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TRUNCATED SPHERICAL DIELECTRIC ANTENNA EXCITED BY A CIRCULAR CYLINDRICAL PERFECTLY CONDUCTING WAVEGUIDE CARRYING THE DOMINANT TE_{11} MODE

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1. Near-field of the Antenna

A theoretical study has been done of a truncated dielectric spherical antenna excited by a circular cylindrical perfectly conducting waveguide carrying the dominant TE_{11} mode. Assuming that the electromagnetic field of the TE_{11} mode in the cylindrical waveguide excites the truncated dielectric sphere by delta-function electric and magnetic sources applied on an annular ring of width $a\Delta\theta \sin\theta_1$ between the waveguide and the sphere (Fig. 1). By solving the electromagnetic problem by applying the proper boundary conditions, it has been shown that an infinite number of hybrid HE_{1n} modes exist inside and outside the dielectric sphere.

The near-field components E_r, E_θ, E_ϕ, H_r, H_θ and H_ϕ very near the surface of the truncated dielectric sphere have been computed for 7 hybrid modes HE_{1n} ($n = 1,2,.., 7$) and compared with experimental results. The experimental results agree fairly well with the theoretical results for the combination of all the 7 modes (Fig. 2). Since the amplitude coefficients decrease with increasing value of n, it is concluded that the higher order modes can be neglected.

2. Radiation Characteristics of the Antenna

The radiation field of the antenna has been derived using Schelkunoff's Equivalence Principle. In this derivation, the electric and magnetic currentson the surface of the antenna have been computed using the tangential components H'_θ, H'_ϕ and E'_θ, E'_ϕ respectively on the surface for the combination of the first seven HE_{1n} ($n = 1,2,..7$) modes. The E_ϕ and E_θ components of the radiation field are given by

$$E_\phi = \left[-j\pi a^2/\lambda_0 r\right]\left[\int_{\theta'=0}^{\theta_1}\left\{ j\eta_0 J_1(x) H_{\theta'} \right.\right.$$

$$\left.- j J_1(x)\cos\theta\, E_{\phi'} - J_0(x)\sin\theta'\sin\theta\, E_{\phi'}\right\}$$

$$\sin\theta' \exp(jz)\exp(-jy).d\theta'$$

(1)

and

$$E_\theta = \left[-j\pi a^2/\lambda_0 r\right]\left[\int_{\theta'=0}^{\theta_1}\left\{\left[\eta_0 j\cos\theta'\cos\theta\, J_1(x)\right.\right.\right.$$

$$\left.\left. + J_0(x)\sin\theta\sin\theta'\right] H_{\phi'} + jJ_1(x) E_{\theta'}\right\}$$

$$\exp(jz)\exp(-jy)\sin\theta' d\theta'$$

(2)

where

$$x = k_o\, a \sin\theta\sin\theta'$$
$$y = k_o\, a \cos\theta\cos\theta'$$
$$z = (k_o r - \omega t),$$

and (r, θ, ϕ) being the distant point and (r', θ', ϕ') a point on the truncated dielectric spherical antenna. The directivity of the antenna is given by

$$D = \frac{4\pi\left[|E_\theta^2|_{max} + |E_\phi^2|_{max}\right]}{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi}\left[|E_\theta|^2 + |E_\phi|^2\right] r^2 \sin\theta\, d\theta\, d\phi} \qquad (3)$$

The radiation patterns and directivity have been computed for different antennas with varying diameters, varying relative dielectric constant at different frequencies in the X-band. Fig. 3 shows the theoretical and experimental E-plane and H-Plane radiation patterns of a truncated dielectric spherical antenna of diameter 75 mm and $\epsilon_r = 2.1$ at a frequency of 8.2 GHz. It can be seen that the theoretical and experimental patterns agree fairly well for the major lobe, but not so for the minor lobes.

