International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-8, June, 2019

Implementation and Testing of Dual Polarized Parabolic Dish Antenna

A.NagaJyothi, T. Pavani, Dharani, G.V. Sai Swetha

***Abstract:** The paper details test of Dual Polarized Parabolic Dish Antenna, at centre frequency of 3GHz, around 10^0HPBW in azimuth, elevation planes and LPDA (Log Periodic Dipolar Antenna) has feed. The antenna has ability to switch peak power of 1.5KW over a bandwidth of 50GHz and also be able to withstand the environmental conditions like wind, rain. The investigations which have taken place previously have concluded that the prime focus Parabolic Antenna is the most apparent one to meet the design requirement. The LPDA is dependent on operational frequency and is at a focal point of 0.25m to the parabolic reflector of 0.6m diameter. Investigations on the Parabolic Antenna contain gain, VSWR, Half Power Beam Width in both planes of the antenna. The Parabolic Dish Antenna with LPDA feed has been found with 8.56^0 and 10.5^0 HPBW of both azimuth and elevation respectively. The gains at different frequencies are comparable with the theoretical values. The antenna fabricated is tested and is in compact size to meet all the requirements of power, bandwidth. Finally, the results are shown with the antenna meeting all the requirements and ready for practical use.*

I. INTRODUCTION:

This paper is all about testing a dual polarized Parabolic Dish Antenna with azimuth bandwidth of 8.56^0, which is enough to be setup on a truck. These parabolic reflectors are of many forms, though the necessary operation mode will be the same. The parabolic reflector receives parallel EM waves and focuses in the direction of focal point. The antenna feed is located on focal point, where the strong EM waves are received. It is true that emitted EM waves from the feed get reflected by the parabolic reflector.[1]The Fig shown below demonstrates the various Parabolic Antenna models used maximum. The Parabolic Reflector Antennas are examined by the authors, so as to meet the project requirements. The examined results are here concluded as: A Dish Antenna can be a dual polarized and it can handle high levels of power, so as to maintain a small structure. A shortened Parabola Dish Antenna is needed for automotive radars. Due to the requirement of dual polarization, the feed has to remain symmetrical; also the spillover and side lobe levels must be measured properly. The aperture of the Parabolic Dish Antenna is quite bigger when compared with other antenna models. The volume of the dish is less than a horn or pillbox antenna. The blockage of the feed as well as the efficiency of a small dish antenna is always an engineering challenge. The advantages and disadvantages of a Parabolic Dish Antenna are considered, so that the antenna with most feasible design is pursued in a Parabolic Reflector Antenna for the purpose of use in RADARs.[2]

