Analysis of the Asymmetric Dual Reflector Antenna Systems by Using Equivalent Feed and Antenna Concepts

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Abstract

In this study the equivalent paraboloid model is formulated and applied for dual asymmetric antennas that can give the same scattered fields as in dual symmetric antenna systems. This type of modeling leads to the application of Physical Optics (PO) and Geometric Theory of Diffraction (GTD) analysis for finding the radiation pattern of off-focus fed asymmetrical dual reflector antenna systems.

1. Introduction

Off-focus feeds and offset dual reflector antennas [1] are preferred for single and double reflector antenna systems in order to decrease the losses due to the aperture blockage problems. For this reason some scientists have been working to derive the formulation of the radiation fields of off-focus and off-set type dual reflector antenna systems [2]. It is possible to solve off-focus fed and asymmetrical dual antenna systems by using an equivalent point source model. Instead of an off-focused feed, equivalent paraboloid technique can be used for the same induced current density vectors on the surface of the reflector antenna systems [3], [4], [5], [6]. The application of both methods in a combined form leads to an easy and fast solution for complex physical structures of off-focus fed and offset dual reflector antenna systems.

2. Formulation

The formulation can be divided in three parts as given as below;

1. Analyzing and design the equivalent parabolid antenna system by using the procedure that was given in [5].

2. Finding the equivalent focus-fed feed instead of 3-D type off-focus feed [6] or feeds for paraboloid by adapting the method that was given for 2-D case in [2].

3. Applying Physical Optics (PO) method for finding the radiation pattern of the new model of the equivalent focus-fed paraboloid antenna [4], [6].

2.1. Modelling the equivalent parabolid antenna

The transformation equations given in [5] can be used to obtain equivalent parabolic antennas for asymmetric Cassegrain and Gregorian antenna systems. Asymmetric Cassegrain antenna and its equivalent paraboloid are seen in Fig.1 and Fig. 2 respectively.

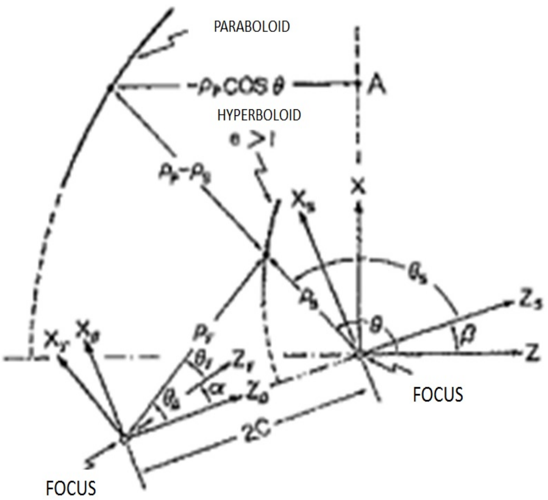

Fig. 1. Cassegrain antenna system

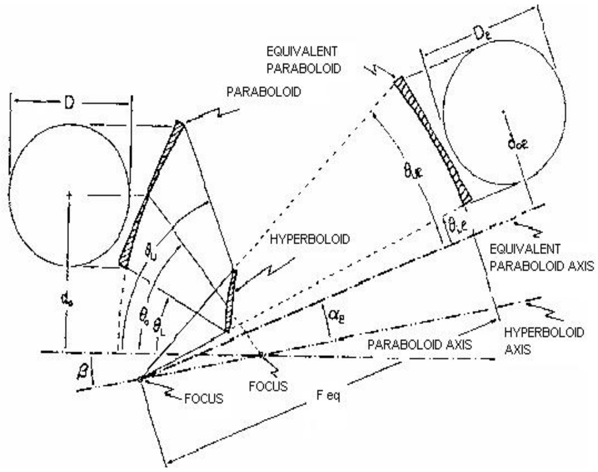

Fig. 2. Equivalent paraboloid antenna

The parameters in Fig. 2 can be explained as below;

d_o and D: The distance (asymmetry distance) to the symmetry axis of the center of the asymmetric paraboloidal reflector and the diameter of the circular xy-plane projection aperture

d_{oe} ve D_e: Equivalent paraboloid asymmetry distance and circular xy-plane projection aperture diameter

