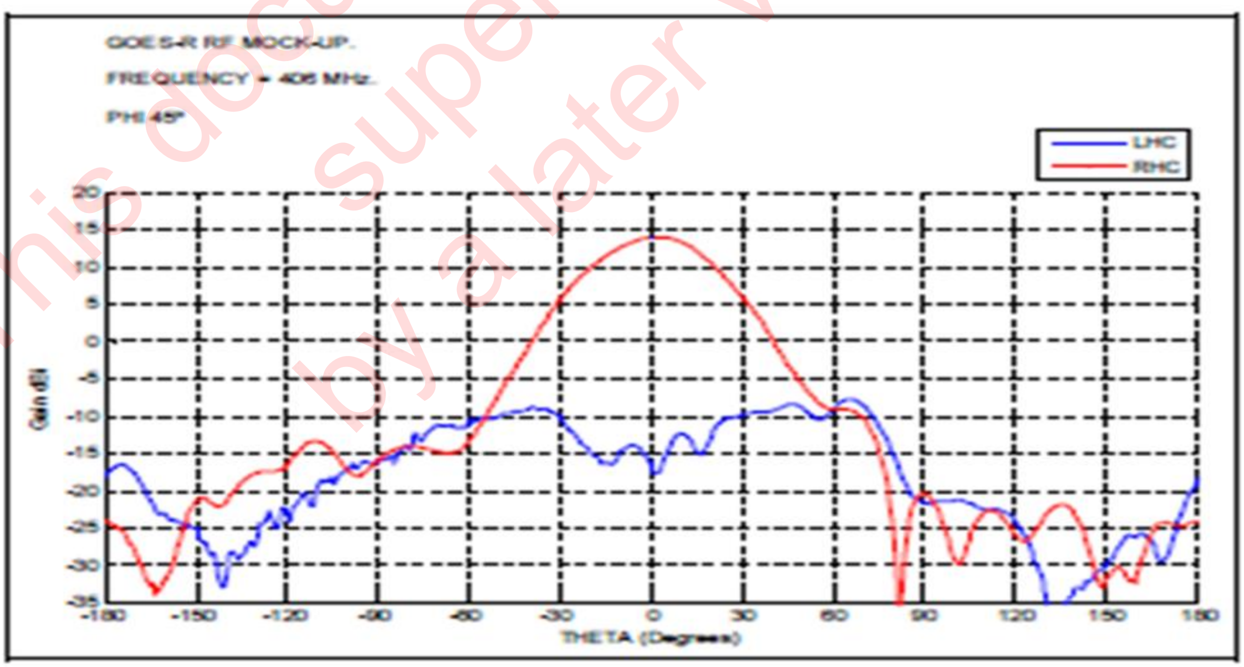


Figure 33 .Cut Phi 45°, frequency 406 MHz.

Figure 3-113~~-11~~: *Typical* GOES-16 *and GOES-17* Receive Antenna Pattern at 406 MHz

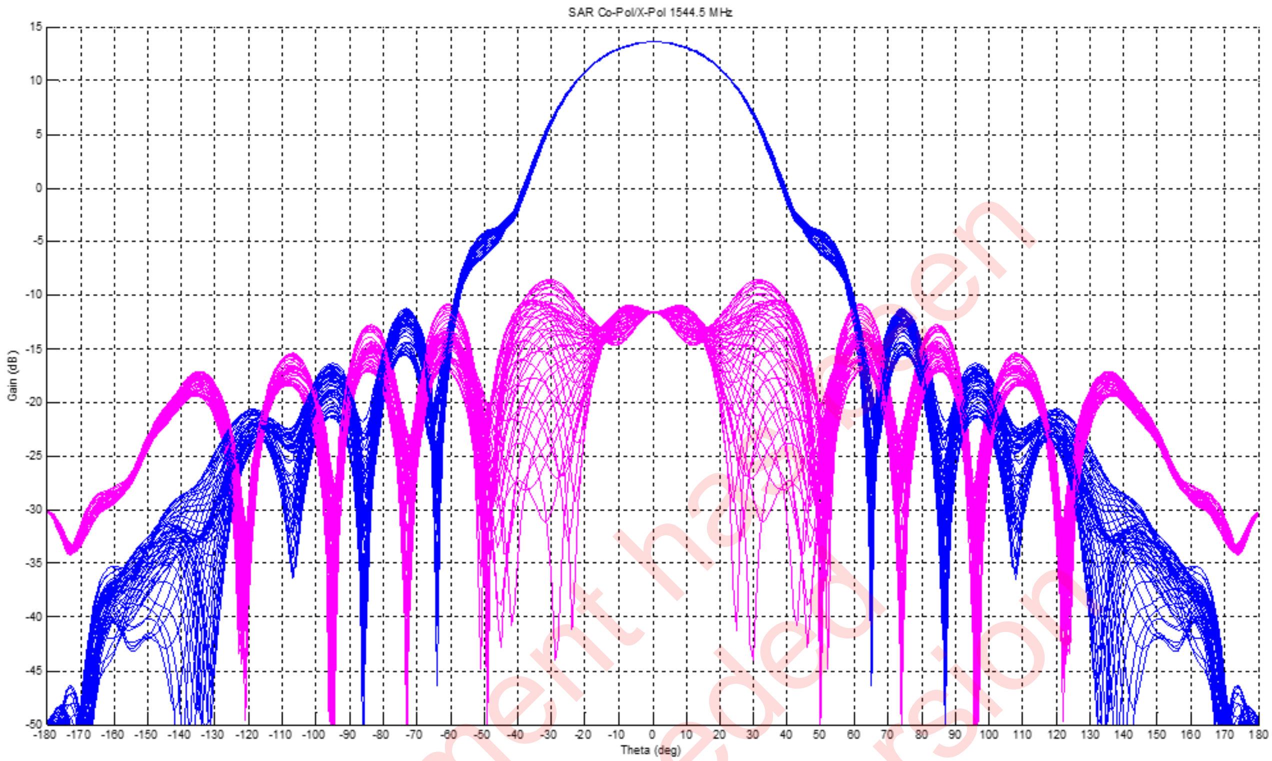


Figure 3-12~~3-12~~: ***Typical*** **GOES-16** ***and 17*** **SAR Transmit antenna measured at 1544 MHz.**

For the GOES-16 *and 17* transmit plot, Figure 3.12, the blue curve is the correct polarization (RHCP) and the red curve is cross polarization (LHCP) plots.

- END OF SECTION 3 -

4. INSAT 406 MHZ GEOSAR REPEATER

4.1 INSAT Repeater Functional Description

SAR instruments are included on the INSAT 3D, 3DR and GSAT-17 satellites. On each of these satellites the SAR payloads share some common circuitry with the Data Relay Transponder (DRT) meteorological instruments. A functional diagram of the INSAT SAR payloads is provided at Figure 4.1.

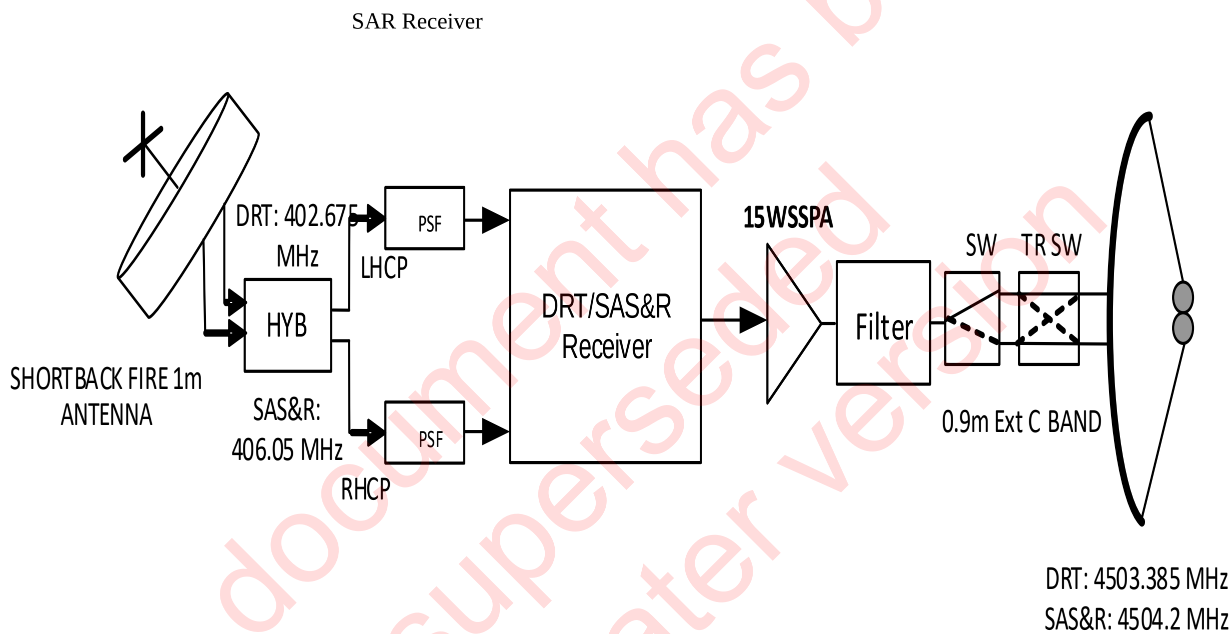


Figure 4-1~~4-14-1~~: INSAT SAR / DRT Repeater Functional Block Diagram

406.05 MHz signals from Cospas-Sarsat distress beacon within the coverage area of the SAR receive antenna are fed to a pre-select helical band pass filter which helps suppress out-of-band interference. The filtered signal is passed to a low noise amplifier (LNA) to achieve the required input noise figure. The signal is first down converted to 73.35 MHz, then passed through a crystal bandpass filter. This signal is further down converted, such that an uplink signal at 406.05 MHz would appear at 100 kHz. The resulting signal is passed to a transistorized limiter circuit and to a low pass filter. The filtered signal is phase modulated and multiplied to achieve a modulation index of ±1 radian at 71.0 MHz.

The main functions of the phase modulator are to:

- Reduce noise in the down link signal; and
- Provide a continuous down link carrier for LUT tracking receivers.

The output signal form the modulator is filtered, combined with the DRT IF signal (70.05 MHz), up-converted to 4504.2 MHz and applied to a 15 Watt solid state power amplifier (SSPA operating at 3dB out back off at 0 dB BOA settings). The composite DRT / SAR transponder signal is passed to an extended C band multiplexer (MUX). Finally the signal is routed to an extended C band antenna which provides an EIRP of 4 dBW for GSAT-17 (minimum).

4.2 INSAT Repeater Operating Modes

Each INSAT repeater has a redundant receiver and a redundant transmitter that can be selected to define a complete repeater configuration. A specific repeater configuration can be operated in the modes described in Table 4.1.

Table 4.1: INSAT Repeater Operating Modes

Mode	Band Center Frequency (MHz)	Receiver 1 dB Bandwidth (kHz)
Wide Band	406.050	80

4.3 INSAT Repeater Spectrum Characteristics

The spectral occupancy of the transmitted signal with the repeater in a wide band mode is shown in Figure 4.2. This output spectrum, therefore, represents the case of maximum spectrum occupancy.

The received 406.05 MHz beacon signals are filtered and translated to a baseband frequency prior to phase modulation in the transmitter. The wide band mode (80 kHz bandwidth) frequency plan is such that a Cospas-Sarsat beacon signal received at 406.05 MHz becomes 100 kHz in the baseband spectrum.

