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Design and Testing of Wide Band Flat Scalar Ring Horn Antenna System for Ground Station Receiver Applications

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Abstract: Three different types of horn antenna systems such as pyramidal horn, conical horn and flat scalar ring horn antennas are designed, compared and finally the suitable antenna is selected for the present application at L-Band and S- Band region. The designed antenna has linear polarization, small size, light weight and multi path rejection. The three different types of antennas are simulated with commercially available software known as Ansoft HFSS, detailed design procedure with dimensions is presented and performance results are discussed. The proposed antenna gives decent gain over operating range of L and S frequency bands with wide 3-dB bandwidth.

Keywords: HFSS, horn antenna, flat scalar ring, multipath rejection.

I .INTRODUCTION

One of the simplest and probably the most widely used microwave antenna is the horn. The horn is widely used as a feeder (called feed horns) for larger antenna structures such as parabolic antenna, as standard calibration antennas to measure the gain of other antennas [2]. Horns are widely used as antennas at UHF and microwave frequencies, above 300MHz [1]. Their advantages are moderate directivity; they can operate over a wide range of frequencies, low standing wave ratio (SWR), broad bandwidth and simple construction and adjustment [3].
Generally Ground Station receiving antenna is a parabolic reflector with horn feed is used. These Ground Station receiving antennas are used for the applications of weather and climate research. The system should be capable of receiving, archiving, displaying and processing the digital data from GEO satellites in L-Band for the applications like weather and climate studies.

Types of Horn Antennas and their applications:

There are several types of horn antennas, they are Pyramidal horn antenna, sectoral horn antenna (E-plane and H-plane horns), Conical horn antenna, Exponential horn antenna and Corrugated horn antenna (also include scalar feed) as shown in fig1..

Horn antennas are used in many areas; not only because they are convenient, but because they possess a number of feature that make them ideal in many applications [2]. One of the main applications of horn microwave antennas is:

Feeds for parabolic reflector antennas: The horn antenna often known as a feed horn in this application possesses sufficient directivity to illuminate the reflector sufficiently evenly without too much spillage over the edge of the dish.

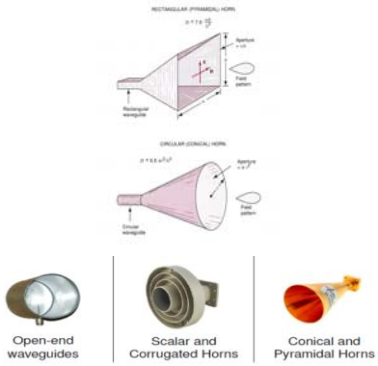

Fig 1: Types of horn antennas pyramidal & conical (on left side), scalar ring in middle (on right side).

The use of the horn antenna also minimizes the spurious responses of the parabolic reflector antenna to signals that are not in the main lobe [2].

II. HORN ANTENNA SYSTEM DESIGN

a) Pyramidal horn Antenna

A horn antenna with the horn in the shape of a four-sided pyramid, with a rectangular cross section. They are a common type, used with rectangular waveguides, and radiate linearly polarized radio waves [5].Pyramidal Horn is the best horn as it has equal radiation patterns in both E-plane and H-plane along with its high gain and directivity.
The Pyramidal Horn Antenna was designed using advance EM simulation software and soft HFSS with waveguide dimensions of a=19.56cm and b=9.78cm, waveguide length of L=18.14cm, Horn dimensions of Horn dimensions a'= 32.66cm and b'=25.4cm, horn Flare

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Length FL=54.43cm and wall thickness t=0.636cm. HFSS uses Finite Element Method as analysis & solution to Electromagnetic problems by developing technologies [7].

The geometrical 3D view of designed Pyramidal Horn Antenna in HFSS is shown below in fig.2 It is very important to remember that the boundaries for the "air-box" and the "ground plane" have been set as an ideal propagation space and a perfect electric conductor, respectively [9].

