Performance Comparison of a Matched Feed Horn with a Potter Feed Horn for an Offset Parabolic Reflector

S. B. Sharma (1), Dhaval Pujara* (2), S. B. Chakrabarty (1), and V. K. Singh (1)
(1) Antenna Systems Area, Space Applications Centre, Ahmedabad-380015, India
(2) Institute of Technology, Nirma University, Ahmedabad- 382481, India
E-mail: dapujara@yahoo.com

I. Introduction

Offset parabolic reflector offers a number of significant advantages over its axis-symmetric counter part for many applications, such as, remote sensing, satellite communications, radio astronomy, etc. The advantages offered by an offset parabolic reflector are reduced aperture blockage, isolation between the reflector and the feed and lesser spurious radiation and suppressed side lobe level [1]. However, the offset-parabolic reflectors suffer from drawbacks of higher cross polarization when illuminated by linearly polarized feed, and beam squinting when illuminated by a circularly polarized feed. The problem of higher cross polarization and beam squinting can be solved by selecting a relatively larger F/D ratio. But in case of space applications, it is desirable to use an offset parabolic reflector with lower F/D ratio, as the antenna with larger F/D ratio results into a bulky structure and may cause a space and weight limitations in the satellite structure for the space-borne payloads. For such cases, where cross polarization is a very stringent parameter, the offset parabolic reflector with a conventional feed such as potter horn [2], may not be a suitable option.

The problem of higher cross polarization in an offset parabolic reflector was first addressed by Rudge [3] with a novel concept of 'Matched Feed' / 'Trimode Feed'. Later on, Prasad and Shafai [4] have shown that, for the matched feed illuminated offset reflector, the symmetry of the radiation pattern can be improved by tilting the feed. In a recent paper [5], the matched feed has been used to illuminate the gravitationally balanced back- to- back reflector. Also, in [5] the HFSS simulated results for the matched feed are discussed. In [3]-[5], no detail parametric analysis of cross-polarization with F/D ratio and offset angle was presented and for circularly polarized feed, no data was found.

The present paper deals with the comparison of matched feed performance with that of the conventional potter horn when used with an offset parabolic reflector. The effect of TE_{21} mode amplitude on the cross polarization has been studied in order to ascertain the suitable TE_{21} modal amplitude. Followed this, the behavior of change of TE_{21} modal amplitude with offset angle (θ_0) has been investigated. The effect of cross - polarization variation as a function of (F/D) ratio has been studied for both the matched feed and the potter horn. Finally, the beam squinting phenomenon in case of circular polarization has been studied for the matched feed and the results were compared with that of the potter horn. To the best of authors' knowledge, such comparison in case of circular polarization has not been reported in open literature.

II. Problem Formulation

As shown by Bem [6], it is possible to estimate the cross polarization offered by an offset parabolic reflector from the electric field distribution in the focal plane. The contour map of an estimated cross polarization [3] shows a pair of lobes. The effect of these cross-

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polarized lobes in the focal plane can also be observed in the secondary radiation pattern of an offset parabolic reflector. As discussed in [3], this undesirable cross polarization in the secondary radiation pattern can be counter balanced by adding suitable higher order mode(s), in proper proportion. Such modes in case of smooth-walled cylindrical feed structure are TM_{11} and TE_{21} with the fundamental TE_{11} mode [3]. Thus, in case of a cylindrical wave-guide structure, the matched feed is a 'trimode feed' with three modes such as TE_{11}, TM_{11} and TE_{21} mode. Matched feed can also be considered as the extension of the well-known potter horn [2] in which TM_{11} mode is added with the fundamental TE_{11} mode. In case of a matched feed horn, the TE_{21} mode compensate the asymmetric cross polarization introduced by the offset geometry.

