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

C/S T.011
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**DESCRIPTION OF THE 406 MHz PAYLOADS USED IN THE COSPAS-SARSAT
GEOSAR SYSTEM**

History

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TABLE OF CONTENTS

| | Page |
|--|-------------|
| History..... | i |
| List of Pages..... | ii |
| Table of Contents..... | iii |
| List of Tables | iv |
| List of Figures | v |
| <hr/> | |
| 1. INTRODUCTION | 1-1 |
| 1.1 Overview..... | 1-1 |
| 1.2 Purpose..... | 1-1 |
| 1.3 Scope..... | 1-1 |
| 1.4 Reference Documents | 1-1 |
| 2. 406 MHz GEOSAR SYSTEM DESCRIPTION | 2-1 |
| 2.1 406 MHz GEOSAR Payload Functional Description..... | 2-1 |
| 2.2 GEOSAR Orbit Summary..... | 2-2 |
| 2.3 GEOSAR System Coverage..... | 2-2 |
| 3. GOES 406 MHz GEOSAR REPEATER..... | 3-1 |
| 3.1 GOES Repeater Functional Description | 3-1 |
| 3.2 GOES Repeater Operating Modes | 3-2 |
| 3.3 GOES Repeater Spectrum Characteristics | 3-2 |
| 3.4 GOES Repeater Coverage Area | 3-3 |
| 3.5 GOES Repeater Performance Parameters | 3-6 |
| 3.5.1 GOES SAR Receiver Parameters | 3-6 |
| 3.5.2 GOES SAR Transmitter Parameters..... | 3-7 |
| 3.5.3 GOES SAR Antennas | 3-7 |
| 4. INSAT 406 MHz GEOSAR REPEATER..... | 4-1 |
| 4.1 INSAT Repeater Functional Description | 4-1 |
| 4.2 INSAT Repeater Operating Modes | 4-2 |
| 4.3 INSAT Repeater Spectrum Characteristics..... | 4-2 |
| 4.4 INSAT Repeater Coverage Area..... | 4-4 |
| 4.5 INSAT Repeater Performance Parameters..... | 4-4 |
| 4.6 INSAT SAR Antennas | 4-6 |

| | | |
|-----------|---|------------|
| 5. | ELECTRO-L GEOSAR REPEATER..... | 5-1 |
| 5.1 | Repeater Functional Diagram Description..... | 5-1 |
| 5.2 | Electro-L Repeater Operating Modes | 5-1 |
| 5.3 | Electro-L Repeater Baseband Spectrum | 5-3 |
| 5.4 | Electro-L Repeater Coverage Area | 5-3 |
| 5.5 | Electro-L Repeater Performance Parameters | 5-3 |
| 5.5.1 | Electro-L SAR Receiver Parameters | 5-3 |
| 5.5.2 | Electro-L SAR Transmitter Parameters..... | 5-4 |
| 5.5.3 | Electro-L SAR Antennas | 5-4 |
| 6. | MSG 406 MHz GEOSAR REPEATER..... | 6-1 |
| 6.1 | MSG Repeater Functional Description | 6-1 |
| 6.2 | MSG Repeater Operating Modes | 6-3 |
| 6.3 | MSG Repeater Spectrum Characteristics..... | 6-3 |
| 6.4 | MSG Repeater Coverage Area..... | 6-5 |
| 6.5 | MSG Repeater Performance Parameters..... | 6-6 |
| 6.6 | MSG SAR Antennas | 6-8 |
| 6.6.1 | MSG SAR Receive Antenna | 6-8 |
| 6.6.2 | MSG SAR Transmit Antenna..... | 6-8 |

LIST OF TABLES

| | | |
|-----|---|-----|
| 2.1 | GEOSAR Space Segment Orbit Parameters | 2-2 |
| 3.1 | GOES Repeater Operating Modes..... | 3-2 |
| 3.2 | GOES SAR Receiver Parameters | 3-6 |
| 3.3 | GOES SAR Transmitter Parameters | 3-7 |
| 4.1 | INSAT Repeater Operating Modes | 4-2 |
| 4.2 | INSAT Repeater Performance Parameters | 4-4 |
| 5.1 | Electro-L Repeater Operating Modes | 5-1 |
| 5.2 | Electro-L SAR Receiver Parameters | 5-3 |
| 5.3 | Electro-L SAR Transmitter Parameters..... | 5-4 |
| 6.1 | MSG Transmitter LO Phase Noise | 6-4 |
| 6.2 | MSG SAR Repeater Performance Parameters | 6-7 |

LIST OF FIGURES

| | | |
|-------|--|------|
| 2.1 | GEOSAR Payload Functional Diagram | 2-1 |
| 2.2 | Nominal GEOSAR 5 Degree Elevation Contour Coverage (October 2012) | 2-3 |
| 3.1 | GOES Search and Rescue Repeater Functional Diagram | 3-1 |
| 3.2 | GOES L-Band Transmitter Output Spectral Occupancy..... | 3-3 |
| 3.3.a | GOES Narrow Band Baseband Spectrum | 3-4 |
| 3.3.b | GOES Wide Band Baseband Spectrum | 3-4 |
| 3.4 | GOES-E and GOES-W 0° Elevation Angle Coverage Contours..... | 3-5 |
| 3.5 | GOES Receive Antenna Pattern at 406.05 MHz | 3-8 |
| 3.6 | GOES Transmit Antenna Pattern at 1544.5 MHz..... | 3-9 |
| 4.1 | INSAT SAR / DRT Repeater Functional Block Diagram | 4-1 |
| 4.2a | INSAT Transmitter Output Spectral Occupancy with no Test Signal | 4-3 |
| 4.2b | INSAT Transmitter Output Spectral Occupancy with Test Signal | 4-3 |
| 4.3 | INSAT 3A/3D 0 Degree Uplink Elevation Angle Contour and Downlink Contour..... | 4-5 |
| 4.4* | INSAT 406.05 MHz Receive Antenna Pattern | 4-6 |
| 4.5 | INSAT Transmit Antenna Pattern..... | 4-6 |
| 5.1 | Electro-L SAR Functional Diagram..... | 5-2 |
| 5.2 | Electro-L1 0°, 5°, 10° Elevation Angle Coverage Contours..... | 5-5 |
| 6.1 | MSG Search and Rescue Repeater Functional Diagram..... | 6-2 |
| 6.2.a | MSG L-Band Transmitter Output Spectral Occupancy | 6-3 |
| 6.2.b | Measured Pass-band of MSG Transponder..... | 6-4 |
| 6.3 | MSG Transmitter LO Phase Noise Spectrum Plot..... | 6-5 |
| 6.4 | MSG 5° Elevation Angle Coverage Contour | 6-6 |
| 6.5 | MSG SAR Receive Antenna Pattern..... | 6-9 |
| 6.6 | MSG SAR Transmit Antenna Pattern | 6-10 |

* Not available at the time the document was published

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-

This document has been
superseded by a later version

2. 406 MHz GEOSAR SYSTEM DESCRIPTION

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.

| <u>Spacecraft</u> | <u>Country/Organization</u> | <u>Status</u> |
|-------------------|-----------------------------|---------------|
| GOES-13 (East) | USA | Operational |
| GOES-15 (West) | USA | Operational |
| ELECTRO-L | Russia | Operational |
| INSAT 3A | India | Operational |
| INSAT 3D | India | Planned |
| MSG-1 | EUMETSAT | Operational |
| MSG-2 | EUMETSAT | 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.

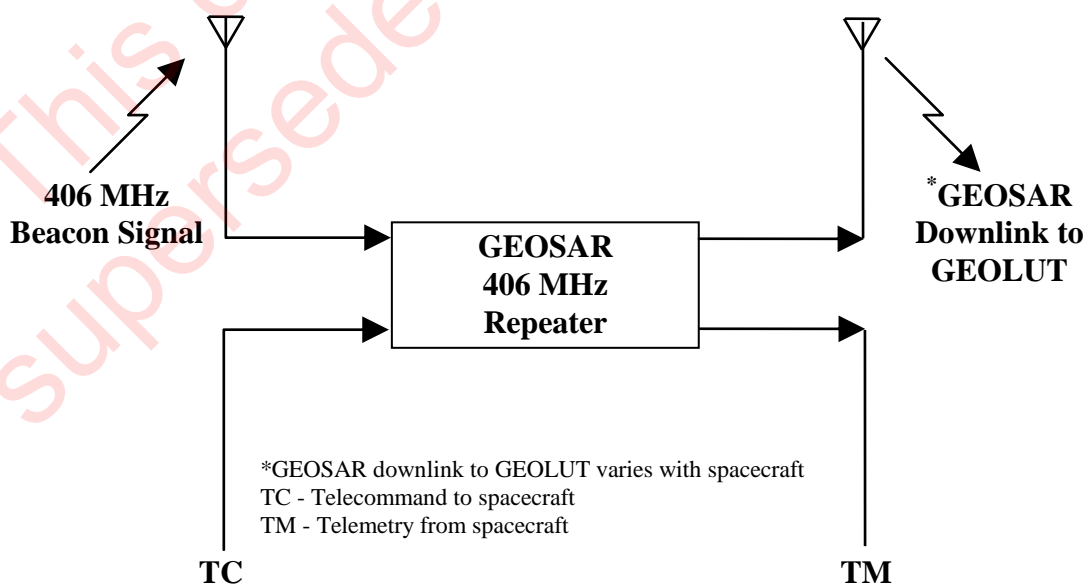


Figure 2.1: GEOSAR Payload Functional Diagram

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. The Geostationary Operational Environmental Satellite (GOES) repeater is described in section 3. The Indian National Satellite System (INSAT) repeater is described in section 4. The Luch-M repeater is described in section 5. The Meteosat Second Generation (MSG) repeater is described in section 6.

2.2 GEOSAR Orbit Summary

Each of the GEOSAR satellites is 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 |
|----------------|--------------------|-------------------|-------------------------------|-----------------------|
| GOES-13 (East) | 75° W | 0° | 42164 | ±0.5° long. & lat. |
| GOES-15 (West) | 135° W | 0° | 42164 | ±0.5° long. & lat. |
| ELECTRO-L | 76° E | 0° | 42164 | ±2.0° long. & lat. |
| INSAT-3A | 93.5° E | 0° | 42164 | ±0.1° long. & lat. |
| INSAT-3D | 82° E | 0° | 42164 | ±0.1° long. & lat. |
| MSG-1 | 9.5° W | 0° | 42164 | ±0.5° long.; ±1° lat. |
| MSG-2 | 0° | 0° | 42164 | ±0.5° long.; ±1° lat. |