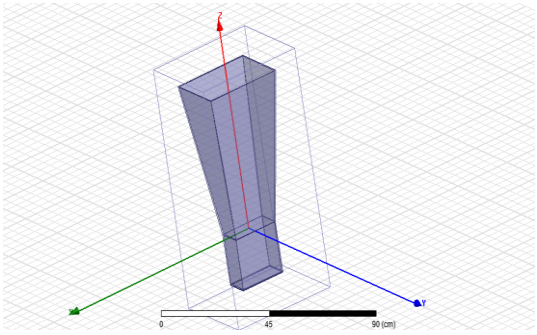

Fig 2: 3D view of Pyramidal Horn in HFSS

Results and Discussion

There are certain parameters which verify the success of antenna design as when measurement results match simulation analysis well such as gain, directivity, polarization, impedance matching, beam width, front lobe to side lobe ratios and many more[7]. The first slop return loss of the pyramidal horn antenna versus frequency is -32.93dB at 1.36GHz and the second slop return loss of the pyramidal horn antenna versus frequency is -29.75dB at 1.60GHz is shown in Fig.3

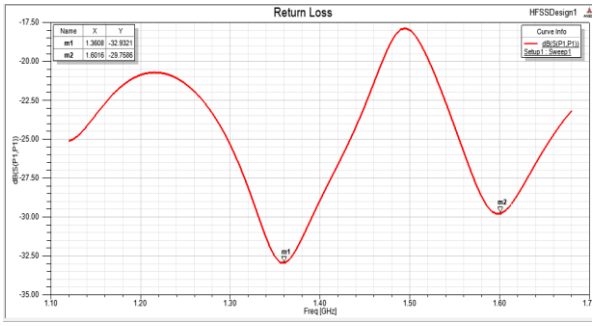

Fig.3 Return loss $|s_{11}|$ db over frequency range

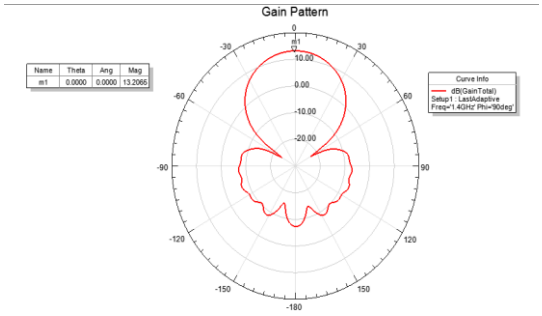

Fig.4 Radiation pattern of the antenna in HFSS

The Radiation pattern for the pyramidal horn antenna design and its Gain 13.2dB is shown in Fig.4.
The Radiation pattern for the pyramidal horn antenna design in 3D is shown in Fig.5. HFSS has the capability to calculate and plot a 3D image depicting the real beam of the gain [9].

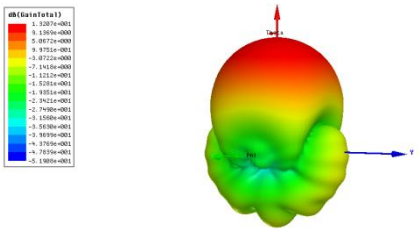

Fig.5 3D Radiation pattern of the antenna in HFSS

b) Conical Horn Antenna

Another very practical microwave antenna is the conical horn, the feed of a conical horn is often a circular waveguide. The conical horn antenna has a circular cross section and is seen less frequently than the rectangular version [4]. The Conical Horn Antenna was designed by using a soft HFSS software with circular waveguide dimensions of waveguide diameter a=20cm and waveguide length L=20cm, Horn dimensions of Horn radius a'= 28cm and horn Flare Length FL=40cm and wall thickness t=0.4cm. The geometrical 3D view of designed Conical Horn Antenna in HFSS is shown below in fig.6

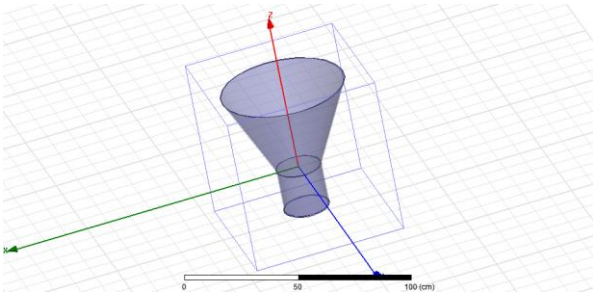

Fig 6: 3D view of Conical Horn in HFSS

Results and Discussion

The first slop return loss of the conical horn antenna versus frequency is -37.72dB at 1.32GHz and the second slop return loss of the pyramidal horn antenna versus frequency is -35.30dB at 1.57GHz is shown in Fig.7