Following the general expressions of the polar and the azimuthal radiation pattern components of the TE and the TM waves, as given by Silver [7]; the expressions for the matched feed can be obtained as,

$$\begin{aligned}
E_{\theta}^{TE\,11} + \alpha_1 \cdot E_{\theta}^{TM\,11} + j\alpha_2 \cdot E_{\theta}^{TE\,21} &= \left[\left(1+\frac{\beta_{11H}}{k}\cdot\cos\theta\right)\cdot\left(\frac{J_1(ka\sin\theta)}{ka\sin\theta}\right)\cdot\sin\phi\right] \\
&+ \alpha_1 \cdot \left[\left(\frac{\beta_{11E}}{k}+\cos\theta\right)\cdot\left(\frac{J_1(ka\sin\theta)}{ka\sin\theta}\right)\cdot\left(\frac{1}{1-\left(\frac{k_{11E}\cdot a}{ka\sin\theta}\right)^2}\right)\cdot\sin\phi\right] \\
&+ j\alpha_2 \cdot \left[2\cdot\left(1+\frac{\beta_{21H}}{k}\cdot\cos\theta\right)\cdot\left(\frac{J_2(ka\sin\theta)}{ka\sin\theta}\right)\cdot\sin(2\phi)\right]
\end{aligned} \tag{1}$$

$$\begin{aligned}
E_{\phi}^{TE\,11} + j\alpha_2 \cdot E_{\phi}^{TE\,21} &= \left[\left(\frac{\beta_{11H}}{k}+\cos\theta\right)\cdot\left(\frac{J_1^{'}(ka\sin\theta)}{1-\left(\frac{ka\sin\theta}{k_{11H}\cdot a}\right)^2}\right)\cdot\cos\phi\right] \\
&+ j\alpha 2 \cdot \left[\left(\frac{\beta_{21H}}{k}+\cos\theta\right)\cdot\left(\frac{J_2^{'}(ka\sin\theta)}{1-\left(\frac{ka\sin\theta}{k_{21H}\cdot a}\right)^2}\right)\cdot\cos(2\phi)\right]
\end{aligned} \tag{2}$$

Where, α_1 and α_2 are the arbitrary constants defining the relative power in TM_{11} and TE_{21} mode with respect to the fundamental mode. For the suitable values of α_1 and α_2, (1) and (2) represents the polar and the azimuthal radiation pattern components of the matched feed horn.

III. Numerical Results and Discussion

The offset parabolic reflector as shown in Fig. 1 was illuminated by both the potter horn and the matched feed horn to study the various parameters such as cross polarization, band width, side lobe level, and beam squinting. First, using the equations derived in the previous section and following the mathematical model as described in [1], the simulated secondary radiation pattern of an offset parabolic reflector with an F/D ratio of 0.5, offset angle of 43^0, with a linearly polarized matched feed was obtained and compared with that of the pattern obtained using the commercially available antenna design software GRASP- 8W. The results are shown in Fig. 2. The effect of TE_{21} modal amplitude variation on the cross polarization has been studied for the same matched feed. As shown in Fig. 3, the maximum cross polarization isolation can only be achieved for a specific value of TE_{21} amplitude. Thus, proper care should be taken while deciding the proportion of TE_{21} modal amplitude; otherwise it will result into higher cross polarization. Also, the variation of TE_{21} modal amplitude has been investigated by changing the value of offset angle (θ_0). As shown in Fig. 4, the TE_{21} modal amplitude increases with increase in the offset angle. The cross polarization variation with changing F/D ratio was obtained for both the potter horn and the matched feed horn and the results are shown in Fig. 5. The effect of ‘beam squinting’ has been also studied by illuminating the reflector with a circularly polarized matched feed and a potter horn feed. As shown in Fig. 6 and 7, it is observed that the beam squinting is negligible in case of matched feed as compared to the potter horn. The plot of cross polarization as a function of frequency is shown in Fig. 8. A significant improvement in the cross polarization isolation BW has been noticed in case of the matched feed as compared to the potter horn. The side lobes were also found under the acceptable limit.

IV. Conclusion

In the present paper the comparison of various performance parameters of the matched feed is made with that of the conventional potter horn. The results are very encouraging and it is expected that the matched feed will become the best option with the offset parabolic reflector antenna for the future remote sensing-radiometry applications.