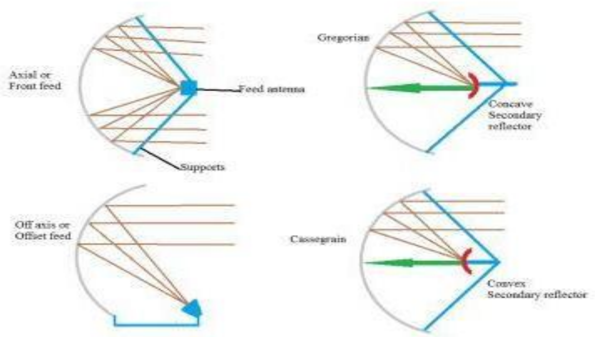

Fig 1: Parabolic Dish Antenna with front feed main focus, Parabolic Dish Antenna with Gregorian secondary reflector, Parabolic Dish Antenna with offset feed, Parabolic Dish Antenna with Cassegrain Secondary Reflector. LPDA consists of a range of wide frequency that makes it a good application for reflector antenna feeds.[3] LPDA provides a high gain above a large bandwidth, or else it is difficult to find with regular wideband antennas. These LPDA antennas are less in cost, appropriate for the illumination of reflector antenna. Whenever there is an increase in substrate dielectric constant, the length of the dipole and the dimensions of the antenna can be reduced.[4] An individual LPDA can be optimized for desired characteristics of the antenna, such as gain, bandwidth, and half power beam width. On the other hand, when it is used as feed, parameters of the performance can be degraded when compared to a standalone or an individual LPDA. The radiation pattern significantly changes because of the near field coupling along with the reflector that is measured in Voltage Standing Wave Ratio (VSWR). [5]On the other hand the standalone LPDA has a problem of defocusing which can be rectified and fixed by optimizing the LPDA as a reflector feed; as required optimizing is done on LPDA structure and also the geometry of the reflector antenna. This makes the design complex, whenever a large operating bandwidth is measured. Increasing the quantity of elements with their apex angle as well as scaling factor, LPDA is designed with a desired frequency band of 3-18GHz.[6] Proper attention has to be given as the dipoles become minor, the impedance matching and also the coupling of each element makes the design more complex.

Revised Manuscript Received on June 12, 2019.
Dr. A. Naga Jyothi, ECE, VIIT, Visakhapatnam, India.
Dr. T. Pavani, Industrialist, Ambica Mart, India.
Dharani, ECE, VIIT, Visakhapatnam, India.
G.V. Sai Swetha, ECE, VIIT, Visakhapatnam, India.

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First designing of LPDA is done, next the reflector antenna integration and then the testing is taken place.

II. DESIGN CONSIDERATIONS

The reflector always falls in the aperture portion of the antennas; whereas the structure of feed radiates EM energy in the direction of reflector, which is reflected ahead in the form of concentrated beam. The reflector antennas are regularly used when there is need of high gain, high power and moderate bandwidth. Considering the geometric configurations, the reflector antennas are of many types, the most commonly used are plane, corner and curved. These various types of shaped reflectors are to improve the radiation property such as gain, radiation pattern, antenna efficiency, polarization purity and etc.[7]

Feeding of the parabolic reflector is done in different ways; here the antenna used is LPDA. First the feed is positioned at the focal point of the antenna, known as main focus antenna, this makes the manufacture and design of the antenna easy, but there are drawbacks in it. Its main drawback is that the transmission line given to the feed should be quite long enough, so that it can reach the transmitting and receiving parts.

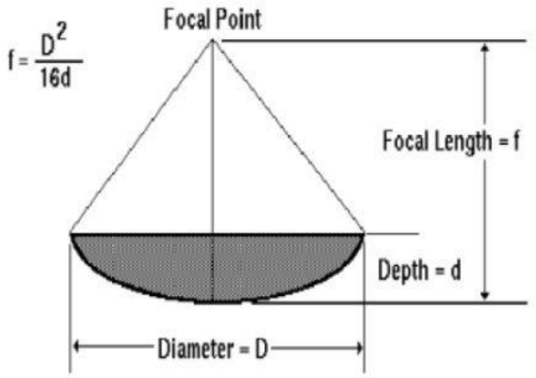

Fig 2: Mathematical representation of parabolic reflector

The following terms are used while describing a parabolic reflector. The point where all the arriving radio waves are focused is called the focus. The point that is innermost at the centre of parabolic reflector is called as vertex. The distance between the focus and the vertex is called as focal length 'f'. The opening of the parabolic reflector is called as aperture and its length is measured by its diameter 'D'. The f/D ratio is generally an industrial practice.[8] So as to specify the diameter of its aperture and shape of the parabolic reflector, 'f' (focal length) is directly obtained by the product of its f/D ratio and D (diameter).[9]

