Performance Analysis and Design Consideration of Cassegrain for Satellite Communication

Ms.Myint Myint Soe, Dr.Zaw Min Aung, Dr.Zaw Min Naing, Dr.Khaing Theingi Oo

Abstract- **A high performance of an antenna defines the quality of service of a communication system. The most widely used narrow beam antennas in satellite communication systems are reflector types such as Cassegrain and Garegorian. This paper provides a design and analysis for obtaining high performance of antenna specific to Cassegrain antenna considering the effects of losses in the system. The efficiency of the antenna system is discussed, and parametric curves showing losses as a function of the Cassegrain design parameters are presented. The performance of the designed antenna system leads to the useful relationships for choosing the design parameters for optimum gain performance.**

keywords:Performance,Cassegrain,satellite,efficiency, losses

I . INTRODUCTION

Cassegrain antenna is a double reflector system which has many interesting features such as high efficiency, low noise temperature performance, and easy accessibility to electronic equipment. For small size of antennas ($D/\lambda<100$) cassegrain system is not attractive due to large blockage and inefficiency scattering mechanism.
In dual reflector antennas: feed, feed support beams and subreflector especially cause distribution losses and large blockings in antenna apertures. The radiation pattern from the sub reflector is then calculated at a large number of points on the main reflector and is used to establish current distribution on the main reflector.

Geometric theory of diffraction is used to improve the accuracy of far field pattern by including edge effects. Total efficiency calculation for a large cassegrain antenna includes illumination efficiency, sub reflector spillover, main reflector spillover, blockage losses, phase errors and surface errors, polarisation loss, mismatch loss. The efficiency for the ratios of various sub-reflector diameters over the main reflector diameters (D_S/D) will be examined. Simulation of the proposed antenna has been carried out using ICARA (Induced Current Analysis of Reflector Antennas) software which has been developed for the analysis and design of reflector antennas [9].

II. DESIGN CONSIDERATION

The optimum design of a complete antenna system is rather complicated, but some published descriptions use mathematics which makes it seem even more complicated. The notations used in proposed antenna are shown in fig.1. The analyzed configuration is a Cassegrain antenna. The geometric values are described in the following Table I.

The feed is circular horn feed. Frequency of design being taken is 6GHz.The finite sub reflector size produces diffractions that cause main reflector spillover,cross-polarized sub reflector reflections, phase error losses, and additional amplitude taper losses. The loss depends on the effective focal length and the diameter of the sub reflector.

Table.I: Geometrical parameters for selected Cassegrain antenna

Geometry Configuration	
Type	Casse grain
Focal length	f_m=1.5meter
Aperture size X	D_x=2meter
Aperture size Y	D_y=2meter
Magnification	M=5
Interfocal length	f_s=1.3meter

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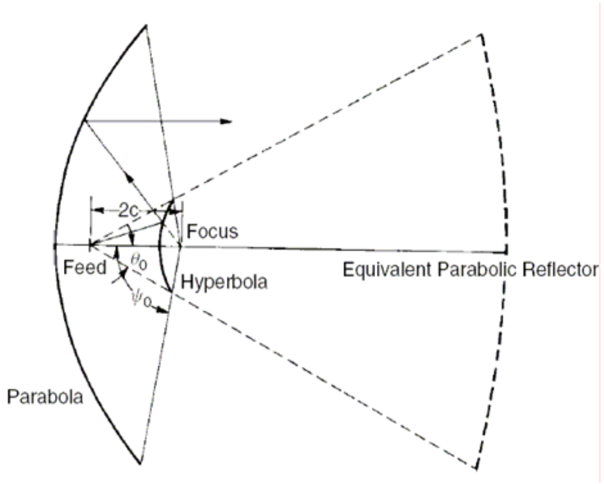


Fig-1 Cassegrain Antenna

The directivity for a random antenna can be stated as:

$$D_0 = 4\pi A \eta_v / \lambda^2 \qquad (1)$$

Where η_v is the antenna efficiency.

The half subtended angle of the reflector, ψ_0, relates to f/D by

$$\psi_0 = 2\tan^{-1}\frac{1}{4f/D} \qquad (2)$$

The spherical wave spreading multiples the feed distribution by $\cos^2(\psi/2)$ in the aperture.

Added edge taper = $\cos^2(\psi_0/2)$

The sub reflector diameter can be calculated from

$$D_s = \frac{2eP\sin(\pi-\psi_0)}{1-e\cos(\pi-\psi_0)} \qquad (3)$$

Where e is the eccentricity and P is the design parameter which can solve in terms of the distance between focuses 2c.

