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SOME INVESTIGATIONS ON DIELECTRIC AERIALS

Part IV

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ABSTRACT

The propagation constant for the HE_{11} mode as a function of the dielectric constant and diameter of a dielectric rod aerial has been calculated and the variations are shown graphically. The beam width of the major lobe and the positions of maxima and minima of side lobes as a function of the dielectric constant and diameter of a dielectric rod have been experimentally determined and verified with the theoretical results. There is close agreement between the two.

PROPAGATION CONSTANTS

The theory of the radiation characteristics of a dielectric rod aerial excited in the HE_{11} mode has already been derived[1,2] and verified experimentally[3-6] (Chatterjee, *et al.* 1956-58). The previous reports include discussions on the variations of the radiation characteristics in the $\phi = 0^{\circ}$ plane with respect to d/λ_0 and L/λ_0 of a dielectric rod aerial. The object of the present paper is to present a report on the variations of the propagation constant γ and radiation characteristics as a function of d/λ_0 and $\bar{\epsilon}$ where λ_0 represents the free space wavelength and $\bar{\epsilon}$ and d represent the dielectric constant and the diameter of the dielectric rod, respectively.

The field components[1,2] of the HE_{11} mode in a circular dielectric rod of diameter d involve B and b which are related to the propagation constant $\gamma = j\beta$ of the mode by the following relation

$$\frac{B}{b}=\frac{j\omega\mu_1}{\gamma\epsilon_1}\frac{x_1^2x_2^2}{(x_1^2-x_2^2)}\left[\frac{\epsilon_1}{x_1}\frac{J_1'(x_1)}{J_1(x_1)}-\frac{\epsilon_2}{x_2}\frac{H_1^{(1)'}(x_2)}{H_1^{(1)}(x_2)}\right] \quad [1]$$

$$x_1=k_1\,d/2$$
$$x_2=k_2\,d/2$$
$$k_1^2=\omega^2\mu_0\epsilon_1+\gamma^2$$
$$k_2^2=\omega^2\mu_0\epsilon_0+\gamma^2$$

The factors x_1 and x_2 are the solutions of the following equations derived from the field components by imposing proper boundary conditions.

$$\left[\frac{1}{x_1}\frac{J_1'(x_1)}{J_1(x_1)}-\frac{1}{x_2}\frac{H_1^{(1)'}(x_2)}{H_1^{(1)}(x_2)}\right]\left[\frac{\bar{\epsilon}_1}{x_1}\frac{J_1'(x_1)}{J_1(x_1)}-\frac{1}{x_2}\frac{H_1^{(1)'}(x_2)}{H_1^{(1)}(x_2)}\right]=\frac{(x_1^2-x_2^2)(x_1^2-x_2^2\bar{\epsilon}_1)}{x_1^4x_2^4} \quad [2]$$

and
$$x_1^2+(x_2/j)^2=(\pi d/\lambda_0)^2(\bar{\epsilon}_1-1) \quad [3]$$

The equations (2) and (3) have been solved graphically by expressing the equation in the form $f(x_1)=x_2/j$ and on the same scale a circle of radius

$$(\pi d/\lambda_0)\sqrt{(\bar{\epsilon}_1-1)}$$

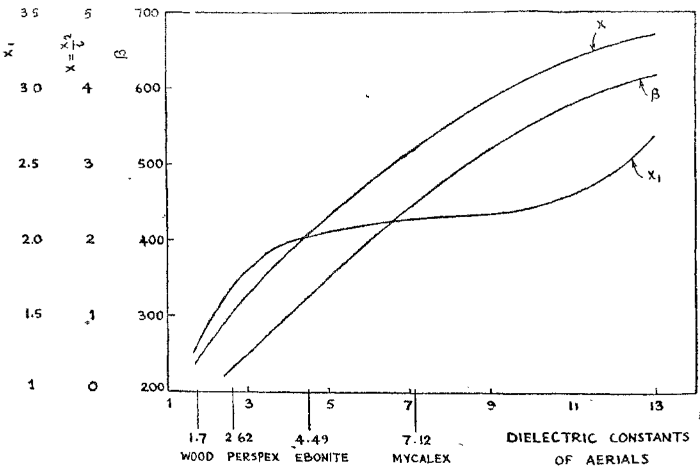

Fig. I

Variation of propagation constant β, x_1, and x_2/j with respect to dielectric constant of a dielectric rod aerial for $d/\lambda_0=0.5$.

