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CROSS-POLARIZATION REDUCTION FOR COMPACT OFFSET REFLECTOR ANTENNA USING CONJUGATE FEED

Balvant J. Makwana[1], S. B.Sharma[2]

[1]Asst Asst Prof, EC Department Government Engineering College, Rajkot, Gujarat, India
[2]Former outstanding scientist, SAC, ISRO, Ahmedabad, Gujarat, India

Abstract - *This paper presents the design of a conjugate matched feed to get significant cross polar level reduction in secondary field pattern of offset reflector antenna system having very low F/D. This kind of feed will be advantageous in many practical applications where the available space and weight for antenna structure is limited. The conjugate feed is implemented in cylindrical waveguide by utilizing higher order modes, $\boldsymbol{TE_{21}}$ and $\boldsymbol{TM_{11}}$ in addition to fundamental $\boldsymbol{TE_{11}}$ mode with proper amplitude and phase. The designed conjugate feed was then used to illuminate offset parabolic reflector antenna with F/D of 0.4 and offset angle of 90 degree, the secondary far field radiation patterns were computed. It is shown that significant reduction in the cross polarization level is observed compared to that of illumination of offset reflector by conventional feed*

Keywords- *horn; conjugate feed; cross polarization; compact offset reflector antenna; , multimode horn.*

I. INTRODUCTION

Offset reflector antennas are widely used in many practical applications like satellite communications, compact test ranges, remote sensing, radio telescope etc. since long time because of its attractive features like high antenna efficiency, low side lobes and high isolation between primary feed and reflector [1]. However, it is well known fact that offset geometry itself generates very high level of cross polarization because of asymmetry when fed by linearly polarized signal. [2], [3]. The level of cross polarization is proportional to the offset angle and is maximum when offset angle is 90 degree. By selecting relatively larger F/D ratio, it is possible to minimize the cross polarization [4]. However, the larger F/D ratio results in a bulkier antenna system and may not be preferred for space borne applications where the available space for antenna structure is limited.

In single offset parabolic reflector configuration the high level of cross-polarization can be reduced by using multimode feed. The concept of multimode (Tri mode) feed with two post was introduced by Rudge and Adatia [5]. Recently the trimode feed was introduced by K.Bahadori and Y. Rahmat-Samii [6], and revisited by them [7].Also it is further investigated by S.B.Sharma et.al [8][9].it was observed from the literature that very less cross polar bandwidth have been reported .This encourage further investigation on to improve the cross polar bandwidth in offset configuration .
The designed conjugate corrugated feed is presented in this paper. A MATLAB code is implemented utilizing Meta heuristic optimization technique to estimate the required amplitude and relative phase of higher order modes at given offset angle and F/D ratio for minimizing high cross polarization of offset reflector antenna. Based on the results from the optimization a feed is design and implemented in HFSS. Finally this horn is used as feed to the offset reflector and the secondary radiation pattern is evaluated using PO technique.

II. THEORY AND DESIGN OF CONJUGATE FEED

A. Conjugate Feed:

A minimum cross polarization level is obtained when the tangential electrical field component at the aperture of primary feed is complex conjugate of electric field component at the focal region of offset parabolic reflector. The feed having this property is known as conjugate feed.
To design conjugate feed, field in focal region of offset parabolic reflector must be known. Various studies have been carried out by many researchers to predict the field at the focal region. Bem[12] studied and derived the well known expressions of the focal plane field for offset reflector using PO in simple closed form which can be written as

$$E_x(p,\emptyset_0) = \frac{2J_1(p)}{p} + \frac{jD\sin\theta_0}{F}.\frac{J_2(p)}{p}.\cos\emptyset_0 \quad (1)$$

$$E_y(p,\emptyset_0) = -\frac{jD\sin\theta_0}{F}.\frac{J_2(p)}{p}.\sin\emptyset_0 \quad (2)$$

Where J_1, J_2 is Bessel function of first and second order with first kind respectively and θ_0 is offset angle.
Valentino and Toulios[13] verifies Bems results , Ingerson and Wong[14] also done analysis to determine beam deviation for offset reflector system.