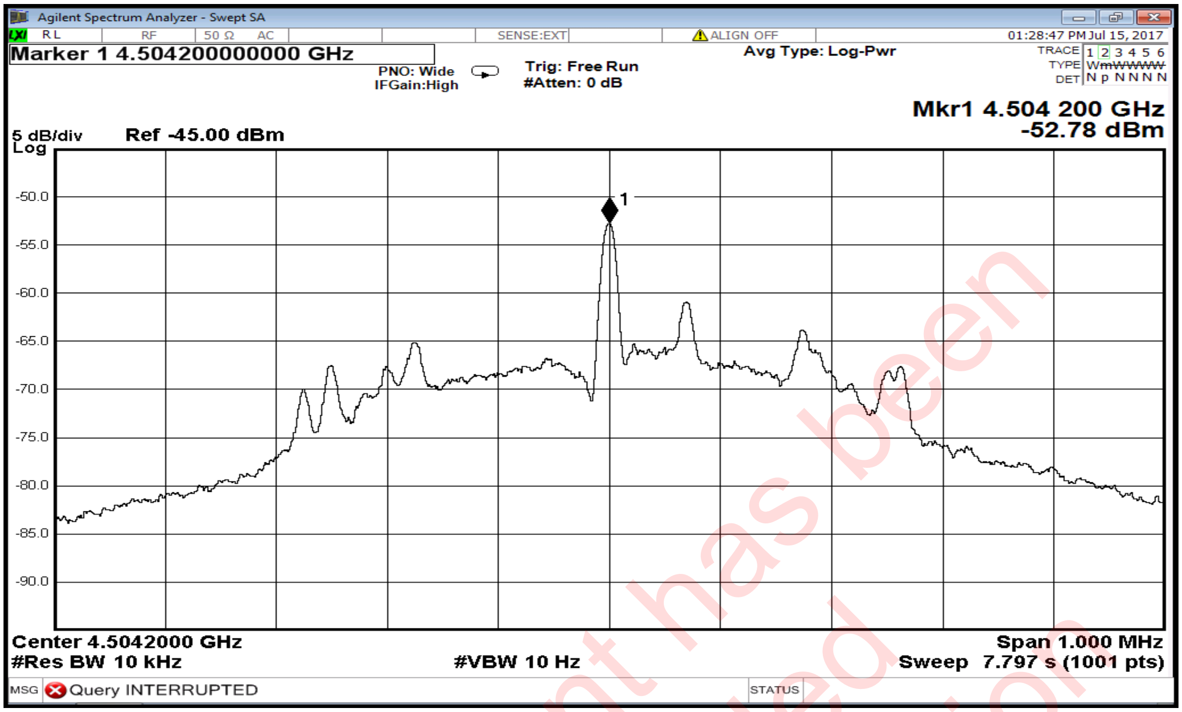


Figure 4-2~~4-24-2~~: INSAT Transmitter Output Spectral Occupancy with No Test Signal

4.4 INSAT Repeater Coverage Area

The zero degree elevation angle coverage contours for the INSAT 3D, 3DR and GSAT-17 are shown in Figure 4.3, in Figure 4.4 and in Figure 4.5 respectively. The receive antennas are broad beam earth coverage types. The downlink antennas are directive beams that can be received in the Indian region.

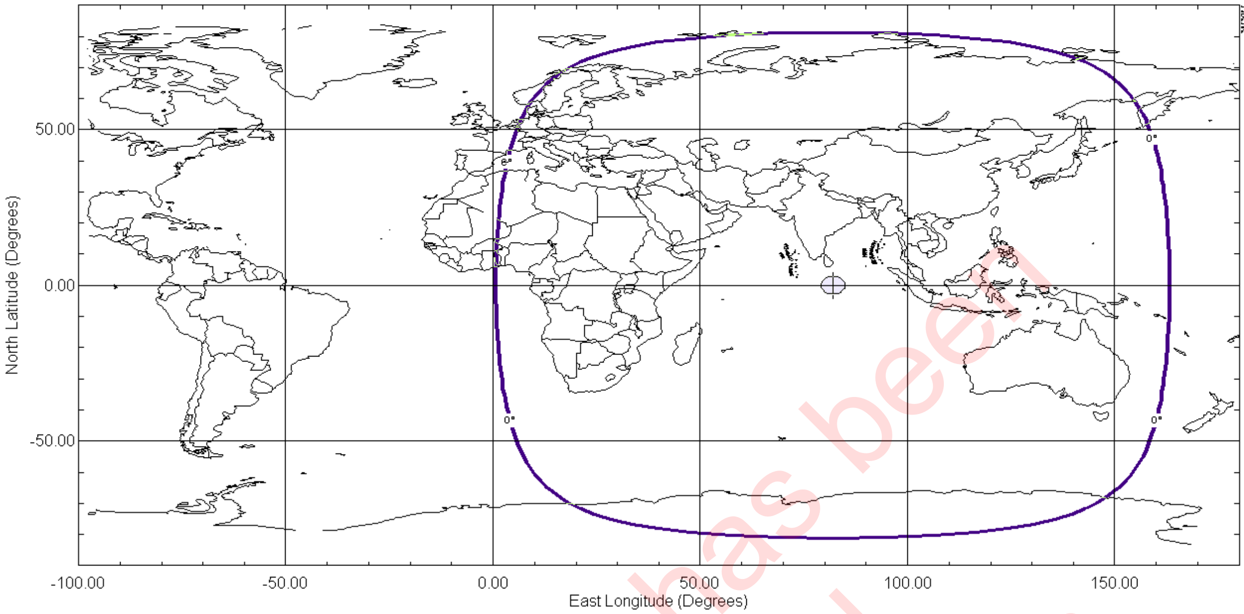


Figure 4-3~~4-34-3~~: INSAT-3D 0-degree Elevation Angle

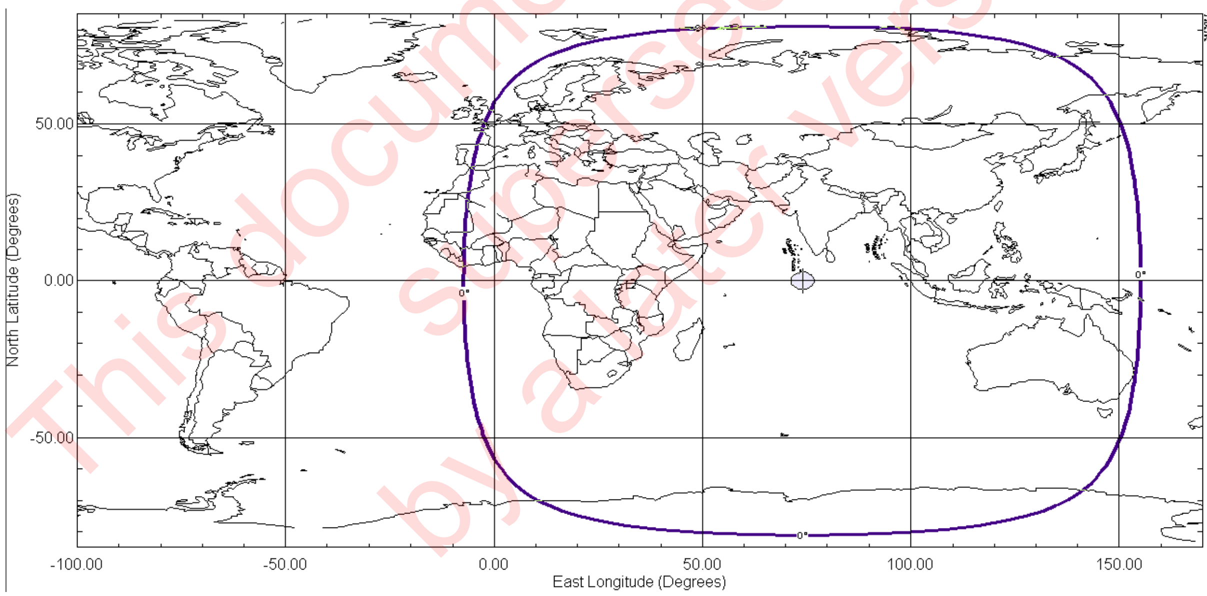


Figure 4-4~~4-44-4~~: INSAT-3DR 0-degree Elevation Angle

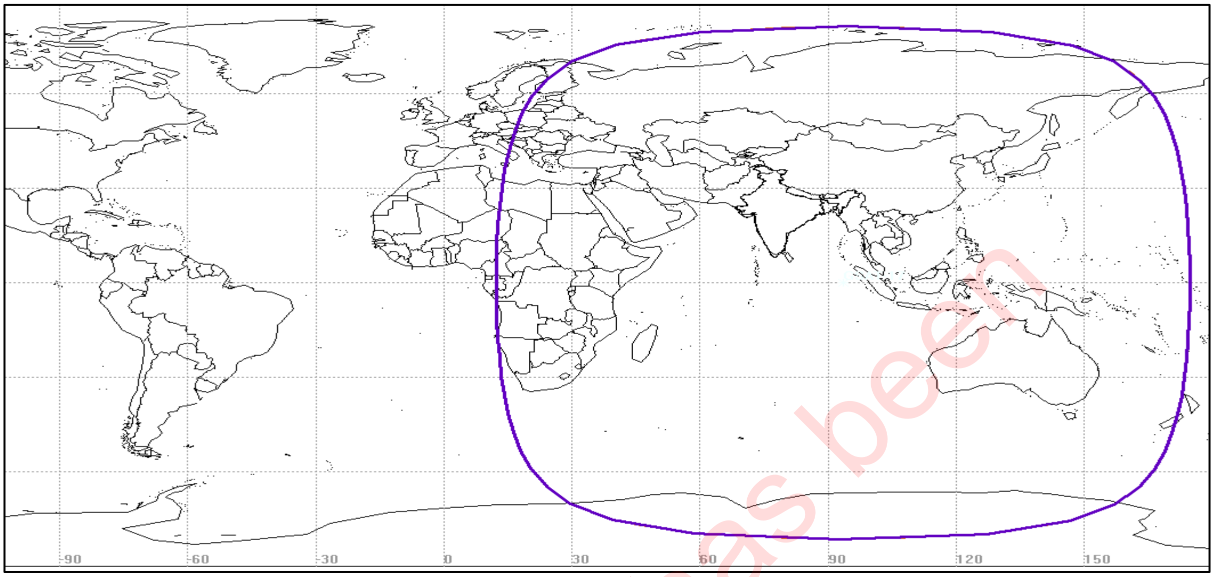


Figure 4-54-54-5: GSAT-17 0-degree Elevation Angle

4.5 INSAT Repeater Performance Parameters

The INSAT SAR repeater performance parameters for both INSAT-3D, INSAT-3DR and G-SAT-17 are provided in Table 4.2.

