Design of Dual Reflector Cassegrain Feed System Antenna

Jay Trivedi[#1], Smit Shah[*2]

Electronics & communication Department, SVBIT,Vasan,Gujarat,India.
Electronics & communication Department, LDRP-ITR,Gandhinagar,Gujarat,India.

***Abstract*— This paper introduces a Design of dual reflector Cassegrain feed system antenna with suitable design aspects like smaller reflector and sub reflector diameter for higher sub reflector efficiency, lower Cassegrain blockage losses and desired illumination taper. Design parameters are computed from the simple and explicit analytical formulas. Design example is represented to differentiate the efficacy of the approach.**

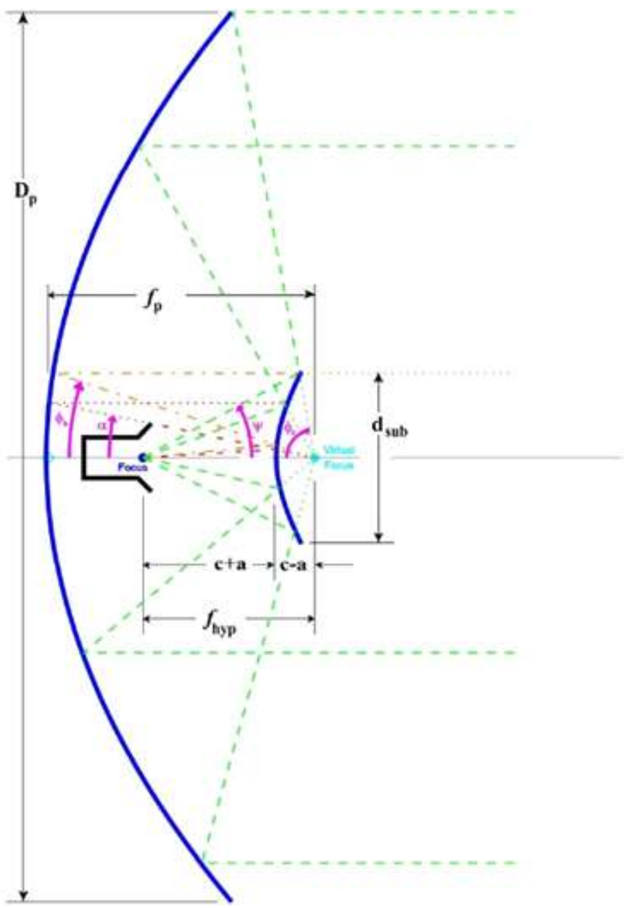
***Keywords*— dual reflector, Cassegrain, feed system**

I. INTRODUCTION

The dual reflector antenna consists of two reflectors and a feed antenna. The feed is conveniently located at the apex of the main reflector. This makes the system mechanically robust, the transmission lines are shorter and easier to construct. The most popular dual reflector is Axisymmetric Cassegrain antenna. The main reflector is parabolic and sub reflector is hyperbolic. A second form of the duel reflector is Gregorian reflector. It has a concave elliptic sub reflector. The Gregorian sub reflector is more distant from main reflector and, thus, it requires more support.

Cassegrain feed system is named after an early – Eighteenth, century astronomer and is adopted directly from astronomical reflecting telescopes. It consists of 1)A Horn antenna as a feed antenna 2) A secondary reflector which is hyperbolic in shape 3) A Primary Reflector which is parabolic .A Hyperbolic sub reflector to this arrangement , acting as a mirror to reflect the feed position back to words the main reflector. The difficulty is finding the right Hyperbolic sub-reflector to match the main reflector to the feed, Since the Hyperbola is not a single curve, but a whole family of curves with different focal lengths and curvatures. The amount of curvatures is called eccentricity. The optimum design of a complete Cassegrain antenna system is rather complicated, but some mathematical formulas make it seem even more complicated.

The Cassegrain feed arrangement is shown in the figure. The primary antenna which is a Horn is placed near the apex of the parabolic Reflector.