Equation of a parabola: in terms of focal length it is

$$Y = ax^2 \tag{1}$$

Depth of a parabolic reflector: while designing a parabolic reflector, it is always preferred to use its depth'd', in the place of focal length 'f', the equation of depth is

$$d = \frac{D^2}{16f} \tag{2}$$

At the same time, diameter 'D' and depth 'd' are used to find the focal length, so focal length equation is

$$f = \frac{D^2}{16d} \tag{3}$$

Depending on the segment or slice of a parabolic envisaging during the manufacture, the dish antennas structure may be deep or shallow. Actually it is tough to illuminate the dish in a uniform manner, with the feed in the aperture plane as our eyes peer in single direction. Later the placing of focal point outside the aperture plane will modify the chances of receiving unwanted signals and noise. There is a chance of loss, if the feed point is not properly protected. The efficiency 'η' is given as:

$$\eta = \frac{f}{D} = \frac{\text{focal length}}{\text{Diameter of dish}} \tag{4}$$

Beam width calculation of parabolic antenna:

As the gain of the Parabolic Antenna keeps increasing, as the beam width falls. Generally, the beam width is described as the points where the power falls down to half of the maximum. The equation of beam width is:

$$\Psi = \frac{70\,\lambda}{D} \tag{5}$$

The antenna which is placed at the focal point of the parabolic reflector is used to illuminate the parabolic reflector. Beam width is a property antenna, whether it is in receiving type or transmitting type. For proper illumination in parabolic reflector, the beam width of the antennas has to match the f/D ratio of it.

Gain of a parabolic antenna:

Aperture area of the Parabolic Antenna is calculated using the area of the circle formula that is:

$$A = \pi\frac{D^2}{4} \tag{6}$$

This formula of area is used to calculate the gain of parabolic antenna. The antenna gain G is directly proportional to the ratio of aperture area to the square of wavelength of the arriving radio waves.

$$G = 10\log_{10}\frac{\eta\, 4\pi A}{\lambda^2} \tag{7}$$

where η is efficiency, its value is equivalent to 50%. G is the gain and its units are dB.

Gain	Frequency
12.04 dBi	1 GHz
18.06 dBi	2 GHz
21.5 dBi	3 GHz

Table I: theoretical values of Gain at different frequencies

III. DESIGN OF LPDA:

The dipoles of LPDA are designed in such a manner that, each dipole has half wavelength. The width of feed line has to be considered while calculating the length of printed dipole. At a certain rate, there is a change of logarithmic decrease of the dipoles.[10]

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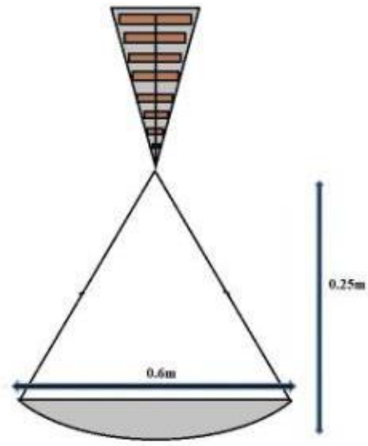

Fig 3: combined antenna with diameter 0.6m, focal length 0.25m

Lowest frequency can be calculated by largest dipo

le and highest frequency can be calculated by shortest dipole. The geometric scaling factor (τ) is used in calculations of other dimensions, the equation of scaling factor (τ) is

$$\tau = \frac{l_m}{l_{m+1}} = \frac{s_m}{s_{m+1}} = \frac{w_m}{w_{m+1}} \quad \textbf{(8)}$$

The most regular way to combine wideband feeds is to use prime focus parabolic antennas. The critical design parameters are: geometry, subtended angle, location of the feed of the reflector. A good gain and a low cross polarization ratios are dependent on the feed antenna aperture distribution and projection of it on the reflector. If LPDA is used as feed for reflector antenna, phase centre of it has to be stable in order to achieve optimum f/D ratio. It is not easy to achieve, but it is a must to maintain stability in phase centre prior to optimize f/D ratio for reflector illumination. The process repeats until required stability is found.

IV. SIMULATION RESULTS

When LPDA is excited at the apex of the feed line, its voltage VSWR is shown in Fig. 4. LPDA exhibits excellent performance with maximum VSWR at 1.74 at 1 to 3 GHz frequency range.

