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Design and Analysis of Parabolic Reflector with High Gain Pencil Beam and Low side lobes by Varying feed

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ABSTRACT

The far field radiation pattern from a parabolic reflector depends on the primary radiation pattern which is the radiation pattern of the feed element placed and also on the type and dimensions of reflector used. Therefore in this paper first analysis of the primary patterns of different elements like dipole, horn is done by considering different dimensions. In addition the beam efficiency and the dipole multiplication patterns for different lengths were also calculated. . A parabolic reflector has been selected as the reflector because it produces high gain pencil beam with low side lobes. Using general and aperture approximation methods the radiation patterns have been plotted in both the azimuth and elevation planes. The comparison of dipole, square corner and horn feeds based on the characteristics like intensity, directivity has also been done and the resultant patterns were obtained.

Keywords - **Antenna, beam width, gain, power radiated, beam width, directivity, 2D E-Plane pattern and 3D Radiation intensity pattern.**

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1. INTRODUCTION

Reflector antennas, in one form or another, have been in use since the discovery of electromagnetic wave propagation in 1888 by Hertz. Although reflector antennas take many geometrical configurations, some of the most popular shapes are the plane, corner, and curved reflectors. It has been shown by geometrical optics that if a beam of parallel rays is incident upon a reflector whose geometrical shape is a parabola, the radiation will converge at a spot which is known as the focal point. In the same manner, if a point source is placed at the focal point, the rays reflected by a parabolic reflector will emerge as a parallel beam. Since the transmitter (receiver) is placed at the focal point of the parabola, the configuration is usually known as front fed. The illumination of a parabolic reflector antenna depends on the properties of the feed used. The widespread use of reflectors has simulated interest in the development of feeds to improve the aperture efficiency and to provide greater discrimination against noise radiation from ground. In order to obtain a high efficiency it is necessary that the radiation pattern as uniform as possible and produces little spill over energy. Besides it is desirable that the radiation pattern of the feed is symmetrical and the feed should possess a well defined phase centre. When fed effectively from the focus paraboloid reflectors produce high gain pencil beam with low side lobes and good cross polarization discrimination characteristics. The symmetrical focus fed paraboloid is the most widely used reflector for medium and high gain pencil beam applications such as in Radio Astronomy and it is considered to be a good compromise between performance and cost. This paper describes the analysis of the focus fed parabolic reflector and its Radiation properities in general method and aperture approximation method.

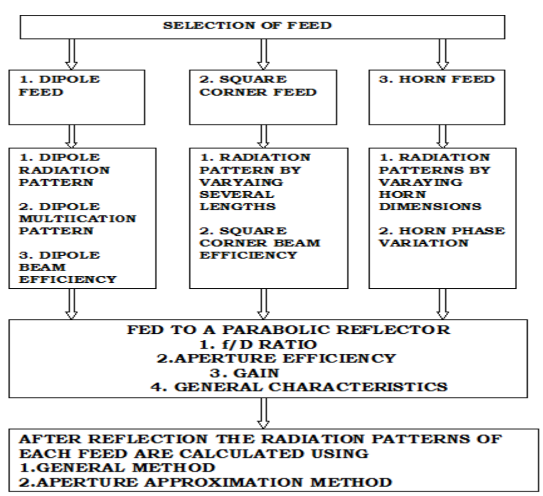

Fig.1: Processing Steps

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2.DIPOLE

A Dipole antenna is defined as a straight radiator, usually fed in the center and producing a maximum of radiation in the plane normal to the axis. This distribution assumes that the antenna is center-fed and the current vanishes at the end points. The finite dipole antenna is subdivided into a number of infinitesimal dipole of length z'. As the number of subdivisions is increased, each infinitesimal dipole approaches a length dz'. For an infinitesimal dipole of length dz' positioned along the z-axis at z', the electric and magnetic field components in the far-field are given as

$$dE_\theta = jn\frac{KI_e(Z')e^{-jkR}}{4\pi R}\sin\theta dZ' - (1)$$

$$dH_\phi = jn\frac{KI_e(Z')e^{-jkR}}{4\pi R}\sin\theta dZ' - (2)$$

$$dE_r = dE_\phi = dH_r = dH_\theta = 0 - \quad (3)$$

To find the total power radiated, the average poynting vector is integrated over a sphere of radius r. The radiation pattern of a dipole becomes more directional as its length increases. When the overall length is greater than about one wavelength, the number of lobes increases and the antenna loses its directional properties. The parameter that is used as a "figure-of-merit" for the directional properties of the antenna is the directivity. The input impedance was defined as "the ratio of the voltage to current at a pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point." The real part of the input impedance was defined as the input resistance which for a lossless antenna reduces to the radiation resistance. It is through the radiation resistance that the antenna radiates real power.