θ_{ue} ve θ_{le}: Angles between the top and bottom edges of the equivalent paraboloid and the positive z_f-axis

In order to obtain the parameters D_e and d_{oe} for the equivalent paraboloid at y=0 plane the following equalities can be used:

$$\theta_\beta = \theta_f + \alpha \tag{1}$$

$$\tan\left(\frac{\theta_f+\alpha}{2}\right) = \frac{|e-1|}{e+1}\left[\tan\left(\frac{\theta-\beta}{2}\right)\right]^\sigma \tag{2}$$

and

$$\tan\frac{\theta_f}{2} = \frac{e^2+1-2e\cos\beta}{|e^2-1|}\left(\tan\frac{\theta}{2}\right)^\sigma - \frac{2e}{e^2-1}\sin\beta \tag{3}$$

The equivalent paraboloid D_e and the distance to the equivalent paraboloid axis d_{oe} *can* be written as below

$$D_e = 2F\left(\tan\frac{\theta_l}{2} - \tan\frac{\theta_u}{2}\right) \tag{4}$$

and

$$d_{oe} = F_e\left(\tan\frac{\theta_{ue}}{2} + \tan\frac{\theta_{le}}{2}\right) \tag{5}$$

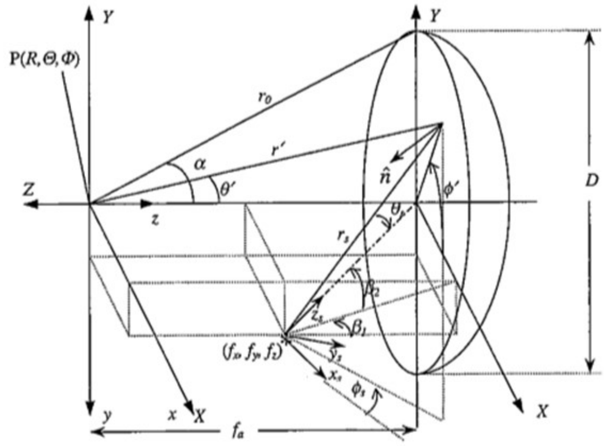

Fig. 3. Off-focus fed paroboloidal antenna geometry and related coordinate variables

θ_{ue} and θ_{le} are used instead of θ for Gregorian antenna system. Similarly $\pi-\theta_{ue}$, *and* $\pi-\theta_{le}$ are substituted instead of θ for Cassegrain antenna system.

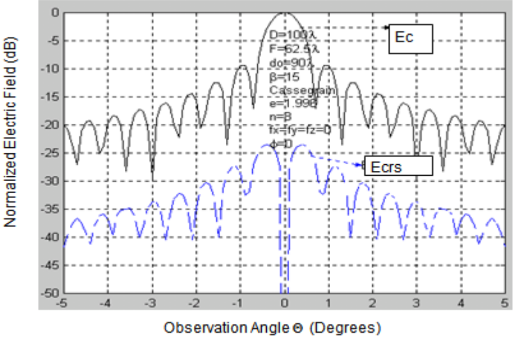

Fig. 4. Radiation Pattern of a Focus Fed Cassegrain Antenna with $D=100\lambda$, $do=90\lambda$, $F=62.5\lambda$, $\beta=150$, $e=1.996$, $n=8$ by using Equivalent Paraboloid Technique

2.2. Finding the equivalent focus-fed feed

The 3-D off-focus feed is defined as below:

$$\overline{H}^i = H_{\theta_s}(r_s,\theta_s,\phi_s)\hat{\theta}_s + H_{\phi_s}(r_s,\theta_s,\phi_s)\hat{\phi}_s \tag{6}$$

3-D off-focus fed paroboloidal antenna geometry and related coordinate variables are seen in Fig. 3.