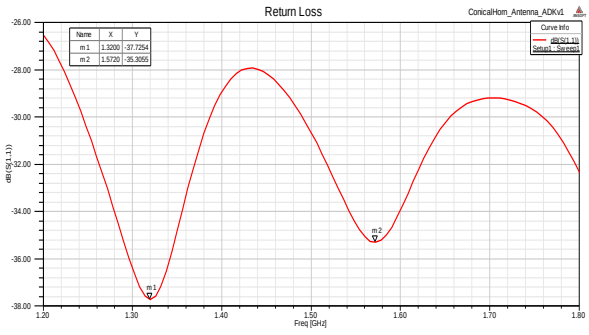

Fig.7 Return loss |s11| db over frequency range

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The Radiation pattern for the pyramidal horn antenna design and its Gain 16.89dB is shown in Fig.8

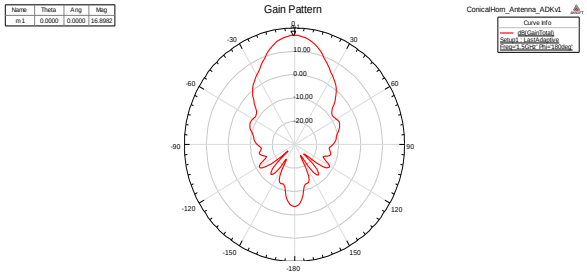

Fig.8 Radiation pattern of the antenna in HFSS

The Radiation pattern for the conical horn antenna design in 3D is shown in Fig.9. HFSS has the capability to calculate and plot a 3D image depicting the real beam of the gain [9].

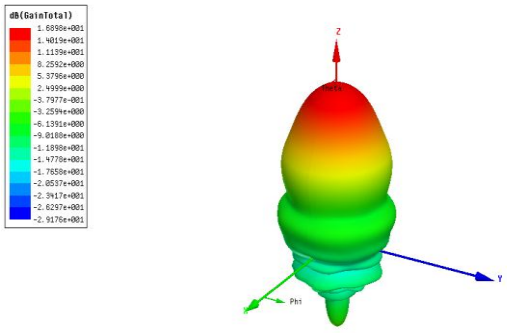

Fig.9 3D Radiation pattern of the antenna in HFSS

c) Flat Scalar Ring Horn Antenna

Scalar ring is one type of horn antenna system and the concentric metallic rings on a scalar-ring deflect the signals arriving at sharp angles (from the fringes of the dish, outside the dish etc.,) away from the mouth of the feedhorn. Signals arriving at sharp angles are mostly bad, and contribute to noise. Good signals come only from the non-peripheral portions of the dish [8].

The Flat Scalar Ring Horn Antenna was also designed by using advance EM simulation software Ansoft HFSS with circular waveguide dimensions of waveguide diameter a=15cm and waveguide length L=18.5cm, the scalar ring dimensions of scalar ring radius a'= 15cm and scalar ring Length SRL=5cm and wall thickness t=0.2cm.

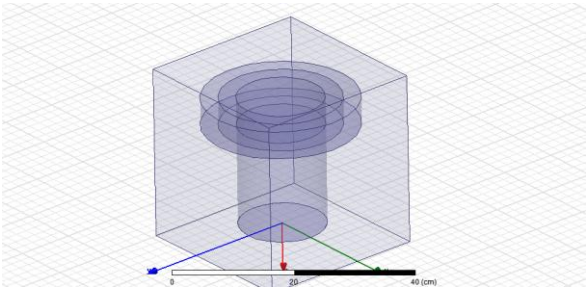

Fig 10: 3D view of Flat Scalar Ring Horn in HFSS

The first scalar ring diameter d1=21cm and scalar ring height h1=5cm, second scalar ring diameter r2=27cm and scalar ring height h2=5cm.The geometrical 3D view of designed Flat Scalar Ring Horn Antenna in HFSS is shown below in fig.10

Results and Discussion

The return loss of the first curve of Flat Scalar Ring horn antenna is -25.64dB at 1.39GHz, return loss of the second curve indicates-15.86dB at 2.15GHz and third return loss curve indicates -13.83dB at 2.91GHz is shown in