To refer the radiation resistance to the input terminals of the antenna, the antenna itself is first assumed to be lossless (R_L =o). Then the power at the input terminals is equated to the power at the current maximum. Aperture area is area part of total area which is utilized to transmit or receive waves. For greater efficiency of antennas aperture effective area should be more.

3. PARABOLIC ANTENNA

A parabolic reflector can take two different forms. One configuration is that of parabolic right cylinder whose energy is collimated at a line that is parallel to the axis of the cylinder through focal point of the reflector. The most widely used feed for this type is linear dipole, a linear array, slotted waveguide etc. The other reflector, is formed by rotating the parabola around its axis, is referred to as a paraboloid. A pyramidal or a conical horn has been widely used as a feed for this arrangement. The overall radiation characteristics of a reflector can be improved if the structural configuration of its surface is upgraded. In geometrical optics, if a beam of parallel rays is incident upon a reflector whose geometrical shape is a parabola, the radiation will converge at spot, which is known as a focal point. In the same manner, if a point source is placed at the focal point, the rays reflected by a parabolic reflector will emerge as a parallel beam. Rays that emerge in a parallel formation are usually said to be collimated. Collimation is often used to describe the highly directional characteristics of an antenna even though the emanating rays are not exactly parallel. Since the transmitter (receiver) is placed at the focal point of the parabola, the configuration is known as front-fed.

Directivity and Efficiency

$$D_o = \frac{\pi d}{\lambda} \quad (4)$$

Aperture Efficiency

Aperture efficiency is a figure of merit, which indicates how efficiently the physical area of the antenna, is utilized and it is defined as

$$\varepsilon_{ap} = \cot^2(\theta_o/2)\left|\int_0^{\theta_o} G_f(\theta)\tan(\theta/2)d\theta\right| \quad -(5)$$

Spillover Efficiency

Since the feed pattern will extend beyond the rim of the reflector the reflector into the main beam will not redirect the associated power and consequently the gain is reduced. This is referred to as spillover and the associated efficiency factor is called spillover efficiency. It measures that portion of the feed pattern i.e. intercepted by the main reflector.

$$\varepsilon_s = 1 - \cos^{(n+1)}(\theta_o) \quad -(6)$$

Radiation Pattern : The radiation pattern produced by the feed is called the primary pattern and that radiated by the aperture is called secondary pattern. The total pattern of the system is represented by the sum of the secondary pattern and the primary pattern of the feed element. For most feeds (such as horns), the primary pattern in the bore sight direction of the reflector is of very low intensity and usually can be neglected.

The normalized electric fields is

$$E_\theta = 1 - \sin\theta \quad (7)$$

Radiation intensity is U=

$$\frac{16\pi^2}{\lambda} f^2 \frac{p_t}{4\pi}\left|\int_0^{\theta_o}\sqrt{G_f(\theta')}\tan\frac{\theta'}{2}d\theta'\right|^2 \quad (8)$$

Directivity is D=

$$\frac{16\pi^2}{\lambda} f^2 \frac{p_t}{4\pi}\left|\int_0^{\theta_o}\sqrt{G_f(\theta')}\tan\frac{\theta'}{2}d\theta'\right|^2 \quad (9)$$

