RF Performance Optimization of S-band Ship Borne Terminal (SBT) Antenna for Satellite Tracking Applications

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***Abstract* – In this paper the RF characterization and performance optimization o f4.6m S-band prime focal parabolic reflector of ship borne terminal (SBT) is discussed. General the RF characterization of the ISRO antenna was performed by measuring pattern, beam width, side-lobe level (SLL), cross polarity isolation and gain in Compact Antenna Test Facility (CATF), ISRO, Bangalore. Further performance improvement was done by optimizing the sub reflector location of the antenna feed. With this optimization the performance of the SBT was improved and the measured results were showing good match with the simulated results. The optimized results obtained from the characterization like pattern measurements, null depth measurements and gain measurements also presented at the end of the paper.**

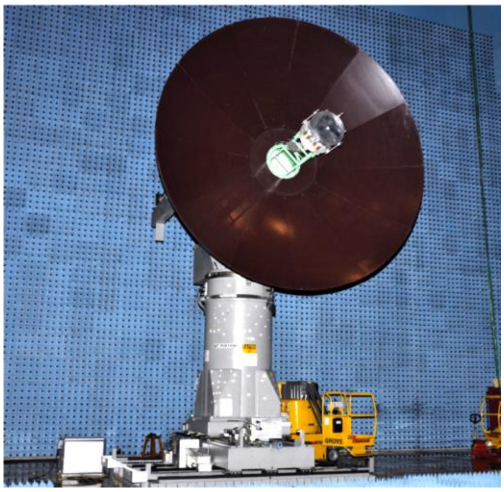
Keywords: CATF, Compact Range, SBT, Antenna Measurement, CCR, ISRO, XPI

I. INTRODUCTION

It is a standard practice to perform RF performance optimization of the tracking ground station antenna of SBT before taking it into service. ISRO has developed an SBT in S-band for tracking an orbiting satellite at various ship borne terminal based on the mission requirement. Before inducting it into service it was tested for CATF for its RF performance optimization and characterization. A detailed test methodology and procedure was developed to optimize its various parameters viz radiation pattern, Side lobe level, beam width, Cross polarization isolation (XPI) and peak gain.

II. CATF: OVERVIEW

The CATF (refer Fig. 1) produces plane waves leading to formation of quiet zone using doubly curved dual reflectors. This region is then used to test the antenna at both sub-system and satellite level.



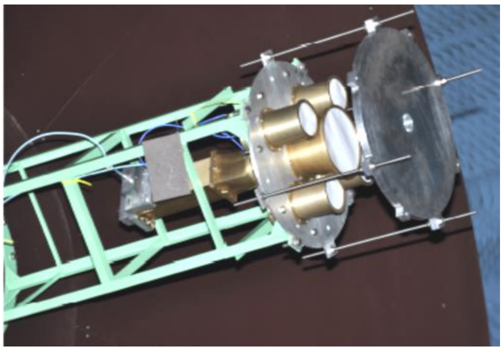


Figure 1SBT Antenna in CATF Chamber

spherical waves coming from a range feed are collimated by reflectors to create a quiet zone (QZ) having dimensions (WxHxD) of 5.5 m x 5.0 m x 8.0 m. Fig. 2 shows the creation of quite zone and Nominal Plane-wave axis (NPA) of the facility. The measured plane wave performance is summarized as: (1) Amplitude Taper < 1dB (2) Phase Taper <5 deg (3) Cross-polarization < -40dB (4) Shielding Effectiveness > 80 dB.

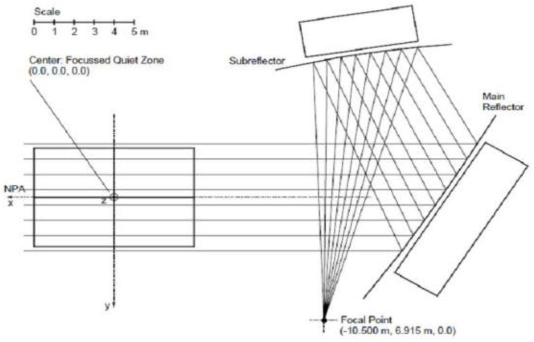


Figure 2 Diagram of quite Zone Creation at CATF

III. RF CHARACTERIZATION

(a) Radiation pattern measurements:

The radiation pattern measurement of the SBT reflector antenna has been carried out with the DUT in receiving mode

- The prime azimuth and Elevation cuts of±10deg with step size of 0.025 deg were carried out for all the axis frequencies with each polarization @ El= $0^0$and Az=0^0 respectively.
- Step size was intelligently selected so that the accuracy of the measurement will be maintained as well as positioner speed should be optimum. Scan angles of ±10^0 were chosen as per the measurement requirements.
- Channel balance and linear to circular conversion

(b) Gain Measurements:

Gain measurement of CATF is carried out using a power measurement method (PPM) using a two channel power meter. For this, power measurement the CCR feed port and at the DUT antenna port were measured then using Friis transmission equation DUT antenna's (test antenna) gain is calculated. The gain measurements were carried for both polarizations.

IV. RFPERFORMANCE OPTIMIZATION

(a) Pattern optimization by the sub reflector adjustment

To achieve the desired performance the sub reflector was moved towards feed in forward and (z-axis) backward directions w.r.t. existing value of -10 mm (explained in Fig. 3) in the steps of ±10mm. The movement of feed in other two orthogonal directions was not showing any improvement in the performance of null depth and XPI, however the full pattern was shifting according to the location of feed w.r.t. reflector axis. The step size was limited due to mechanical spacing limits of bracket assembly.

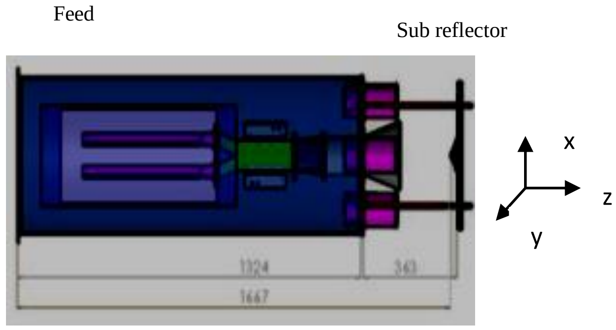


Fig.3 Sub reflector optimization (z- direction movement of sub reflector towards feed)

But the sub reflector movement in z-direction gives the optimized pattern parameters. Fig. 4 shows the variation in null depth and XPI with varying sub reflector position. From the sub reflector location optimization the better null depth and XPI was obtained at -30mm of separation between sub reflector aperture to feed aperture.

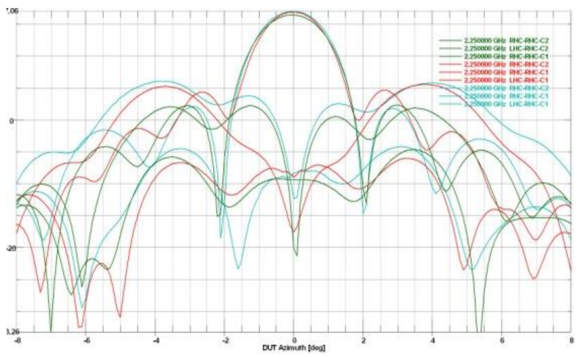


Fig.4Azimuth patterns comparison at 2.25 GHz (20mm,-30mm, -20mm)

(b) Gain Optimization by the sub reflector adjustment

To achieve better gain, the gain optimization using sub reflector adjustment towards feed in forward and backward directions w.r.t initial existing value of -10mm (explained in Fig. 3) in the steps of ±10mm. The gain variations observed in different locations of sub reflector towards and away from the feed. Sub reflector moved towards feed gain improvement observed and sub reflector away from feed gain reduction observed. Sub reflector adjustment at -30mm optimized high output power level observed as shown in table 1.

Table 1 Gain optimization using sub reflector adjustment

Subreflector adjustment (mm)	Freq (GHz)	Ref I/P Power (dBm)	Test O/P Power (dBm)
-10	2.25	-27.45	-12.59
-20	2.25	-27.45	-12.56
-30	**2.25**	**-27.45**	**-12.47**
-40	2.25	-27.45	-12.60
+20	2.25	-27.45	-12.82

(c) Transmit Radiation Pattern Measurement Result

After optimizing the null depth and XPI parameters, all radiation patterns were measured at -30mm location. A typical plot of Azimuth cut with RHCP & RHCP polarization at frequency 2.07 GHz is presented here. Rest all plots of various other frequencies are showing similar behaviour. But due to paucity of space those are not included in this paper.