Table 4.2: INSAT Repeater Performance Parameters

Parameter	Unit	Specification
Receiver Band Pass Characteristics Wide band mode center frequency Wide band mode bandwidth	 MHz KHz	 406.05 80
Antenna Type (UHF)	N/A	Short back fire (SBF)
Rx Antenna Polarization	N/A	RHCP
SBF Antenna Gain	dBi	12
UHF receive antenna axial ratio	dB	2.0
Receive coverage	N/A	Global
Receive Gain to Noise Temp Ratio (G/T)	dB/K	-19.0
Nominal Input Level	dBW	–173
Dynamic Range	dB	10
Spurious outside the transmit band in any 4 KHz Band	dBW	< -60
Gain Stability (over operating life)	dB PP	4.0
Transmit Center frequency	MHz	INSAT-3DR : 4504.2 INSAT-3D : 4507.0 GSAT-17 : 4504.2
Tx Antenna Polarization	N/A	Linear V
Transmit Antenna Input	dBm	7.5
Transmit Antenna Gain (EOC)	dB	26.5
EIRP (EOC at end of life)	dBW	4
Tx Antenna Beam Coverage	N/A	INDIA Mainland
SAR Signal Modulation	N/A	Phase modulation
Modulation Index (Nominal)	Radian	1.0 +/- 0.2
Over all Frequency translation error (Over life time)	PPM	± 8.0

4.6 INSAT SAR Antennas

The SAR receive antenna (SBF type) for INSAT satellites provide global coverage. The antenna is right hand circular polarized (RHCP) with an edge of coverage (EOC) gain of 12.2 dB. The pattern for INSAT-3D is shown in Figure 4.6, for INSAT-3DR in Figure 4.7 and for GSAT-17 in Figure 4.8. The receive antenna has a maximum axial ratio of 2 dB.

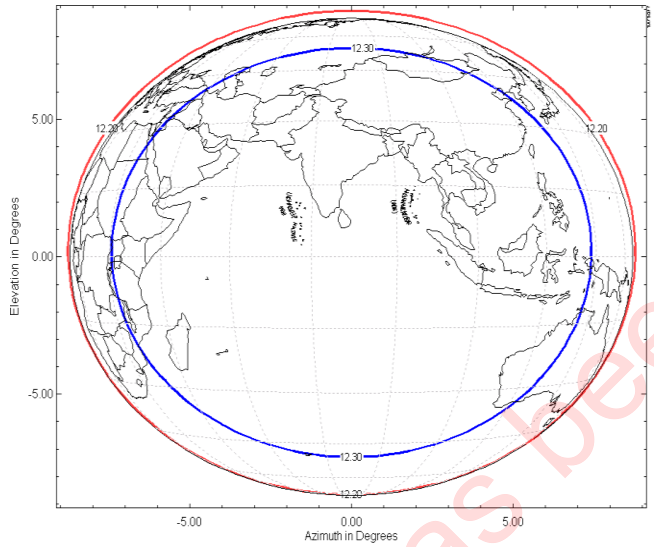


Figure 4-64-64-6: INSAT-3D SASR 406.05MHz Receive Antenna Contour Pattern

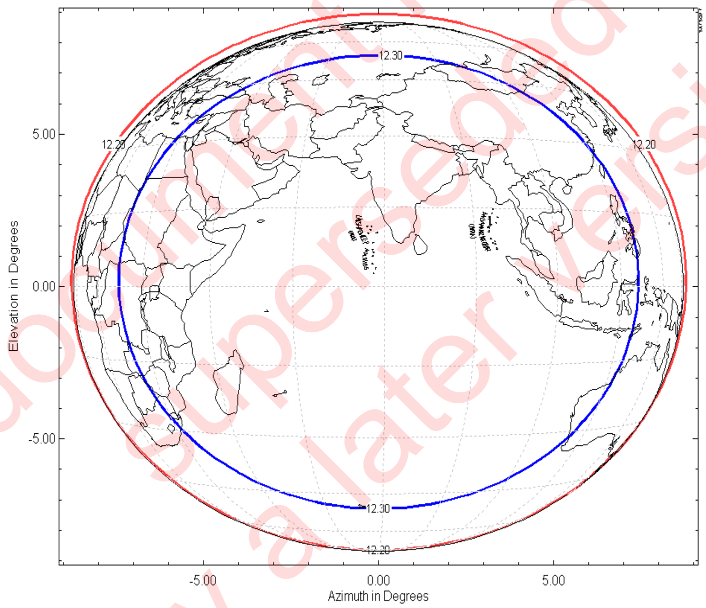


Figure 4-74-74-7: INSAT-3DR SASR 406.05MHz Receive Antenna Contour Pattern

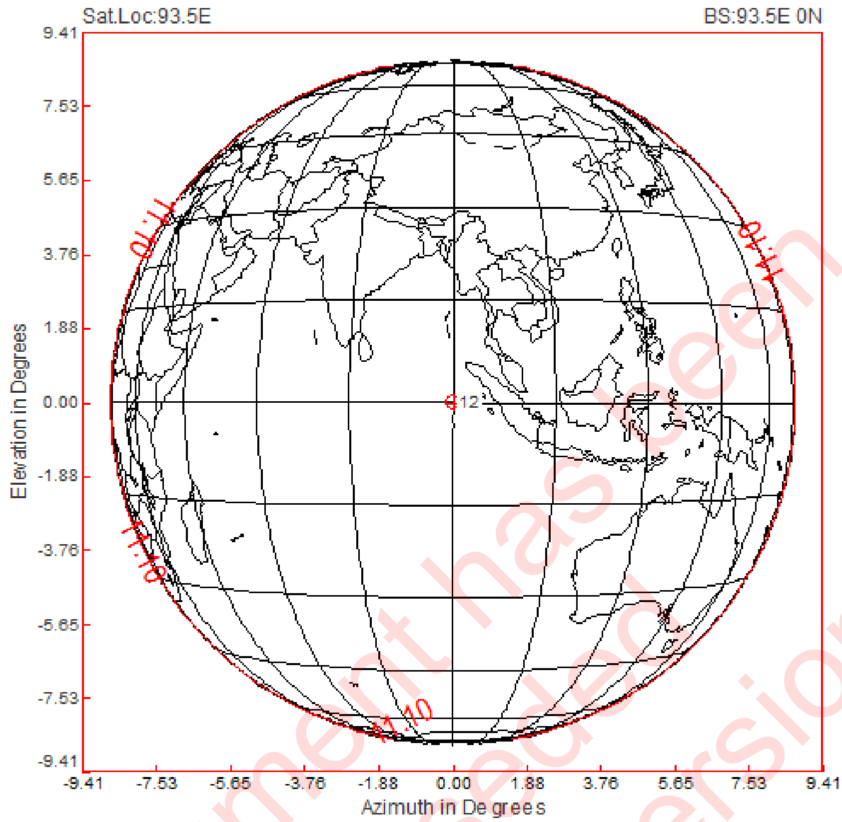


Figure 4-8~~4-84-8~~: GSAT-17 SAR 406.05MHz Receive Antenna Contour Pattern

The INSAT extended C-Band transmit antenna is a directive antenna that provides coverage for the Indian region. The pattern is shown in Figure 4.9 for INSAT-3D, in Figure 4.10 for INSAT 3-DR, and in Figure 4.11 for GSAT-17. The antenna is vertically polarized with an EOC gain of 26.0 dB.

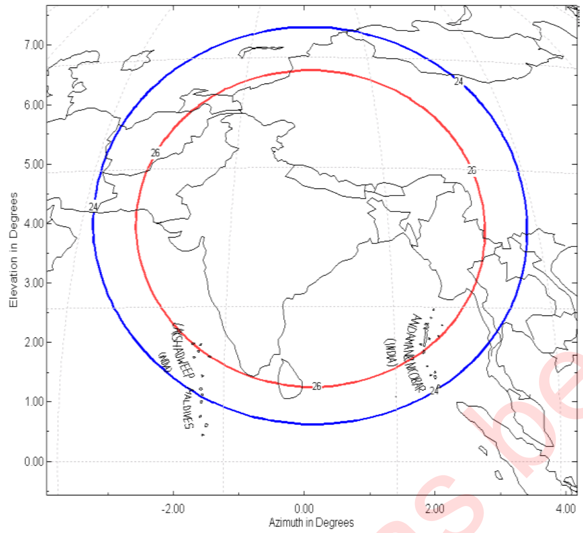


Figure 4-9~~4-94-9~~: INSAT-3D Transmit Antenna Contour Pattern

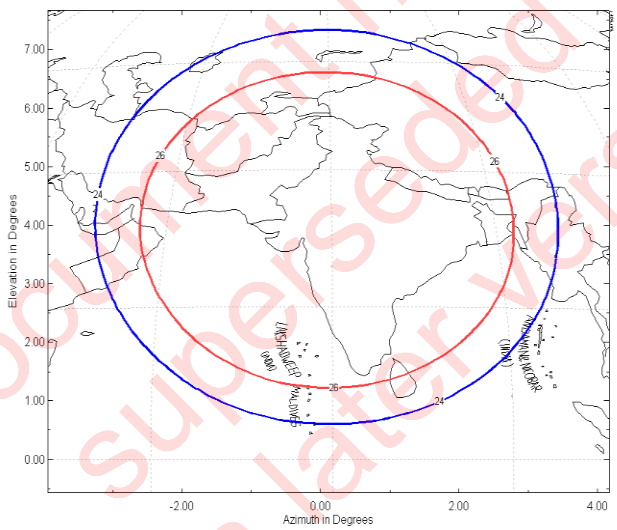


Figure 4-10~~4-104-10~~: INSAT-3DR Transmit Antenna Contour Pattern

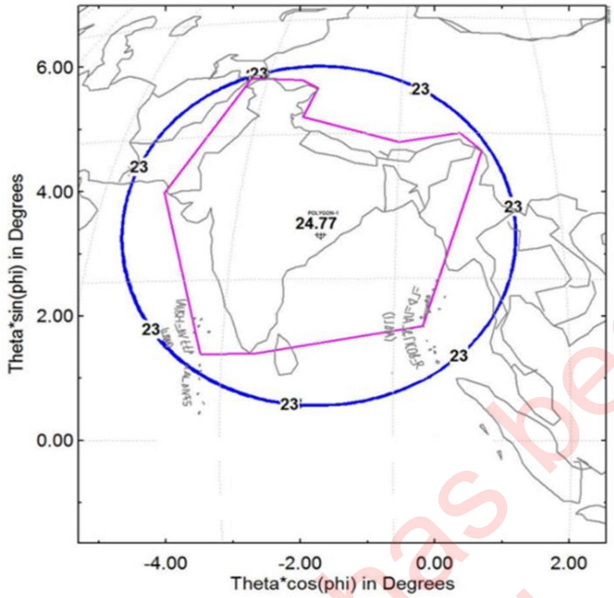


Figure 4-11~~4-11~~~~4-11~~: GSAT-17 Transmit Antenna Contour Pattern

– END OF SECTION 4 –

5. ELECTRO-L GEOSAR REPEATER

5.1 Repeater Functional Diagram Description

A functional diagram of the Electro-L SAR repeater is shown in Figure 5.1. The repeater is redundantly configured and consists of the following units:

- two 406 MHz low-noise amplifiers (shared with another satellite subsystem);
- two dual conversion 406 MHz receivers (down converter, up converter);
- two 4 Watt 1.5 GHz transmitters;
- one 406 MHz receive antenna; and
- one 1544.5 MHz transmit antenna.

406 MHz signals from 406 MHz beacons are received by the antenna and fed through the diplexer and switch to a low-noise amplifier. The low-noise amplifier output is connected to the SAR receiver. The signal is down-converted for bandpass filtering in accordance with one of two commandable band with modes; a narrow band mode of 20 kHz or a wide band mode of 80 kHz.

The filtered output signal is further down-converted to the near baseband and fed through amplifiers to the SAR transmitter. The overall gain of the SAR receiver is selected into a fixed gain mode only.

The SAR transmitter linear phase modulates the signal 1544.5 MHz and amplifies the modulated carrier to 4 Watts. The phase-modulated signal has the nominal modulation index set to 0.7 radian (rms). A baseband limiter restricts the modulation index from exceeding 2 radians. The transmitter output is applied through a 4 MHz bandwidth filter to antenna.