From the expression (1) and (2) it is observed that cross polarization has inverse relation with F/D, proportional to offset angle and amplitude varies as Bessel function of second first kind and second order. Also negative sign in (2) indicate that cross polar field is having quadrature phase relationship with copolar field. Now having compact antenna system using single offset reflector mean it is having low F/D ratio and high offset angle. Both of this account for very high cross polarization at the focal region field.

This high cross polarization can be reduced if we add TE_{21} mode in proper amplitude and phase, because this mode have same characteristic like cross polar field at focal region. Also in addition to TE_{21} mode small portion of TM_{11} mode is also added which improves axial symmetry of copolar component.

So for conjugate feed having aperture radius 'a', theta (θ) and phi (ϕ) component for far field of primary feed radiation are

$$E_\theta = E_\theta^{TE_{11}} + C_{11}E_\theta^{TM_{11}} + C_{21}E_\theta^{TE_{21}} \quad (3)$$

$$E_\emptyset = E_\emptyset^{TE_{11}} + C_{11}E_\emptyset^{TM_{11}} + C_{21}E_\emptyset^{TE_{21}} \quad (4)$$

Where,
C_{11} = constant representing the relative power in TM_{11} mode with respect to power in TE_{11} mode.
C_{21}= constant representing the relative power in TE_{21} mode with respect to power in TE_{11} mode.

The expression for components of TE and TM are obtained from Silver [15].

B. Design of Conjugate Feed:

The geometry of proposed feed is as shown in Figure (1).the input waveguide section is excited by fundamental TE_{11} mode. The input radius of waveguide R1 is selected such a way that it excites only pure TE_{11} mode at the operating frequency range. The higher order mode TM_{11} is generated at the step having radius R2. The amplitude and phase of TM_{11} can be varied by changing R2 and phasing length L3 and L2. Since TM_{11} mode is higher mode than asymmetrical TE_{21} mode so any asymmetrical discontinuity will generate TE_{21} mode. Here asymmetrical discontinuity in form of cone having height H is chosen. the amount of power coupled to TE_{21} mode can be can be varied by diameter and height of cone, phase can be controlled by phasing length L2.the length of L2 is chosen so that phase difference between TE_{11} and TM_{11} is zero (0), and between TE_{21} and TE_{11} it is -90 degree at the aperture of horn.

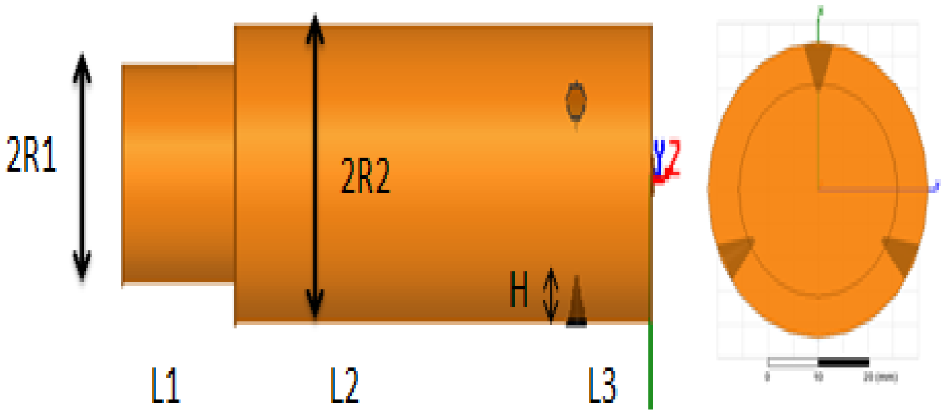

Figure 1. Simulated design of the conjugate feed with R1=15.875mm, R2=22mm, L1=38.354mm, L2=132.35mm, L3=25.57mm, H=6.8mm (a)Front view (b) Side View

III. RESULTS AND DISCUSSION

The offset reflector geometry for compact system under consideration is as illustrated in Figure (4).the projected diameter (D) of reflector is 1m, F/D=0.4 and offset angle (θ) of 90 degree.