3. Conclusions

This study of the truncated dielectric spherical antenna excited by a circular cylindrical waveguide carrying the dominant TE_{11} mode, has shown that there is an optimum value of the relative dielectric constant ϵ_r for which the gain of the antenna is optimum for a given diameter at a given frequency. It is also seen that the major lobe has approximately E- and H-plane patterns symmetrical as compared with the radiation pattern from the open end of the cylindrical waveguide. Hence the main beam has almost a circular cross-section. The radiation pattern also is almost gaussian in character. The sphere increases the gain and compresses the beam of the waveguide pattern.

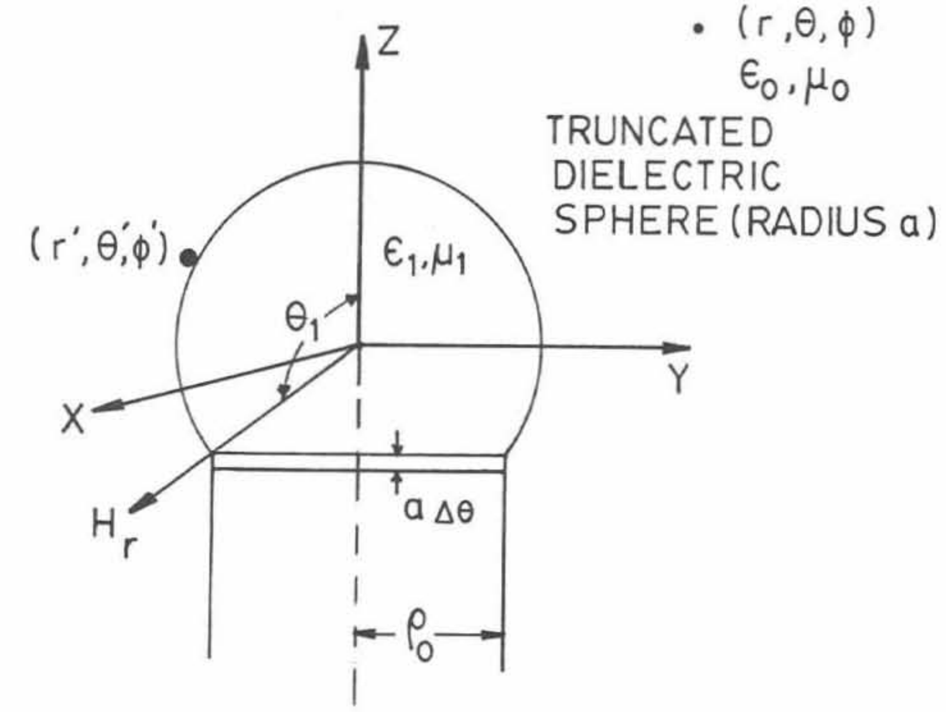

FIG.1 GEOMETRY OF THE STRUCTURE

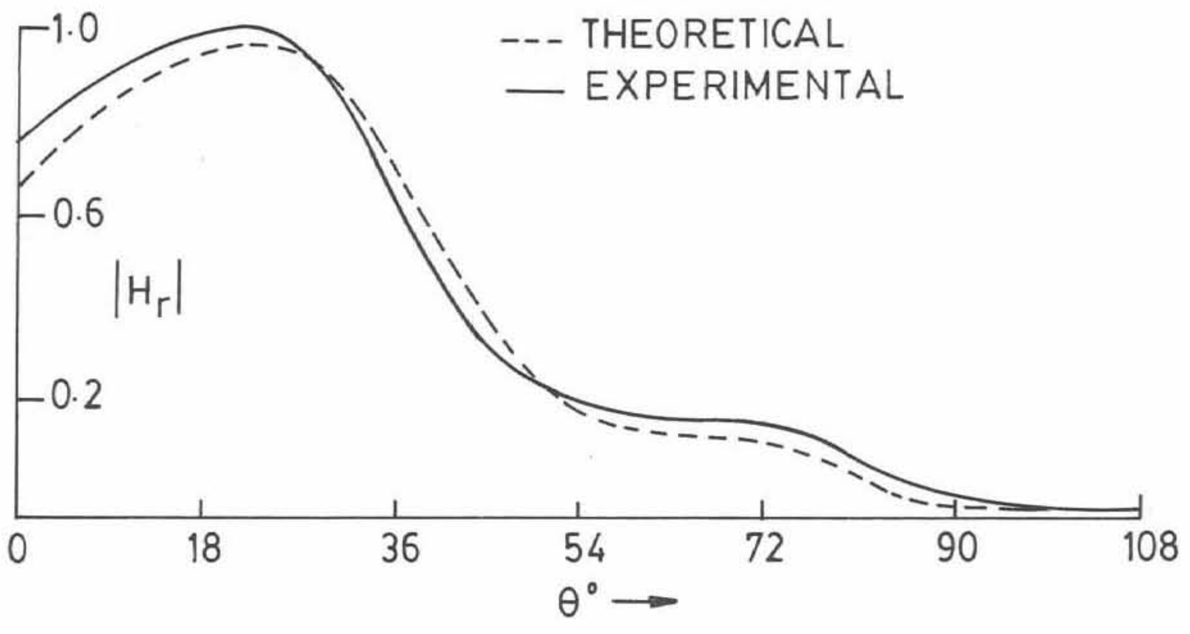

FIG. 2 NEAR FIELD THEORETICAL AND EXPERIMENTAL RESULTS

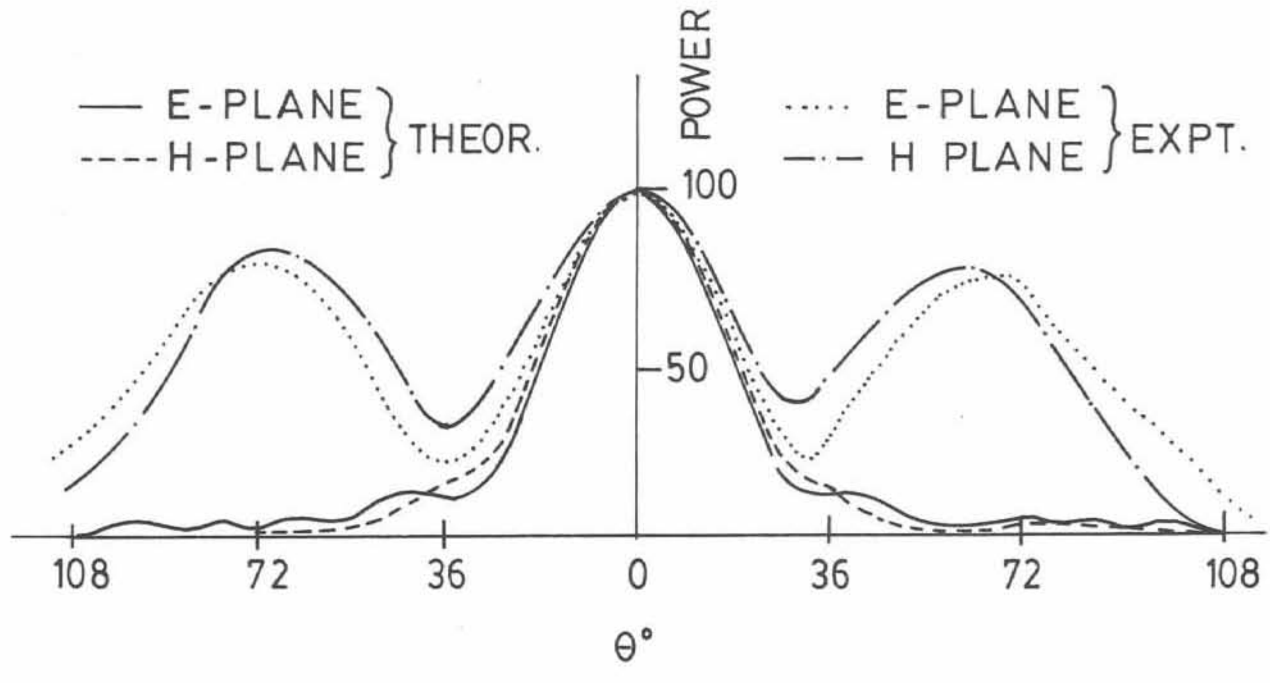

FIG. 3 RADIATION PATTERN OF ANTENNA