5.2 Electro-L Repeater Operating Modes

A specific repeater configuration can be operated in the modes described in Table 5.1.

Table 5.1: Electro-L Repeater Operating Modes

Mode	Band Center Frequency (MHz)	Receiver 3 dB Bandwidth (kHz)
Narrow Band with Fixed Gain	406.025	20
Wide Band with Fixed Gain	406.050	80

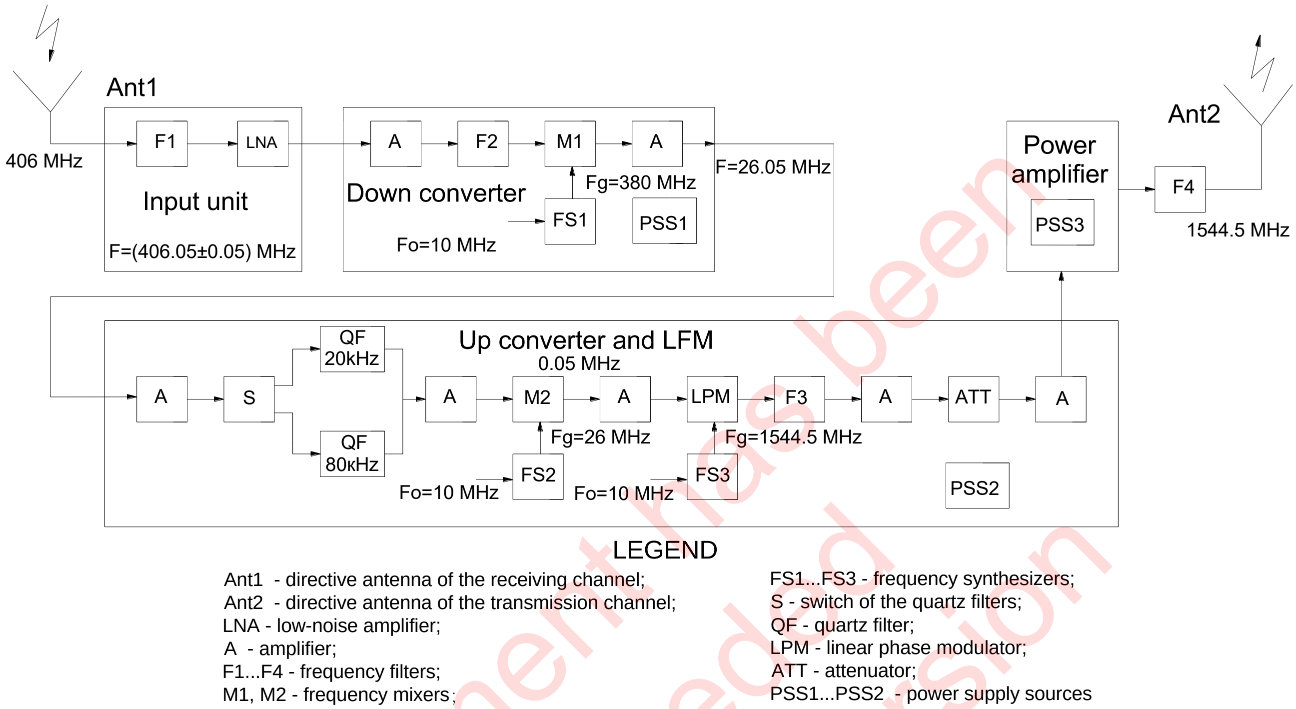


Figure 5-1~~5-15-1~~: Electro-L SAR Functional Diagram

5.3 Electro-L Repeater Baseband Spectrum

The received 406 MHz signals are filtered and translated to a baseband frequency prior to phase modulation in the transmitter. The modulation plan is such that a beacon received at the 406.025 MHz will be at 25 kHz in baseband spectrum. The 20 kHz and 80 kHz filters control the baseband spectrum width.

The Electro-L SAR downlink spectrum occupancies in WB and NB modes are depicted in Figures 5.2 and 5.3 respectively. Note that out-of-band emissions are not greater than 30 dB below the carrier frequency level.

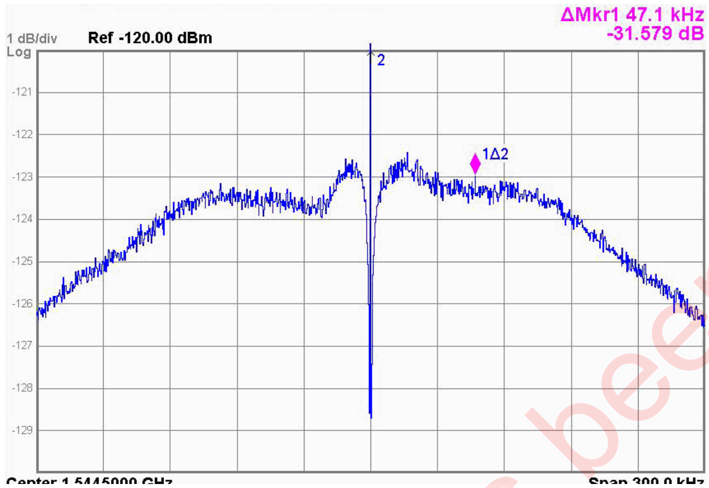


Figure 5-2~~5-25-2~~: Spectrum occupancy of downlink signal in WB mode spanned 300 kHz around 1544.5 MHz

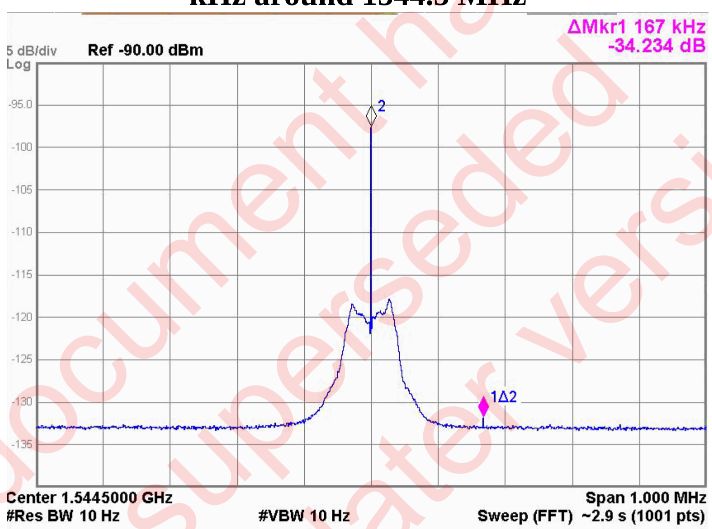


Figure 5-3~~5-35-3~~: Spectrum occupancy of downlink signal in NB mode spanned 1 MHz around 1544.5 MHz

5.4 Electro-L Repeater Coverage Area

The 0, 5 and 10-degree elevation angle coverage contour for the Electro-L satellite is provided in Figure 5.4. The receive and transmit antennas are broad beam earth coverage types. Therefore, the coverage patterns in Figure 5.4 apply to both receive and transmit functions.

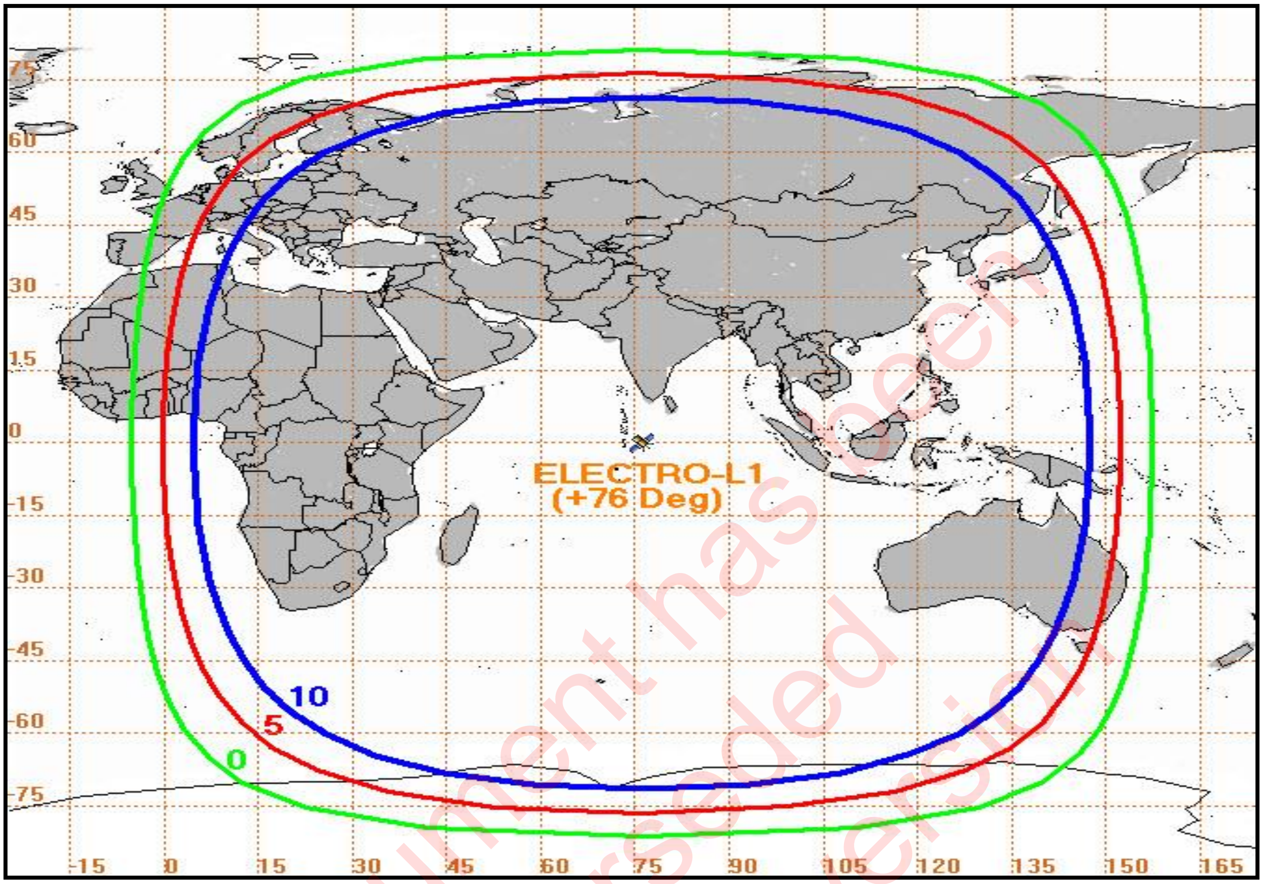


Figure 5-4~~5-45-4~~: Electro-L1 0º, 5º, 10º Elevation Angle Coverage Contours

5.5 Electro-L Repeater Performance Parameters

5.5.1 Electro-L SAR Receiver Parameters

The receiver parameters are shown in Table 5.2.