From Fig. 5 & 6 it is clear that measured XPI is -28.75 dB in both the polarizations. Further Null depth is better than 30 dB.

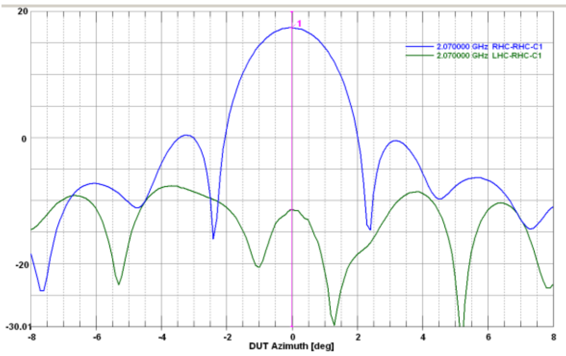


Fig.5 Azimuth cut at 2.07 GHz (RHCP)

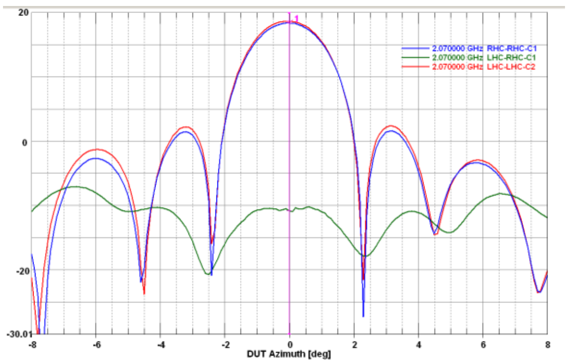


Fig.6 Azimuth cut at 2.07 GHz (LHCP)

Fig 7 and 8 shows Elevation cut plot @ 2.07 GHz and are showing similar behaviour in X-pol and Null depth performance.

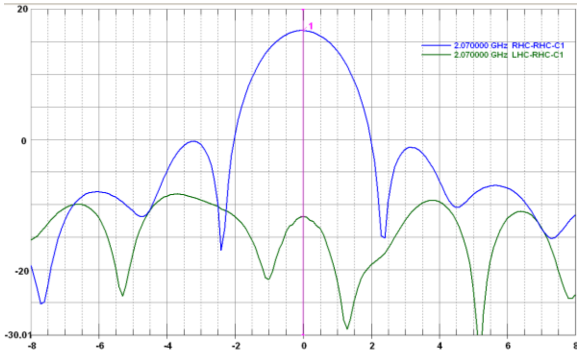


Fig.7 Elevation cut at 2.07 GHz (RHCP)

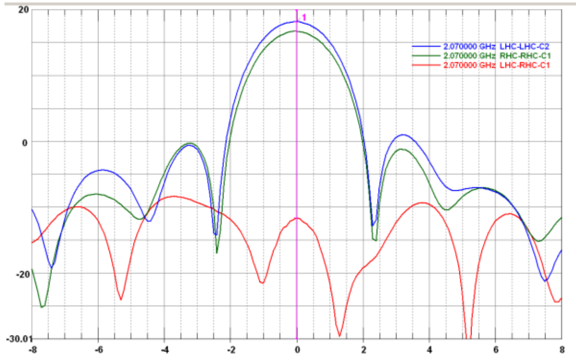


Fig.8 Elevation cut at 2.07 GHz (LHCP)

(c) Receive radiation pattern measurement result:

After optimizing the Null depth parameter, all radiation patterns were measured at -30mm location. A typical plot of Azimuth cut with RHCP & LHCP polarization at frequency 2.25GHz is presented here. Rest all plots of various other frequencies are showing similar behaviour. But due to paucity of space those are not included in this paper.