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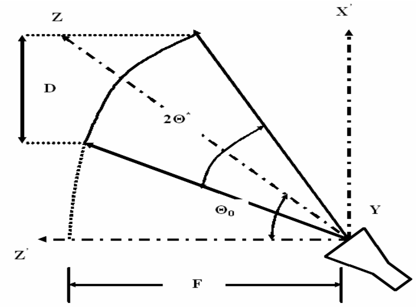

Fig. 1 Geometry under consideration

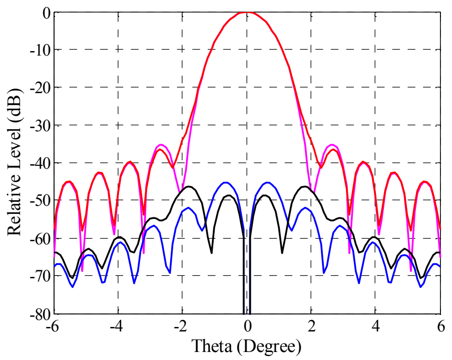

Fig. 2 Secondary radiation pattern with F/D=0.5

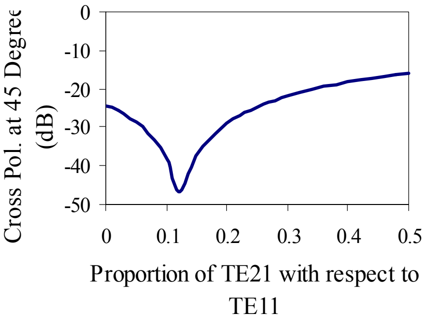

Fig. 3 Cross pol. as a function of TE_{21} amplitude

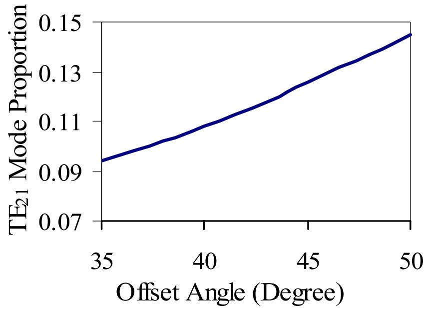

Fig.4 TE_{21} Variation

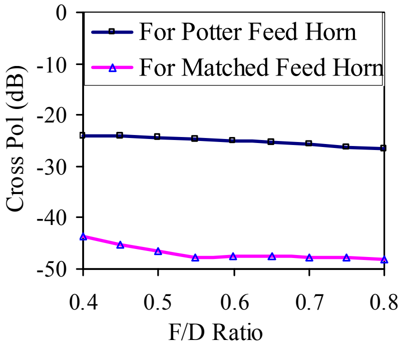

Fig. 5 Cross pol. as a function of F/D ratio

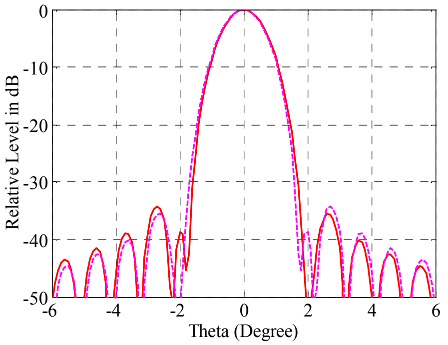

Fig.6 Secondary pattern (circular polarized trimode feed horn as feed)

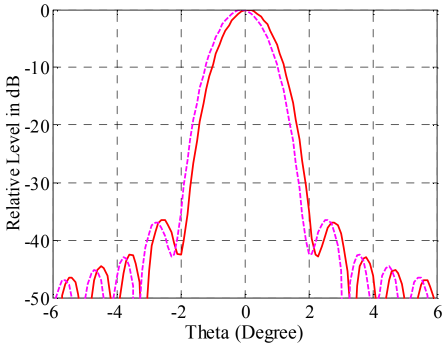

Fig. 7 Secondary pattern (circular polarized potter horn as feed)

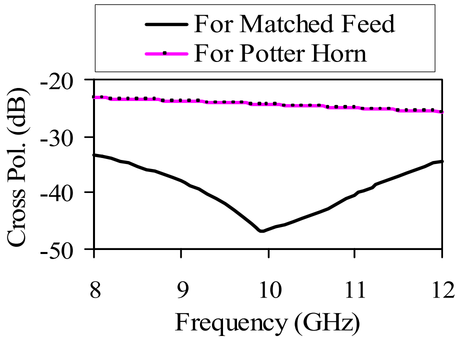

Fig.8 Cross pol. as a function of frequency