Design of Gregorian Reflector for Imaging

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***Abstract*— A Gregorian Dual Reflector configuration is proposed to scan an area ranging from -1.8° to 1.8°. The Proposed Configuration consists of a paraboloidal main reflector and elliptical sub-reflector operating at Ku-Band and sharing common feed point. Imaging arrangement is obtained by translation, rotation and focal length adjustment of the feed. An attractive feature of the imaging arrangement is that they are capable to scan one beam electronically and generate multi beam coverage in a limited field of view. As an application, 0.6m diameter main reflector with a cluster of WR-51 Waveguides has been utilized to obtain an H.P.B.W of 1.9°.**

Keywords— Ku-Band, WR-51, Dual Reflector, Prime focal feeding, Side lobe level, MLFMM.

I. Introduction

Reflector antennas with limited electronic scanning are of interest in communication and satellite applications. The imaging systems, also known as magnified arrays consist of a feeding phased array properly magnified by usually two reflector antennas. The most typical imaging reflector systems are constituted by a phased array and two confocal parabolic reflectors in a Gregorian configuration.

Magnified phased array has an advantage of creating a 3D image of the targets at which the device is aimed. The reflector system is capable of capturing images even when there is heavy cloud cover or a similar obstacle and it can be used to see through things like forests, layers of soil or sand [1-3].

In [4] 2m diameter Ku-band Gregorian reflector system with f/D=0.6 is designed which obtained a peak directivity of 48.3dBi. Our target is to produce an arbitrary shaped beam with a cluster of waveguides around the focal point. This configuration makes the design most suitable for imaging applications [5].

Using CST Microwave Studio [6] we have verified several concepts of sub-reflector construction and optimum position for the feed. Main reflector of 0.6m diameter is used and different configurations were analyzed with different dimensions of sub-Reflector.

II. Design

As shown in "Fig.1" geometry of the Gregorian reflector consists of a main reflector with a diameter 0.6m and sub-reflector 0.09m. For Effective f/D= 0.75, 1.0 & 1.25 structure has been analyzed and optimized with multilevel fast monopole method.

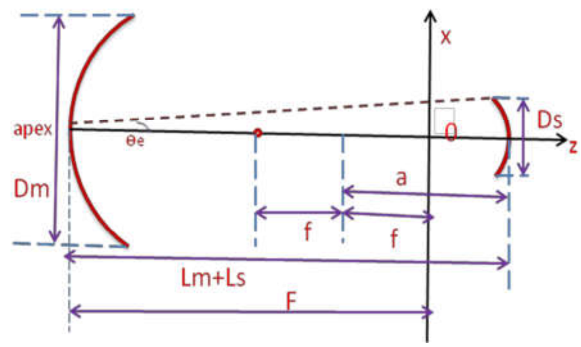

Fig. 1: Geometry of Gregorian Reflector System.

For placing the Main Reflector, Sub-Reflector and feed at appropriate position, "L_m" distance between the apex of the main reflector to phase centre of the feed and "L_s" distance between the apex of the Sub-Reflector to the phase centre of the feed plays a key role. These unknown parameters are found by making use of set of design equations using which a Mat lab code is developed. The design equationsare

$$Lm = -\frac{1}{16}\frac{y_3}{Dm\sin(\theta_e)F(\sigma Dm + 4y_1)} \quad (1)$$

$$Ls = -\frac{\sigma Dm(Lm - F)}{\sigma Dm - 4F\tan\left(\frac{\theta_e}{2}\right)} \quad (2)$$

$$f = \frac{Dsy_2(\sigma Dm - 4y_1)}{32\sin(\theta_e)\,F(\sigma Dm + 4y_1)Dm} \quad (3)$$

$$a = \frac{Dsy_2}{32\sin(\theta_e)Dm} \quad (4)$$

Where, σ = -1 for a Gregorian system, D_m is diameter of the main reflector, D_s is the diameter of the sub-reflector, Y_1, Y_2, Y_3 are variables which can be calculated using θ_e [7] where

$$\theta_e = 2\tan^{-1}\left(\frac{1}{4\frac{Eff}{D}}\right) \quad (5)$$

For a small size of antenna (D/λ<100) Gregorian system is much attractive as shown in "Fig .2", since it provides less blockage and avoids diffraction losses [8]. To avoid grating lobes, inter-element spacing of λ (17.14mm) is maintained between the feed elements.

Cluster of waveguides are individually excited and arranged in a linear array structure is shown in "Fig. 3". With a larger array, scan area can be improved at a cost of increasing complications for interconnections between the feed elements.

Fig .2 Perspective view of Ku-Band Gregorian System

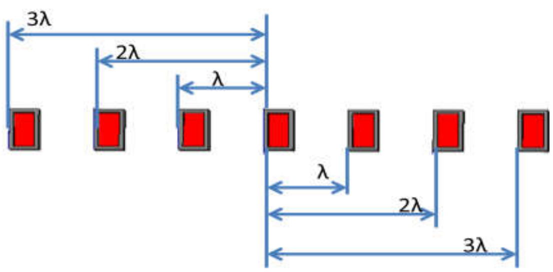

Fig 3 Feed Elements

TABLE 1

Comparison of Effective focal length to Diameter of Main Reflector

Scan Angle	Directivity(dBi)			HPBW(degrees)			Side lobe level (dB)		
	Eff f/D=0.75	Eff f/D=1.0	Eff f/D=1.25	Eff f/D=0.75	Eff f/D=1.0	Eff f/D=1.25	Eff f/D=0.75	Eff f/D=1.0	Eff f/D=1.25
-1.7°	21.7	22.8	23.2	1.6	1.6	1.6	9.5	10.9	11.9
-1.2°	22.5	23.4	23.7	1.7	1.8	1.8	12.3	14.1	13.5
-0.7°	22.9	22.9	23.6	1.8	1.7	1.8	10.3	10.8	11.8
0°	21.5	21.2	22.8	1.7	1.6	1.7	9.7	9.2	10.2
0.7°	21.8	22.9	23.3	1.6	1.6	1.6	9.7	11.0	11.9
1.2°	22.7	23.5	23.9	1.7	1.8	1.8	12.6	14.3	13.7
1.8°	22.8	22.8	23.5	1.8	1.7	1.8	10.3	10.9	11.8

