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Design and Analysis of Parabolic Reflector Using MATLAB

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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 analysis of the E-plane and H-plane normalized radiation patterns in dB by using MATLAB programming 2010a. In addition the beam width and efficiency patterns for different center frequencies, focal lengths and diameters were also calculated. A parabolic reflector has been picked as the reflector because it produces high gain pencil beam with small side lobes. Using aperture approximation methods the radiation patterns have been plotted and elevation planes. The simplest reflector antenna consists of two components: a reflecting surface and a much smaller feed antenna, which frequently is located at the reflector's focal point. Paraboloidal reflector is entirely defined by the respective parabolic line, i.e., by three basic parameters: the center frequency the diameter and the focal length.

KEYWORDS –parabolic reflector, beam width, efficiency, gain

I.INTRODUCTION

A parabolic antenna is used for microwave radio communications. It is frequently referred to as a dish antenna. It lie of a parabolic reflector which collects and concentrates an incoming parallel beam of radio waves and focuses them onto the actual antenna placed at its focal point or focus.[1] The actual antenna at the focus is sometimes referred to as the antenna feed. See Figure 1. In this paper, the term antenna will refer to the actual antenna at the focal point of the parabolic reflector and parabolic antenna refers to its antenna together with its parabolic reflector.

Satellite television dish antennas are an example of popular parabolic microwave antennas. A parabolic antenna is similar to a reflecting telescope where a parabolic concave mirror gathers incoming light and focuses it into the eye piece. Another optical example is the vehicle headlight. A parallel beam of light is reflected off the parabolic mirror behind the light bulb placed at its focus.

In this paper, the design and the experimental verifications of matched feeds have been presented. Investigations on a multi-mode matched feed using parabolic wave guide structure may be carried out as an advancement of this work. This type of Paraboloidal matched feed will be useful for an application where different beamwidths are required in both E and H planes, and maintaining the low cross-polarization in the secondary radiation pattern. An improved design of a tri-mode matched feed with improved cross-polar bandwidth has been discussed in the paper. Further investigations can be carried out to enhance the cross-polar bandwidth of a rectangular as well as a corrugated matched feed. To achieve the improvement in the cross polar bandwidth, it will be important to maintain the required amplitudes and the phases of all the essential waveguide modes over a wide frequency range. Paper will be a challenging work and will need a new design concept and efficient modelling tools to implement the concept. In this paper, matched feed designs have been proposed for a single offset parabolic reflector antenna. A unique matched feed can also be designed for a shaped offset reflector in which the offset reflector profile is deformed to generate a contoured beam or a shaped beam.

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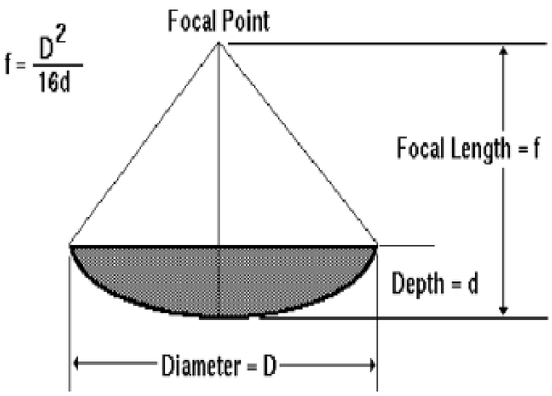

Fig.1. Mathematical diagram of parabolic reflector

The following terminology is used in describing a parabolic reflector. The focus is where all the incoming radio waves are concentrated.[2] The vertex is the innermost point at the center of the parabolic reflector. The focal length of a parabola is the distance from its focus to its vertex. The aperture length of a parabolic reflector is its opening and is described by its diameter. Also of interest is the depth of the parabolic reflector which is discussed below. The two dimensions that describe a parabolic reflector are the focal length f and the diameter D of its aperture. The industrial practice is to use the f/D ratio to specify the shape of the parabolic reflector and the diameter D of its aperture. For a given parabolic reflector, the focal length f is directly obtained by multiplying its f/D ratio by its diameter D.

II.METHODOLOGY

A. Design and analysis formulas for a parabolic reflector

The following design formulas are useful for designing a parabolic reflector.

Equation of a parabola

The equation of a parabola in terms of focal length f is

$$Y = ax^2$$

Depth of a parabolic reflector

In designing a parabolic reflector, it is frequently convenient to use its depth d instead of its focal length. The formula for getting the depth is

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

Conversely, given a parabolic dish and its measurements for the diameter D and the depth d, then its focal length f is obtained with

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

A dish antenna may be shallow or deep depending on the slice of the parabolic envisaged during manufacture. Practically speaking, it is difficult to illuminate the dish uniformly with the feed inside the aperture plane. This is because waves arriving from opposite directions tend to cancel through superposition. So our eye peers in one direction only. And next, placing the focal point well outside the aperture plane modifies the chance of receiving unnecessary signals and noise. The feed point is not well protected, and this configuration increases the chance of loss. Signals from the feed horn may lose the edge of the dish. The ratio of the focal distance to the dish diameter, denoted f/D is a standard component parameter used by systems installers.[3]

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

Parabolic antenna beam width calculation:

The gain of the parabolic antenna, increases, so the beam width falls.