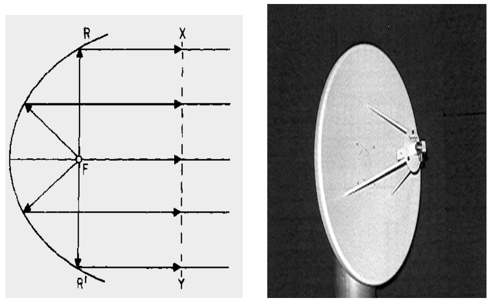

Fig.2 Parabolic Antenna

4.RESULTS

DIPOLE RADIATION PATTERNS

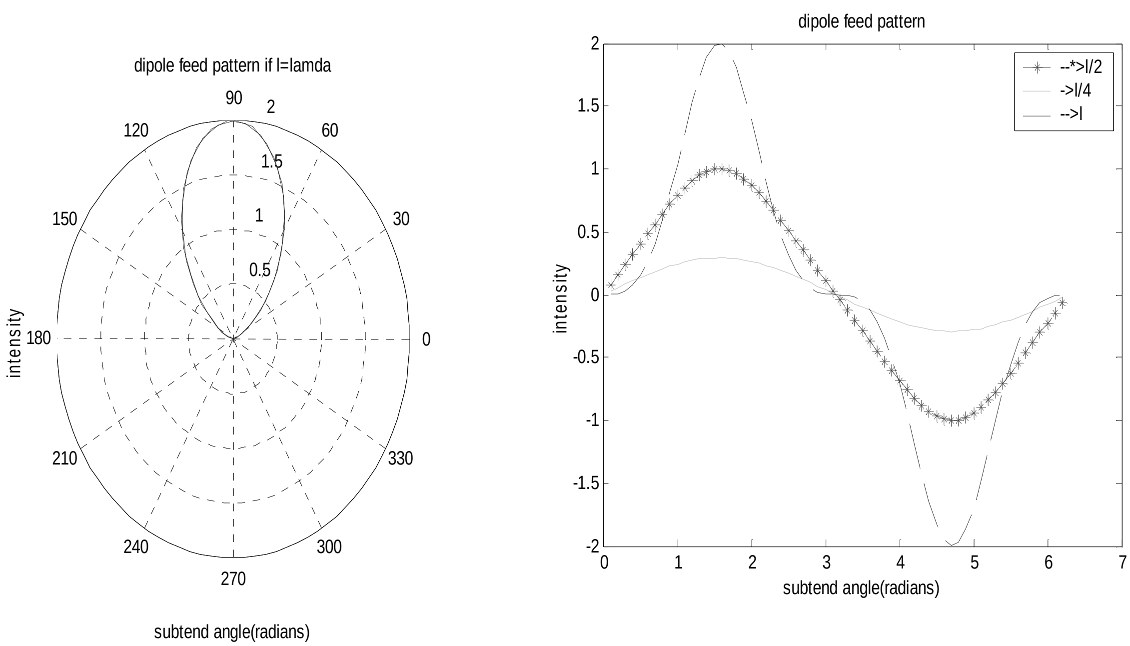

Fig:-3

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DIPOLE BEAM EFFICIENCY

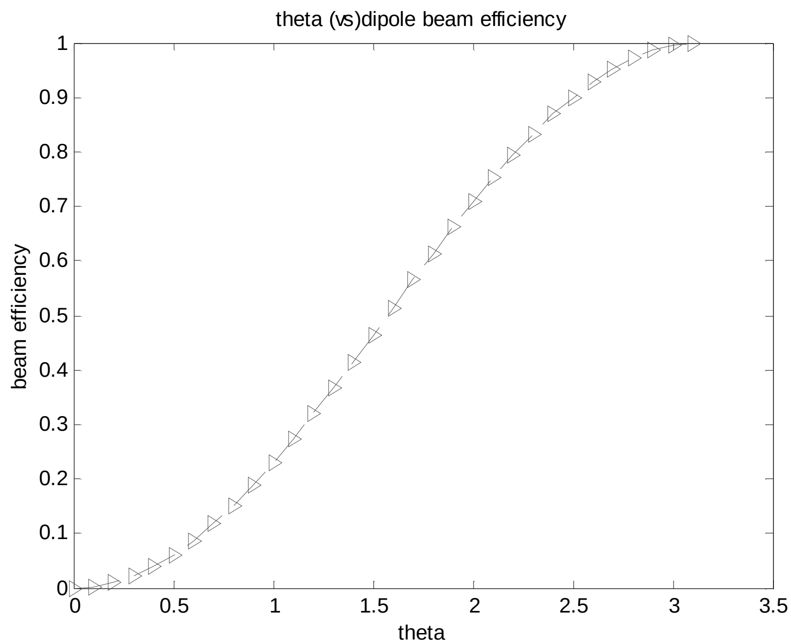
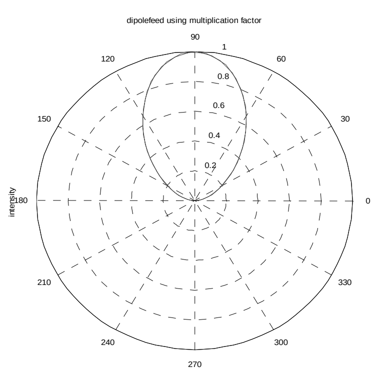
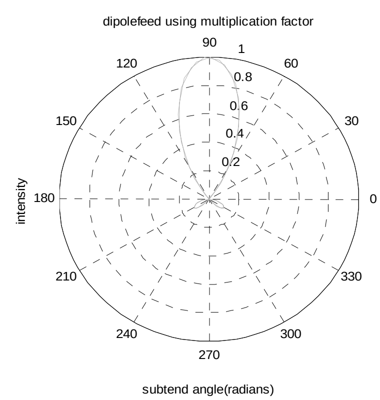


Fig:-4

DIPOLE MULTIPLICATION PATTERNS





N=1 N=3(number of array elements)

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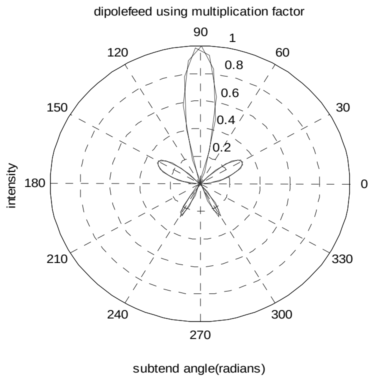
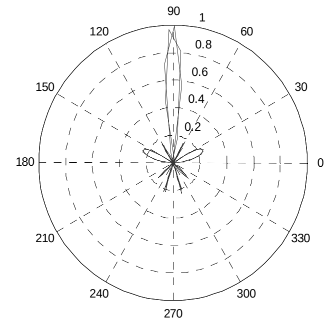