Table 5.2: Electro-L1 SAR Receiver Parameters

No.	Parameter	Unit	Values
1.	Nominal input level at Antenna	dBW	-173
2.	System Noise Temperature (referred to LNA)	K	890
3.	G/T	dB/K	-16.5
4.	Receiver Bandpass Characteristic : Narrow Band Mode (relat. to 406.025) Wide Band Mode (relat. to 406.050) For more information see Figures 5.5 and 5.6.	 kHz kHz	 33 (-1dB) 39 (-3dB) 64 (-20dB) 78 (-1 dB) 138 (-3 dB)
5.	Dynamic Range	dB	≤ 15
6.	Group Delay (over 4 kHz)	µs	≤ 13
7.	Image Rejection	dB	30
8.	Frequency Stability for 24h/10 years	dB	± 2.5 10^{-6}

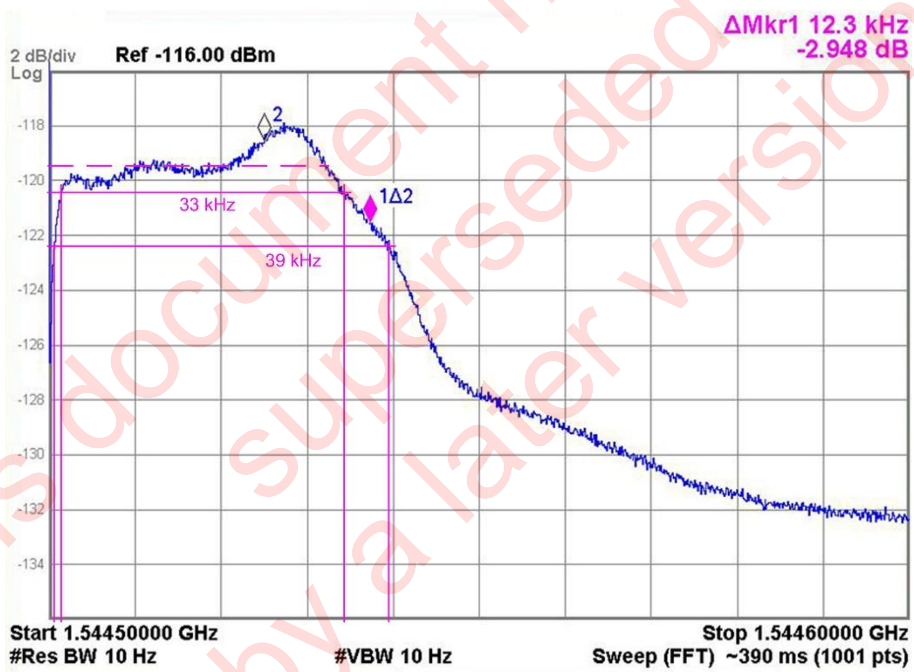


Figure 5-55-55-5: Electro-L1 SAR receiver bandpass filter amplitude-frequency response (repeater in NB mode)

Figure 5-6~~5-65-6~~: Electro-L1 SAR receiver bandpass filter amplitude-frequency response (repeater in WB mode)

5.5.2 Electro-L SAR Transmitter Parameters

The transmitter parameters are shown in Table 5.3.

Table 5.3: Electro-L1 SAR Transmitter Parameters

No.	Parameter	Unit	Values
1.	Centre Frequency	MHz	1544.5
2.	Output Power of Transmitter	dBW	6.0
3.	Repeater EIRP	dBW	20.1
4.	Phase Jitter (in 50 Hz bandwidth)	deg	≤ 10 (r.m.s.)
5.	Modulation Type		Linear Phase
6.	Nominal Modulation Index	radian	0.7 (rms)
7.	Modulation Index Limit	radian	2.0
8.	Frequency Stability		± 2.5 10^{-7}
9.	Amplitude Ripple (over any 24 hour)	dB	±1
10.	Linearity		See Note 1

Note 1: Fixed gain mode: Two equal test tones each at 2 dB above the receiver noise applied to the receive input will not produce intermodulation products within the transponder bandwidth greater than 20 dB below the test tone output level.

5.5.3 Electro-L SAR Antennas

The SAR receive antenna is right-hand circularly polarized (RHCP) with an on-axis gain of 15 dB including line loss. The receive antenna has a maximum axial ratio of 3 dB.

The SAR transmit antenna is also LHCP with an on-axis gain of 12 dB (± 9° beamwidth) including line loss. The transmit antenna has a maximum axial ratio of 3 dB.

– END OF SECTION 5 –

6. MSG 406 MHZ GEOSAR REPEATER

6.1 MSG Repeater Functional Description

A functional block diagram of the overall MSG telecommunications payload, including the SAR transponder is shown in Figure 6.1. The SAR transponder comprises the following:

a) A UHF receive antenna which is made up of an array of 16 crossed dipoles located close to the periphery of the main satellite drum. The dipoles of this array are electronically switched in order to form an electronically de-spun antenna beam that fully covers the Earth.

b) An input filter.

c) A redundant UHF receiver which provides low-noise amplification for the SAR channel.

d) A non-redundant SAR transponder which provides channel filtering, amplification, and up-conversion for the SAR channel. The SAR channel has fixed gain and bandwidth.

e) A wave-guide output multiplexer (OMUX) in which the SAR signals are multiplexed with the other L-band downlink signals.

f) An L-band transmit antenna comprising an array of dipoles arranged in 32 columns each with 4 dipoles connected in parallel. The columns of this array are also electronically switched to make a de-spun antenna beam that fully covers the Earth.

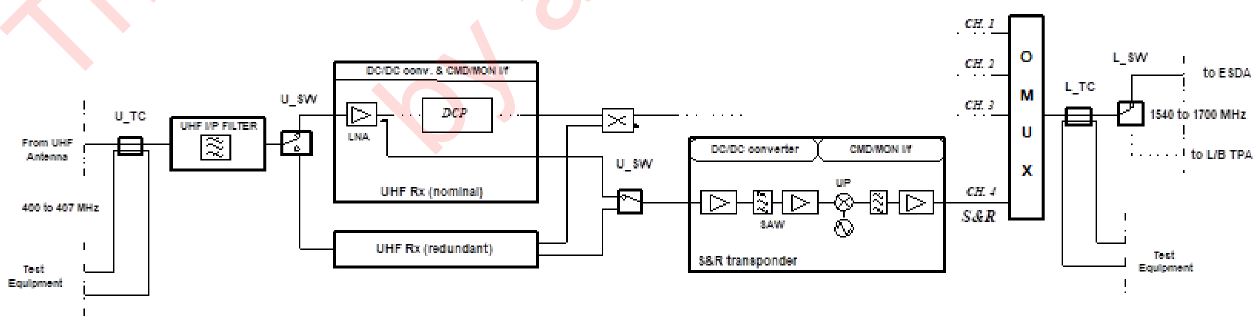


Figure 6-1~~6-16-1~~: MSG Search and Rescue Repeater Functional diagram

6.2 MSG Repeater Operating Modes

The only operating modes of the MSG SAR payload are SAR transponder off and on. The mode switching operations must be performed by EUMETSAT.

6.3 MSG Repeater Spectrum Characteristics

The spectral occupancy of the transmitted signal is shown in Figure 6.2.

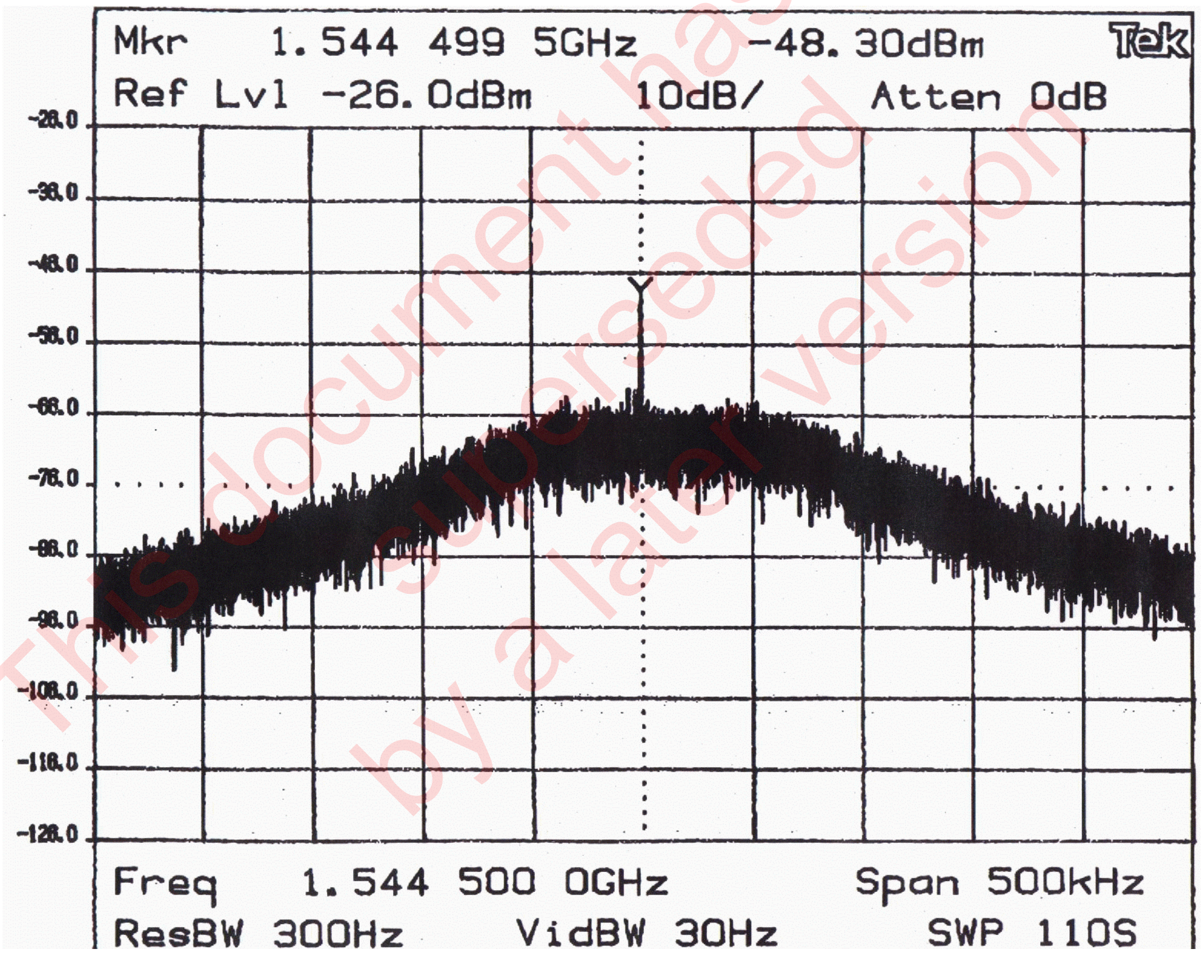


Figure 6-2~~6-26-2~~: MSG L-Band Transmitter Output Spectral Occupancy

The received beacon signals in the nominal 60 kHz uplink band from 406.020 MHz to 406.080 MHz, are directly translated to the L-band downlink centred at 1,544.5 MHz. The signal is not converted to baseband or a low intermediate frequency at any point. Signals at 406.05 MHz are converted to 1,544.5 MHz. The frequency stability is +/- 6 ppm and +/ 9 ppm at beginning and end of satellite life respectively. The main filtering of the band is performed in the SAR transponder block using a SAW filter operating in the uplink frequency band.

The specified useful channel bandwidth is > 60 kHz. The measurements (see Figure 6.3) indicate that a 0.5 dB-channel bandwidth of approximately 100 kHz is achieved. The measured noise-equivalent bandwidth is in the order of 180 kHz.