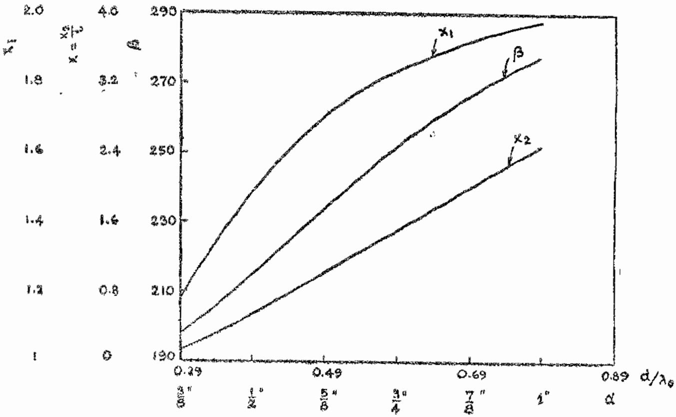

Fig. II

Variation of β, x_1, x_2/j with respect to d/λ_0 of a dielectric rod aerial having $\bar{\epsilon} = 2.65$

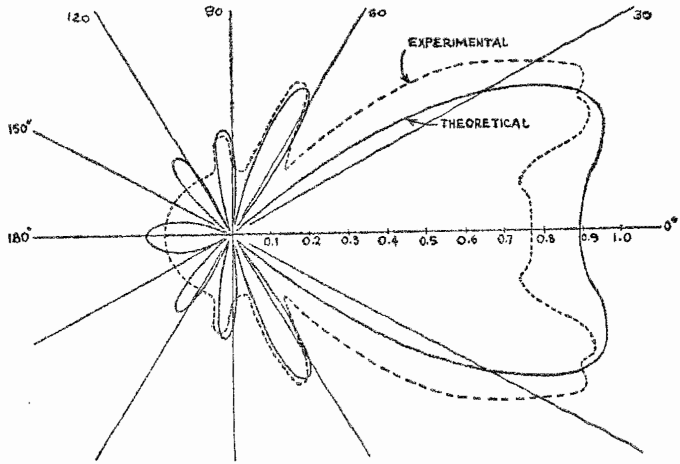

Fig. III

Radiation characteristic of a dielectric (ebonite $\bar{\epsilon} = 4.49$) rod aerial of $d/\lambda_0 = 0.5$, $L/\lambda_0 = 2$

with origin as centre is also drawn. The points of intersection of the two curves give the values of x_1 and x_2 which satisfy the equations (2) and (3) for each value of $\bar{\epsilon}_1$ and d/λ_0. The method of solution has been described in detail elsewhere[1].

The variations of x_1, x_2/j and the propagation constant β as a function of $\bar{\epsilon}_1$ and d/λ_0 are shown in Figures I and II, respectively.

RADIATION CHARACTERISTICS

In the $\phi = 0^0$ plane, the radiation characteristics of a dielectric rod aerial is given by the following relation (Chatterjee, *loc. cit.*)

$$\mathbf{E}_P = \mathbf{u}_\phi \, \omega\mu_0 K_1^H \left[\frac{\text{Sin}\,\{(\beta - k\cos\theta)L\}}{(\beta - k\cos\theta)}\right] 2\pi J_1\left(\frac{kd}{2}\sin\theta\right)$$
$$+ \mathbf{u}_\theta \, k K_1^E \left[\frac{\cos\{(\beta - k\cos\theta)L\} - 1}{(\beta - k\cos\theta)}\right] \frac{2\sqrt{(2\pi)}}{(\frac{1}{2}kd\sin\theta)^{\frac{1}{2}}} J_{\frac{1}{2}}\left(\tfrac{1}{2}kd\sin\theta\right). \qquad [4]$$

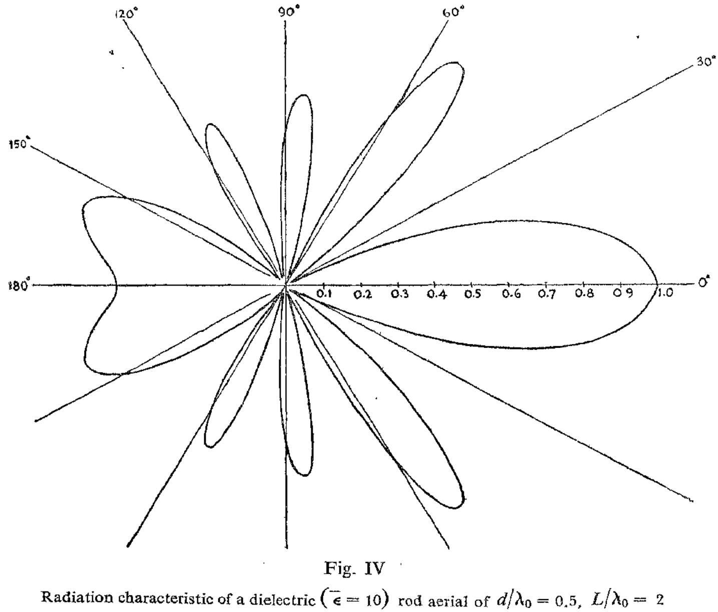

Fig. IV

Radiation characteristic of a dielectric ($\bar{\epsilon} = 10$) rod aerial of $d/\lambda_0 = 0.5$, $L/\lambda_0 = 2$