N=5



N=9(array elements

Fig-5

INTENSITY VARIATIONS BY CHANGING SPACING BETWEEN DIPOLES

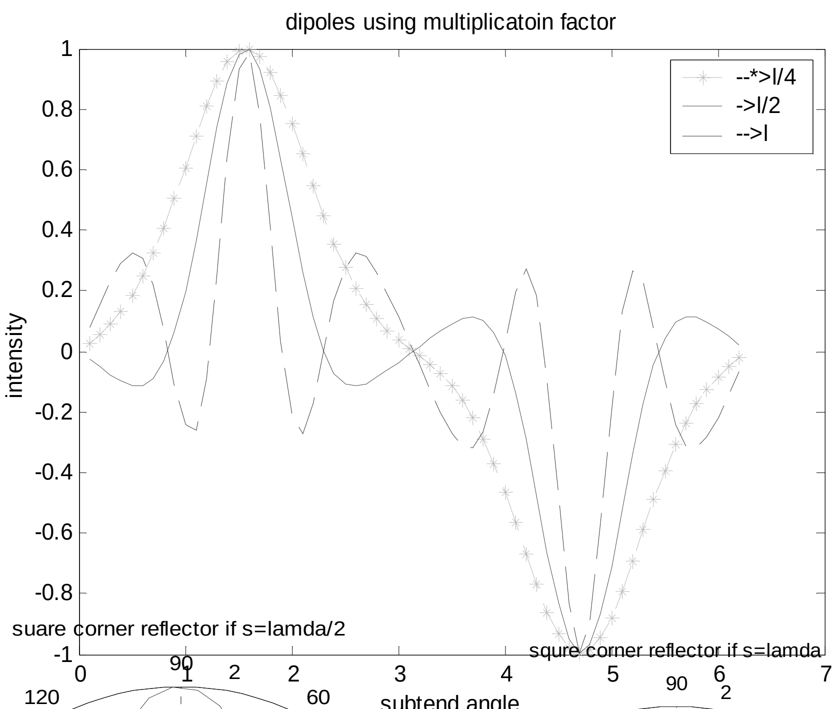
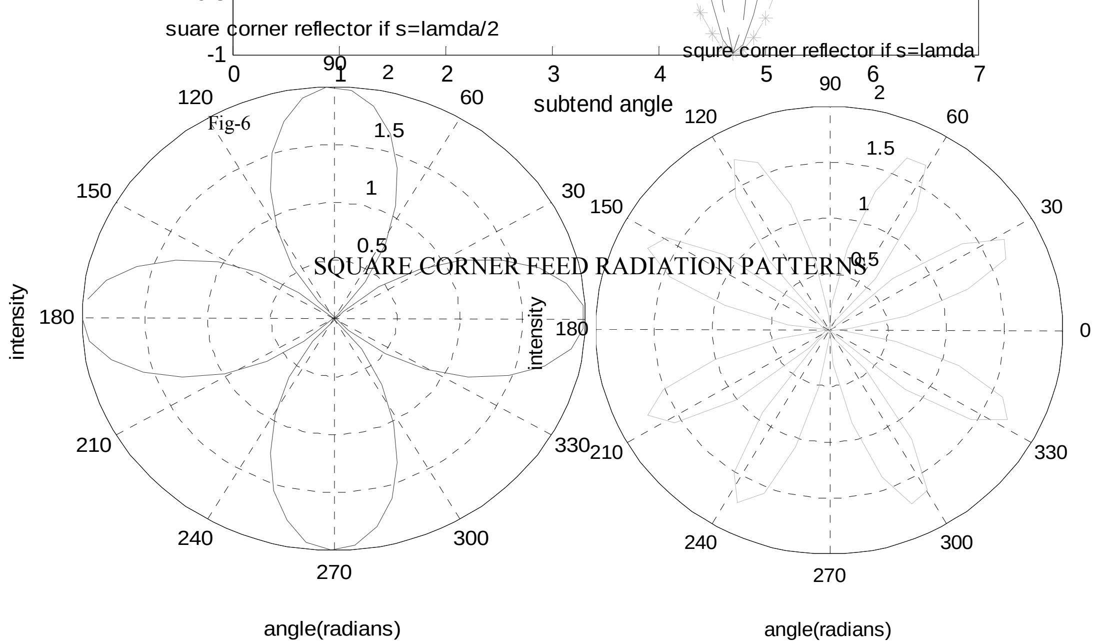