The given offset reflector is first fed by conventional feed with TE_{11} and TM_{11} modes are in phase at the aperture as given by Potter[16], whose radiation pattern is as shown on Figure (2). The secondary Radiation pattern (Figure (3).) obtained by this feed shows very high crosspolarization level of around -13 dB at the design frequency of 9.6 GHz.

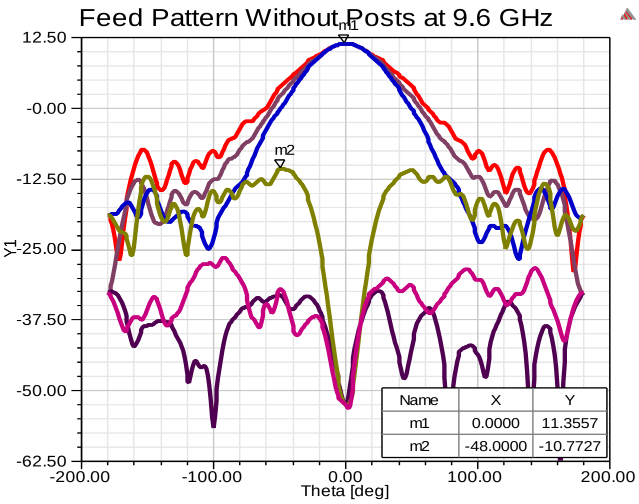

Figure 2. Simulated primary radiation pattern of the conventional dual mode feed horn

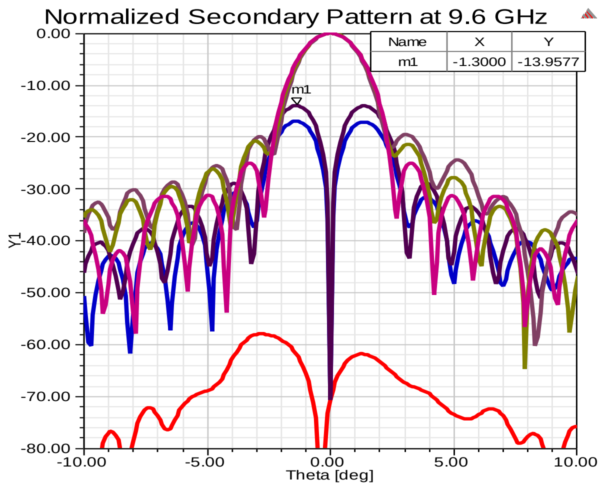

Figure 3. Simulated secondary radiation pattern of the conventional dual mode feed horn

Next, the given offset reflector is illuminated by proposed conjugate feed whose far field pattern is as shown in Figure (5),which shows high level of cross polarization.which is due to the generation of TE21 mode. The secondary pattern so obtained is as plotted in Figure (6).comparison of Figure (3) and Figure (6) shows reduction of cross polarization from -13 dB (conventional feed) to -24 dB (conjugate feed).

Finally, the comparison cross polarization for frequency band of 9.5 GHz to 9.7 GHz are plotted in Figure (7).which shows the significant reduction in cross polarization compared to conventional feed

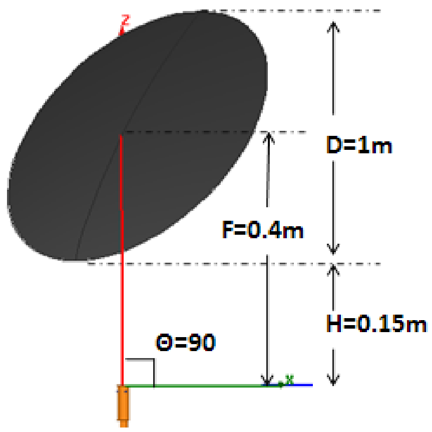

Figure 4. Side view of a 1 m offset parabolic reflector antenna with F/D=0.4,offset angle=90^0 and H=0.15m (F is the focal length, D is the diameter and H is the clear- ance height of the reflector)