"Reference [9]"

Figure 3.1 [Basic principle of Cassegrain feed Antenna system]

Dp = Parabolic dish diameter

fp = Parabolic dish focal length

dsub = Sub reflector diameter

fhyp = focal length of hyperbola – between foci

a = parameter of hyperbola

c = fhyp /2 = parameter of hyperbola

φo = angle subtended by parabola

ψ = angle subtended by sub reflector

φb = angle blocked by sub reflector

α = angle blocked by feed hornFigure Captions

This reduces the feed wave guide always easy to access and adjustments such as feed rotation. In front of horn opening there is a hyperboloid secondary reflector used. One of its foci coincides with the focus of the paraboloid. The rays emitted from the feed horn antenna are reflected from hyperboloid mirror towards parabolic reflector. The paraboloid reflector reflects the ray similarly as the feed antenna is at the focus of it. Thus the waves radiated by the horn are collimated in the forward direction.

II. MATHEMATICAL ANALYSIS

A. Optimum sub reflector size:

Kildal had derived a formula for optimum sub reflector size to reduce the combination of blockage and diffraction losses.

$$\frac{d_{sub}}{D_p} = \left[\frac{\cos^4\left(\frac{\Psi}{2}\right)}{(4\pi)^2 \sin\emptyset_0} \bullet E\frac{\lambda}{D_p}\right]^{\frac{1}{5}}$$

Where E is the edge tapper as a ratio

$$E = 10^{\left(\frac{taper\ in\ dB}{10}\right)}$$

B. Approximate sub reflector efficiency:

Kildal found the approximate subreflector efficiency for the combination of blockage and diffraction losses.

$$\eta = \left[1 - C_b\left(\left(1 + 4\sqrt{1 - \frac{d_{sub}}{D_p}}\right) \bullet \left(\frac{d_{sub}}{D_p}\right)^2\right)\right]^2$$

Where

$$C_b = \frac{-\ln(\sqrt{E})}{1-\sqrt{E}}$$

C. Feed horn:

We can calculate the hyperbola dimensions for the sub reflector required to reshape the feed horn pattern to correctly illuminate the dish, as well as the desired focal length of hyperbola and the distance between the two focus of the hyperbola.

The suspended half angle to illuminate f/D is as below:

$$\Psi = 2\tan^{-1}\left(\frac{1}{4 \bullet \frac{f}{D}}\right)$$

To adjust this for edge tapper we chose above, we use Kelleher's universal horn equation

$$\Psi' = \Psi \bullet \sqrt{\frac{taper\ in\ dB}{10}}$$

To correct the illumination angle for our desired edge tapper

D. Hyperbola focal length

$$f_{hyp} = 0.5 \bullet d_{sub} \bullet \left(\cot(\Psi') + \cot(\emptyset)\right)$$

E. Feed blockage

We have to concern with feed blockage. The ray near the centre of the beam that reflect from sub reflector at the angles less than φb can eventually blocked by sub reflector. If $\alpha > \varphi_b$, then the angle shadowed by the feed horn is

$$\emptyset_b = \sin^{-1}\left(\frac{d_{sub}}{2 \bullet F_p}\right)$$

$$\alpha = \tan^{-1}\left(\frac{d_{sub}}{2 \bullet f_{hyp}}\right)$$

We decide a feed horn and angle, the effective f/d for the feed can be given as:

$$\textit{Effective feed f/d} = \frac{1}{4\tan\left(\frac{\Psi}{2}\right)}$$

F. Sub reflector geometry:

The sub reflector has to reshape the illumination from the effective feed f/d to F_p / D_p for the dish, a magnification factor M is shown below.

$$M = \frac{\textit{effective feed}\ \frac{f}{D}}{\frac{f_p}{D_p}}$$

Eccentricity and hyperbola parameters are ,

$$e = \frac{M+1}{M-1}$$

Finally, the hyperbola parameters can be calculated as

$$c = \frac{f_{hyp}}{2}$$

$$a = \frac{c}{e}$$

$$b = \sqrt{c^2 - a^2}$$

III. DESIGN ANTENNA

As shown in below figure it is a virtual image of Cassegrain feed system.