Fig-6



SQUARE CORNER FEED RADIATION PATTERNS

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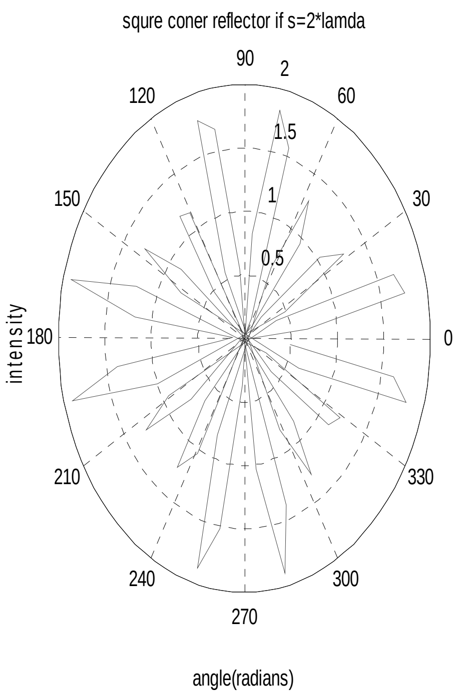


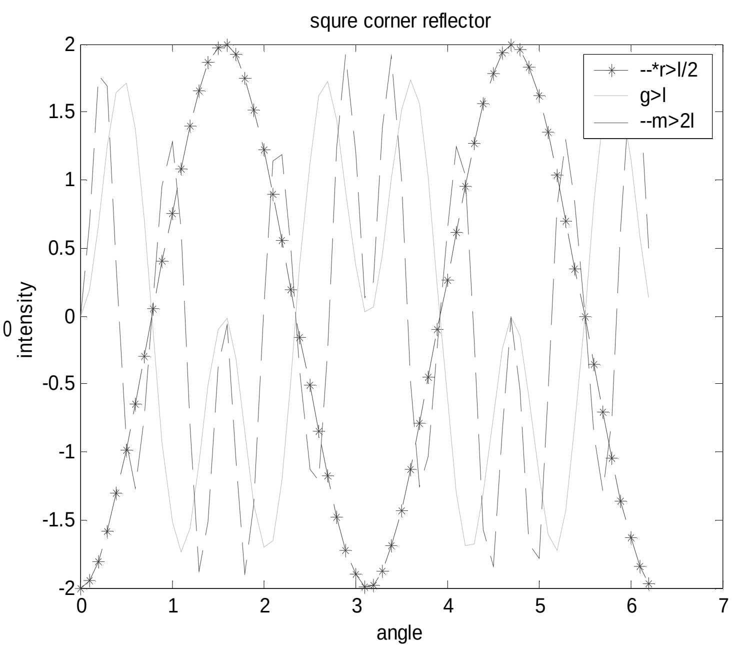
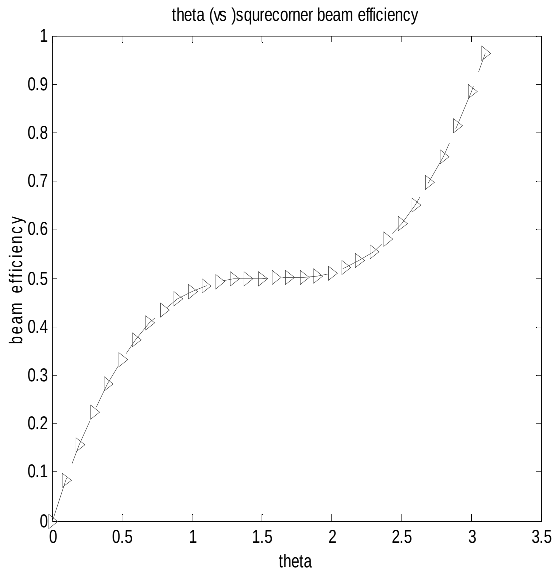