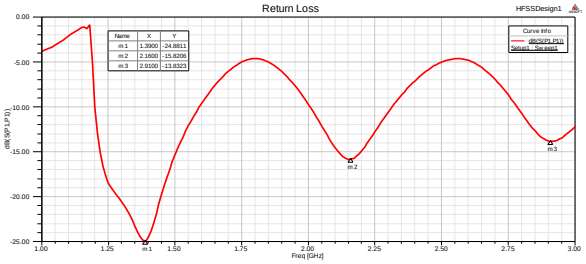

Fig.11 Return loss $|s_{11}|$ db over frequency range

The Radiation pattern for the Flat Scalar Ring horn antenna design and its rE Total is about 23.7282dB is shown in Fig.12

The Radiation pattern for the flat scalar ring horn antenna design in 3D is shown in Fig.13. HFSS has the capability to calculate and plot a 3D image depicting the real beam of the gain [9].

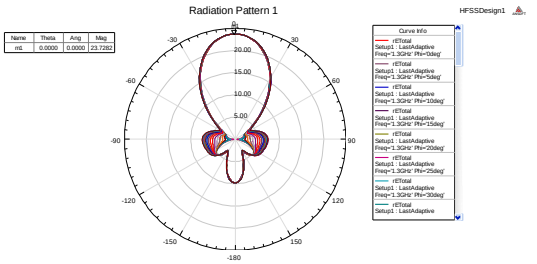

Fig.12 Radiation pattern of the antenna in HFSS

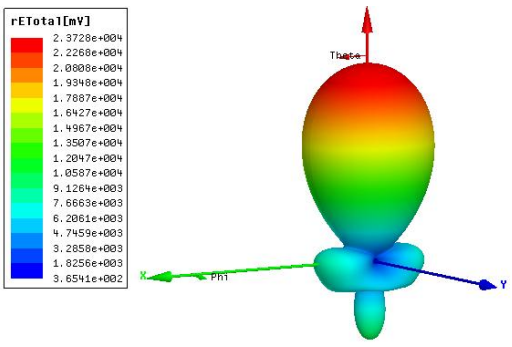

Fig.13 3D Radiation pattern of the antenna in HFSS

The Gain in Total for the proposed horn antenna was calculated and it is around 9.46dBi as shown in fig.14.

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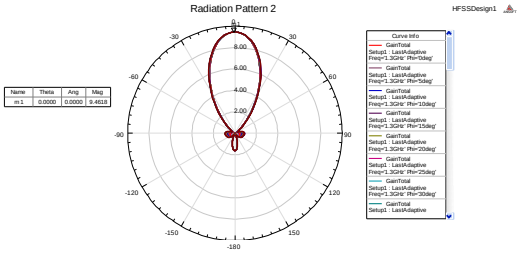


Fig.14 Radiation pattern for Gain Total in HFSS

The Gain Total Radiation pattern for the flat scalar ring horn antenna design in 3D is shown in Fig.15.

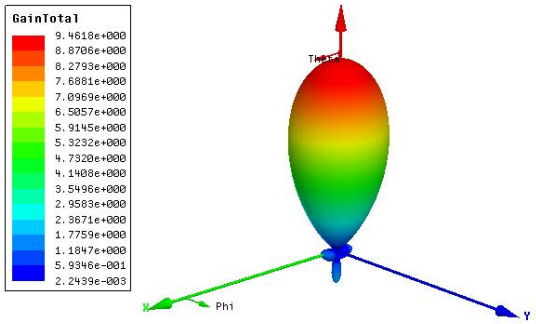


Fig.15 3D Gain Total Radiation pattern in HFSS

III. COMPARISON OF HORN ANTENNA SYSTEMS

Here the three-types of horn antenna systems i.e Pyramidal, Conical and flat Scalar Ring horn feeds are compared based on their simulated results.

