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Investigation of Radiation Characteristics of 1.2M Satellite Dish Antenna.

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ABSTRACT

The high gains and narrow beamwidth of reflector antennas make them very attractive for radio telescope, deep space exploration, line of sight satellite and microwave communication. An investigative study on the radiation characteristics of a parabolic antenna was carried out in this work, and the radiation pattern illuminated by a dipole was examined. The method used for this analysis is known as Geometrical Optics (GO), while the software utilized is MATLAB. A physical diameter of 10**λ**, with an electrical diameter of 1.2m at a frequency of 2.5GHz was utilized for the purpose of this analysis. The results obtained revealed the E and H-planes exhibiting similar characteristics, and sidelobes are absent. Furthermore, the back radiation was considerably large, and the directivity of the antenna was low. However, the effect of the back radiation is only visible in the polar plot and not visible in the rectangular plot.

Keywords: Satellite Dish, Antenna, Parabolic Reflector, Geometrical Optics

I. INTRODUCTION

A Satellite dish is a parabolic television antenna that receives signals from communication satellites in orbit around the earth. The first communication satellite, Echo 1, was launched by the United States in 1960, transmitting telephone signals. In 1961, Relay began transmitting television signals, and in the same year, Syncom established itself as the first geosynchronous satellite capable of transmitting signals to one particular section of the earth's surface continuously.

Satellite dishes will become ubiquitous in upcoming yearsthus, more communication satellites will certainly be launched, and the growth explosion in individual satellite dish will continue. However, one factor that should affect home satellite dish ownership in the near future is the switchover to more powerful satellites that will transmit signals in the K band (12GHz), and this is because most of the present satellite dishes accept signals in the C band (3.7 to 4.2GHz). Researchers and designers are contemplating even smaller dishes that could be placed on a rooftop or outside a window and still function as well as the larger satellite dishes of today [1].

Wireless communication is the transfer of information or power between two or more points that are not connected by an electrical conductor. The most common wireless technologies use radio, however, the waves distance can be short using a radio (such as a few meters for television or as far as thousands or even millions of kilometers for deep-space radio communications. It encompasses various types of fixed, mobile, and portable applications, including two-way radios, mobile telephone, personal digital assistant, and wireless networking. Other examples of applications of radio wireless technology include GPS units, garage door opener, wireless computer mice, keyboards and headsets, headphones, radio receivers, and satellite television.

Nowadays, satellite communications play an important role in telecommunications, and the two major elements of satellite communication systems are the space segment, where the satellite itself is orbiting, and where the satellite control center for station keeping of the satellite is located, while the second element is the ground segment, which transmits the signal to the satellite, and receives the signal from the satellite. Antennas are the main part of this process, and they have the responsibility to receive, decode and convert the physical signal into electric current, or vice-versa. Dealing with space communications require a parabolic antenna able to communicate with satellites operating at certain frequency ranges. According to IEEE, an antenna or aerial is defined as a "transmitting or receiving system that is designed to radiate or receive electromagnetic waves".

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The objectives of the study are:
i.To review satellite dish antenna characteristics.
ii. To review radiation pattern derivation techniques.
iii. To derive the radiation pattern of the parabolic dish antenna using Geometrical Optics (GO).
iv. To compute and plot the E & H-plane radiation pattern of a 1.2M parabolic dish antenna fed by an Hertzian dipole.

II. LITERATURE REVIEW

[8] studied two theoretical methods; Aperture Field Method (AFM) and Induced Current Method (ICM) to obtain the radiation fields of parabolic reflector antenna fed by two types of micro-strip antenna. The result shows that both methods agree in the study of the radiation patterns in principle planes (E and H) at far-field region.

[4] presented the analysis of radiation patterns and feed illumination of the reflector antenna using the physical and geometrical optics. Reflector antennas are characterized by very high gains (30dB and higher) and narrow main beams. In this paper, we analyzed the effects of feeds relating to the parabolic reflectors such as waveguide and horn. The variations of the gain in the electric and magnetic planes (E and H) were also displayed according to the angle of incidence.

[6] presented the design an analysis of a rectangular micro-strip patch antenna for S-band wireless communication systems. In this paper, a compact-sized microstrip patch antenna was designed for high gain resonating at 2.4GHz. The gain, return loss, bandwith, VSWR, and radiation efficiency are 6.75dBi, -2700dB, 0.0645GHz, and 84% respectively. These results demonstrate that the proposed antenna is well suitable for use in an S-band.