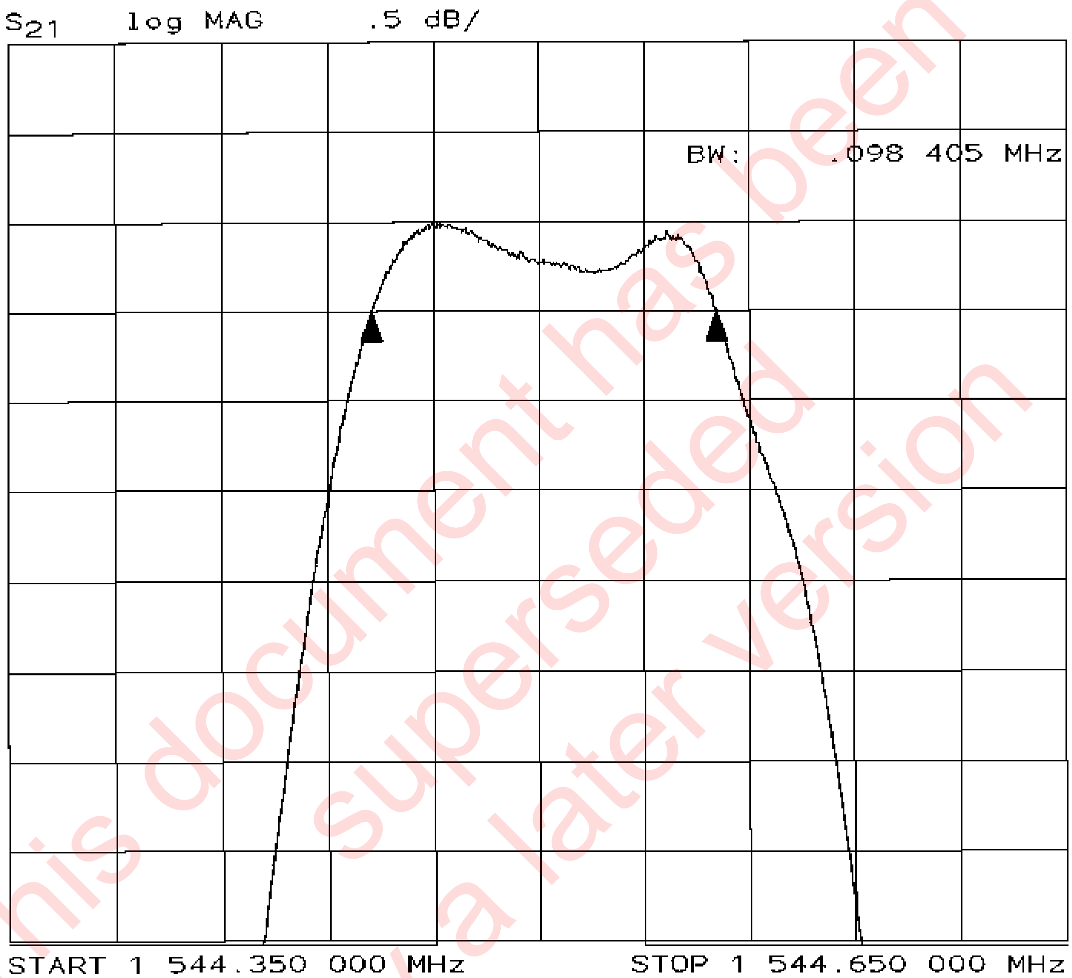


Figure 6-36-36-3: Measured Pass-band of MSG Transponder

Although a single figure cannot be used to describe short term frequency conversion stability characteristics of the MSG GEOSAR payload, the phase noise table (Table 6.1) and phase noise spectrum (Figure 6.4) of the transmitter local oscillator (LO) as measured for the first MSG flight model provide an indication of anticipated MSG performance.

Table 6.1: MSG Transmitter LO Phase Noise

Random Spurious Modulation	
Frequency	**Measured FM-1 [dBc/Hz]**
f_o + 10Hz	-65
f_o + 100Hz	-83
f_o + 1KHz	-94
f_o + 10KHz	-96
f_o + 100KHz	-102

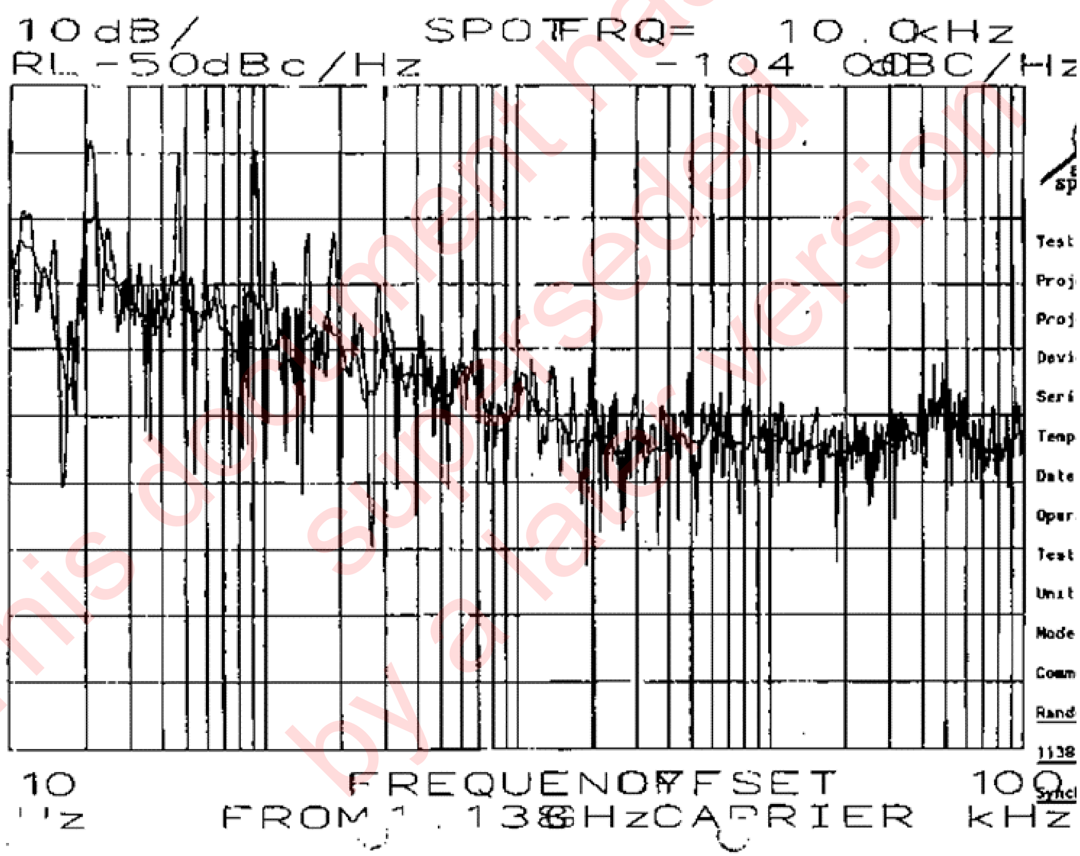


Figure 6-46-46-4: MSG Transmitter LO Phase Noise Spectrum Plot

6.3.1 MSG Repeater Coverage Area

Both the UHF receive antenna and the L-band transmit antenna provide coverage of the full Earth as seen from longitude 0.0°. Both antenna boresights are slightly tilted to the North. The design of the SAR transponder has been based upon the following minimum satellite elevation angles:

- from the emergency beacons: 5 degrees,
- from the receive ground stations (GEOLUTs): 18 degrees.

The geographical coverage area is indicated in Figure 6.5.

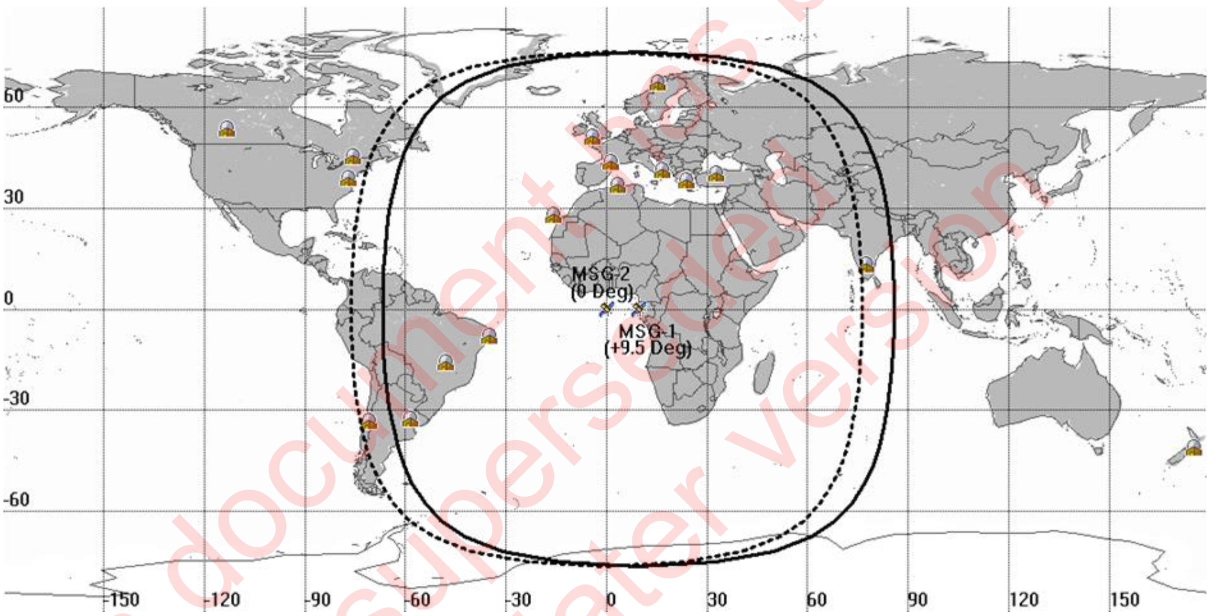


Figure 6-5~~6-56-5~~: MSG 5 º Elevation Angle Coverage Contour

6.4 MSG Repeater Performance Parameters

The principal worst case MSG repeater performance parameters as measured on the first flight model are shown in Table 6.2.

Table 6.2: MSG SAR Repeater Performance Parameters

Parameter	Unit	Values
Uplink Centre Frequency	MHz	406.050
Nominal Input Level at Antenna[*]	dBW	-176.9
System Noise Temperature	K	301
Receive Antenna G/T	dB/K	-21.3
Bandpass Characteristic Specified Band Measured 0.5dB-Band Noise-Equivalent Band (approx.)	 KHz	 >60.0 100.0 180.0
Dynamic Range[†]	dB	n/a
Phase Linearity (overall in band, specified)	deg	4.0
AM/PM Conversion	°/dB	0.9
Image Rejection	dB	>80.0
AGC Time Constant[‡]		No AGC
Transponder Gain	dB	148[§]
Transponder Linearity (C/I)	dB	20.0
Gain Stability (over Temperature, Frequency & Lifetime)	dB pk-pk	2.0
Output Frequency Stability	ppm	+/- 9
Downlink Centre Frequency	MHz	1,544.5
Downlink Polarisation		Lin. Horiz.
Maximum Output Power of Transmitter	dBW	0.0
Repeater EIRP per Useful Carrier[**]	dBW	-19.0
Modulation Type		As uplink
Transmitter Nominal Modulation Index		As uplink

6.5 MSG SAR Antennas

The MSG satellite spins at a rate of 100 rpm +/- 1%. To provide continuous coverage of a portion of the earth's surface, the MSG SAR instrument utilises electronically switched de-spun antennas. The electronic switching has a cyclical impact on the performance of the transmit and receive antennas as described below.

---

[*] Nominal input level at antenna from a 5 Watt Cospas-Sarsat beacon located at 5° elevation angle to the satellite. Includes 6.8 dB polarisation loss.