Fig-7

SQUARE CORNER BEAM FFICIENCY RADIATION



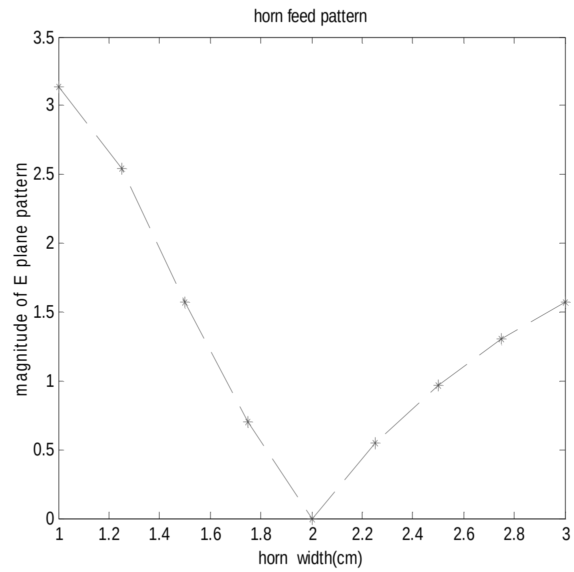
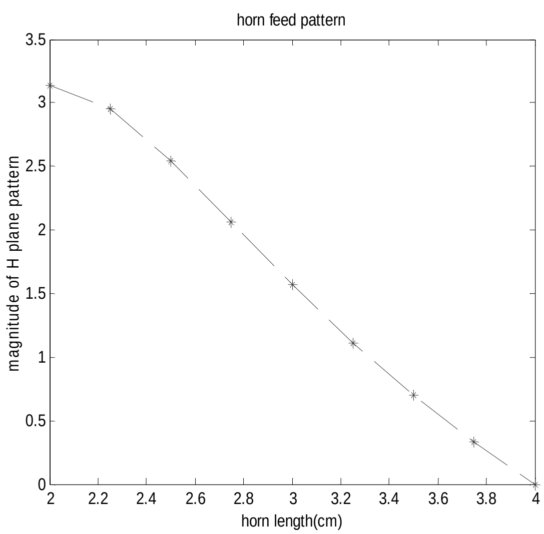
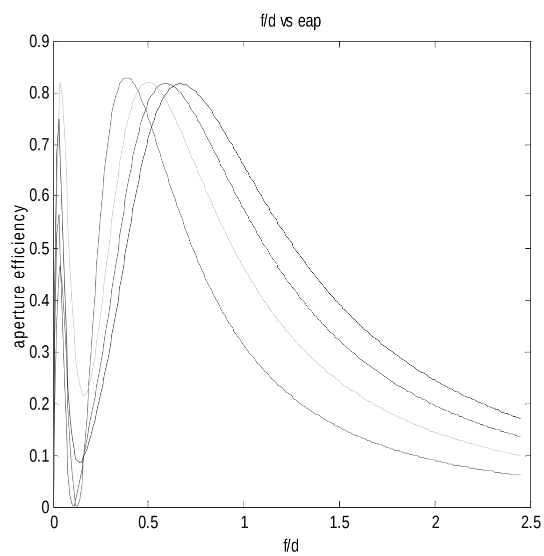


Fig-8

HORN FEED RADIATION PATTERN (WIDTH WISE)



f/D (VS) APERTURE EFFICIENCY



Fig;-9

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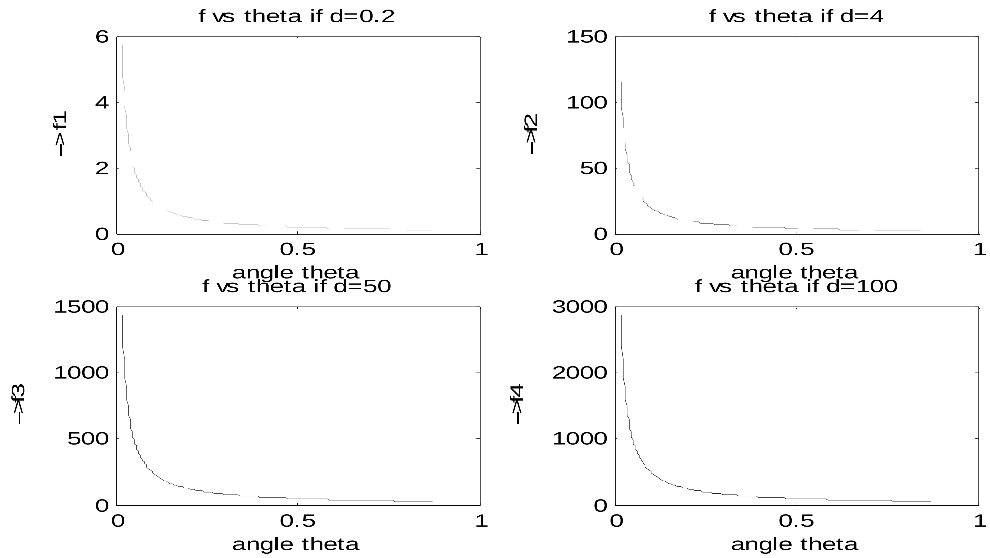
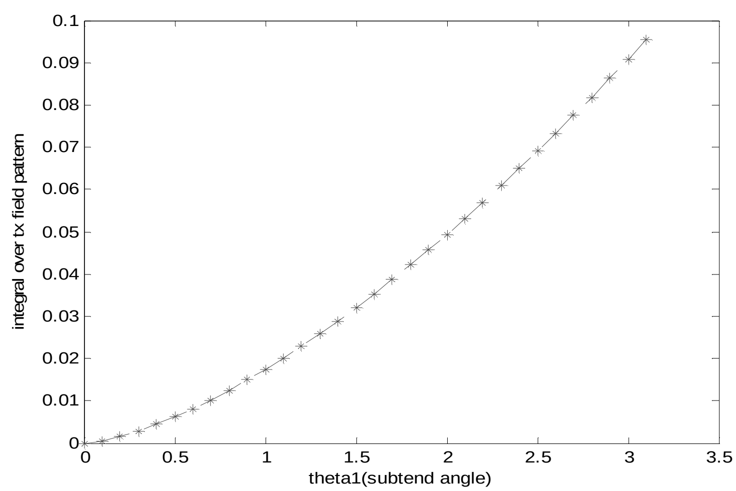
f/D RATIO