[7] presented the merits and demerits of some of the most visible outdoor components of a Television Receive Only (TVRO), namely; the antenna dish reflector. The parabolic reflector efficiency, and its ability to collect satellite signals under various conditions were highlighted. Furthermore, different features including installation of screened mesh dishes and solid dishes were compared. The received signal strength from 8 geostationary satellites by different types of parabolic dishes were presented and compared, and the results obtained revealed that the solid dish was more efficient than the screen mesh with satellites of low elevation, due to better stability with wind caused vibration.

[10] analyzed the effect of water film at the dish surface on the radiation characteristics of single-dish antennas. The gain and radiation pattern of single-dish antennas with different geometry were also calculated using the method of physical optics and solving the model problem on scattering of the plane electromagnetic wave at a dielectric area located on a perfectly conducting substrate. It was shown that the proposed calculation method ensures a good agreement between the experimental and theoretical data.

[2] presented the analysis of various types ofantennasused in C-band for satellite communication. This paper gives great insights on antennas suitable for use in C-band for satellite communication such as an overview of the patch antenna and dish antenna, including their individual losses and performance. Furthermore, antennas that can be used for future aspects in satellite communication were also discussed.

[3] presented the design and simulation of a reduced size VSAT antenna with appreciable gain. This paper proposed the design of a simulation dish that is very small in size (diameter), but working effectively as the usual dish for internet data transmission. The design parameters were varied using Ka band frequency.

[5] presented approaches for parabolic antenna control. This article covered various control strategies for position control in the presence of internal and external disturbances as well as to improve the system performance. The techniques surveyed were classified into: the linear, adaptive, computer, meta-heuristic, artificial neural networks and fuzzy logic methods.

III. METHOD

The radiation characteristics of a parabolic antenna fed by a dipole will be used to investigate and analyze the behavioral characteristics of the antenna at 1.2M.

To determine the direction and the phase, we need to first determine the field radiated by the feed antenna and then trace its path as it propagates as a plane wave along the z-axis to the aperture plane.

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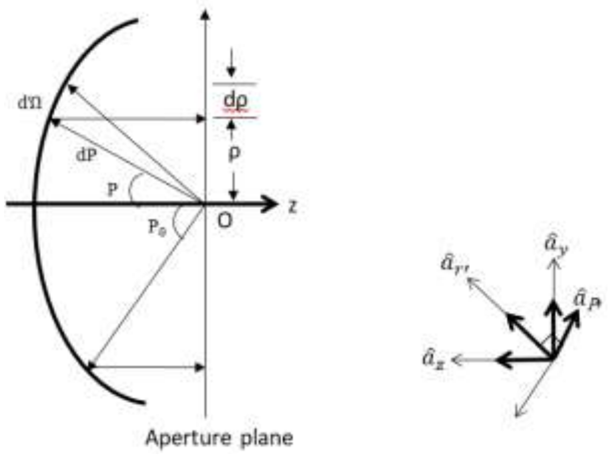

Figure1. Reflection on the Aperture Plane of a Parabolic Reflector

Where;

$$\hat{R} = \hat{x}\sin\psi\cos\chi + \hat{y}\sin\psi\sin\chi - \hat{z}\cos\psi$$
$$\hat{\psi} = \hat{x}\cos\psi\cos\chi + \hat{y}\cos\psi\sin\chi + \hat{z}\sin\psi$$
$$\hat{\chi} = -\hat{x}\sin\chi + \hat{y}\cos\chi$$

And

$$\hat{x} = \hat{R}\sin\psi\cos\chi + \hat{\psi}\cos\psi\cos\chi - \hat{\chi}\sin\chi$$
$$\hat{y} = \hat{R}\sin\psi\sin\chi + \hat{\psi}\cos\psi\sin\chi + \hat{\chi}\cos\psi$$
$$\hat{z} = -\hat{x}\sin\chi + \hat{y}\cos\chi$$

Parametrizing points on the reflector surface by the spherical coordinates (R, ψ, x) as shown in Figure 3.1, the wave radiated by the feed at an incident point(R, ψ, x) on the reflector can be expressed as;

$$E_i = \frac{e^{-jkR}}{R} f_i(\psi, x) \qquad (1)$$

Where;