[†] This is a transparent transponder. It is driven by noise so that dynamic range is less relevant.

[‡] The SAR transponder operates only in fixed-gain mode.

[§] Signal gain is sensitive to the composite power loading of the transponder (which is dominated by noise). Strong ground interference may cause a reduction of gain. Link margin can be provided by adequate receiving ground station G/T selection.

[**] Assumes two beacons operating at nominal levels and 3 interfering carriers transmitted from ground with EIRP 3 dB higher than the beacon signals and randomly distributed within 60 kHz operational bandwidth.

6.5.1 MSG SAR Receive Antenna

The MSG SAR instrument uses an electronically switched de-spun (ESDA) right hand circularly polarised receive antenna, with gain performance as depicted at Figure 6.6. The values provided in this figure represent the minimum dynamic gain over the coverage area, and with the satellite spin, the gain fluctuates above this value at a rate of 26.7 Hz. The measured fluctuation (gain ripple) is 1.3 dB peak to peak in the south and up to 1.8 dB peak to peak in the north.

The minimum gain (co-polar component) in the coverage area ranges from 3.1 dBi to 4.5 dBi, while during the scan the gain can be as high as 5.6 dBi. The cross-polar component (XPD) varies in the coverage and ranges from -9.0 dB to 14.2 dB.

Both the gain and the polarisation loss are directly involved in the uplink quality, the worst case combination of the two effects has been estimated: min[(Gain Polarisation Loss)]. This occurs at a point in the west of the coverage where G = 3.45 dBi and XPD = 9 dB (i.e. polarisation loss = -6.78 dB). Since this represents the worst case situation, these values should be used when designing GEOLUTs which will operate with the MSG satellite.

6.5.2 MSG SAR Transmit Antenna

The MSG SAR instrument uses an electronically switched de-spun (ESDA) horizontally polarised transmit antenna, with typical gain performance as depicted at Figure 6.7. The values provided in this figure represent the minimum dynamic gain over the coverage area, and with the satellite spin, the gain fluctuates above this value at a rate of 53.3 Hz. The measured fluctuation (gain ripple) is typically 0.8 dB and will not exceed 1.6 dB peak to peak from column to column.

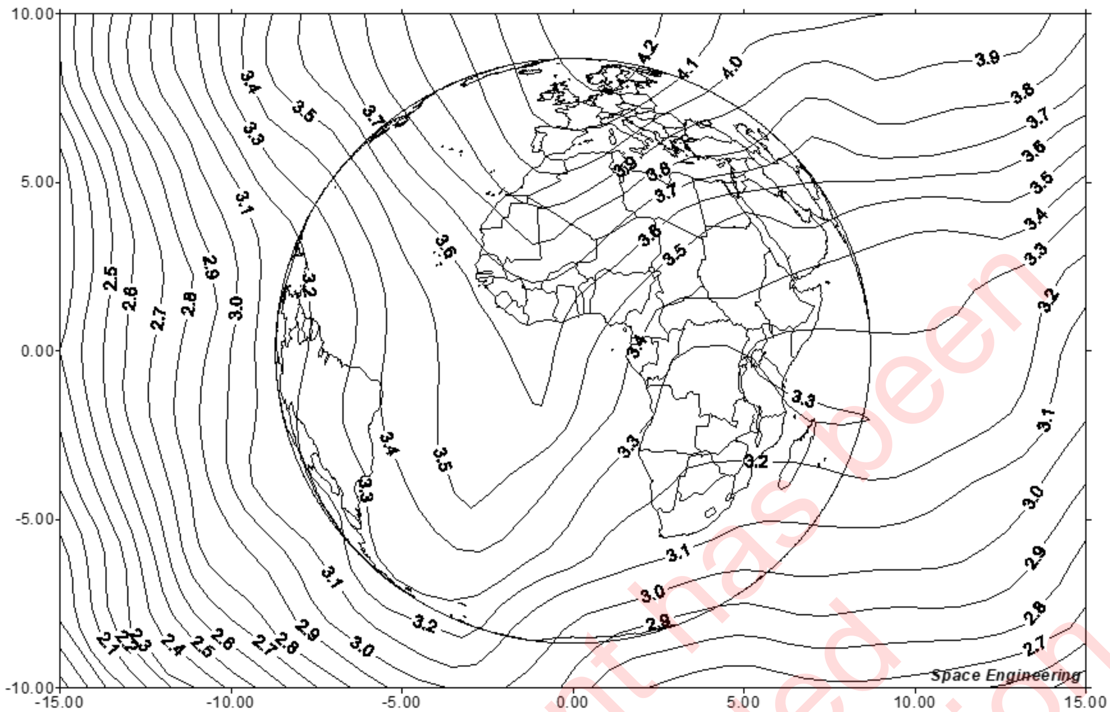


Figure 6-6~~6-66-6~~: MSG SAR Receive Antenna Pattern

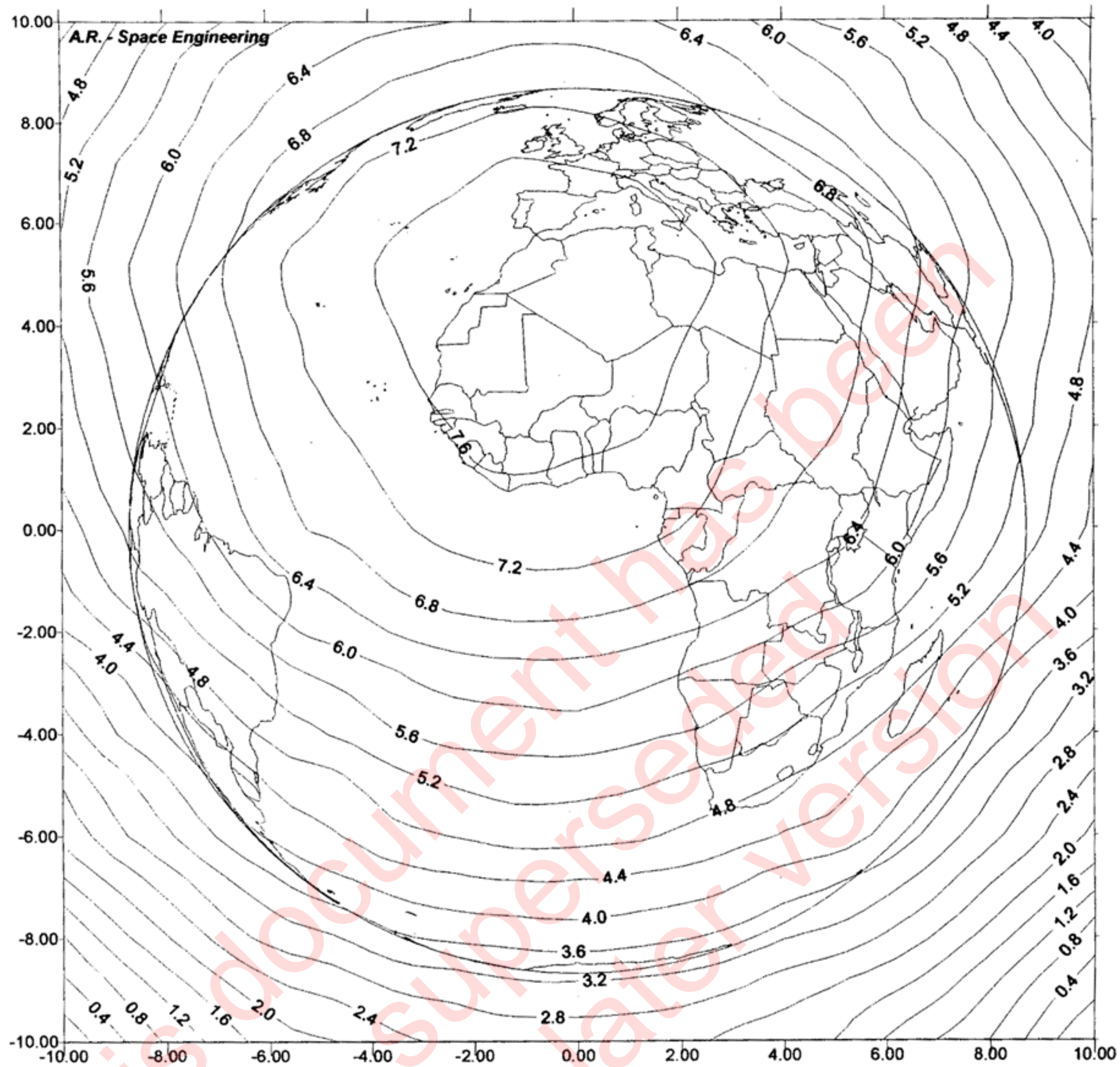


Figure 6-76-76-7: MSG SAR Transmit Antenna Pattern

Note: The figures depicted above depict the antenna gain at 1,544.5 MHz.

- END OF SECTION 6

7. LOUCH-5A GEOSAR REPEATER

7.1 Louch-5A Repeater Functional Description

A functional block diagram of the combined SAR and environmental data dissemination network (EDDN) channels transponder is shown in Figure 7.1. The transponder comprises the following:

a. Low noise amplifier that enables minimal effective noise temperature of the transponder

b. SAR channel filter with 80 kHz pass band (at -3 dB)

c. Down-converter that translates the input signal down to a first IF band (41.375±0.5 MHz)
d. Amplifier (gain not less than minus 10 dB)

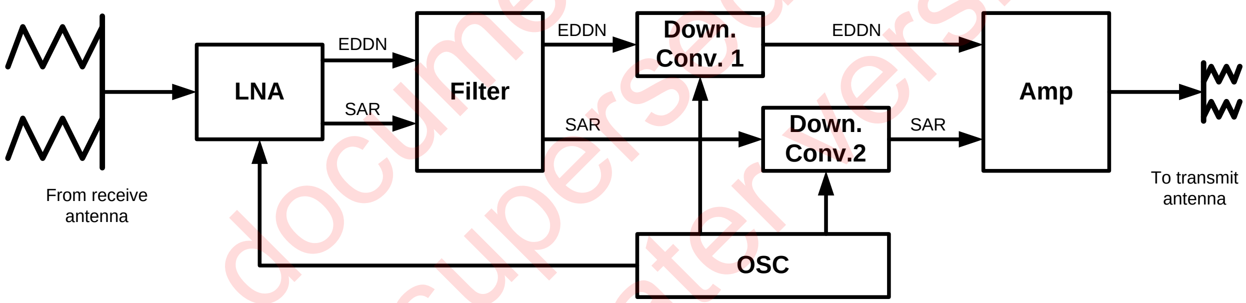


Figure 7-1~~7-17-1~~: Louch-5A Combined SAR and EDDN Transponder

7.2 Louch-5A Repeater Operating Modes

The only operating modes of the Louch-5A SAR payload are SAR transponder on and off with gain setting variation.

7.3 Louch-5A Spectrum Characteristics

The spectral occupancy of the transmitted signal is shown in Figure 7.2.

