GTD Analysis of Dual-Polarised Parabolic Cylindrical Reflector Antennas with Dipole Feeds

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Abstract

Dual polarised antenna enable to transmission/reception, or both, of RF in two orthogonal po-larisations. A metallic parabolic cylindrical reflector with dipole feeds at a slant of $+45°$ when viewed from the front acts as a dual polarised antenna. This antenna is analyzed using geometrical theory of diffraction (GTD) technique. Vertically and horizontal polarized far-field electric field are computed and plotted for radiation pattern.

Keywords: dipole antenna, dual-polarization, edge diffraction, geometrical theory of diffraction (GTD), parabolic cylinder reflector, uniform theory of diffraction (UTD).

1 Introduction

The performance of an isolated antenna, radiating in free space is quite different when the antenna is placed in the reflector platform. This change in radiation pattern is caused by the scattering from complex structure of the reflector. In the radiation/scattering problems where electrically large structures are involved, efficient solution is provided by, the Geometrical Theory of Diffraction (GTD) [1], Uniform Theory of Diffraction (UTD) [2], Uniform Asymptotic Theory of Diffraction (UAT) [3], [4] or finite edge GTD (FEGTD) [5] where the others numerical techniques fail. The analysis of complex scatterer is usually carried out by breaking the problem into simpler problems involving structures like half-plane, wedge, finite cylinders, finite cone etc. Due to the local nature of diffraction at high frequencies, GTD analysis can be developed by, simulating these structures with components having shapes that locally provide a sufficiently accurate representation of the dominant reflection and diffraction effects.

A parabolic cylindrical reflector made with perfectly conducting material is fed with a dipole antenna. The dipole, which is set at a slant of $+45°$ when viewed from the front, will appear to be vertically polarized when viewed from the side and will then appear at a slant of $-45°$ when viewed from the rear. The polarization of radiated field is varying and the vector of the radiated electrical field strength is fully described by a pair of orthogonal (horizontal and vertical) vector components E^i_H & E^i_V. The incident electric fields from dipole antenna are reflected from the reflector surface and diffracted from the edges and corner of the reflector. As the center of the dipole is on the mid point of focus line of the parabolic cylinder, reflected rays are parallel with the axis of the parabola and illuminate very small angular region but the diffracted field will be available through whole sphere. Diffracted fields from the edges of the reflector are calculated using Uniform Theory of Diffraction (UTD) [2] technique. As the incident field on the reflector edge from the dipole source has the horizontal and vertical vector components, the diffracted fields from the reflector edges also have vertical and horizontal components. Reflector antennas have good potential for making dual-polarized antennas