$f_r$satisfies$|f_r| = |f_i|$, hence

$$f_r = -f_i + 2\hat{n}(\hat{n}.f_i) \qquad (2)$$

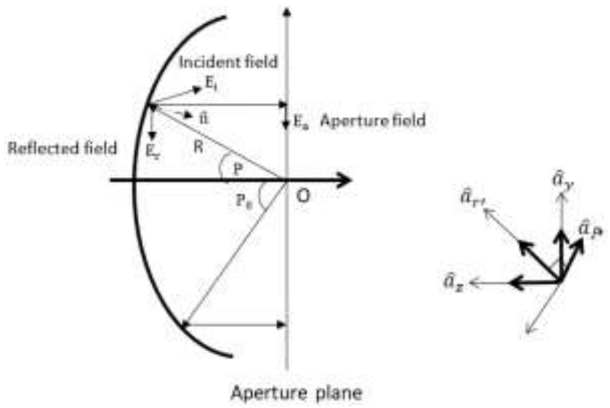

Figure 2. Geometrical Relationship between Reflected and Incident Electric Field

Decoupling the radial dependence of the radiation field on R from the angular dependence on P,x. The corresponding magnetic field will be:

$$H_i = \frac{1}{\eta}\hat{R}\ X\ E_i = \frac{1}{\eta}\frac{e^{-jkR}}{R}\quad \hat{R}\ X\ f_i\ (\psi, x) \qquad (3)$$

Where the radiation intensity of the feed antenna can be related to the vector function f_i using;

$$U_{feed}\ (\psi, x) = R^2\frac{1}{2\eta}|E_i|^2 = \frac{1}{2\eta}|f_i(\psi, x)|^2 \quad (4)$$

Assuming a plane wave reflection from the surface of the perfectly conducting reflector, the following conditions must be satisfied:

$$\hat{n}\ X\ E_r = -\hat{n}\ X\ E_i\ , \qquad \hat{n}.E_r = \hat{n}.E_i$$
$$\hat{n}\ X\ H_r = H_i\ , \qquad \hat{n}.H_r = -\hat{n}.H_i$$

Hence the reflected field at the point R, ψ, x from the reflector can be expressed as;

$$E_r = \frac{e^{-jkR}}{R} f_r(\psi, x) \qquad (5)$$

3.1.1 Antenna Gain

The gain of a parabolic reflector antenna is a key parameter which makes it ideal for high gain applications such as satellite television and radio telescope.

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In terms of physical area, the antenna gain can be expressed as:

$G_{max} = \frac{\pi(D)^2}{\lambda^2}$ (6)

Thus, the actual gain can be expressed as:

$G = \varepsilon\frac{\pi(D)^2}{\lambda^2}$ (7)

$G(\text{indB}) = 10\log_{10}\varepsilon\frac{\pi(D)^2}{\lambda^2}$ (8)

Where;

λ = Operating wavelength.

ε = Antenna efficiency.

3.1.2 Geometrical Optics

The method utilized in deriving the radiation pattern of the parabolic dish antenna is known as Geometrical Optics.

Basically, a parabolic dish antenna is made up of a feed antenna and a parabolic reflector. The feed antenna which could be a dipole or horn points towards the parabolic reflector. The radiation propertiesof the overall system such as radiation pattern, impedance, and directivity are largely influenced by the polarization of the radiating source and its position relative to the reflecting surface.

Based on the geometrical structure of the antenna, the equations relating the parameters of a parabolic antenna are displayed in this section. The parabola can be completely described by the diameter and focal length as given in the equations below:

$\frac{F}{D} = \frac{1}{4\tan\left(\frac{\theta_0}{2}\right)}$ (9)

$F = \frac{D^2}{16H}$ (10)

Where;

D = The diameter of feed antenna.

F = Focal length.

θ_0= Maximum angle between focal point and edge of dish.

H = Vertical height of reflector.