2.3 GEOSAR System Coverage

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

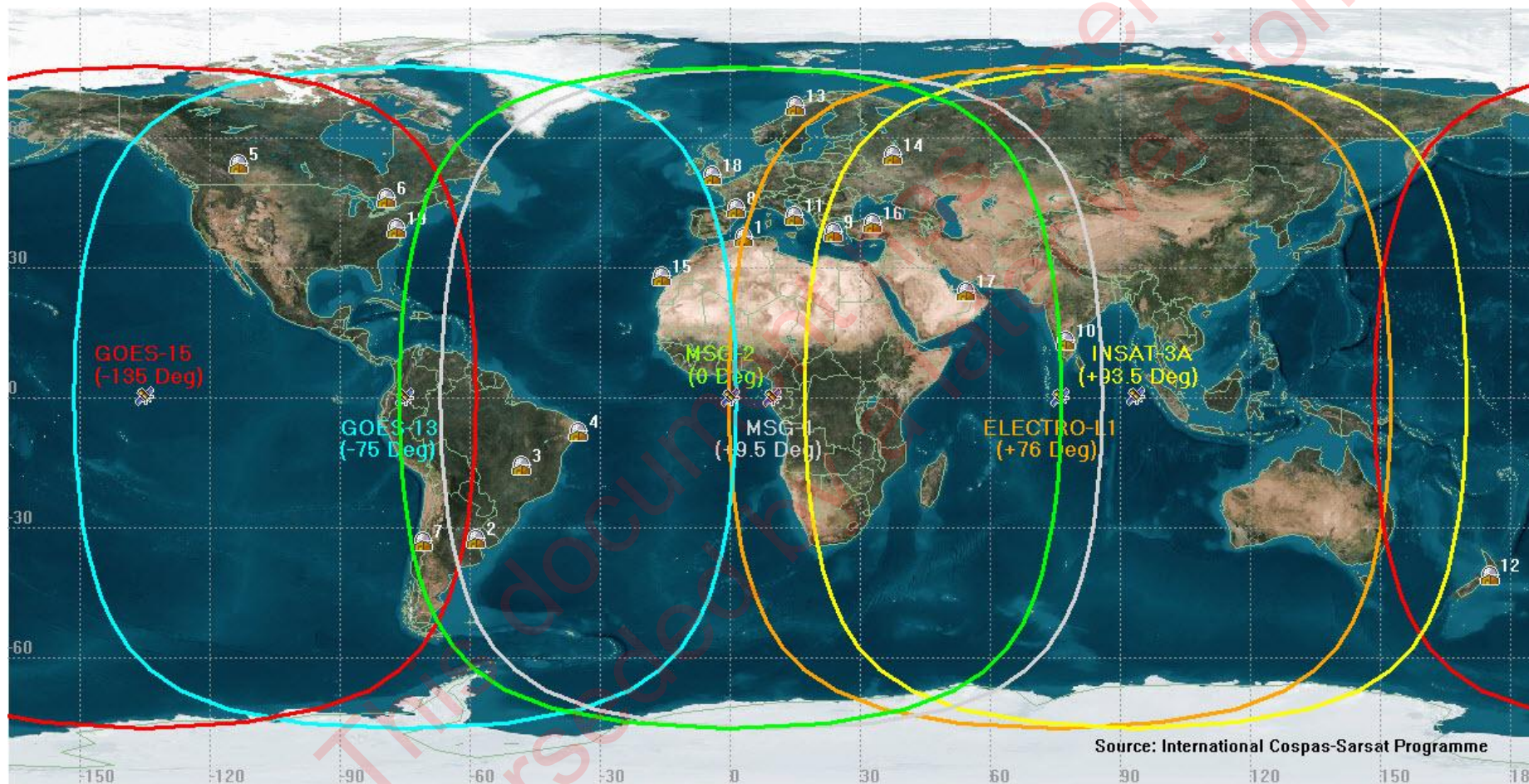


Figure 2.2: Nominal GEOSAR 5 Degree Elevation Contour Coverage (October 2012)

-END OF SECTION 2-

3. GOES 406 MHz GEOSAR REPEATER

3.1 GOES Repeater Functional Description

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:

- two 406 MHz low noise amplifiers (shared with another satellite subsystem);
- two dual-conversion 406 MHz receivers;
- two 3 watt phase modulated L-Band transmitters;
- one 406 MHz receive antenna and one 1544.5 MHz transmit antenna; and
- command and telemetry points interfaced with the spacecraft telemetry and command subsystem.

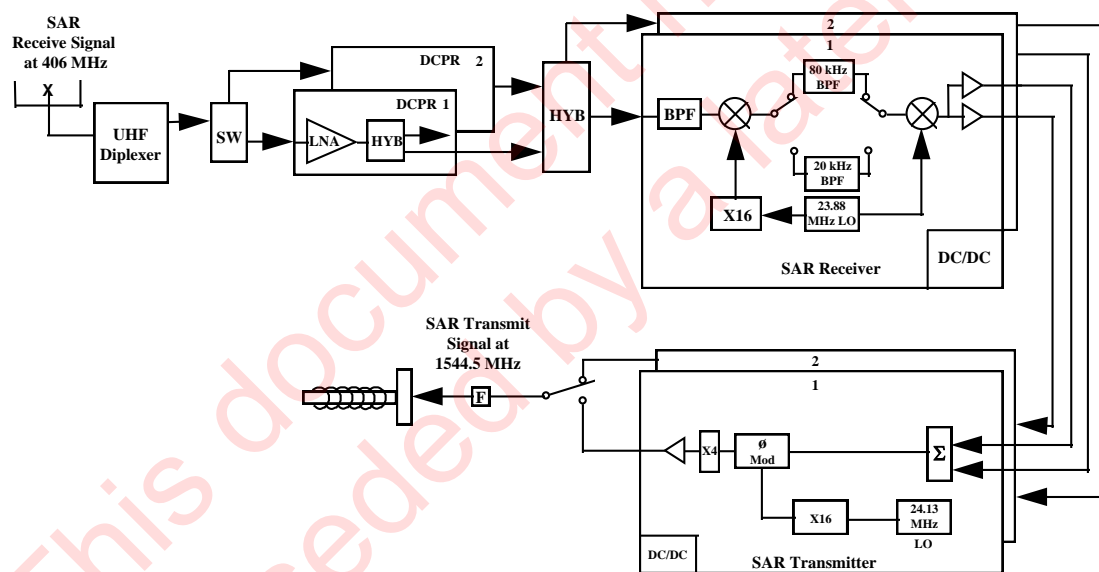


Figure 3.1: GOES Search and Rescue Repeater Functional Diagram

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.

3.2 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.

Table 3.1: GOES Repeater Operating Modes

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

3.3 GOES Repeater Spectrum Characteristics

The spectral occupancy of the transmitted signal with the repeater in the wide band mode is shown in Figure 3.2. This output spectrum, 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.

The baseband spectral characteristics are shown in Figures 3.3a and 3.3b. 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 3.3a. The wide band spectrum is shown in Figure 3.3b.

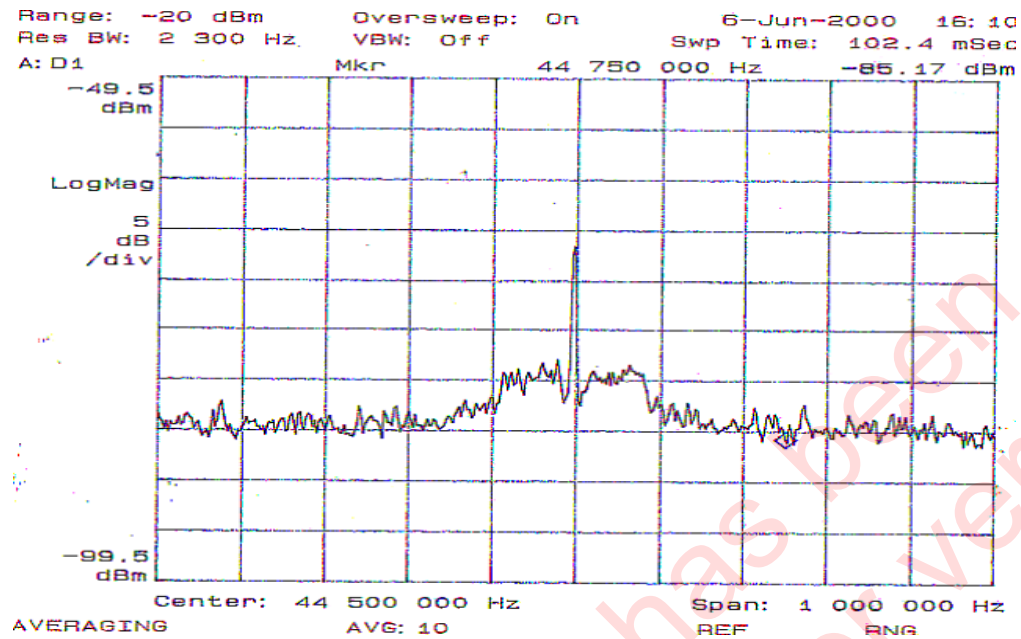


Figure 3.2: GOES L-Band Transmitter Output Spectral Occupancy

3.4 GOES Repeater Coverage Area

The zero degree elevation angle coverage contour for the GOES-E and 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 3.4 apply to both the receive and transmit functions.