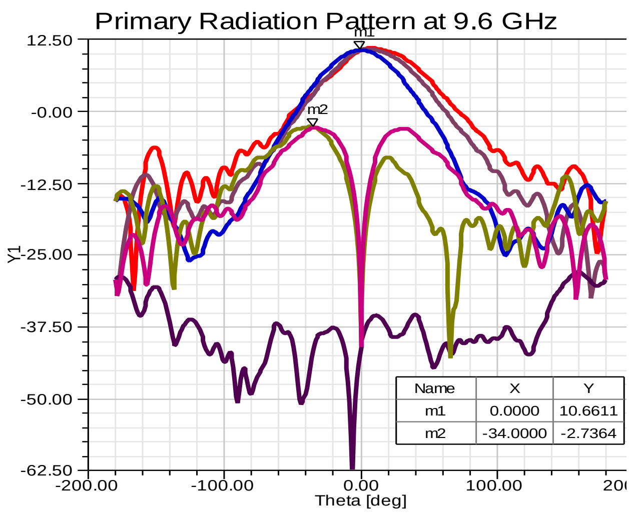

Figure 5. Simulated primary feed far field radiaton pattern of the conjugate horn at 9.6 GHz

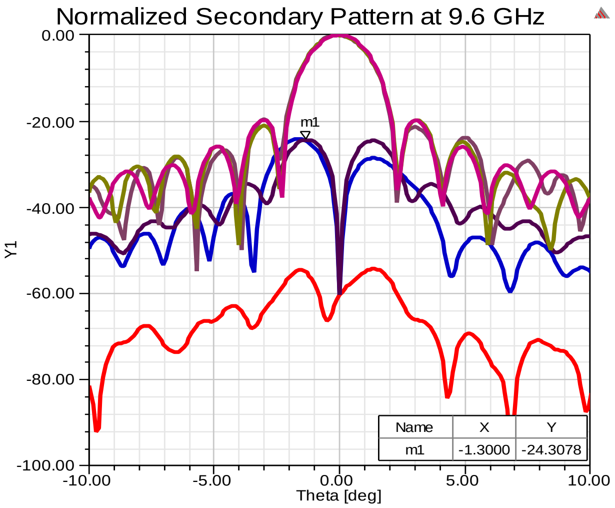

Figure 6. PO simulation result of far-field pattern of the reflector fed by conjugate horn at 9.6 GHz

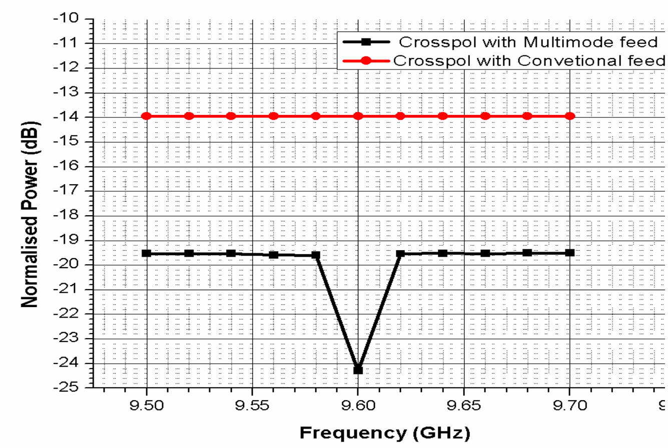

Figure 7. Simulated cross-pol level of 1 m offset reflector when fed conventional corrugated horn and multimode corugated horn.

IV. CONCLUSION

The cross polar performance of single compact offset reflector was studied with conjugate feed. It was concluded that given conjugate feed provides significant reduction in crosspolarization level. Such reflectors can be used for space born application where size and space is concerned; also it can be used for compact antenna test ranges.

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