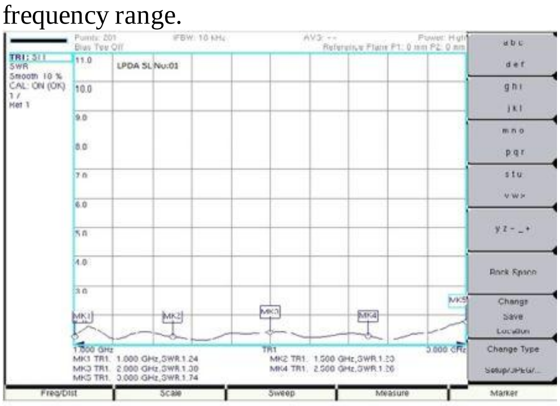

Fig 4: LPDA VSWR plot

The gain of parabolic reflector for different frequencies is shown from Figs 5-7.

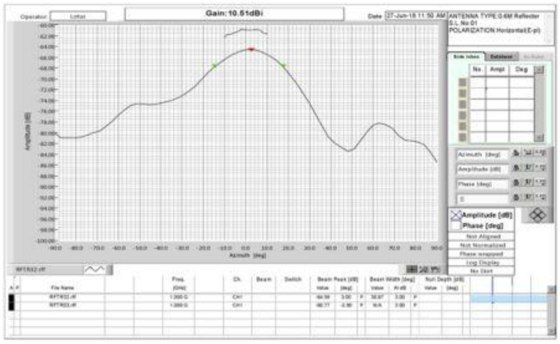

Fig5: Gain at 1GHz

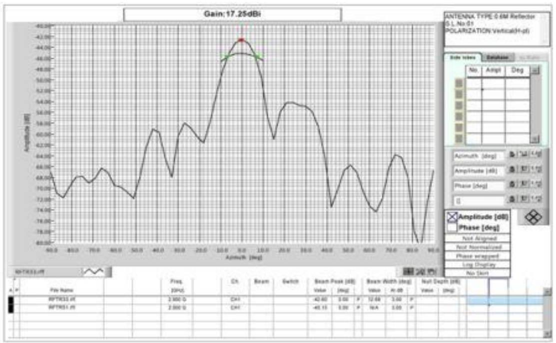

Fig 6: Gain at 2GHz

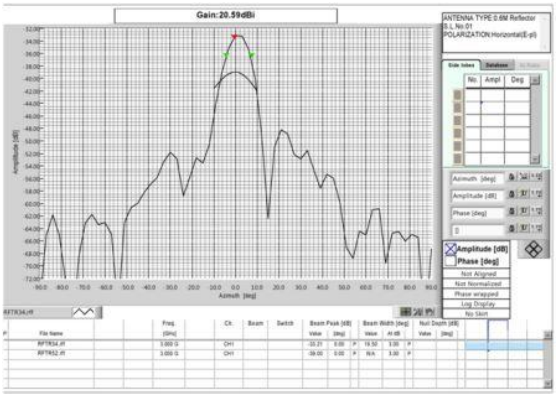

Fig 7: Gain at 3GHz

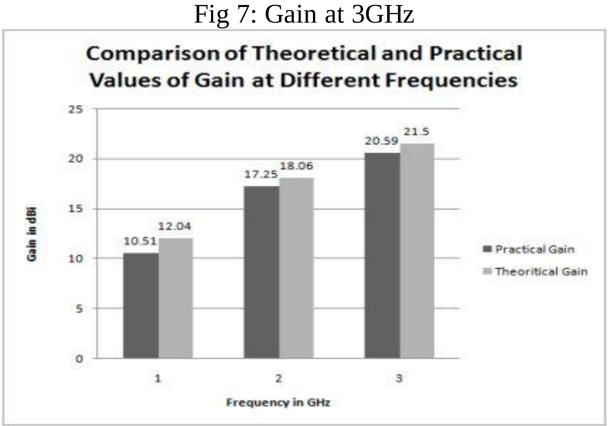

Fig 8: Comparison of theoretical and practical gains

The gain of the reflector antenna are presented from Figs 5-7 . It exhibits 10.51 dBi at the lowest frequency i.e 1 GHz and 20.59 dBi at the highest frequency i.e 3GHz. Gain increases steadily with frequency as expected. The same trend followed in theoretical gain which is shown in Fig 8.