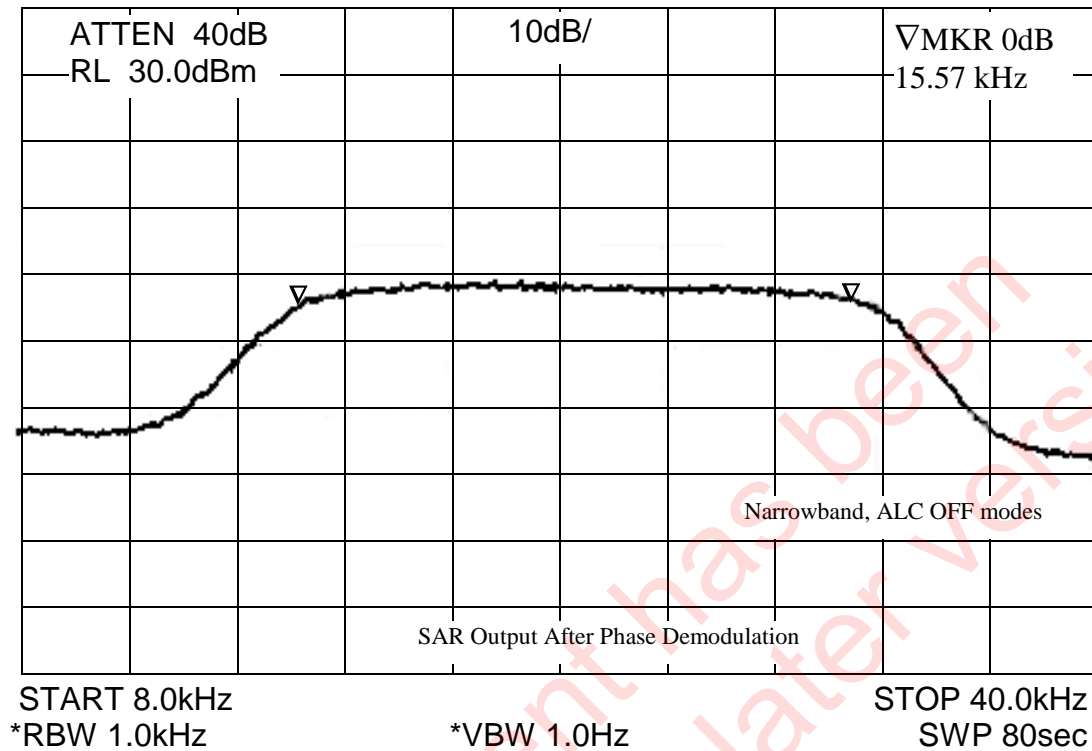


Figure 3.3a: GOES Narrow Band Baseband Spectrum

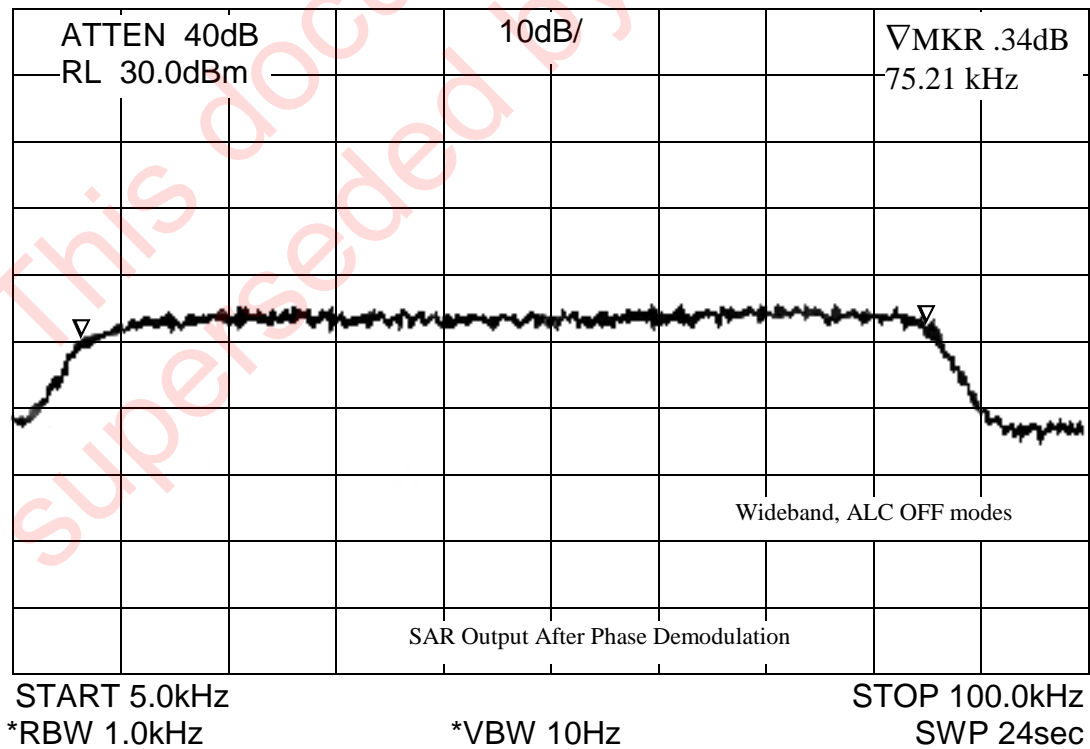


Figure 3.3b: GOES Wide Band Baseband Spectrum

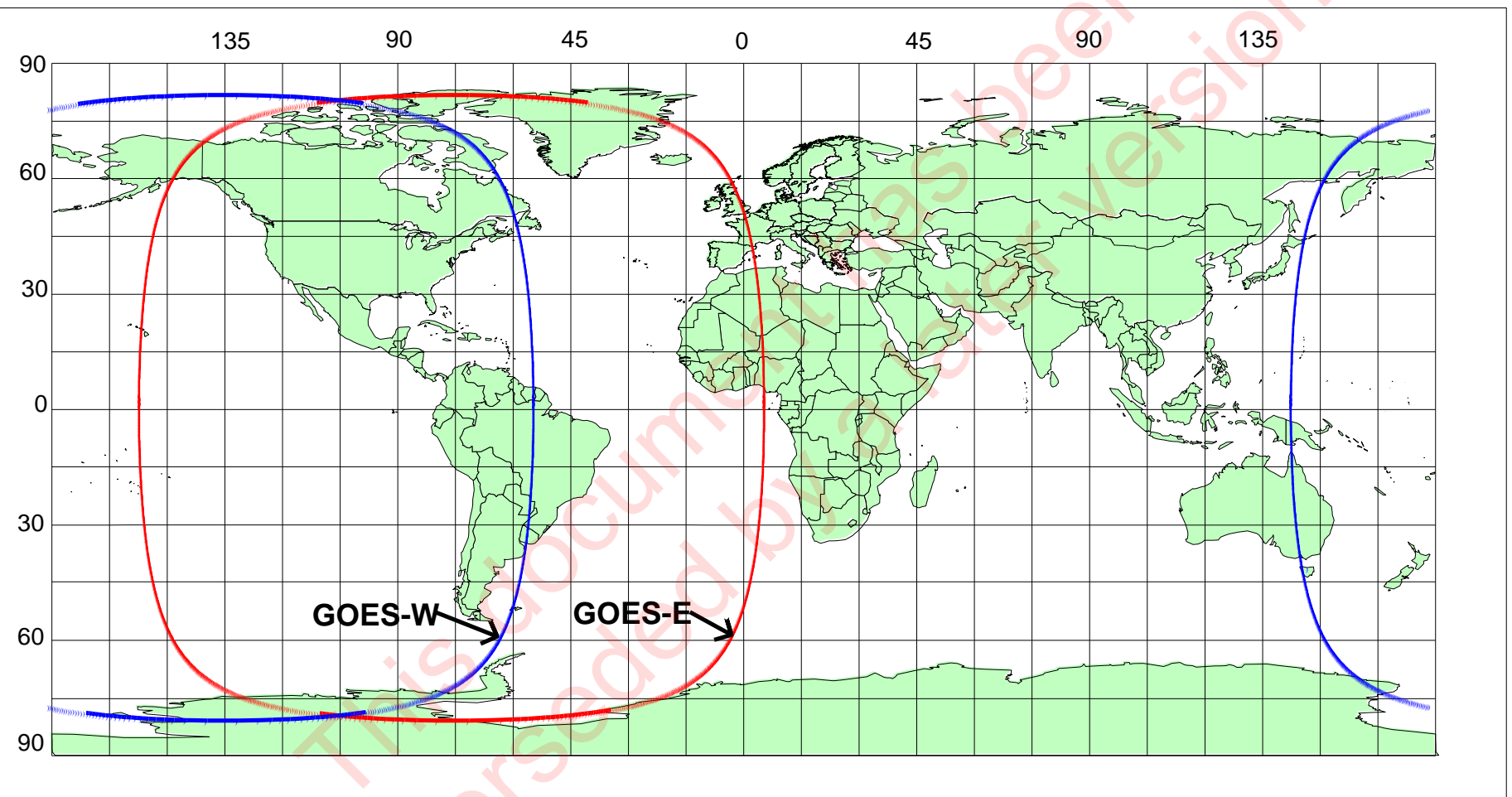


Figure 3.4: GOES-E and GOES-W 0° Elevation Coverage Contours

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 | Values |
|---|--------|---|
| Nominal Input Level at Antenna ¹ | dBW | -173.1 |
| System Noise Temperature (referred to preamp input) | K | 359 |
| G/T | dB/K | -18.5 |
| Receiver Bandpass Characteristic | | |
| Narrow Band Mode (relative to 406.025 MHz) | kHz | ± 6.0 (1 dB BW) ± 10.0 (3 dB BW) ± 20.0 (20 dB BW) |
| Wide Band Mode (relative to 406.05 MHz) | kHz | ± 30.0 (1 dB BW) ± 40.0 (3 dB BW) ± 50.0 (20 dB BW) |
| Dynamic Range | dB | ≤ 15 |
| Group Delay (over 4 kHz) | μs/kHz | ≤ 13 |
| Image Rejection | dB | 60 |
| AGC Time Constant | ms | ≤ 40 |
| Frequency Stability | | |
| Frequency Conversion Oscillators (over 0.25 s) | N/A | ± 1 x 10 ⁻⁹ |

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 | Values |
|--|--------------|--------------------------|
| Centre Frequency | MHz | 1544.5 |
| Output Power of Transmitter | W | 3.0 |
| Repeater EIRP | dBW | + 15.0 |
| Phase Jitter (in 50 Hz bandwidth) | deg. (rms) | ≤ 10 |
| Modulation Type | type | Linear Phase |
| Transmitter Nominal Modulation Index | radians peak | 1.0 |
| Modulation Index Limit | | 2.0 |
| Frequency Stability of downlink carrier | N/A | $\pm 2.5 \times 10^{-6}$ |
| Amplitude Ripple (over any 24 hour period) | dB | ± 1 |
| Linearity | N/A | see note 1 |

Note 1: Fixed Gain Mode - 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.

ALC Mode - 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 3.5. The antenna is right hand circular polarized (RHCP) with an on-axis gain of 10 dB. The receive line loss between the antenna terminal and the low noise preamplifier is 1.9 dB. Therefore, the effective gain relative to the preamplifier input is 8.1 dB. The receive antenna has a maximum axial ratio of 3 dB.

The relative gain pattern for the GOES SAR transmit antenna is shown in Figure 3.6. 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.