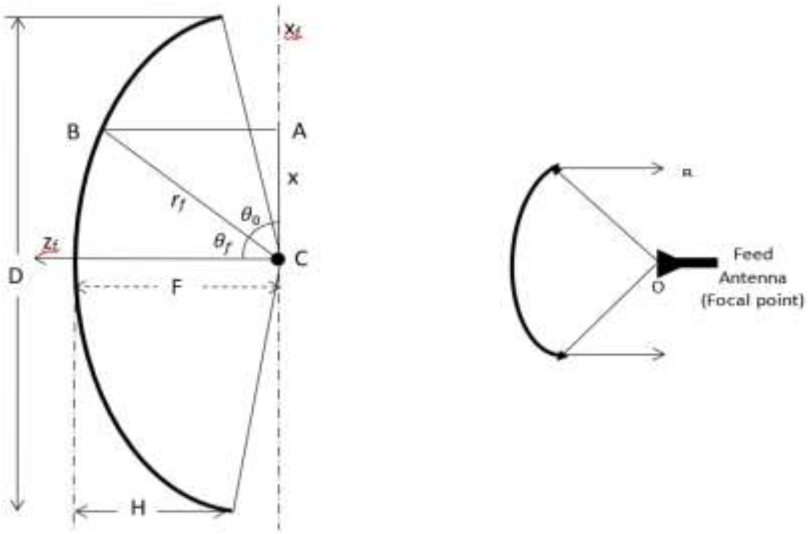

Figure 3. Geometrical Configuration of a Parabolic Reflector Antenna

IV. RESULTS AND DISCUSSION

For the purpose of analysis, the following feed systems were used to illuminate a Hertzian Dipole Fed Parabolic Reflector [9].

F = 10**λ**

D = 40**λ**

$\theta_0 = 90^0$

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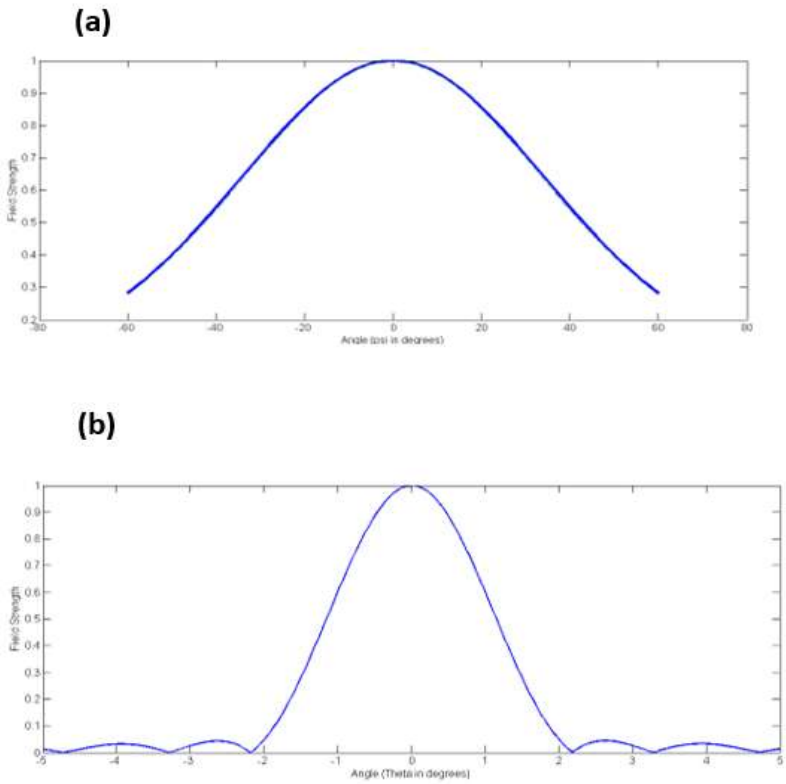

Figure 4.1 Feed Illumination Pattern and Radiation Characteristics

Figure 4.1(a) displays the feed illumination pattern of a Hertzian dipole feed while Figure 4.1(b) displays the paraboloid reflector radiation pattern. From the above Figures, the increase in directivity and the increase in gain is evident as the paraboloid further concentrated the radiation in the forward direction.

4.2 Variation of Gain with Diameter

Table 4.1 Variation of Frequency and Diameter with the Gain of the Antenna

Frequency Diameter	L-band 1GHz (dB)	S-band 3GHz (dB)	C-band 8GHz (dB)	X-band 12GHz (dB)	K-band 18GHz (dB)	L-band 20GHz (dB)
0.2m	-3.59	18.38	32.24	46.11	54.21	56.32
0.4m	10.27	32.24	46.11	59.97	68.08	70.18
0.6m	18.38	40.35	54.21	68.08	76.19	78.29
0.8m	24.13	46.11	59.97	73.83	81.94	84.05
1.0m	28.60	50.57	64.43	78.29	86.40	88.51
1.2m	32.24	54.21	68.08	81.94	90.05	92.16

From equation (3.3) and Figure 4.2, it can be observed that the gain of the antenna increases almost linearly with an increase in diameter, and the gain also increases with frequency. Thus, the antenna experiences greater gain at higher frequencies.