Comparison Table:

S.No	Parameter	Pyramidal horn antenna	Conical horn antenna	Flat Scalar Ring Feed horn antenna (proposed model)
1	Return Loss in dB	-32.93dB @ 1.36GHz -29.73dB @ 1.6GHz	-37.72dB @ 1.32GHz -35.30dB @ 1.57GHz	-25.64dB @ 1.39GHz -15.86dB @ 2.15GHz
2	Gain in dB	13.2065	16.8982	9.7458
3	Frequency Band of operation	L-Band	L-Band	L-Band & C-Band
4	3dB-Bandwidth	40 MHz	60 MHz	90 MHz
5	Size of the Design	72.57cm	60cm	23.5cm

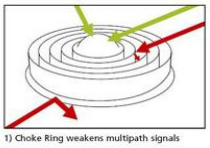
IV. ADVANTAGES AND DISADVANTAGES OF PROPOSED HORN ANTENNA SYSTEM

Advantages:

1. Proposed model can be operated in two frequency bands(L-Band and C-Band)
2. Wider 3-dB bandwidth
3. Overall size of the proposed model is small i.e 23.5cm
4. Scalar rings improves the signal quality
5. Multipath rejection

Disadvantages:

1. Gain is Less



V. DESIGN OF PROPOSED FLAT SCALAR RING HORN ANTENNA

The proposed Flat Scalar Ring Feed Horn Antenna was designed based on the above simulated dimensions. The Scalar Ring horn hardware consists of two parts i.e. circular wave guide as first part and scalar rings (choke rings) as second part as shown in fig 16. And it has the following dimensions.

Fig 16: Scalar ring hardware top view (Left) and Side view (Right)

Circular Wave Guide Diameter=7.5cm
Circular Wave Guide Height=23.5cm
First Scalar Ring Dia=10.5cm & Height= 5cm
Second Scalar Ring Dia=13.5cm & Height= 5cm

The Proposed horn antenna system is used as feed for parabolic reflector. It is also designed and its diameter is 3.6m as shown in fig17.

Fig 17: Parabolic Reflector Dish at NARL

Hardware results:

The Proposed Flat Scalar Ring feed Horn Antenna system with parabolic reflector was tested. The return loss of the parabolic antenna was measured by using site mater and the return loss value is -22.72dB @ 1.358GHz as shown in fig 18.

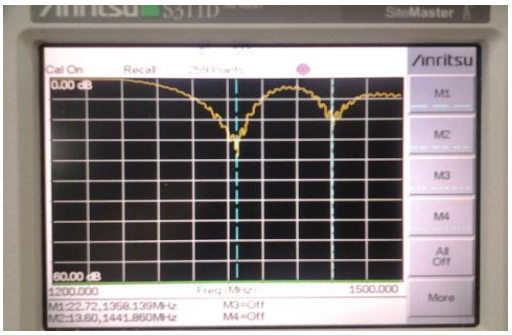


Fig 18: Return loss $|s_{11}|$ db tested in Site Master at NARL

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VI. CONCLUSION

The horn antenna system was designed and optimized by using HFSS software. The proposed model of flat scalar ring feed horn antenna was operating in L-band frequency and it can also be operated in S-band. This scalar ring horn antenna may be used for ground station receiver applications because the scalar rings improves the signal quality and provide multipath rejection.

All the parameters of antenna have been carefully optimized to achieve superior performance with in the limited constraints. This linearly polarized antenna regardless of its gain is smaller in size and less weight. The antenna's gain is around 10dBi, with return loss of -25 dB in simulation and -22dB in hardware testing. These measurement results confirmed the results of the simulations and results of the hardware are satisfied the design requirements.

VII. ACKNOWLEDGEMENT

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BIOGRAPHIES

P. Nanda Kumar completed his B.Tech in Electronics & Communication Engineering at Sreenivasa Institute of Technology and Management Studies (SITAMS), JNTU-A, Chittoor, INDIA in 2012. He is pursuing his M.Tech Degree with specialization Signal Processing (SP) at Sri Venkateswara University College of Engineering (SVUCE), SV University, Tirupati, INDIA. His areas of interest include Antennas, RF and Microwave components and signal processing.

M. Durga Rao, born in 1980, passed B.E. (E.C.E) at Sir. C.R.R. College of Engineering, Eluru in 2002 and M.Tech (Electronic System design and Communication Engineering) at NIT, Rourkela, in 2005. He worked at Vikram Sarabhai Space Centre, Trivandrum, during the period 2004-2010 and joined NARL in December 2010. His areas of interest include development of active phased array radars.

D. Gowri Sankar Reddy, passed B.Tech (ECE) at JNTU-Anantapur in 2000 and M.Tech (ICS) at S.V. University, Tirupati Currently he is working in S.V. University College of Engg, as an Asst. Prof in ECE dept. He has 9 years of teaching experience. His area of interest is Instrumentation and Control Systems.