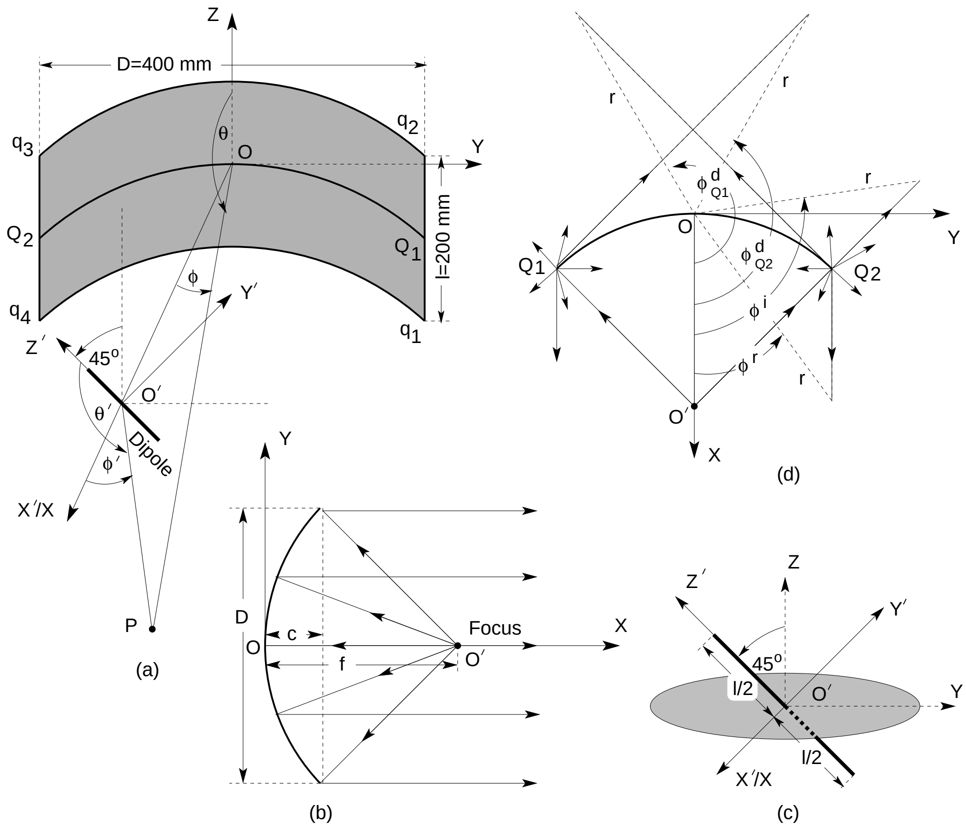


Figure 1: (a) Geometry for parabolic cylindrical reflector. Feed dipole antenna set at a slant of 45°. (b) Dimensions. (c) Dipole at a slant of 45°. (d) Diffraction from edges of the reflector and boundary angles.

due to their several attractive features including high bandwidth, high gain and high efficiency. Many applications require this dual-polarized operating antennas including airborne-based synthetic aperture radar (SAR), and wireless communication.

GTD technique which has found extensive use in radiation and scattering problem, to the best of the author's knowledge has till now not been used explicitly in computing the radiation pattern of a reflector where feed dipole antenna is set at a slant. Also, the GTD has the advantage that the requirement of minimum computer resource and in minimum time. Moreover GTD method gives the physical inside of the problem. Thus this area poses a challenge to researchers to analyze and characterize them and thereby derives the parameters to help understand their operation/function completely. In this paper GTD technique is used to compute the radiation patter of the parabolic cylindrical reflector for vertically and horizontaly polarized field components.

2 GTD Analysis

Geometry and the dimensions of the parabolic cylindrical reflector along with feed dipole antenna are shown in Figs. 1(a) & 1(b). The focal length f is calculated from

$$f = \frac{D^2}{16 \times c} \tag{1}$$

where, D & c are shown in the Fig. 1(b) and the magnitudes are $D = 400$ mm & $c = 72$ mm and the magnitude of the focal length calculated from (1) is $f = 138.9$ mm.

Considering the center of the parabolic cylindrical reflector (O) as the origin of the coordinate system and measuring the angle in counter-clockwise direction, the radiation pattern of the reflector is estimated as follows:

2.1 Feed Dipole Antenna

A dipole of length l is placed such that the center of the dipole is on the center of the focal length of the parabolic cylindrical reflector and making an angle $+45°$ with the Z-axis viewed from the front as shown the Figs. 1(a) & 1(c). This dipole will appear to be vertically polarized when viewed from the side and will then appear at a slant of $-45°$ when viewed from the rear. The das ($'$) coordinate system is along the feed dipole. This ($'$) coordinate system has an angular shift 45° from global coordinate system in counter-clockwise direction taking the X-axis as the axis of rotation and linear shift along X-axis by the distance f as shown in Figs. 1(a) & 1(c). Considering a the dipole is an infinitesimal and the radiated field from [6, eq. (4-26)] is given by

$$E^i\left(\theta', \phi'\right) = \jmath E_0 \frac{e^{-\jmath k r'}}{r'} \sin\theta';\ E^i_{\phi'} = 0;\ E^i_{r'} = 0 \tag{2}$$