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HPBW E- Plane ranges from 30^o to 10.5^o, with increasing frequency and it gets narrower as expected. HPBW E- Plane performances are shown from Figs .9- 11

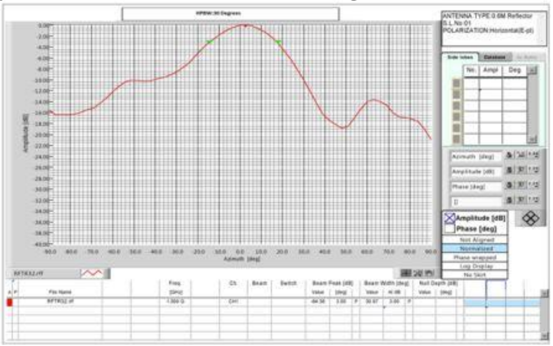

Fig 9: HPBW E- Plane at 1GHz

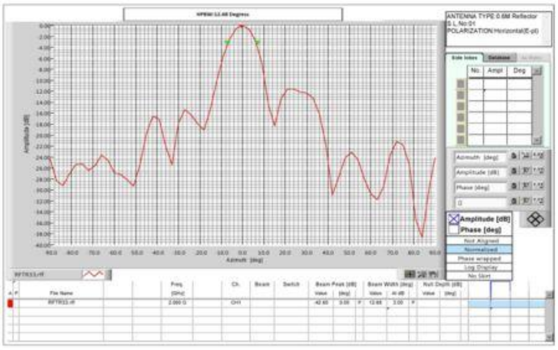

Fig 10: HPBW E- Plane at 2GHz

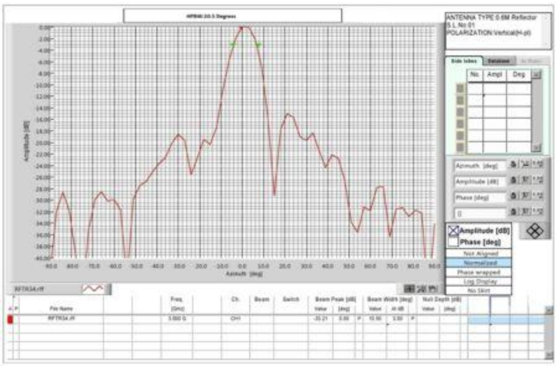

Fig 11: HPBW E- Plane at 3GHz

HPBW H- Plane ranges from 22.38^o to 8.56^o, with increasing frequency and it gets narrower as expected. HPBW H- Plane performances are shown from Figs .12- 14