Fig;-10

FINAL RESULTS(AFTER REFLECTING ON THE PARABOLIC SURFACE)

DIPOLE RADIATION PATTERN ON THE DIRECTION OF PARABOLA AXIS



Fig;-11

HORN FEED

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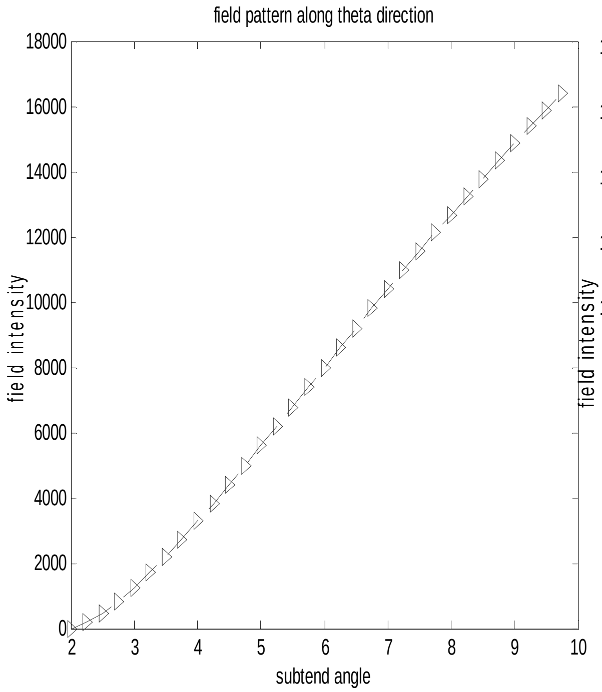
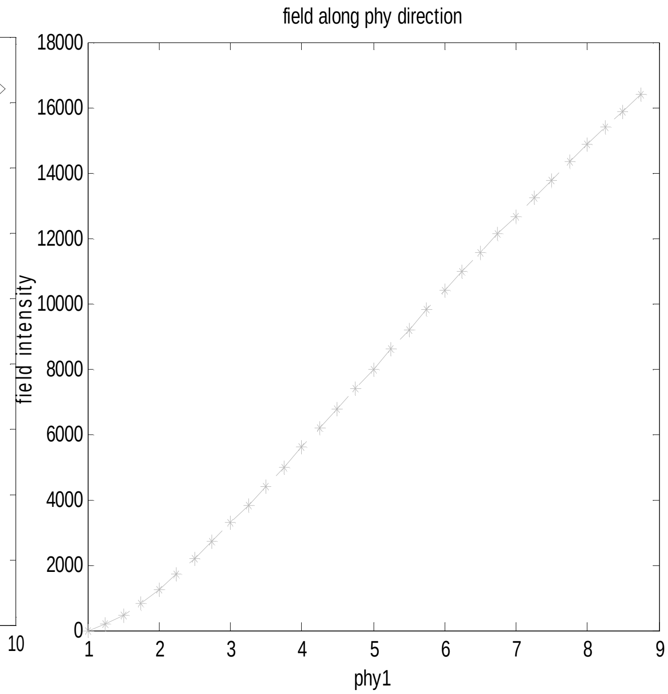
ALONG THETA DIRECTION



ALONG PHY DIRECTION



Fig;-12

APERTURE APPROXIMATION METHOD

The main difference between general method and this method is dependent on aperture efficiency.

Step1: Find vector direction on the parabolic axis.

$$\sqrt{pb} * \hat{er}$$

Step2: Find feed radiation pattern on the axis.

$$\int_0^{\theta}\int_0^{2\Pi} (\sqrt{pb} * \hat{er}) d\theta d\Phi$$

Step3: Find total field intensity by dividing aperture efficiency to the above values

$$E = (\frac{1}{\eta})(\sqrt{\frac{p1}{2\pi}})(2\sqrt{(\frac{\dot{\varepsilon}_o}{\mu_o})}) * \frac{e^{(-ikR)}}{4\pi R} \iint (\sqrt{pb} * \hat{er}) \sin\theta \, d\theta d\Phi$$

Where limits represents through out the reflector surface

Where p1=transmitted power

η= aperture efficiency

Table-1

Length in terms of λ	Directivity (in db)	Radiation Resistance (in ohms)	Effective Area (in sqmt)
.1	1.77	0.19	11.97
.25	1.85	6.72	12.19
.5	2.15	73.12	13.05
.75	2.74	185.8	14.97
1	3.82	199.08	19.18
1.25	5.16	106.53	26.12
1.5	3.47	105.49	17.7