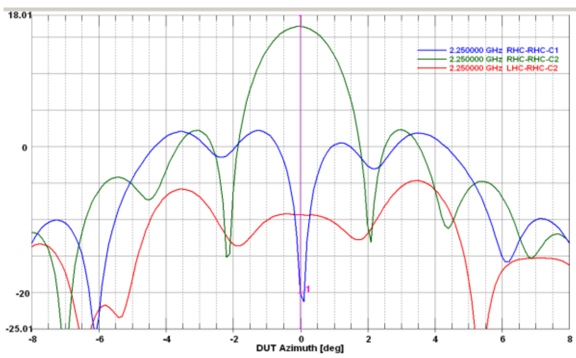


Fig9Azimuth cut at 2.25GHz (RHCP)

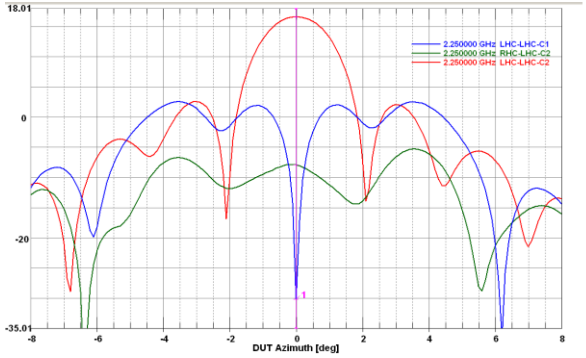


Fig.10Azimuth cut at 2.25GHz (LHCP)

From Fig. 9&10 it is clear that the measured XPI is better than -25 dB in both the polarizations. Further Null depth is -36.55 dB.

Fig 11& 12 shows all El-cut plot @ 2.25 GHz and are showing similar behaviour in X-pol and Null depth performance.

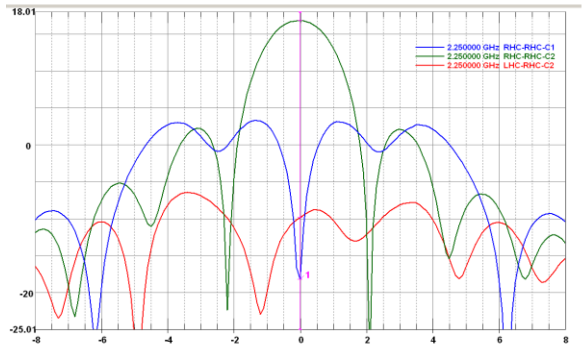


Fig.11 Elevation cut at 2.25GHz (RHCP)

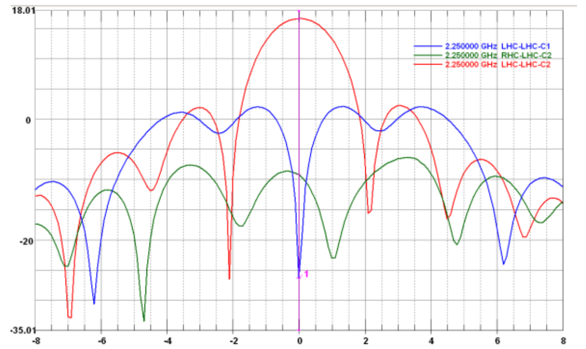


Fig.12 Elevation cut at 2.25GHz (LHCP)

(d) Results of gain measurement:

The RF optimizations were carried out by optimizing the location of the sub reflector for maximizing gains. The measured values of transmit and receive gain for all the frequencies with RHCP & LHCP polarizations are shown in Tables 2& 3. From Tables 2& 3 it is clear that there is an excellent agreement with simulated and measured gain values.

Table 2Gain Measurement Results of Transmit freq.

Frequency (GHz)	Simulated Gain(dBi)	Gain in dBi	
		RHCP	LHCP
2.025	37.61	37.43	37.33
2.07	38.20	38.06	37.91
2.12	37.99	37.54	37.68

Table 3 Gain Measurement Results of Receive freq.

Frequency (GHz)	Simulated Gain(dBi)	Gain in dBi	
		RHCP	LHCP
2.2	38.43	38.16	38.16
2.25	37.82	37.57	37.51
2.3	37.95	37.85	37.54

IX. CONCLUSON

A systematic novel test procedure was developed for the RF optimization and characterization of the S-band 4.6 m reflector ship borne antenna terminal. Performance optimization was achieved by determining the optimum location of the sub reflector towards feed. This resulted in overall improvement in meeting antenna performance w.r.t. null depth, XPI and gain. Further CATF measured results can be taken as a prime reference for ground station operation.

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