By using necessary coordinate transformations [3], the equivalent focus-fed feed can be [2], [6] as below:

$$\overline{H}_{\theta'}^{(e)} = H_{\theta'}(r',\theta',\phi') - \frac{n_{\theta'}}{n_{r'}}H_{r'}(r',\theta',\phi') \tag{7}$$

$$\overline{H}_{\phi'}^{(e)} = H_{\phi'}(r',\theta',\phi') - \frac{n_{\phi'}}{n_{r'}}H_{r'}(r',\theta',\phi') \tag{8}$$

Here $n_{r'}$, $n_{\theta'}$ *and* n_φ *are* components of unit normal vectors of equivalent feed.

Focus-fed reflector antenna radiation pattern can be calculated by using PO integral for main beam region.

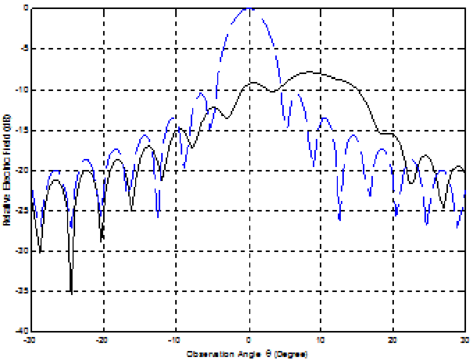

Fig. 5. Radiation Pattern of a Paraboloidal Reflector Antenna D=15λ, α =π/3, ------- focus fed, _______ off-focus fed with $f_x=f_y=f_z=\lambda$..

Also the comparison is done for symmetric and asymmetric single reflectors by using direct PO method and Equivalent method. The results are seen as satisfactory as given in Fig. 5.

2.3. Applying Physical Optics (PO) method for calculation of the radiation pattern

By using the equivalence of the physical optics surface currents on the reflector surface

$$\bar{J}_s = \begin{cases} 2\hat{n}\times\bar{H}^i; \text{ illumination region} \\ 0; \text{ shadow region} \end{cases}$$

and then the electric field can be formulated at the far field as below:

$$\begin{Bmatrix} E_\Theta \\ E_\Phi \end{Bmatrix} = -\frac{jk\eta e^{-jkR}}{4\pi R}\iint_S (2\hat{n}\times\bar{H}^i).\begin{Bmatrix} \hat{a}_\Theta \\ \hat{a}_\Phi \end{Bmatrix} e^{jk\bar{r}'\cdot\hat{R}}\,dS$$

Here;

$\bar{H}^i$: *incident magnetic field*

$\hat{n}$: *unit normal vector to the reflector surface*

Its radiation pattern by using equivalent parabola technique is calculated in order to determine the main and side lobes of copolar and crosspolar fields as in Fig. 6.

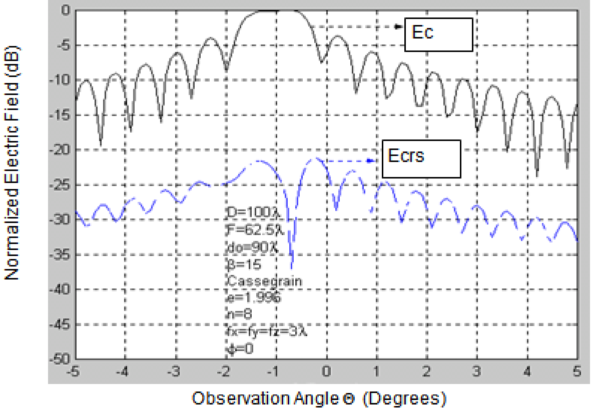

Fig. 6. Radiation Pattern of a Defocus Fed Cassegrain Antenna with D=100λ, do=90λ, F=62.5λ, β=150, e=1.996, n=8 and fx=fy=fz=3λ by using Equivalent Paraboloid Technique

Also the necessary twice solving of the PO integrals for Dual reflectors can be able to reduce to a single solving of PO integral. This leads to the reduction of number of steps in calculations.

3. Conclusions

This method is a time saving method for the radiation pattern calculation by using PO and GTD.

This easy technique can be used for side lobe reduction with the aid of genetic algorithm. By using the equivalent feed and equivalent paraboloid methods, it is possible to find the radiation pattern of a Cassegrain or Gregorian antenna that is fed by an array. For the easiness of the calculations, optimization methods and genetic algorithms can be applied in order to find the required parameters for the feed and reflector parts.

Acknowledgement

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4. References

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