Given the main reflector diameter D, focal length f, and sub reflector half subtended angle θ_0, can solve the quadratic equation for roots X1:

$[8 \text{ f D}-\sigma \tan\theta_0 (16f^2-D^2)] X_1^2-16 D_{pc} \tan\theta_0 \text{ f D } X_1- 16D_f f^2 D \tan\theta_0 =0$ (4)

The parameter σ equals -1 for a Cassegrin dual reflector.

The focal length of the conic-section sub reflector :

$$c = X_1 \frac{8fD-\sigma\tan\theta_0(16f^2-D^2)}{32fD\tan\theta_0} \qquad (5)$$

The approximation efficiency for the combination of blockage and diffraction losses:

$$\eta = \left[1-C_b\left(1+4\sqrt{1-\frac{d_{sub}}{D}}\right).\left(\frac{d_{sub}}{D}\right)^2\right]^2 \qquad (6)$$

where $C_b = \frac{-\ln(\sqrt{E})}{1-\sqrt{E}}$, E is edge taper as a ratio: $E=10^{(\text{taper in dB}/10)}$

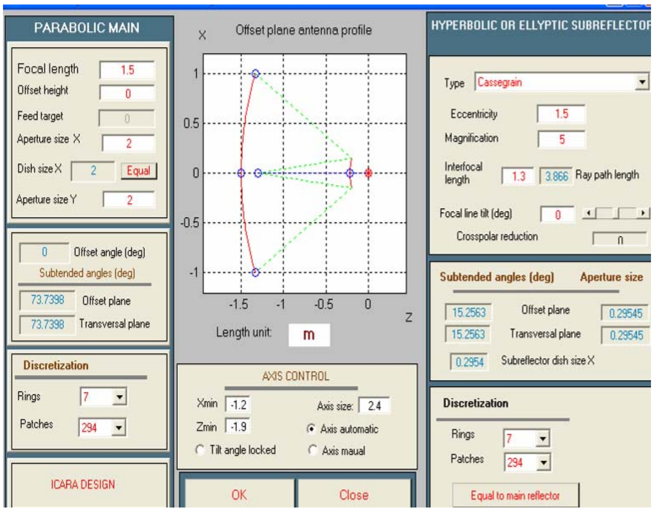
The rest of the parameters of the dual-reflector antenna follow from these parameters.

The design process is an iterative optimization process. In general, first the parameters of the basic geometry were optimized, then the input and output fields and their representation with rays were optimized. Each parameter was optimized by synthesizing the surfaces with a number of different values for the parameter. Then the synthesized surfaces were simulated and the results analyzed. The best value for the parameter, based on the simulation results, was used when the next parameters were optimized. In this way it was possible to study separately how each parameter affected the radiation of the Cassegrain antenna. The design process was repeated many times to find the maximum gain with low side lobes and to find out how to decrease the diffraction losses.

III. RESULTS AND DISSUSIONS

The simulations were done with ICARA(Induced Current Analysis of Reflector Antenna) software by the Antenna Group at the University of Virgo using physical optics (PO) and sometimes also physical theory of diffraction (PTD). Fig.2 (a) shows the geometric values of the Cassegrain antenna. The following demonstration shows how the field from this geometry is analyzed with ICARA.

In the first simulation, the desired parameters placed and the feed is chosen cos-q type. Then, the resulting feed and target points gain as shown in fig.2 (b). The amplitude and phase of the cross-polarization was defined only in the phi constant cut. The radiation pattern is defined in the θ-direction from -30°to30° as shown in fig.2 (c) and (d). In second, the reflector diameter, the focal length and the feed design are changed to enhance the performance. In third simulation, the gain and efficiency are compared between the simulation results with and without PTD. The simulation results of the final design of the Cassegrain antenna are presented in Fig.2 (a-d). The radiation pattern, in fig.2 (e), has been simulated for 5 meter diameter i.e, no change other parameters. The simulation shows that the gain depends on the size of the antennas which reduces the cross-polarization.