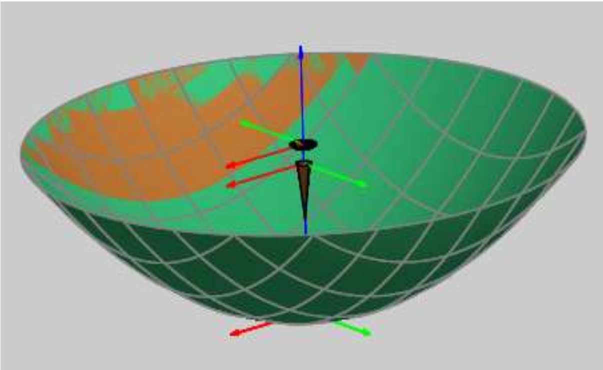


Figure 5.1 [3D view of Cassegrain feed system antenna]

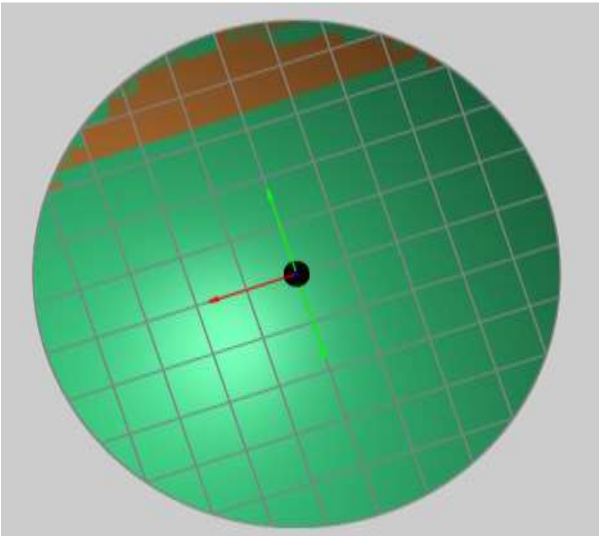


Figure 5.2 [Top view of Cassegrain feed system antenna]

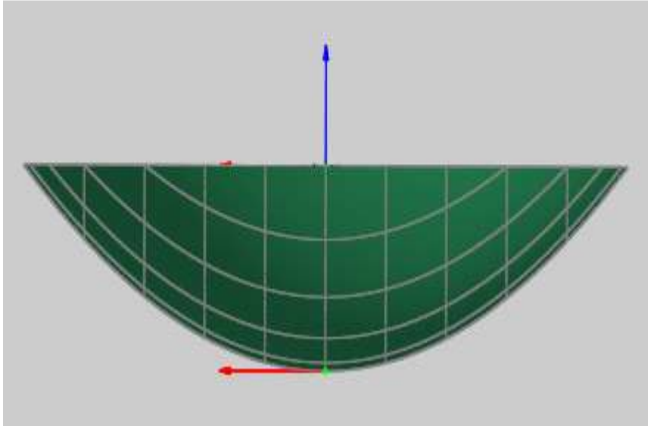


Figure 5.3 [Side view of Cassegrain feed system antenna]