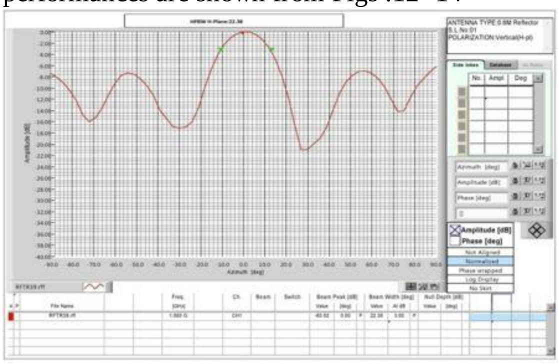

Fig 12: HPBW H- Plane at 1GHz

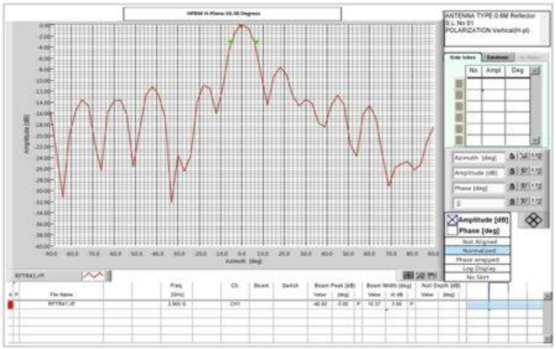

Fig 13: HPBW H- Plane at 2GHz

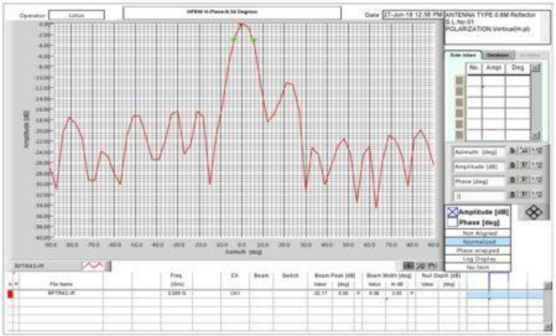

Fig 14: HPBW H- Plane at 3GHz

SL.NO	PARAMETER	SPECIFICATION	FREQUENCY		
			1GHz	2GHz	3GHZ
1	Gain	≤10.5 dBi	10.51	17.25	20.59
2	HPBW E-Plane	≤30°	30.0	12.68	10.50
3	HPBW H-Plane	≤30°	22.38	10.37	8.56
4	VSWR	≤2	1.24	1.38	1.74

Table II: performances of antenna

V. CONCLUSIONS

High gain and wideband reflector antenna with LPDA is optimized for antenna performance. The antenna system can operate in GHz frequency range and is suitable for direction finding and electronic support applications. The performance of the antenna is summarized in Table I.

ACKNOWLEDGEMENT

This work is being supported by Ministry of Science & Technology, of Science and Engineering Research Board (SERB), with the Grant No: ECR 2017-000256 dated 15/07/2017

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AUTHORS PROFILE

Dr.A.NagaJyothi was born in 1982 at Visakhapatnam. She received her B.Tech (ECE) from Nagarjuna University and M.Tech(Radar & Microwave Engineering) from Andhra University College of Engineering(A). She completed Ph.D in Radar Signal Processing from Andhra University College of Engineering (A). She has a teaching and research experience of 12 years. Presently working as an Associate Professor in the department of ECE, VIIT, Visakhapatnam. She has published papers in various National , International journals and conferences. Her areas of interest include Radars, Antennas and Nano technology.Completed project sanctioned under WoS-A. Presently working for a project sanctioned under ECRA –SERB New Delhi with sanction order no. ECR 2017-000256 DATED 15/07/2017.

Dr. T. Pavani received her AMIE with first class from The Institution of Engineers (India), M.Tech and Ph.D. from Andhra University College of Engineering, Andhra University. She is having 10 years of teaching and research experience. Her areas of interest are Antennas, Electromagnetics, EMI/EMC.and Applications of Soft computing. She is a life member of Institution of Engineers and SEMCE.

Dharani pursued b.tech at Sri Vahani Institute Of Science And Technology,Tiruvuru. Now she is pursuing M.tech at Vignan Institute Of Information Technology,Duvvada under the guidance of Dr.A Naga Jyothi.

G.V. Sai Swetha was born in 1991 in Visakhapatnam. She received her B.Tech degree in ECE from NSRIT, Visakhapatnam in 2009-13. M.Tech in VLSI from BITS, Visakhapatnam in 2014-16. Presently working as SRF in a project sanctioned by Science And Engineering Research Board (SERB), with the grant no: ECR 2017-000256 dated 15/07/2017.