A. Different f/D ratio for the main reflector

- Maintaining the dimensions of the main reflector constant and varying the Sub-Reflector, different combinations were observed and results are shown in "Table .1". In the table for different scan angles Half Power Beam width, Directivity and Side lobe level are noted.
- A peak directivity of 23.9 dBi is obtained for the Scan angle 1.2° and Eff f/D = 1.25.
- When Eff f/D = 1.25 most of the energy is radiated in
- The main lobe direction and hence higher SLL are obtained.
- A constant Half Power Beam width is observed for Eff f/D of 0.75, 1.0, and 1.25.

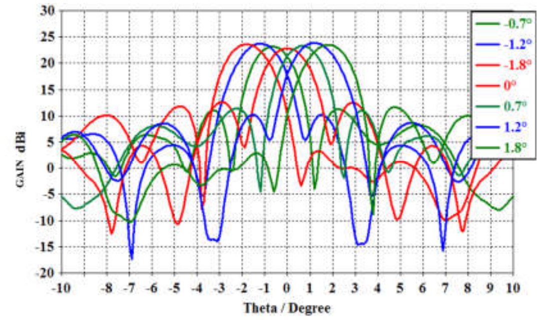

Fig 4.Spatial scanning with individual excitation

B. Observations

The main beam of the Gregorian system was spatially scanned by the individual feeds_arranged in a linear pattern. Here feed is excited individually and it has capability of scanning from -1.8° to 1.8°. This configuration of feed provides another advantage of overcoming the imperfections in the main reflector during fabrication. "Fig. 4" shows the spatial scanning when the waveguides are excited one after other in a serial manner. In the design, all the feeds are completely illuminating the sub-reflector which results in uniform directivity for the scan range from 0° to 1.8°. For a 0.6m diameter main reflector and overall efficiency of 50%, directivity of 23.9 dBi is achieved at 17.5GHz.

Simulated gain patterns for the Gregorian system with spatial scanning in E-plane when extreme ends of feed are excited is shown in "Fig. 5"

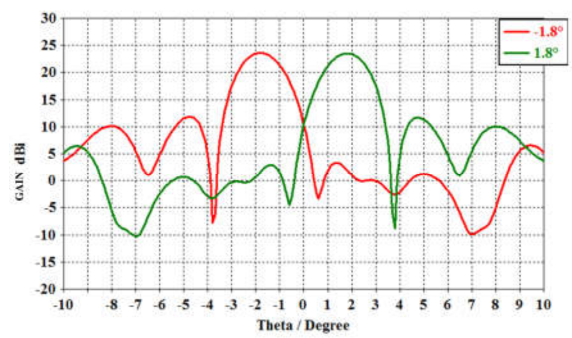

Fig .5 Expanded views of simulated directivity patterns

When Eff f/D=0.75, Sub-Reflector becomes very shallow as a result it fails in illuminating the main reflector completely. It is observed that by increasing the Eff/D, directivity increases. It is shown in "Fig. 6".

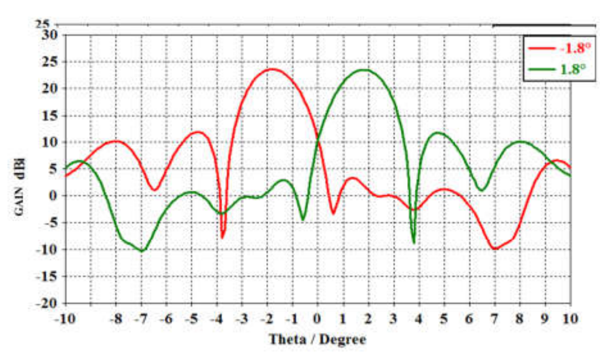

Fig .6 Directivity pattern for varying Eff f/D

By further increasing the Eff f/D i.e. Eff f/D>1.25, directivity increases but for such configuration it is essential to increase size of the feed which will disturb the compactness of the design. Hence an optimum value of Eff-f/D "1.25" is selected.

CONCLUSION

A Gregorian Dual reflector System is fed by cluster of WR-51 waveguides is studied. Feed structure which is excited individually gives an advantage of control over the entire system, numerical electromagnetic simulations based on the multilevel fast multi-pole method is used to analyze and optimize the antenna parameters for limited scanning. With optimized dimensions for the reflectors, feed and optimized position we were able to scan an area ranging from -1.8° to 1.8° maintaining constant directivity of 23.9 dBi and H.P.B.W of 1.9° over the entire range. By placing the waveguide cluster at the apex of main reflector, blockage losses were eliminated. The proposed design resonating at 17.5 GHz is mainly used in L3 bombers for imaging applications. Work can be further extended to W-Band and feed can be replaced with a linear array Vivaldi patch which provides with better scanning range.

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