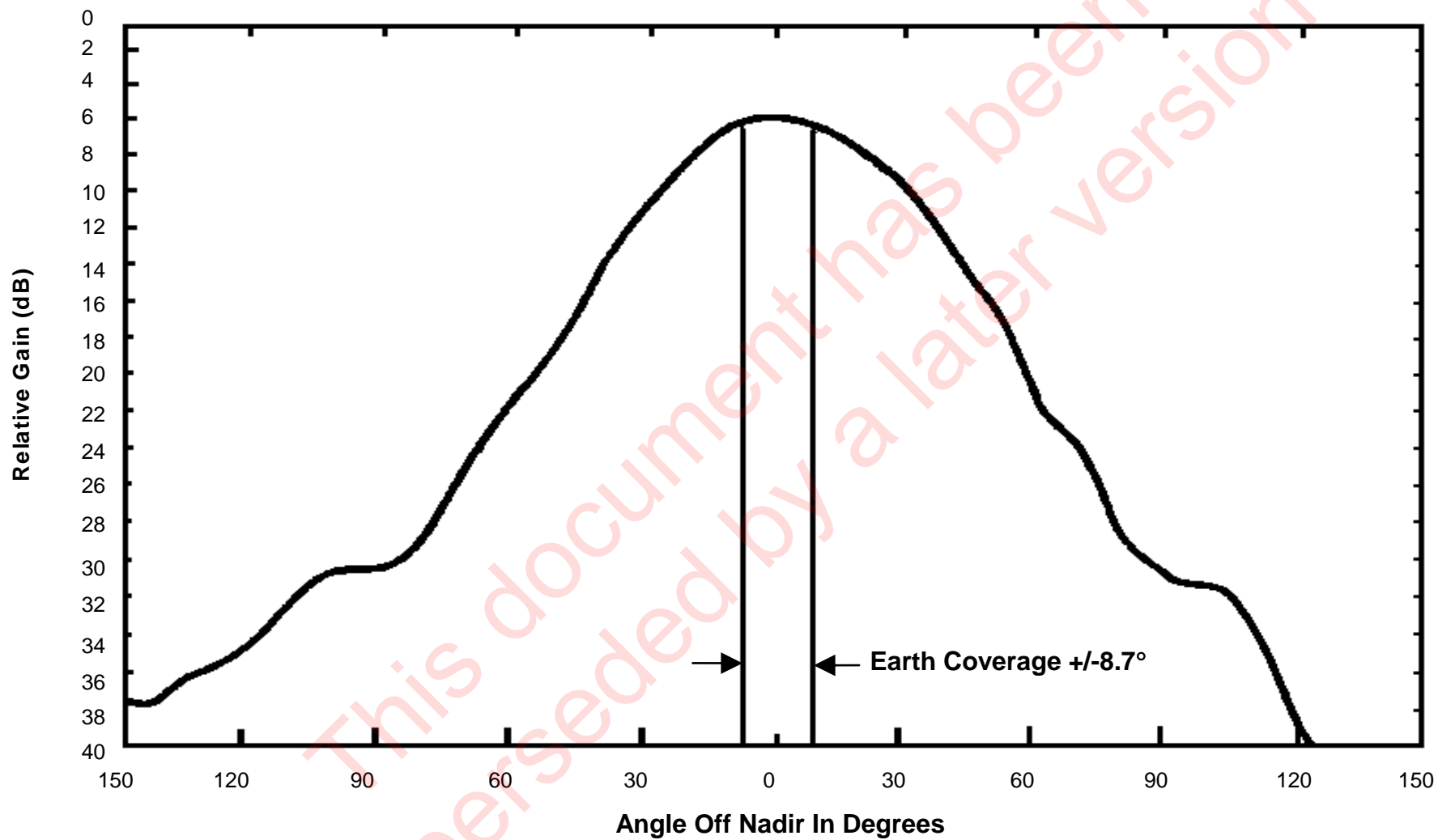


Figure 3.5: GOES Receive Antenna Pattern at 406.05 MHz

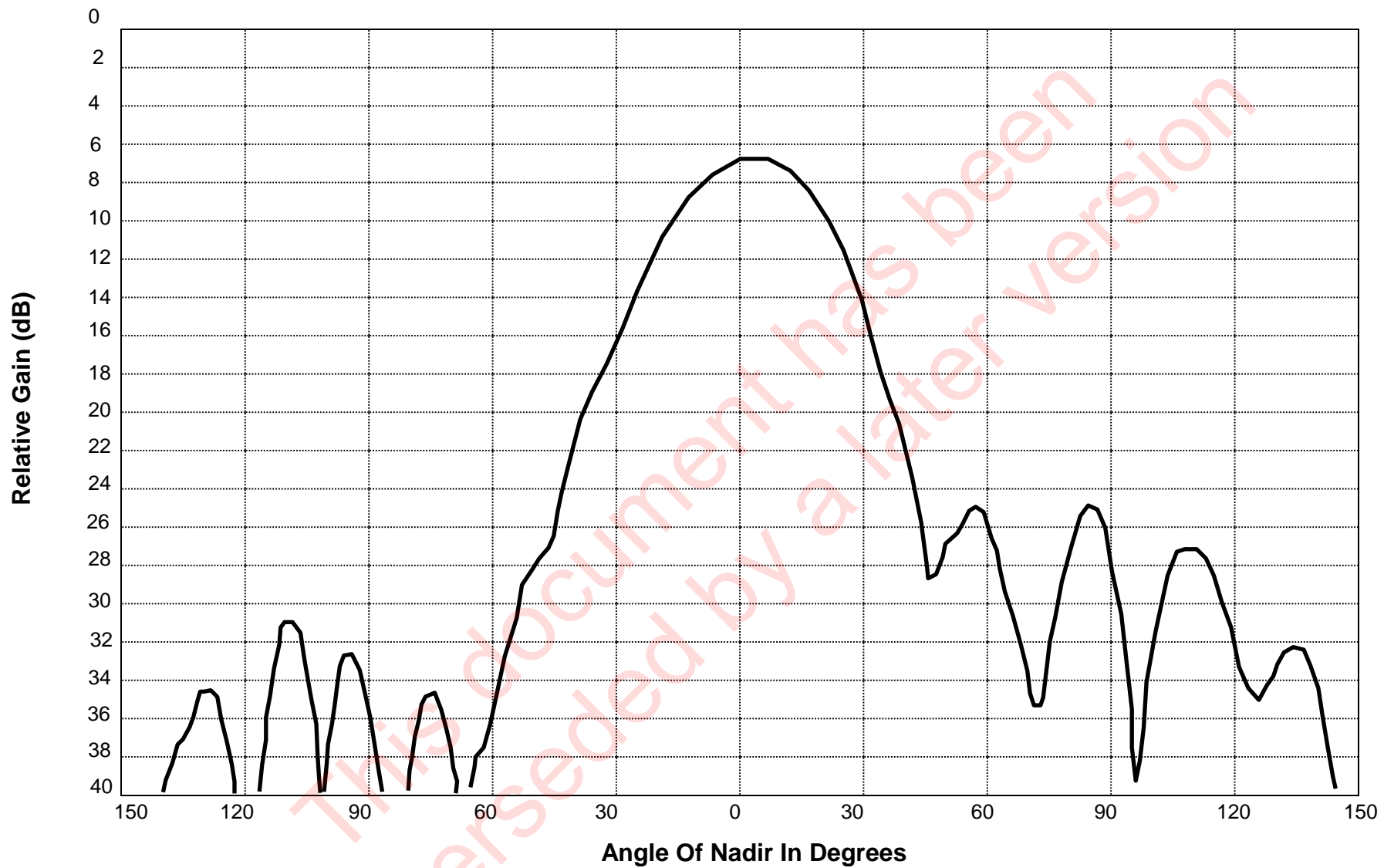


Figure 3.6: GOES Transmit Antenna Pattern at 1544.5 MHz

-END OF SECTION 3-

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4. INSAT 406 MHz GEOSAR REPEATER

4.1 INSAT Repeater Functional Description

SAR instruments are included on the INSAT 3A and 3D 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.

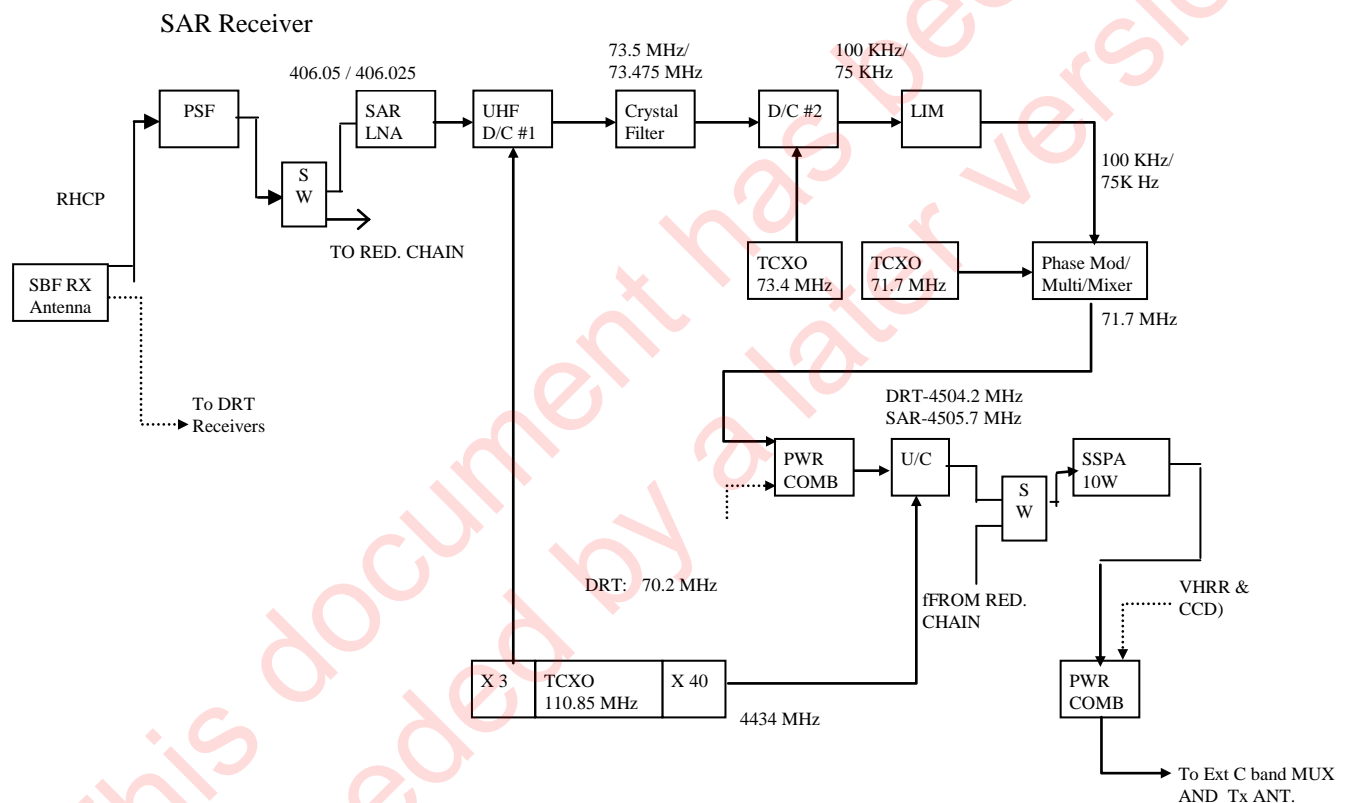


Figure 4.1: INSAT SAR / DRT Repeater Functional Block Diagram

406 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 73.5 MHz / 73.475 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 and an uplink signal at 406.025 MHz would appear at 75 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 71.7 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 from the modulator is filtered, combined with the DRT IF signal (70.2 MHz), up-converted to 4505.7 MHz and applied to a 10 Watt solid state power amplifier (SSPA). The composite DRT / SAR transponder signal is combined with the output from the VHRR and CCD payloads and passed to an extended C band multiplexer (MUX). Finally the signal is routed to an extended C band antenna which provides an EIRP of 4.0 dBW for INSAT 3A (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. The primary channel operates in the wide band mode and the redundant channel operates in the narrow band mode.

Table 4.1: INSAT Repeater Operating Modes

| Mode | Band Center Frequency (MHz) | Receiver 1 dB Bandwidth (kHz) |
|-------------|-----------------------------|-------------------------------|
| Narrow Band | 406.025 | 25 |
| 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.a and 4.2.b. This output spectrum, therefore, represents the case of maximum spectrum occupancy.

The received 406 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.

The narrow band mode (25 kHz bandwidth) frequency plan is such that a Cospas-Sarsat beacon signal received at 406.025 MHz becomes 75 kHz in the baseband spectrum.