PARABOLIC MAIN

Focal length 1.5
Offset height 0
Feed target 0
Aperture size X 2
Dish size X 2
Aperture size Y 2

0 Offset angle (deg)

Subtended angles (deg)
73.7398 Offset plane
73.7398 Transversal plane

Discretization
Rings 7
Patches 294

Length unit: m

AXIS CONTROL
Xmin -1.2
Zmin -1.9
Axis size: 2.4
○ Tilt angle locked
● Axis automatic
○ Axis maual

HYPERBOLIC OR ELLYPTIC SUBREFLECTOR

Type Cassegrain
Eccentricity 1.5
Magnification 5
Interfocal length 1.3
3.866 Ray path length
Focal line tilt (deg) 0
Crosspolar reduction 0

Subtended angles (deg) Aperture size
15.2563 Offset plane 0.29545
15.2563 Transversal plane 0.29545
0.2954 Subreflector dish size X

Discretization
Rings 7
Patches 294

Fig.2 (a) Cassegrain Antenna Geometry

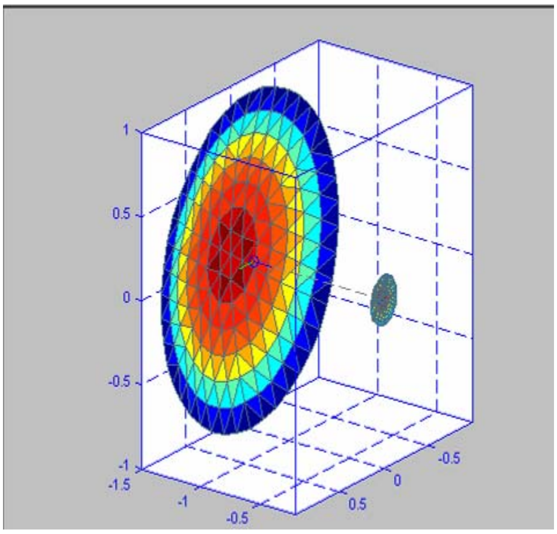


Fig.2 (b)Feed Configuration

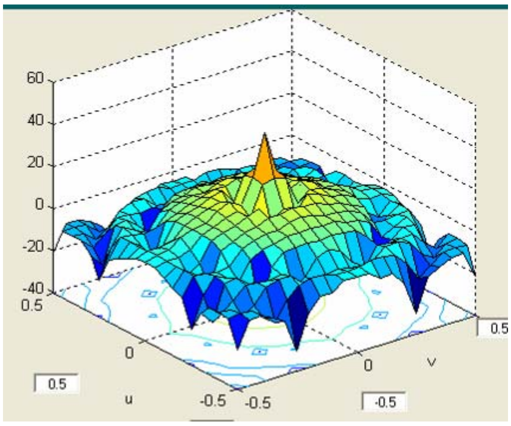


Fig.2 (c) Far Field u-v plot

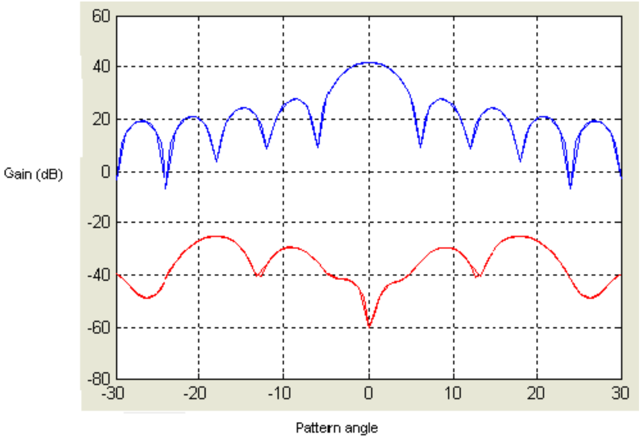


Fig.2 (d) Nominal Radiation Pattern (PO+PTD) for 2meter Cassegrain antenna

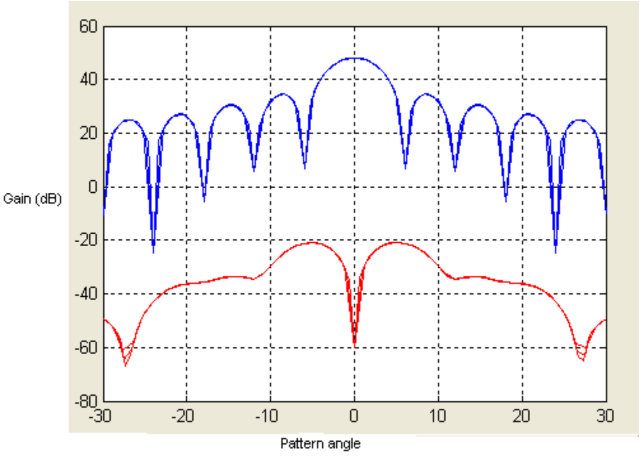


Fig.2 (e)Nominal Radiation pattern (PO+PTD) for 5meter C band antenna

Fig-2(a-e) Analysis of Design Consideration

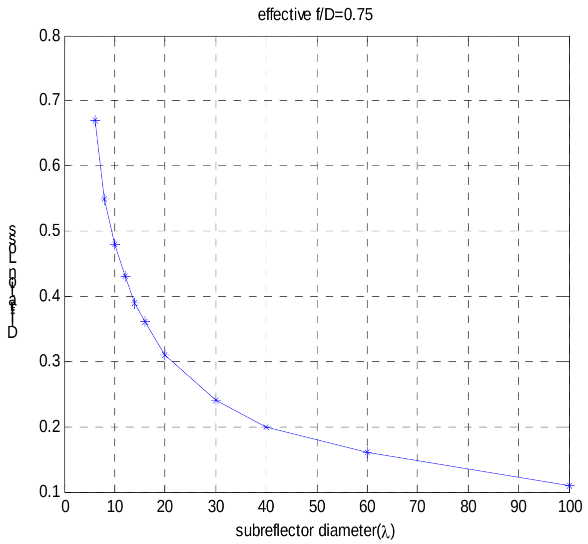


Fig.3 (a)

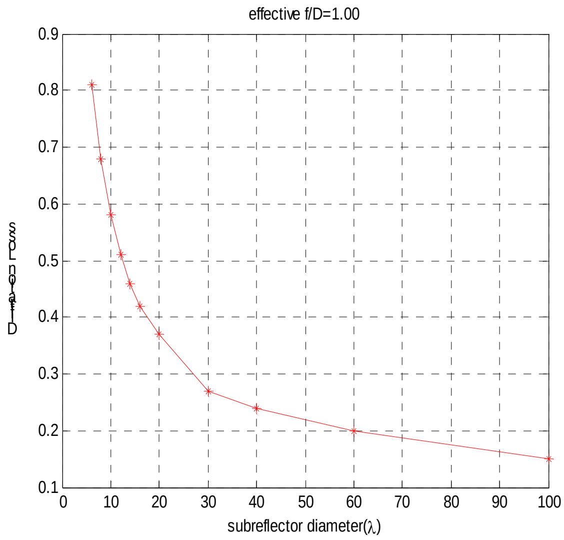


Fig.3 (b)

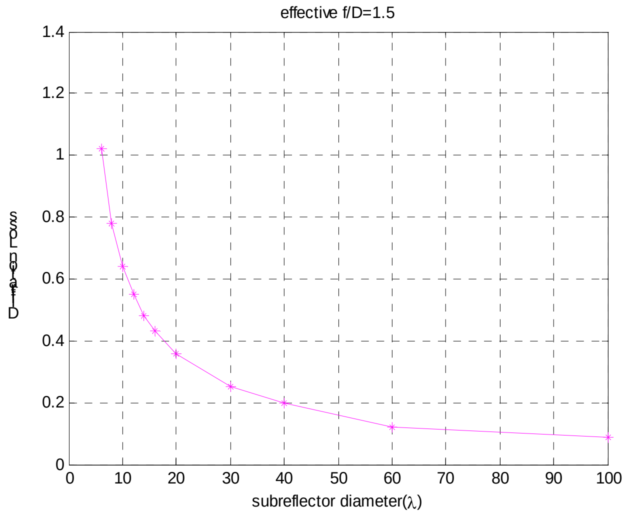


Fig.3 (c)

Fig-3 (a-c) Diffraction loss of a Cassegrain with a 10 dB Feed Edge Taper

Fig.3 (a-c) shows the variation of diffraction loss with subreflector diameter and effective f/D.Rush finds these losses by using PO and GTD where he calculates the currents on the subreflctor [5].The results of GTD calculations are for a circularly polarized feed. From fig.3 (a), it can be seen that the loss has been 0.2 for 40λ diameters, and 0.11 for 100λ in 0.75 of f/D ratio. The fig.3 (b) shows the increased loss at f/D=1.0.But in fig (c), the loss is higher for small size antennas than large size at f/D=1.5. It is cleared that the loss depends on the effective focal length and diameter of the subreflector.

IV.CONCLUSION

In today's use, most of the symmetric dual reflector antennas are based on the traditional Cassegrain reflector system. In the design used, the limitation ratio f/D is generally 0.75 or greater in order to avoid distribution losses and large blockings. If the main reflector diameter is 10λ- 20λ , the subreflector diameter is to be 1λ or 2λ. For high efficiency and low noise performance, the shaped reflectors and corrugated horn techniques are developed improving aperture efficiency from 60% up to as much as 80%.

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