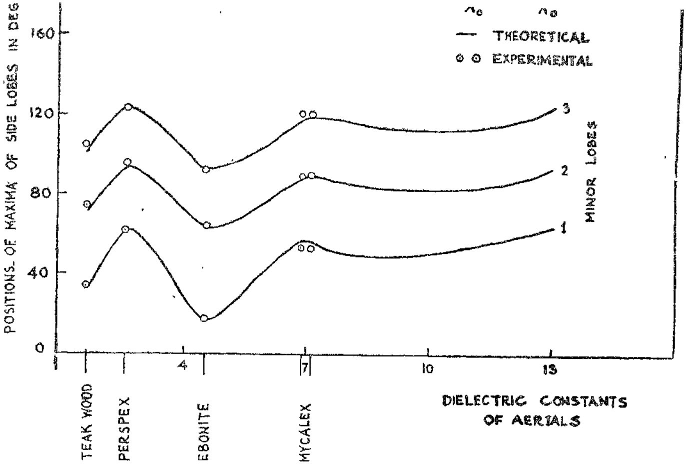

Fig. V

Variation of the positions of maxima of side lobes in degrees for a rod of $d/\lambda_0 = 0.5$, $L/\lambda_0 =$ with respect to dielectric constant

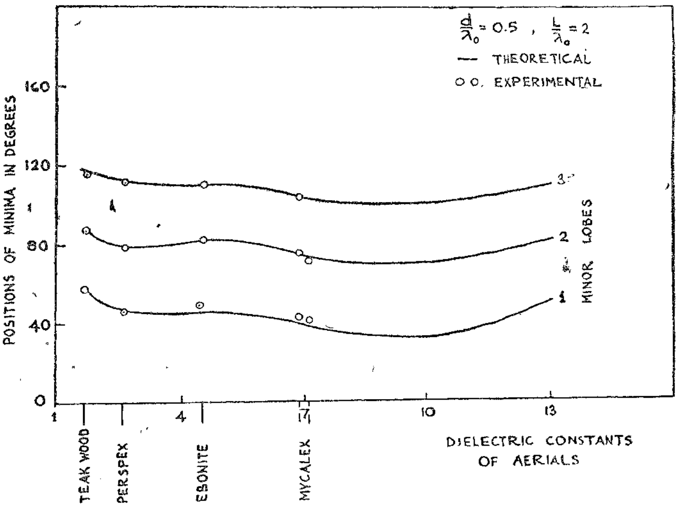

Fig. VI

Variation of the positions of minima of side lobes in degrees for a rod of $d/\lambda_0 = 0.5$, $L/\lambda_0 = 2$ with respect to dielectric constant

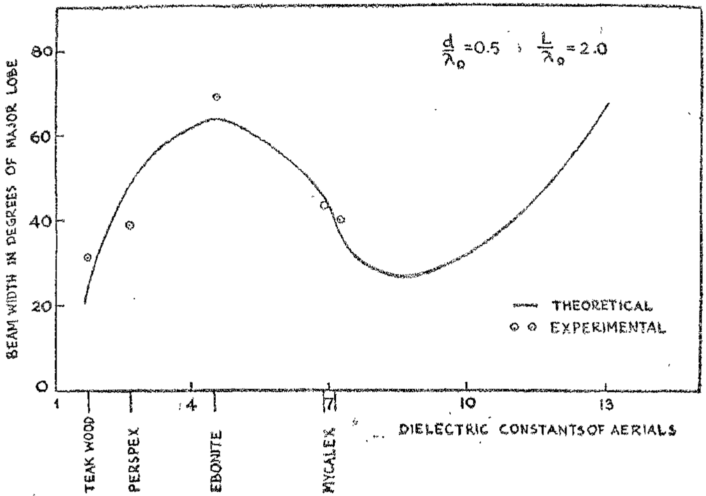

Fig. VII

Variation of beam width in degrees between half power points of major axial ($\theta = 0°$) lobe with respect to dielectric constant

A number of radiation characteristics for different d, L and $\bar{\epsilon}_1$ have been theoretically computed and it is found that there is close agreement in each case between the theoretical and experimental results. One of such characteristics is shown in Fig. III. Fig. IV shows the theoretical radiation characteristic for a dielectric rod of $d/\lambda_0 = 0.5$, $L/\lambda_0 = 2$ and $\bar{\epsilon}_1 = 10$ for the sake of comparison. This characteristic could not be experimentally verified for want of a suitable rod having $\bar{\epsilon}_1$ greater than 7.12.

The theoretical and experimental variations of the positions of maxima and minima of lobes for a rod of $d/\lambda_0 = 0.5$ and $L/\lambda_0 = 2$ as a function of $\bar{\epsilon}_1$ are shown in Figs. V and VI. The theoretical and experimental values of beam width in degrees between the half power points for the major axial ($\theta = 0°$) lobe as a function of $\bar{\epsilon}$ for $d/\lambda_0 = 0.5$ and $L/\lambda_0 = 2$ are shown in Fig. VII.

Conclusion

From the study of a large number of radiation characteristics determined for various values of $\bar{\epsilon}$, d and L, it is concluded that the radiation characteristics of a dielectric rod aerial can be adjusted to a predetermined form by proper selection of d, L and $\bar{\epsilon}$.

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