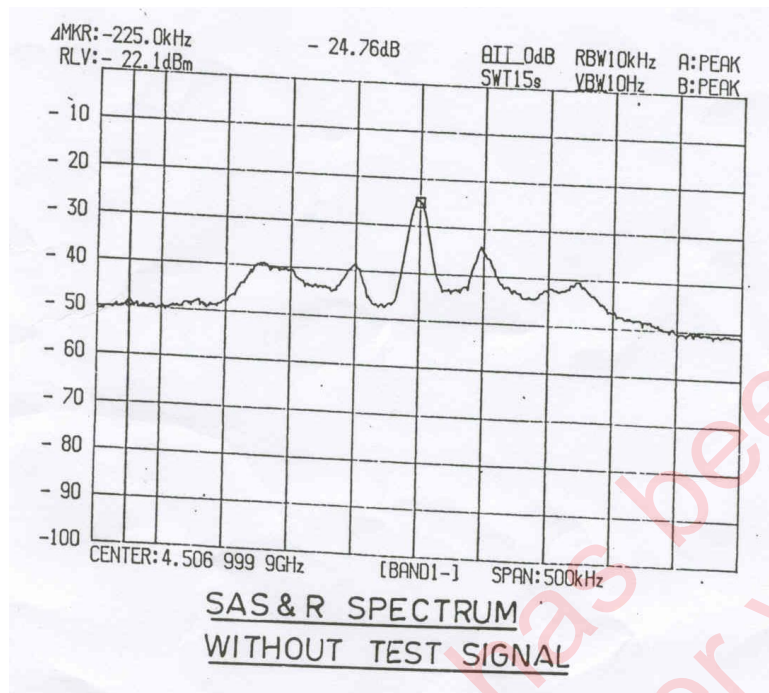


Figure 4.2a: INSAT Transmitter Output Spectral Occupancy With No Test Signal

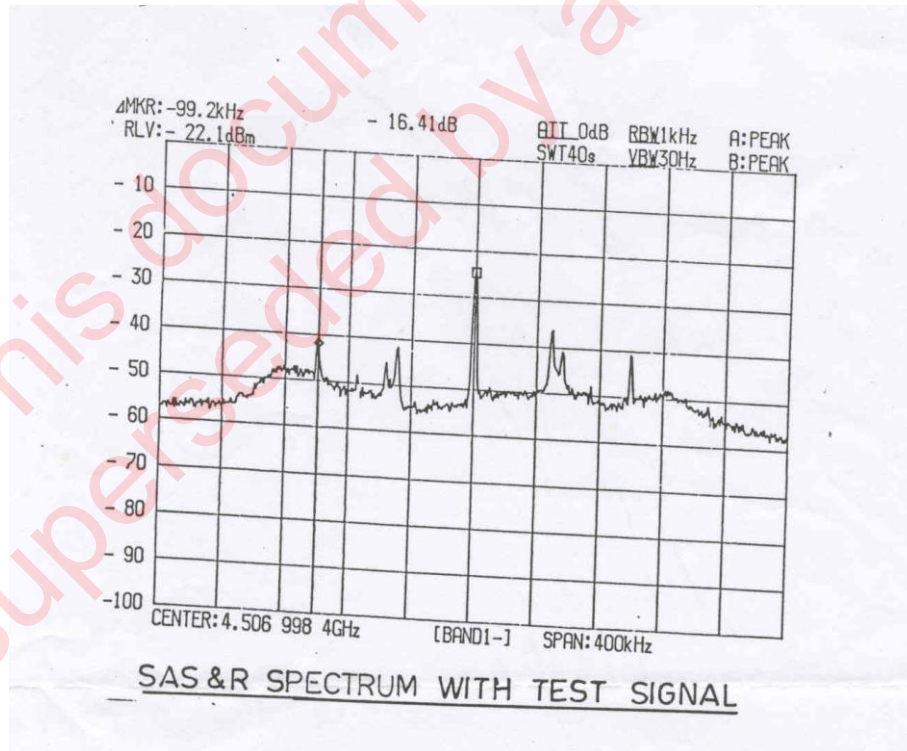


Figure 4.2b: INSAT Transmitter Output Spectral Occupancy With Test Signal

4.4 INSAT Repeater Coverage Area

The zero degree elevation angle coverage contours for the INSAT-3A is shown in Figure 4.3. The receive antennas are broad beam earth coverage types. The downlink antennas are directive beams that can be received in the Indian region.

4.5 INSAT Repeater Performance Parameters

The principal INSAT SAR repeater performance parameters 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 | MHz | 406.05 |
| Wide band mode band width | KHz | 80 |
| Narrow band mode center frequency | MHz | 406.025 |
| Narrow band mode band width | KHz | 25 |
| Antenna Type(UHF) | N/A | Short back fire(SBF) |
| Rx Antenna Polarization | N/A | RHCP |
| SBF Antenna Gain | dBi | 11 |
| UHF receive antenna axial ratio | dB | 3.0 |
| Receive coverage | N/A | Global |
| Receive Gain to Noise Temp Ratio (G/T) | db/K | -19.0 |
| Nominal Input Level | dBW | -173.1 |
| 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 | 4505.7 |
| Tx Antenna Polarization | N/A | Linear V |
| Transmit Antenna Input | dBm | 8.83 |
| Transmit Antenna Gain (EOC) | dB | 28.8 |
| EIRP (EOC at end of life) | dBW | 4.0 |
| Tx Antenna Beam Coverage | N/A | INDIA |
| SAR Signal Modulation | N/A | Phase modulation |
| Modulation Index (Nominal) | Radian | 1.0+/- 0.2 |
| Over all Frequency translation error (Over life time) | PPM | ±9.02 |

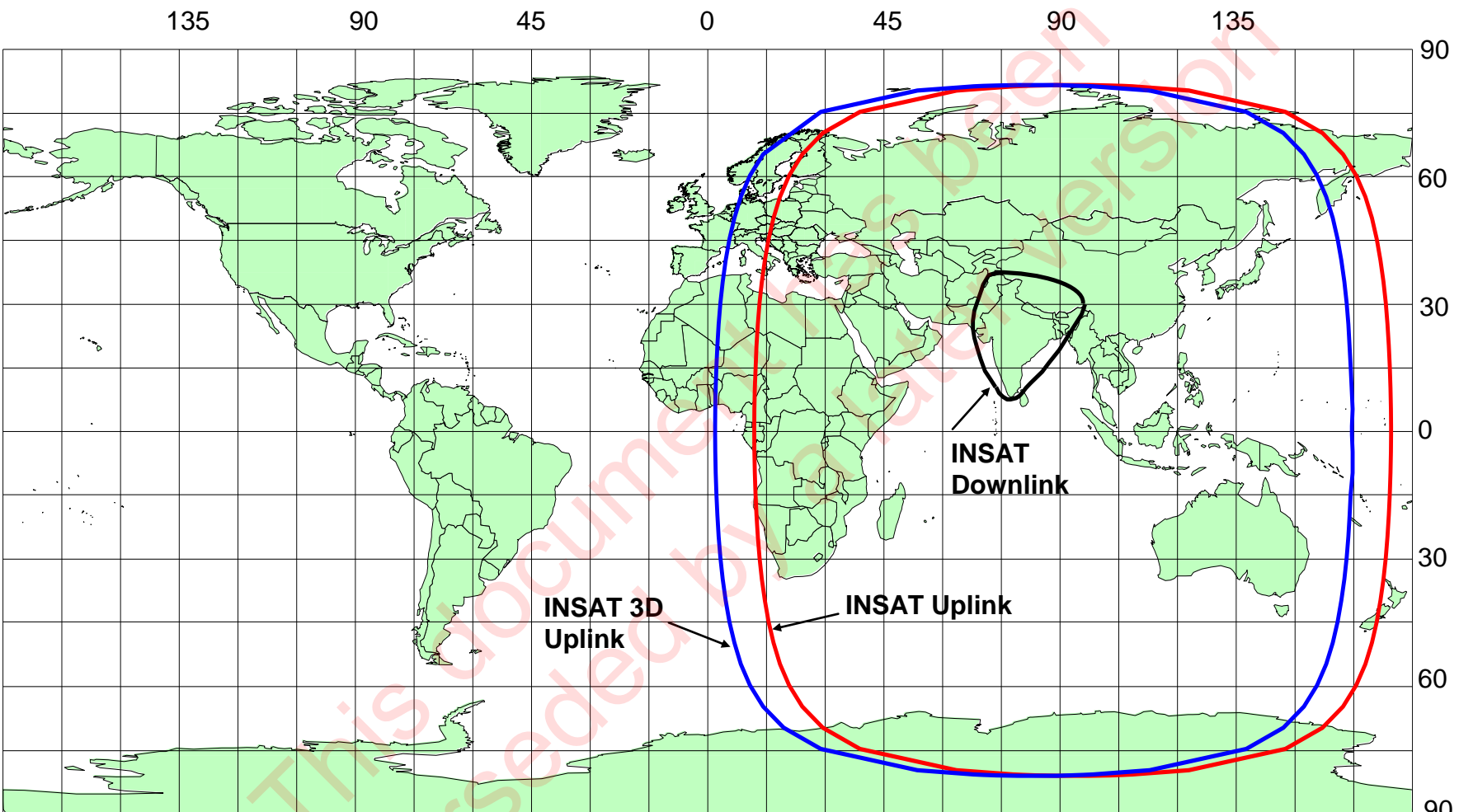


Figure 4.3: INSAT 3A/3D 0 Degree Uplink Elevation Angle Contour and Downlink Contour

4.6 INSAT SAR Antennas

The SAR receive antenna (SBF type) for INSAT satellites provide global coverage; the pattern is shown in Figure 4.4. The antenna is right hand circular polarized (RHCP) with an edge of coverage (EOC) gain of 11.0 dB. The receive antenna has a maximum axial ratio of 3 dB.

The INSAT extended C-Band transmit antenna is a directive antenna that provides coverage for the Indian region. The pattern is shown in Figure 4.5. The antenna is vertically polarized with an EOC gain of 28.8 dB.

Figure 4.4: INSAT 406.05 MHz Receive Antenna Pattern (TBS)