Normally the beam width is defined as the points where the power falls to half of the maximum, i.e. the -3dB points on a radiation pattern polar diagram.[4]

It is possible to estimate the beam width reasonably accurately from the following formula.

$$\text{Beam width } \psi = 70\ \lambda/D$$

An antenna placed at the focal point of a parabolic reflector is said to illuminate the parabolic reflector. The antenna has a beam width which is the how wide an angle the antenna would make if it were radiating a beam of radio waves.[5] The beam width is a property of the antenna itself and is the same regardless if the antenna is used for receiving or transmitting. In design of parabolic antenna, the antenna needs to properly illuminate its parabolic reflector; that is, the beam width of the antenna needs to match the f/D ratio of the parabolic reflector. Similarly , an under illuminated parabolic reflector does not use its total surface area to focus a signal on its antenna.

Gain of a parabolic reflector

Using the formula for the circle area, the aperture area of a parabolic reflector is

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

This area is used in calculating the gain of a parabolic reflector. The gain G of a parabolic reflector is directly proportional to the ratio of the area of the aperture to the square of the wavelength l of the incoming radio waves

$$G = 10\ \log_{10}(\frac{\eta 4\pi A}{\lambda^2})$$

η is the efficiency of the parabolic reflector and has a practical value of 50%. In electrical engineering, it is common practice to express gain ratios such as G in terms of decibels which is 10 times the common logorithm of the gain formula. The unit of G is in dB.[6]

III.RESULT AND DISCUSSION

The antenna radiation pattern is the display of the radiation properties of the antenna as a function of the (θ, φ) spherical coordinates. In most cases, the radiation pattern is determined in the Far-Field region for constant radial distance and frequency. A distinctive radiation pattern is characterized by a main beam with 3 dB beam width and side lobes at different positions. The antenna performance is frequently described in terms of its principal E-plane and H-plane patterns. For a polarized antenna, the E-plane and H-planes are defined as the planes containing the direction of maximum radiation and the electric and magnetic field vectors, accordingly.

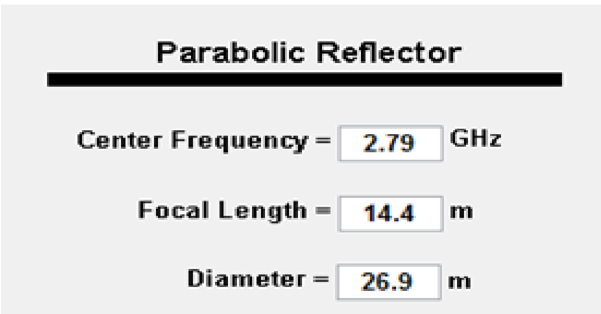

Fig.2. input values of reflector

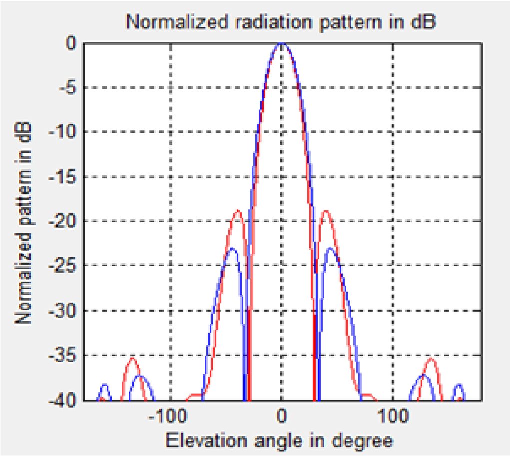

Fig.3.normalized radiation pattern of E-plane and H-plane

This is a normalized antenna and produces a pointed beam. The reflector has an elliptical shape. It will produce a beam. Radars use two different curvatures in the horizontal and vertical planes to achieve the required pencil beam in azimuth and the classical beam in elevation.

This ideal case shown in the figure 3 doesn't happen in the practice. The practical parabolic antennas pattern has a conical form because of irregularities in the production. Main lobe may vary in angular width from one or two degrees in some radar to 15 to 20 degrees in other radars.