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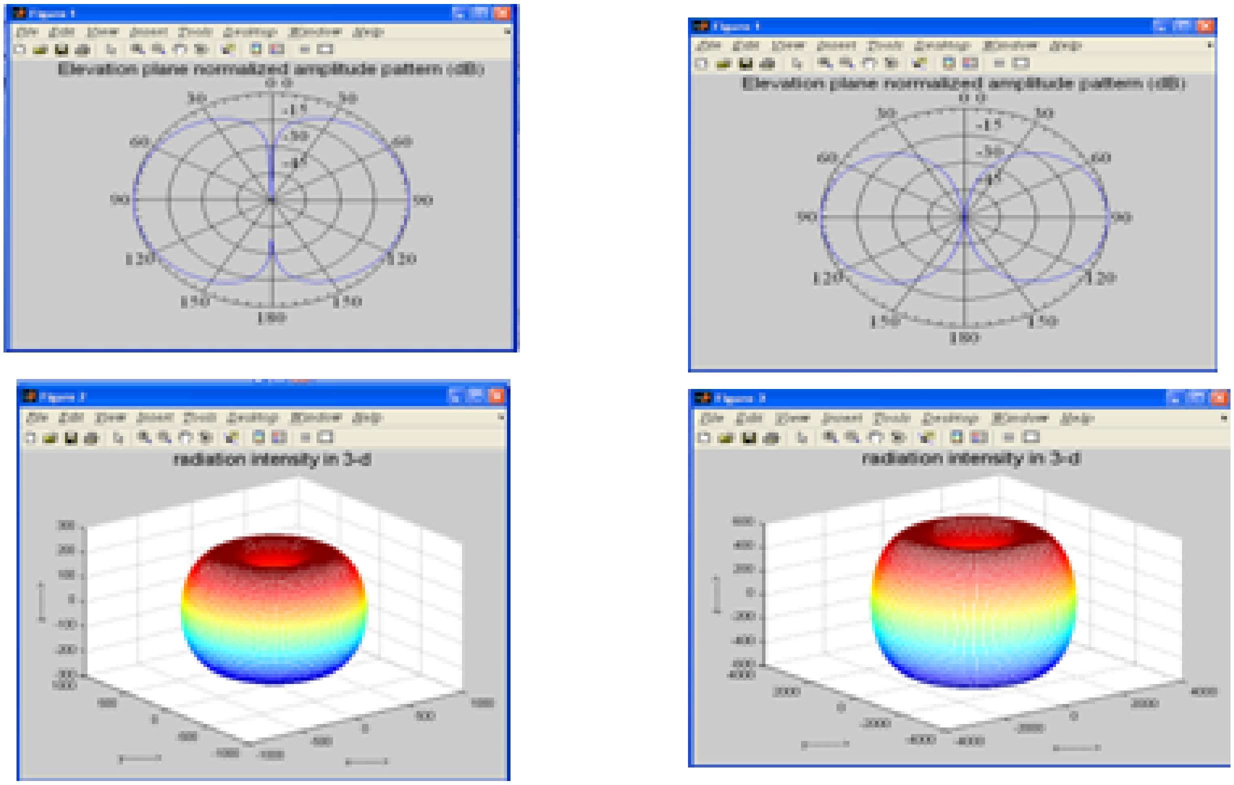
L=0.5λ L=1λ



E-Plane Patterns of Dipole
Fig.13

2D plot Linear plot

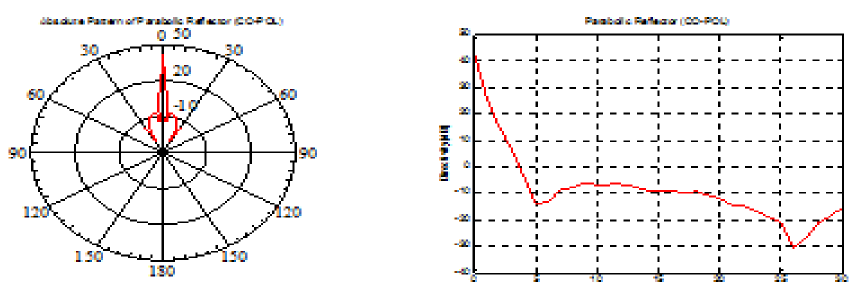


Fig-14

INPUT
Frequency(GHz) = 3
Focus(meters) = 6
Diameter(meters) = 6
Feed location of z axis(meters) = 6

OUTPUT
The Maximum Directivity Is:
15435.6139 (dimensionless);
41.8852 (Db)

5.CONCLUSION

The fundamental antenna concepts and a brief introduction to the types of feeds have been discussed. Analysis of the parabolic reflector characteristics like f/D, gain, radiation patterns has been done and the corresponding results were plotted. The primary radiation patterns of each feed like dipole, square corner and horn were calculated and then the far field pattern of each feed was calculated by using general and aperture approximation methods. Intensity and directivity of feeds were compared. From results it can be concluded Horn feed has more intensity and more directivity among three feeds. Using Aperture approximation method we achieved more intensity and more directivity than general method.

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