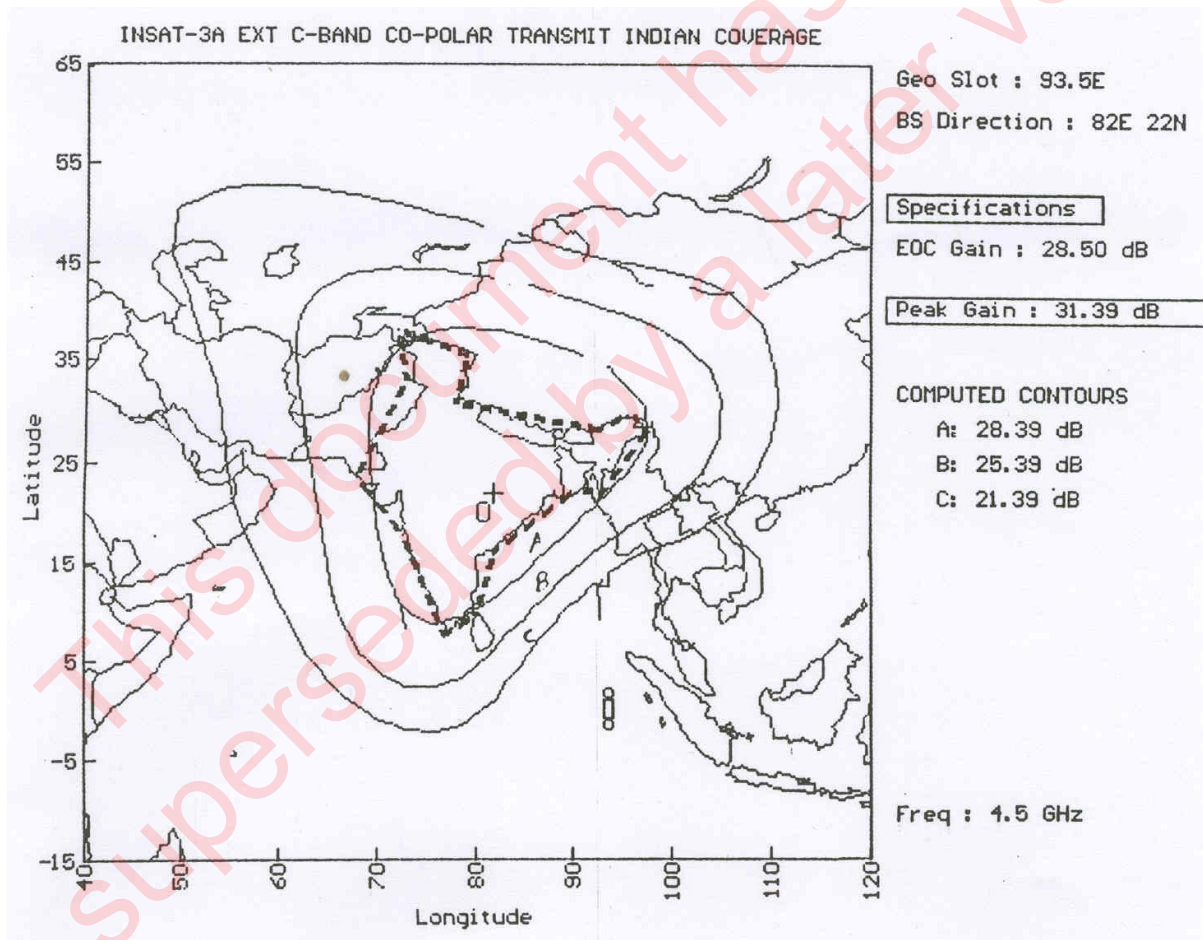


Figure 4.5: INSAT Transmit Antenna Pattern

-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 |

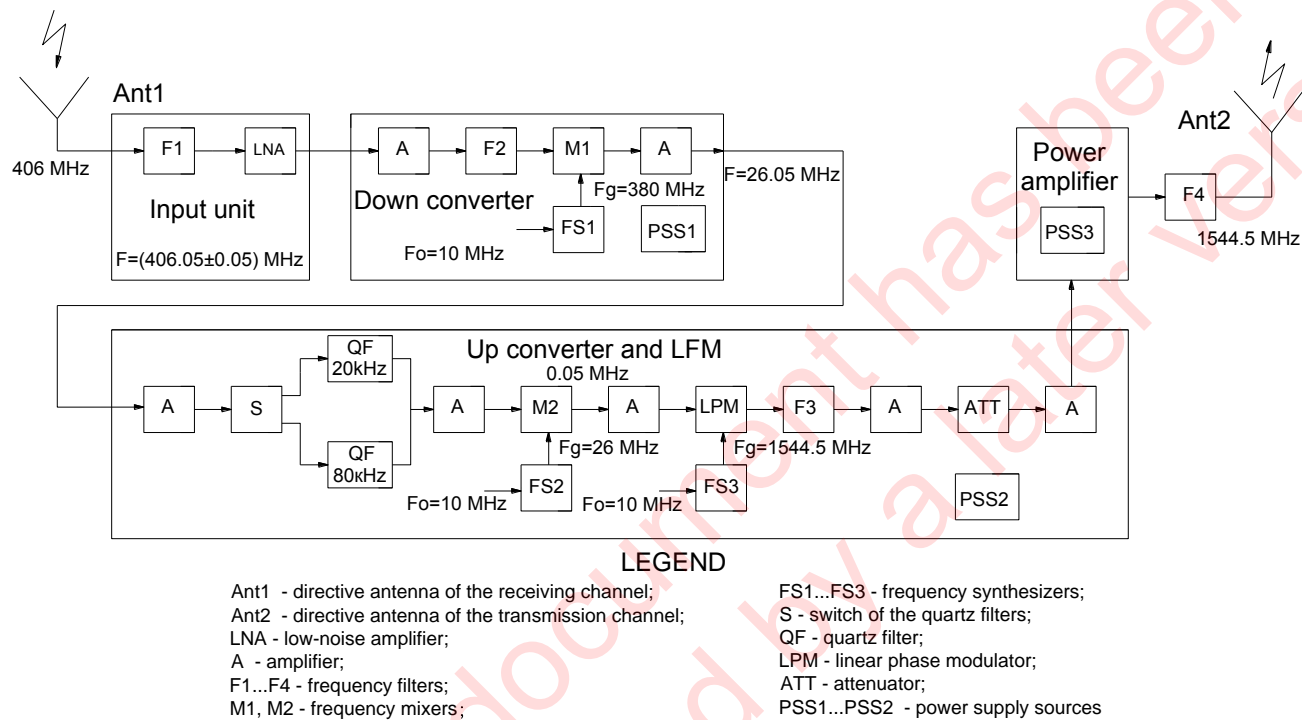


Figure 5.1: Electro-L SAR Functional Diagram

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.

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 5.2. The receive and transmit antennas are broad beam earth coverage types. Therefore, the coverage patterns in Figure 5.2 apply to both receive and transmit functions.

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 5.2 and 5.3. | 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) | μ s | ≤ 13 |
| 7. | Image Rejection | dB | 30 |
| 8. | Frequency Stability for 24h/10 years | dB | $\pm 2.5 \cdot 10^{-6}$ |

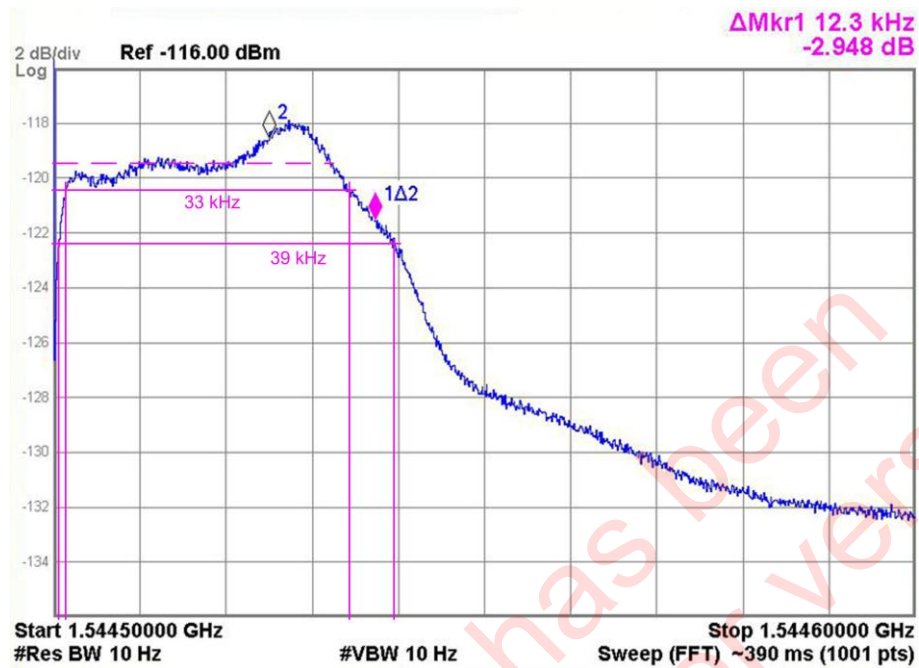


Figure 5.2: Electro-L1 SAR receiver bandpass filter amplitude-frequency response (repeater in NB mode)

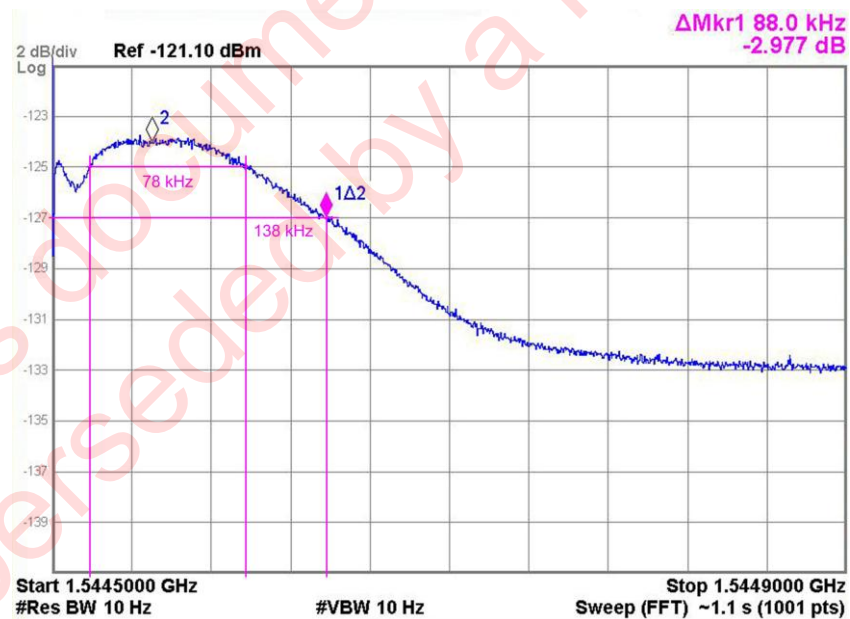


Figure 5.3: Electro-L1 SAR receiver bandpass filter amplitude-frequency response (repeater in WB mode)

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 | | $\pm 2.5 \cdot 10^{-7}$ |
| 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 ($\pm 9^\circ$ beamwidth) including line loss. The transmit antenna has a maximum axial ratio of 3 dB.

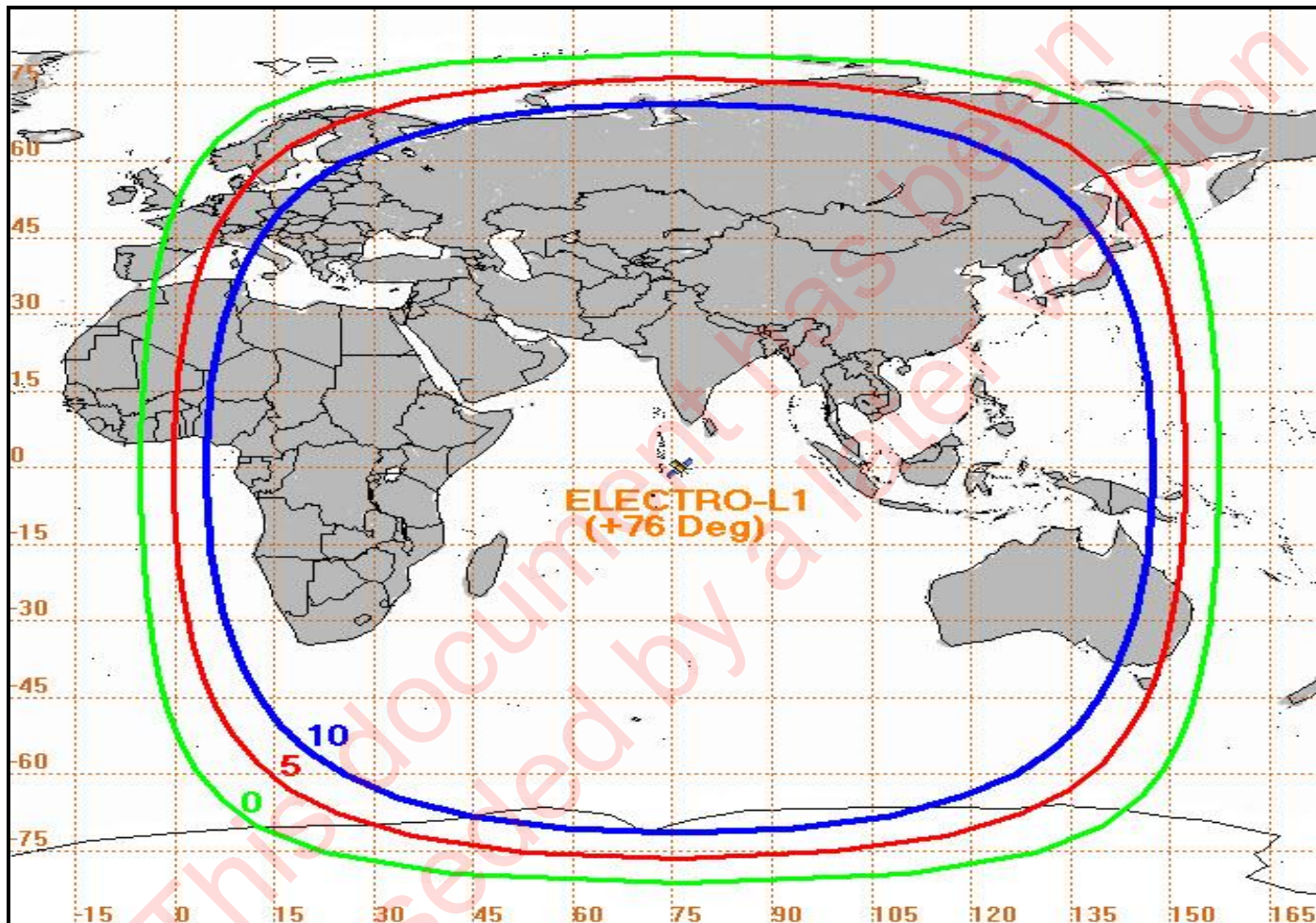


Figure 5.4: Electro-L1 0°, 5°, 10° Elevation Angle Coverage Contours

- 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.