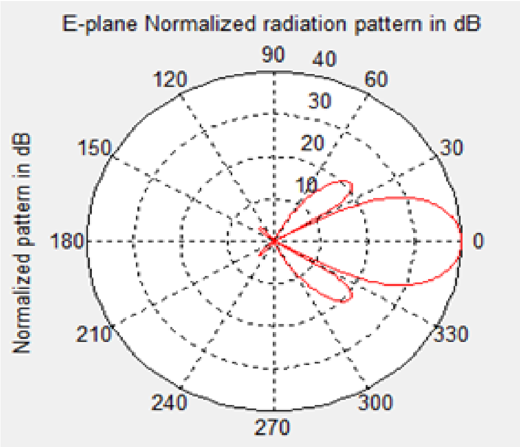

Fig.4. E-plane normalized radiation pattern

This shift in operating frequency may be attributed to the gain enhancing feature of such antenna with air or any other low dielectric constant substrate. The next step is to examine the radiation pattern for two identical antennas; one with conventional substrate and the other with air substrate. Therefore, the radiation patterns are compared between the antennas separately at E and H plane as shown in Figure 4 and Figure 5. It is evident from the figure that, E plane 3 dB beam width is doubled than H plane beam width for conventional antenna with substrate while, those for same antenna with air substrate show no changes in beam widths between its E and H planes. Along with this the gain of this present antenna with air substrate is greater than conventional structure as expected.

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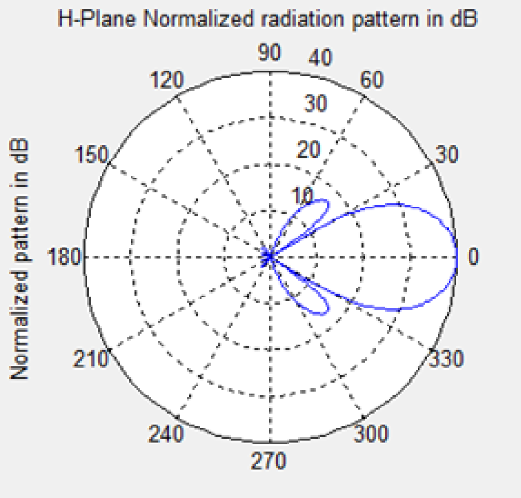

Fig.5. H-plane normalized radiation pattern

In this table frequencies are varied while the focal length and diameters are kept constant. Frequency variation does not affect efficiency but give sharper beam width with varying frequency to produce better beam width.

Table.1.constant focal length and diameter and variable frequency

Frequency (GHz)	Focal Length (m)	Diameter (m)	Efficiency η= f/D	Beam width $\psi = 70\,\lambda/D$
2.79	22.4	26.9	0.83	0.27
3.00	22.4	26.9	0.83	0.26
3.25	22.4	26.9	0.83	0.23
3.50	22.4	26.9	0.83	0.22
3.75	22.4	26.9	0.83	0.21

In this table focal lengths are varied while the frequency and diameter are kept constant. Focal length variation does not affect beam width but produce a better efficiency according to requirement.

Table.2.constant frequency and diameter and variable focal length

Frequency (GHz)	Focal Length (m)	Diameter (m)	Efficiency η= f/D	Beam width $\psi = 70\,\lambda/D$
2.79	22.4	26.9	0.83	0.27
2.79	20.4	26.9	0.75	0.27
2.79	18.4	26.9	0.68	0.27
2.79	16.4	26.9	0.60	0.27
2.79	14.4	26.9	0.53	0.27

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In this table diameters are varied while the frequency and focal length are kept constant. Diameter decrement affects both the efficiency and beam width increase but produce a poor result according to requirement.

Table.3.constant frequency and focal length and variable diameter

Frequency (GHz)	Focal Length (m)	Diameter (m)	Efficiency η= f/D	Beam Width $\psi = 70\,\lambda/D$
2.79	22.4	26.9	0.83	0.27
2.79	22.4	24.9	0.89	0.30
2.79	22.4	22.9	0.97	0.32
2.79	22.4	20.9	1.07	0.35
2.79	22.4	18.9	1.18	0.39

IV.CONCLUSION

The fundamental antenna concepts and a brief introduction to the types of feeds have been discussed. Analysis of the parabolic reflector typically like f/D, gain, radiation patterns has been done and the corresponding results were plotted. The E-plane and H-plane normalized radiation patterns in dB of parabolic reflector were calculated and then the beam width and efficiency was calculated by using general formula. By calculating these different values of beam width and efficiency this paper is conclude that center frequency is 2.79GHz, focal length is 14.4mm and diameter of the parabolic dish is 26.9mm gives the better response of this reflector.

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BIOGRAPHY

Ms Kirti Chaurasiya is presently pursuing M.Tech in Eletronics and Communication Engineering from Amity University, Uttar Pradesh, Lucknow. She has done B.Tech degree course in Electronics & Communication Engineering from Dr Ram Manhor Lohia Avadh University Faizabad Uttar Pradesh in 2013. Presently, she has focused her working area within of parabolic reflector. Her research interests also include Efficiency Improvement of Solar Cell Using Compound Parabolic Concentrator and Sun Tracking System using MATLAB.

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