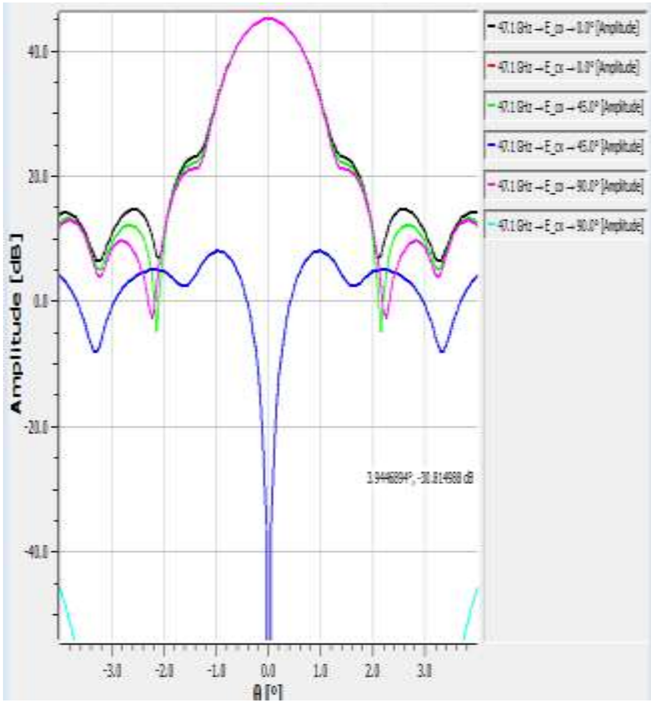


Figure 5.4 [Radiation Pattern of Cassegrain feed system antenna]

IV. CASSEGRAIN ANTENNA DESIGN CALCULATOR :

TABLE 6.1 [CALCULATION TABLE]

Parameter	*Value*	*Value*
Frequency	*47.100GHz*	*10.368GHZ*
Dish diameter	*4.57mm*	*2438mm*
Dish f/D	*0.25*	*0.36*
Feed horn equivalent f/D	*0.6*	*0.75*
Dish focal length	*6.369mm*	*28.935mm*
Dish illumination half angle	*90.0 degree*	*69.7 degree*
Feed horn illumination half angle	*45.2 degree*	*36.9 degree*
Illumination taper	*12.46 dB*	*12.36 dB*
Min. sub reflector diameter	*38.0mm*	*200.7mm*
Sub reflector focal length	*23.3mm*	*172.5mm*
Sub reflector f/D	*0.61*	*0.86*
Feed horn blockage half angle	*10.2 degree*	*9.9 degree*
Sub reflector efficiency	*86.9%*	*82.7%*
Cassegrain loss	*-0.644 dB*	*-0.947dB*
Hyperbola eccentricity	*2.10*	*2.80*
Sub reflector magnification M	*2.81*	*2.11*

V. RESULT & CONCLUSION

In this paper, we have presented design method of dual reflector Cassegrain feed system antenna for two different frequencies in GHz to reduce diameter of main dish as well as sub reflector. As shown in the calculation table, we have taken difference of 47.100GHz and 10.368GHz frequencies which lead to desire illumination taper of 12.46 dB &12.36 dB respectively and sub reflector efficiency of 86.2% & 82.7%. We can reduces blockage losses of Cassegrain antenna to as efficient as bigger Cassegrain sub reflector geometry .So it would be better to use higher frequency like 47.1GHz for antenna design. We would get overall Cassegrain losses included feed horn blockage, sub reflector blockage, space attenuation for main dish. Mathematical calculation of parameters is based on simple and explicit formulae.

VI. REFERENCES

[1] GRASP-TICRA engineering consultants,www.ticra.com

[2] Garnet, "Designing Classical Offset Cassegrain or Gregorian Dual-Reflector Antennas from Combinations of Prescribed Geometric Parameters," *IEEE Antennas and Propagation Magazine*, June 2002.

[3] Aluizio Prata, Jr., Fernando J.S. Madeira, and Luis R. Amaro, "Displaced-Axis- Ellipse Reflector Antenna for Spacecraft Communication

[4] P.A. Jensen, "Cassegrain Systems," in A.W. Rudge, K. Milne, A.D. Olver, P. Knight

[5] Thomas Milligan, *Modern Antenna Design*, McGraw-Hill, 1985, pp. 239-249.

[6] Per-Simon Kildal, "The Effects of Subreflector Diffraction on the Aperture.

[7] Efficiency of a Conventional Cassegrain Antenna — An Analytical Approach," *IEEE Transactions on Antennas and ¯Propagation*, November 1983.

[8] Christophe Granet, "Designing Axially Symmetric Cassegrain or Gregorian Dual- Reflector Antennas from Combinations of Prescribed Geometric Parameters," *IEEE Antennas and Propagation Magazine*, April 1998, pp. 76-82

[9] Multiple Reflector Dish Antennas by Paul Wade