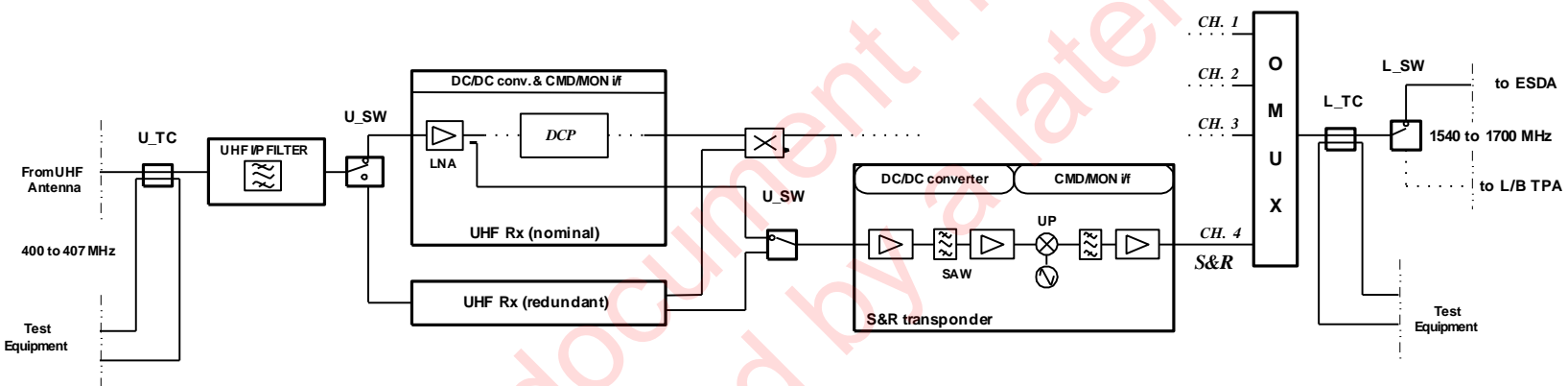


Figure 6.1: MSG Search and Rescue Repeater Functional Diagram

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 6.2a.

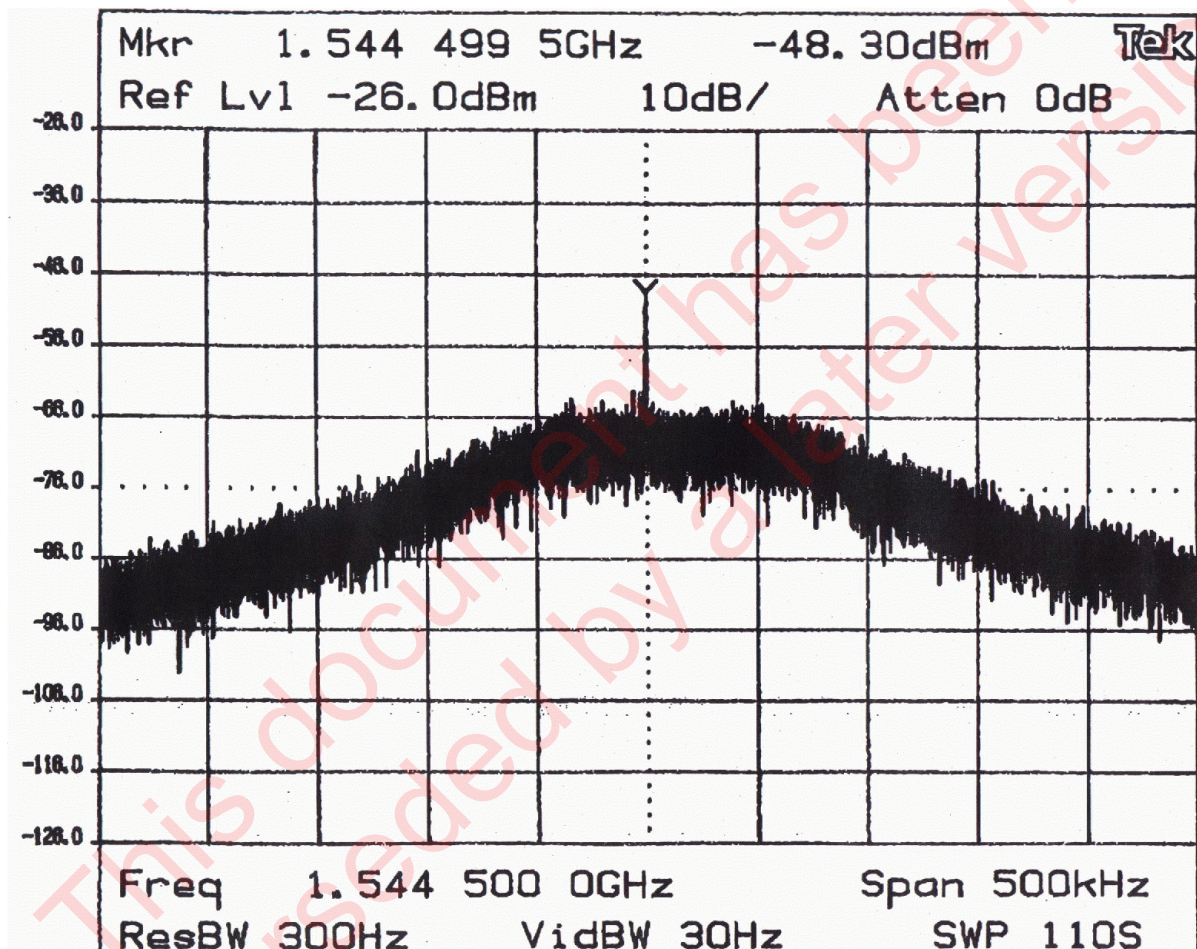


Figure 6.2a: MSG L-Band Transmitter Output Spectral Occupancy

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 6.2b) 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.

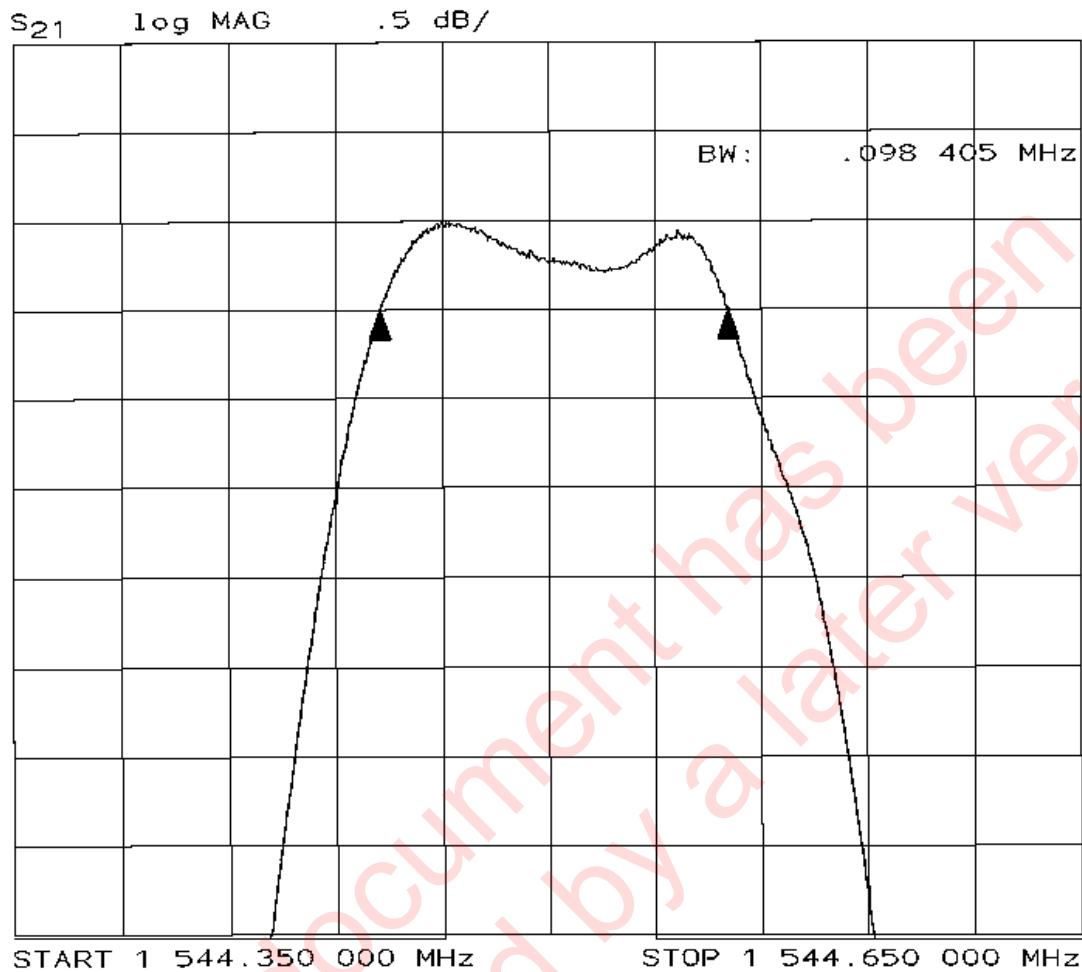


Figure 6.2b: Measured Pass-band of MSG Transponder

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 6.3) 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] |
| $f_o + 10\text{Hz}$ | -65 |
| $f_o + 100\text{Hz}$ | -83 |
| $f_o + 1\text{KHz}$ | -94 |
| $f_o + 10\text{KHz}$ | -96 |
| $f_o + 100\text{KHz}$ | -102 |

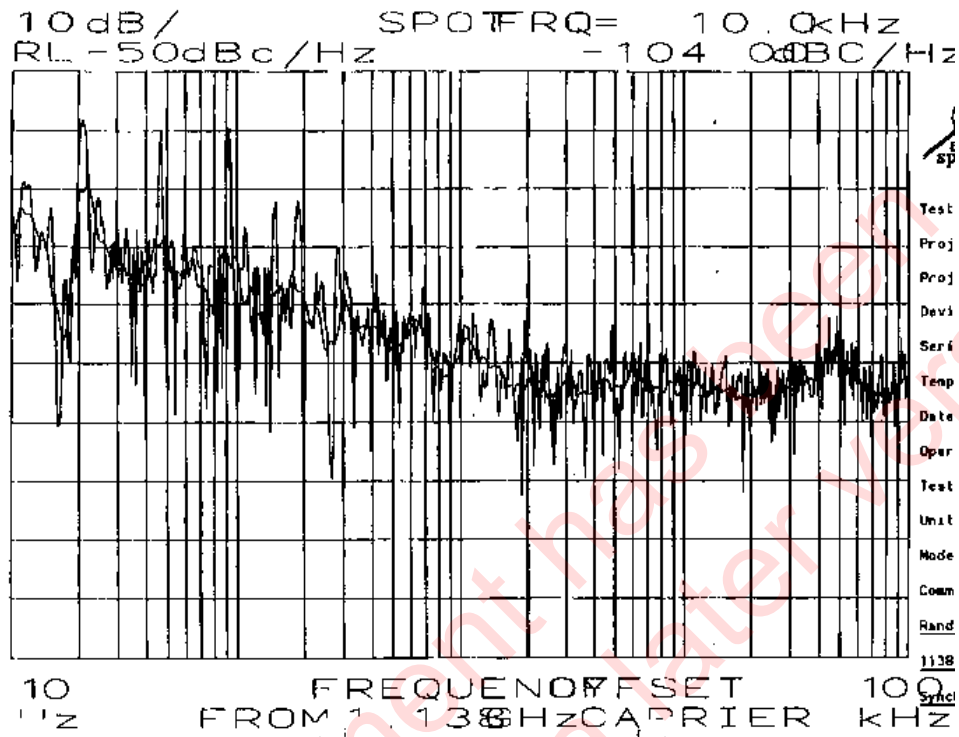


Figure 6.3: MSG Transmitter LO Phase Noise Spectrum Plot

6.4 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 6.4.