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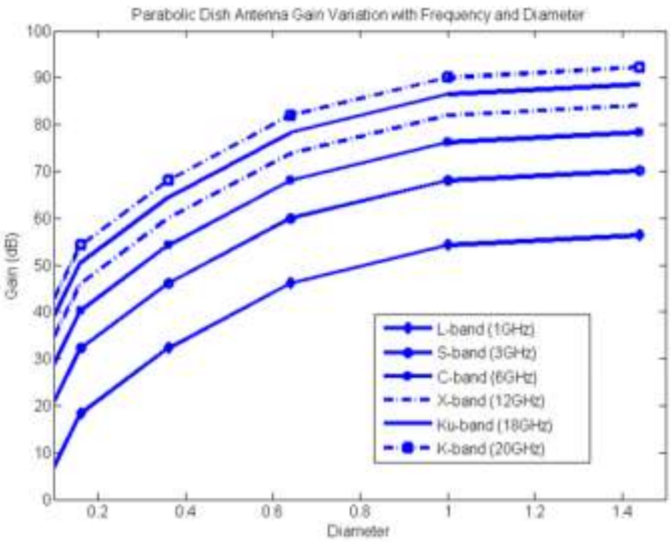

Figure 4.2 Graph of Diameter against Gain of Antenna

As earlier stated, using a physical diameter of 10wavelength, and an electrical diameter of 1.2m, the operational wavelength at this physical length is 12cm and the operational frequency is 2.5GHz.

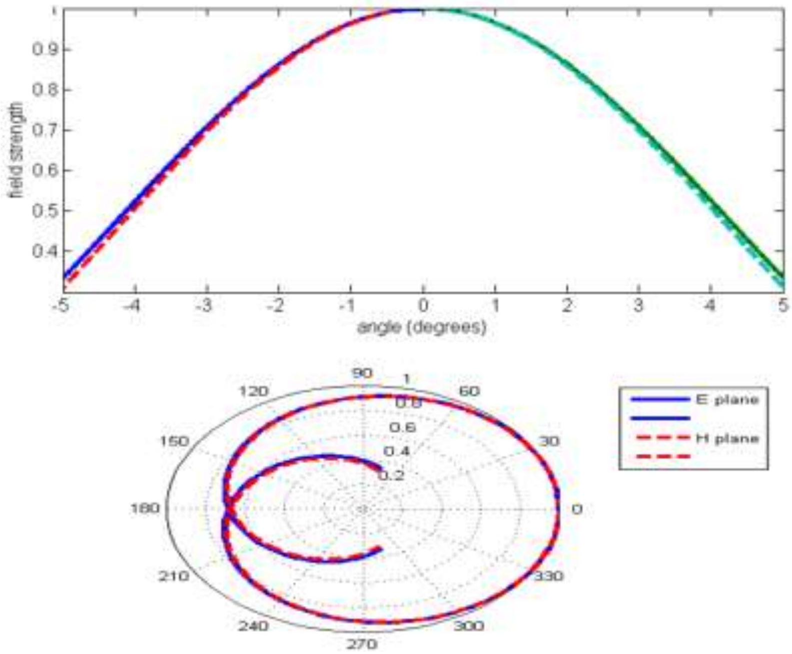

Figure 4.3 Rectangular and Polar Plot of Radiated Fields of Dipole Fed Parabolic Reflector 10λ Physical Diameter

At the diameter of 10 wavelength, it is observed that the back radiation is considerably large and the directivity of the antenna is low. The E-plane and H-plane both exhibit similar behaviour and sidelobes are absent. However, the antenna efficiency will be greatly reduced due to poor front reflection which is traceable to low aperture area to collect incident field and reflect them to increase their gains.

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V. CONCLUSION

The effect of the back radiation is not visible in the rectangular plot, but it is well pronounced in the polar plot which makes the polar plot of great importance to an accurate interpretation of the behaviour parabolic antenna at this diameter length. The back radiation displayed in the polar plot shows that the field reflected is not originating from the source which could be accountable to edge losses due to low aperture area.

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