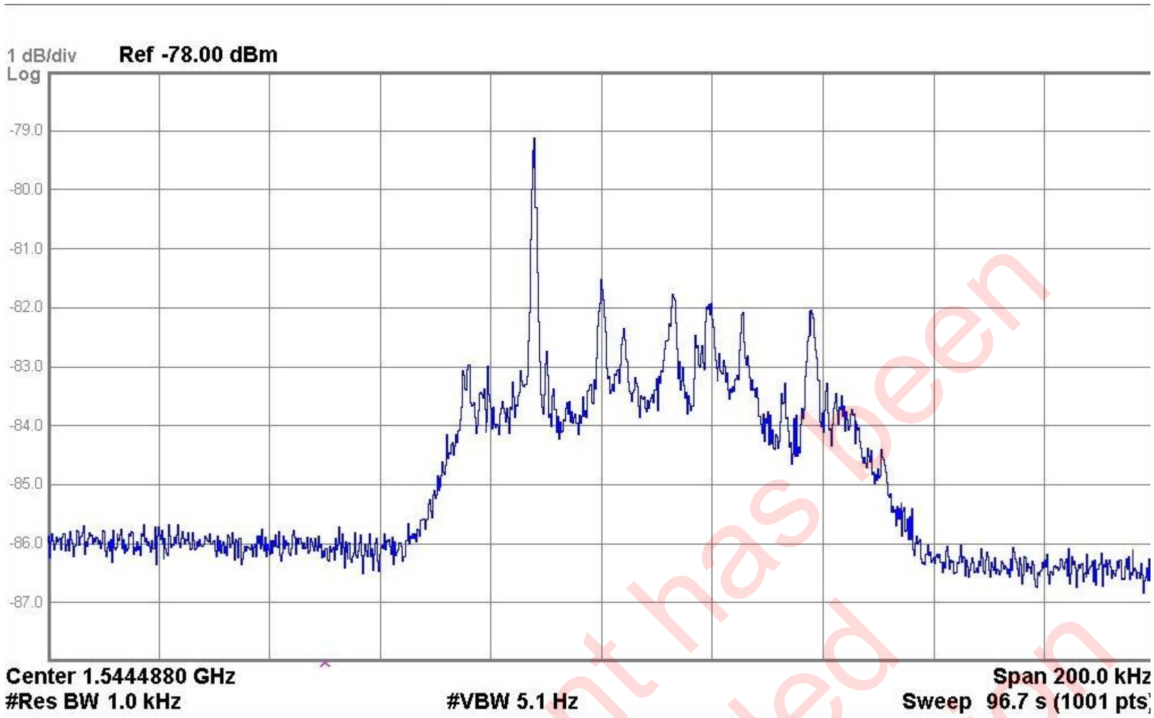


Figure 7-2~~7-27-2~~: Louch-5A Transmitter Spectrum Occupancy

7.4 Louch-5A Coverage Area

The 0, 5 and 10 degrees elevation angle coverage contours for the Louch-5A is shown in Figure 7.3. The zones are determined with the following orbit parameters:

- Sidereal period = 86164 ± 1 sec
- Eccentricity = 0.0 - 0.0006
- Inclination = 0˚ - 5˚

7.5 Louch-5A Repeater Performance Characteristics

The principal Louch-5A repeater performance parameters are shown in Tables 7.1. and 7.2 for SAR receiver and SAR transmitter respectively.
Louch-5A combined SAR and EDDN channels transponder has fixed gain factor over the range between LNA input and power amplifier output. The value of the gain factor can be command set and by default is 138 dB.

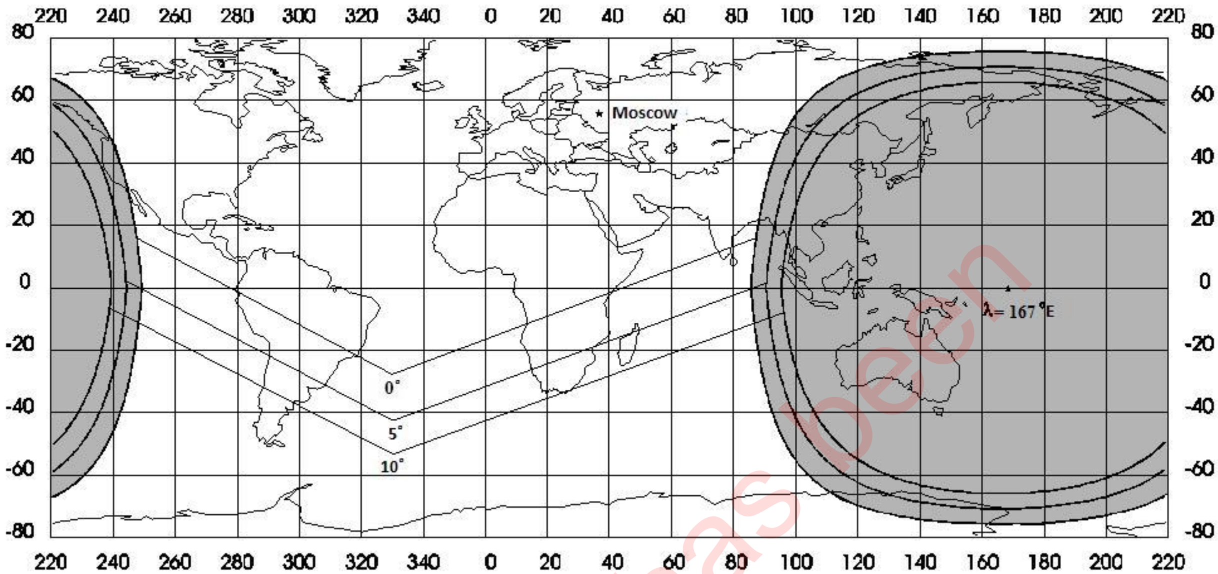


Figure 7-37-37-3: Louch-5A Coverage Zones for 0, 5 and 10 degrees of elevation angle

Table 7.1: Louch-5A SAR Receiver Parameters

No.	Parameter	Unit	Values
1.	Operational bandwidth	Mhz	406.01-406.09
2.	Signal nominal level at LNA input	dBW	-159
3.	G/T (at the edge of service zone)	dB/K	-10.2
4.	Receiver Bandpass Characteristics:	kHz	±40 (at -3dB)
5.	Dynamic Range (for SAR channel relative to nominal level -159 dBW)	dB	±10
6.	Image Rejection	dB	not less than 50
7.	Frequency Stability for: 24 hours: 100000 hours		 $\pm1*10^{-8}$ $\pm1*10^{-7}$

Table 7.2: Louch-5A SAR Transmitter Parameters

No.	Parameter	Unit	Values
1.	Transmitter frequency range	MHz	1544.458-1544.542
2.	Output Power of Transmitter*	dBW	-10.2
3.	Repeater EIRP	dBW	7.1
4.	Phase Jitter (in 50 Hz bandwidth)	deg	0.6
5.	Modulation Type	Radian	n/a
6.	Frequency Stability for: 24 hours: 100000 hours:	MHz	 $\pm 1*10^{-8}$ $\pm 2*10^{-7}$
7.	Amplitude Ripple	dB	less than 1.0
8.	Linearity	dB	-22

7.6 Louch-5A SAR Antennas

The reception of the SAR signal is provided by four spiral P-Band phased array antenna. The transmit antenna is a four spiral L-Band phased array antenna. Both antennas have global beam (17˚x17˚ beamwidth).

The receive antenna is a right hand circular polarized (RHCP) with an on-axis gain of 18.3 dB (16.2 on the edge of the coverage) and axial ratio of 0.7. The receive line loss between the antenna terminal and the low noise preamplifier is 0.6 dB.
The transmit antenna is a right hand circular polarized (RHCP) with an on-axis gain of 19.9 dB (17.1 on the edge of the coverage) and axial ratio of 0.9. The transmit line loss between the antenna terminal and the low noise preamplifier is 1 dB.

The receive and transmit antenna patterns are shown in Figures 7.4 and 7.5 respectively.

* Since the power amplifier installed in the transponder is shared between SAR and EDDN channels the maximum SAR channel output power is not greater than 100 mW (in linear mode)

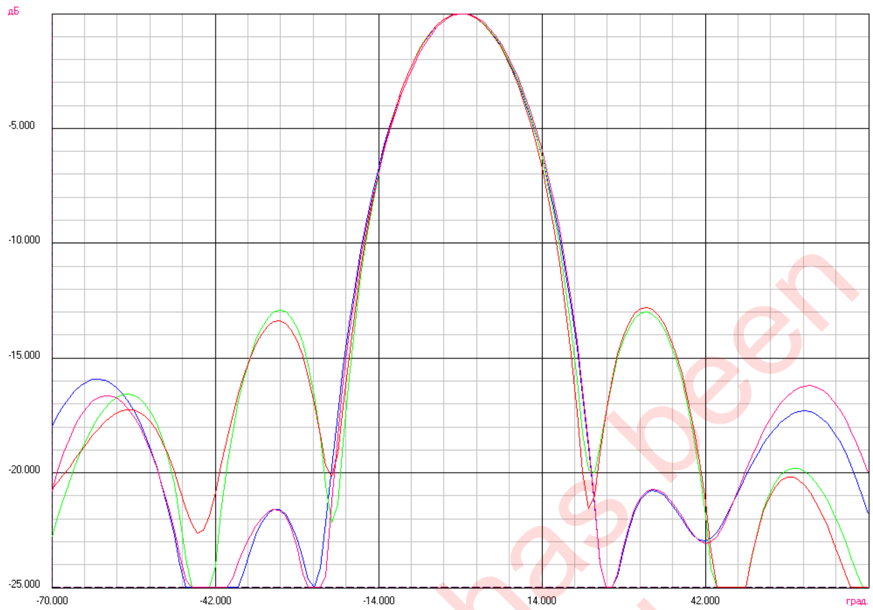


Figure 7-4~~7-47-4~~: Louch-5A Receive Antenna Pattern at 406.05 MHz

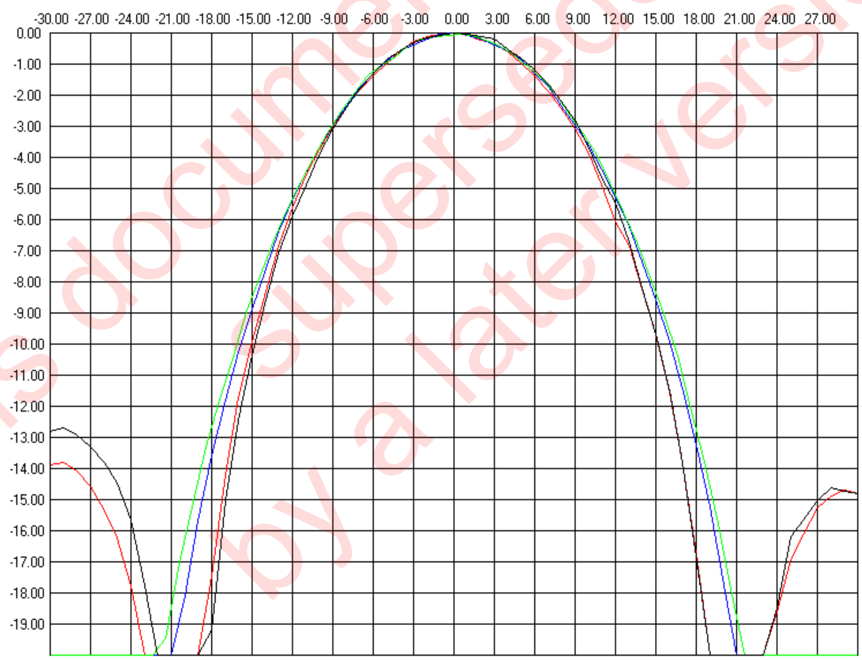


Figure 7-5~~7-57-5~~: Louch-5A Transmit Antenna Pattern at 1544.5 MHz

– END OF SECTION 7–

- END OF DOCUMENT -

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