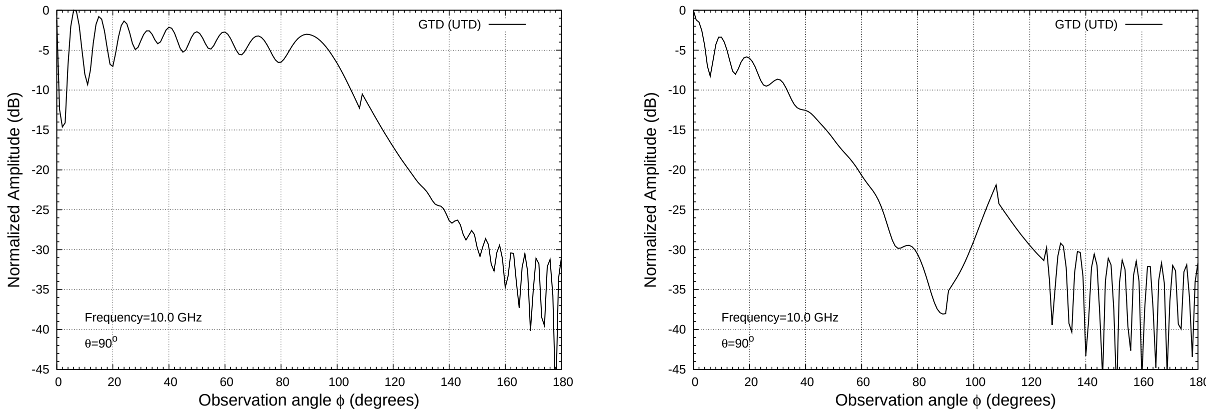
From this field $E^i\left(\theta', \phi'\right)$, the radiated field $E^i\left(\theta, \phi\right)$, from the dipole in global coordinate system is calculated. Radiated field from the dipole illuminates the region $|\phi| \leq \phi^i$ for $\theta = 90°$ shown in Fig. 1(d). The reflected $E^r(P)$ rays from the inter surface of the reflector are parallel to the X-axis and illuminate a small region $|\phi| \leq \phi^r$, depending upon the distance r shown in the Fig. 1(d). But diffracted fields from the edges of the reflector are available in the broad rang of observation regions.

2.2 Diffraction form the Edges of Parabolic Cylindrical Reflector

The radiated field $E^i\left(\theta, \phi\right)$ from the dipole antenna incidents on edges and corners of the reflector and create edge and corner diffractions. In the radiation pattern for $\theta = 90°$ the diffraction from the edges q_1q_2 & q_3q_4 have the important contritions but the diffraction from the curve edges q_2q_3 & q_4q_1 may be neglected. Again in the radiation pattern for $\phi = 0°$ the diffraction from the edges q_1q_2 & q_3q_4 may be neglected but the diffraction from the curve edges q_2q_3 & q_4q_1 have the important contritions. Let, for the radiation pattern for $\theta = 90°$, the edge diffracted fields $E^d_{Q_1}(P)$ & $E^d_{Q_2}(P)$ from the mid points Q_1 & Q_2 of edges q_1q_2 & q_3q_4 due to the incident electric field from the dipole at O' are calculated using UTD [2]. Adding the above diffracted fields and using symmetry the radiation pattern for $\theta = 90°$ is

$$\begin{aligned} E(P) = {} & E^i(P)\big|_{\text{for } |\phi|\leq\phi^i} \\ & + E^r(P)\big|_{\text{for } |\phi|\leq\phi^r} \\ & + E^d_{Q_1}(P)\Big|_{\text{for } 0°\leq\phi\leq\phi^d_{Q_1} \text{ and for } 270°<\phi\leq360°} \\ & + E^d_{Q_2}(P)\Big|_{\text{for } 0°\leq\phi<90° \text{ and for } \phi^d_{Q_2}\leq\phi\leq360°} \end{aligned} \tag{3}$$

The angles are shown in Fig. 1 and the angles ϕ^i & $\phi^d_{Q_2}$ are computed by using method of successive approximations. From the symmetry we can write $\phi^d_{Q_1} = 360° - \phi^d_{Q_2}$.



(a) (b)

Figure 2: Radiation patters of the parabolic cylindrical reflector at $\theta = 90°$ (a) Vertically polarised electric field (b) Horizontaly polarised electric field.

3 Results and Discussions

The computed radiation pattern using (3) for vertical and horizontal polarisation at $\theta = 90°$ are shown in the Figs. 2(a) & 2(a) respectively. From the Fig. 2 it is seen that the field at and near $\phi = 90°$ for the horizontal polarization case is much lower than that of vertical polarization case as it is expected. For the horizontal polarisation case, in a small region of ϕ lying between 105° and 125°, the peaks and nulls are not expected. By adding the corner diffracted fields from the corners of the reflector q_1, q_2, q_3 & q_4, diffraction this pattern can be improved.

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