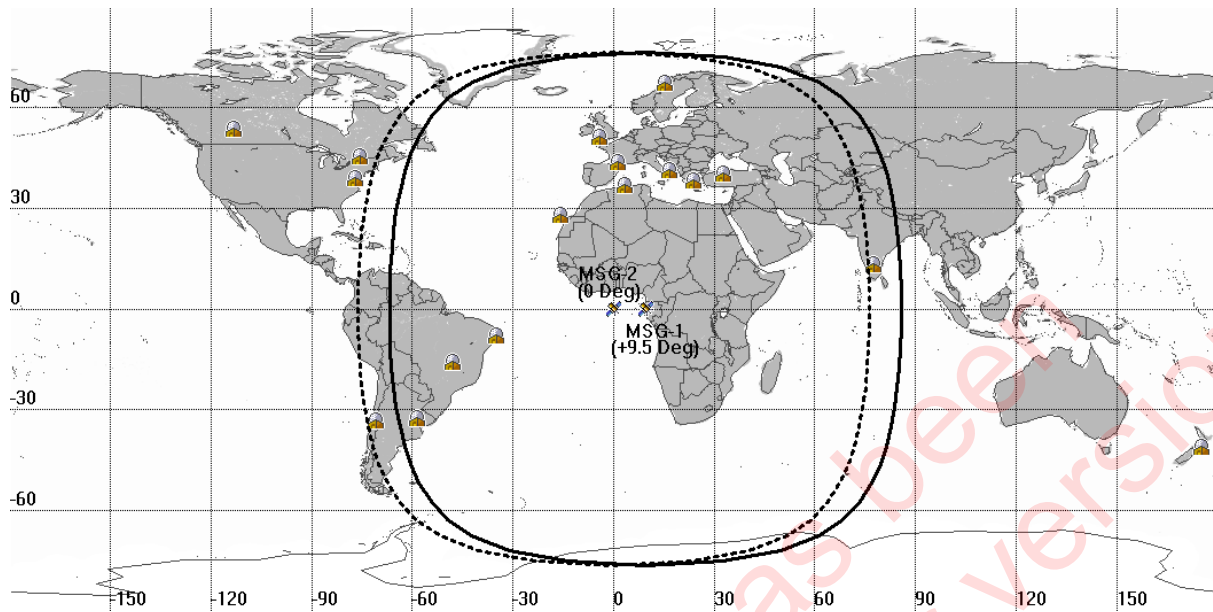


Figure 6.4: MSG 5° Elevation Angle Coverage Contour

6.5 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 ¹ | dBW | -176.9 |
| System Noise Temperature | K | 301 |
| Receive Antenna G/T | dB/K | -21.3 |
| Bandpass Characteristic | | |
| Specified Band | KHz | >60.0 |
| Measured 0.5dB-Band | | 100.0 |
| Noise-Equivalent Band (approx.) | | 180.0 |
| Dynamic Range ² | 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 ³ | | No AGC |
| Transponder Gain | dB | 148 ⁴ |
| 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 ⁵ | dBW | -19.0 |
| Modulation Type | | As uplink |
| Transmitter Nominal Modulation Index | | As uplink |

¹ 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.

² This is a transparent transponder. It is driven by noise so that dynamic range is less relevant.

³ The SAR transponder operates only in fixed-gain mode.

⁴ 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.

⁵ 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.

6.6 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.

6.6.1 MSG SAR Receive Antenna

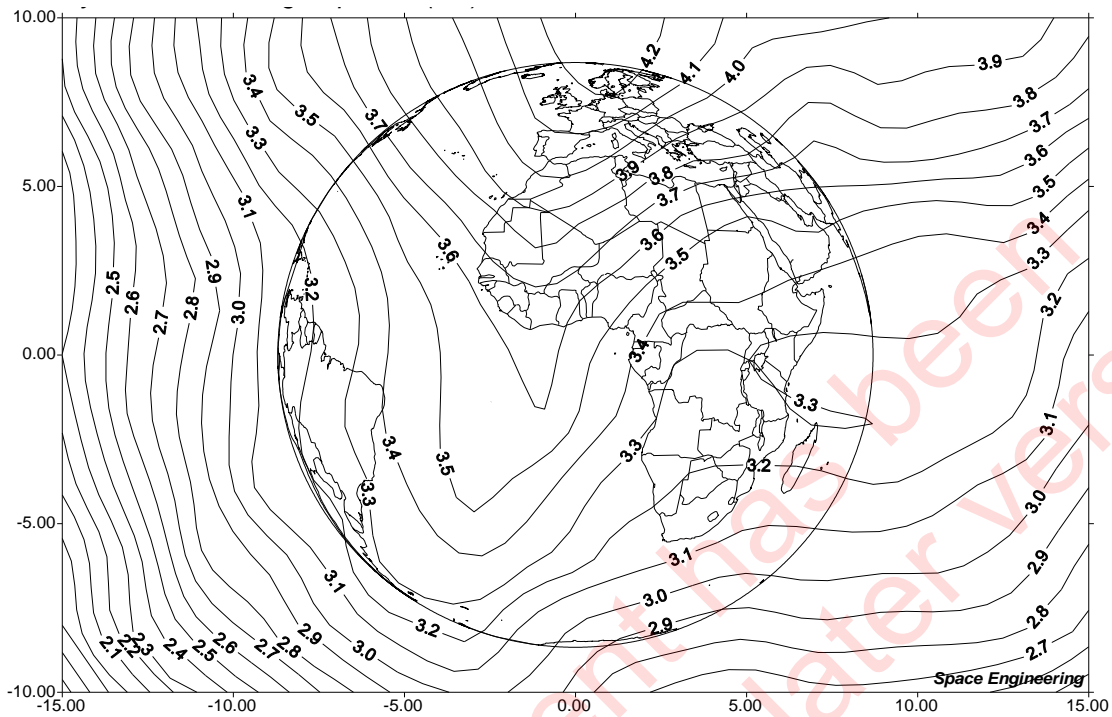
The MSG SAR instrument uses an electronically switched de-spun (ESDA) right hand circularly polarised receive antenna, with gain performance as depicted at Figure 6.5. The values provided in this figure represent the minimum dynamic gain over the coverage area, and with the satellite spin, the gain fluctuates 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.

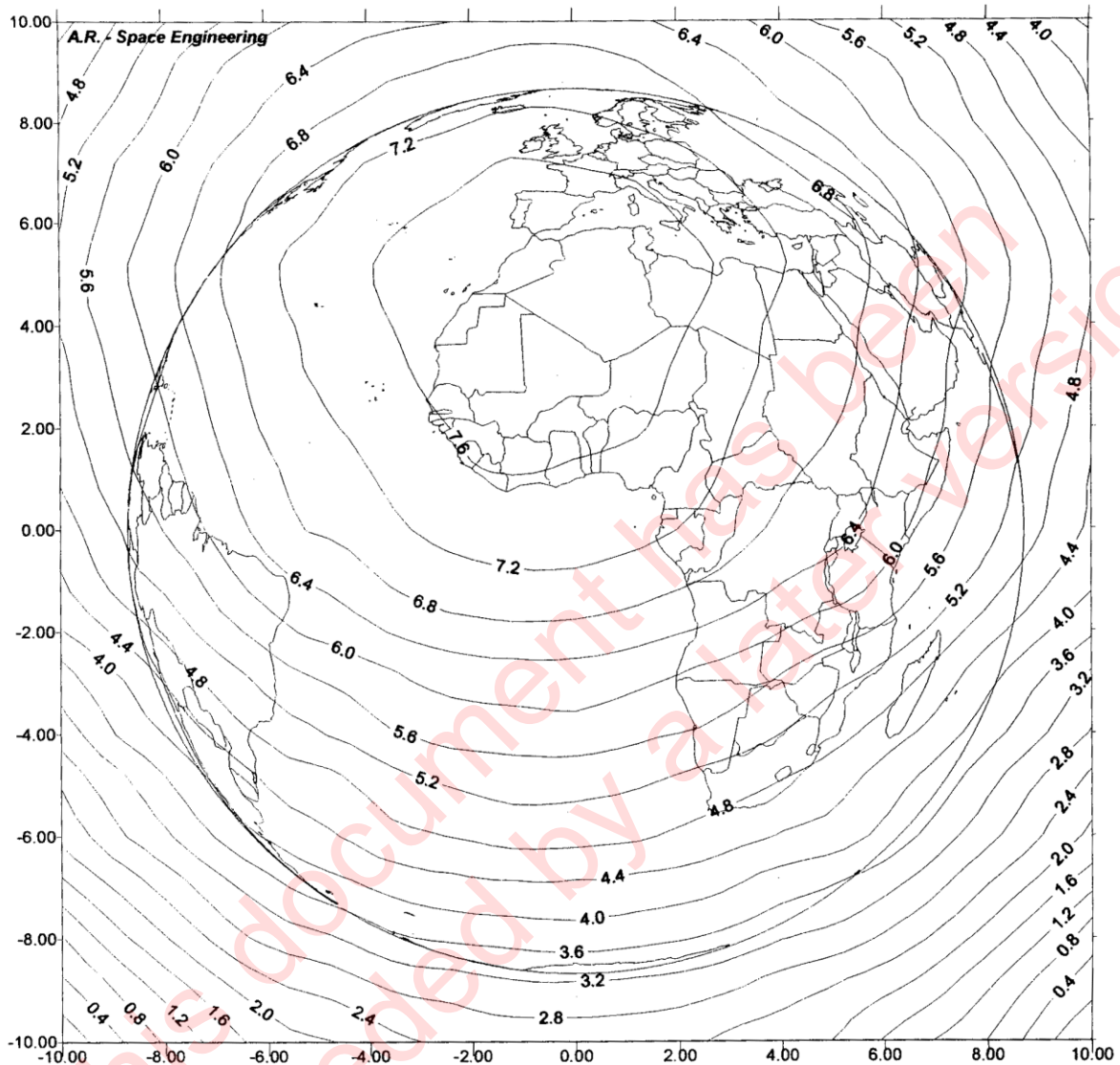
Both the gain and the polarisation loss are directly involved in the uplink quality, the worst case combination of the two effects has been estimated: $\min[(\text{Gain} - \text{Polarisation Loss})]$. This occurs at a point in the west of the coverage where $G = 3.45$ dBi and $\text{XPD} = 9$ dB (i.e. 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.

6.6.2 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 6.6. 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 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 6.5: MSG SAR Receive Antenna Pattern

Note: 0.3 dB to be added for the effect of the spacecraft body.

Figure 6.6: MSG SAR Transmit Antenna Pattern

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

- END OF SECTION 6 -

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