PROPAGATION AND RADIATION BEHAVIOUR OF DIELECTRIC COATED E-PLANE SECTORAL HORN

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Abstract

The analytical and experimental results of the radiation behaviour of an improved feed system with increased directivity, greater gain and low sidelobe levels consisting of a dielectric coated E-plane sectoral horn are reported. The characteristic equation for the separation constant for the HE_{1p} mode is obtained and the radiation characteristics with power gain for the system are derived for HE_{11} mode excitation. Analytical results are established by good agreement with experiments. Results of the experimental investigations in further improving the radiation characteristics of the dielectric coated E-plane sectoral horn using dielectric spheres are also included.

Introduction

For many applications such as satellite communication and radio astronomy, physically small antenna feeds with high directivity and low sidelobe levels are desirable. Here the authors report the analytical and experimental results of the radiation characteristics of dielectric coated E-plane sectoral horn. The theoretical results are derived for HE_{11} mode from the electric vector potential on the basis of Vector diffraction formula. Experimental results with dielectric spheres placed off-set in front of, but displaced from, the aperture of the coated E-plane horn for improving its radiation characteristics are also reported.

Analysis

The device under consideration is shown in fig.1. The narrow walls (E-plane) of the E-plane sectoral horn are coated with a dielectric material of angular thickness. Assuming radial hybrid mode propagation, the components of the fields in the system can be derived from a x-directed electric vector potential function [1] Ψ given by

$$\Psi_{mp}^{TE} = \cos\frac{m\pi}{a}\cos p\theta\, B_p(k_r r) \qquad (1)$$

where $k_r = \sqrt{k_o^2 - (\frac{m\pi}{a})^2}$ with $k_o = \frac{2\pi}{\lambda}$

The different field components inside the dielectric coated region and in the axial region of the horn for HE_{1p} mode are given by

Inside dielectric coated region

$$\bar{E}_r = \frac{1}{r} P\cos\frac{\pi}{a}\sin p\theta[AJ_p(k_{r1}r)+BN_p(k_{r1}r)]$$

$$\bar{E}_\theta = k_{r1}\cos\frac{\pi}{a}x\cos p\theta[AJ'_p(k_{r1}r)+BN'_p(k_{r1}r)]$$

$$\bar{E}_x = 0$$

$$\bar{H}_r = \frac{-k_{r1}}{j\omega\mu_o}(\frac{\pi}{a})\sin\frac{\pi}{a}x\cos p\theta.[AJ'_p(k_{r1}r)+BN'_p(k_{r1}r)] \qquad (2)$$

$$\bar{H}_\theta = \frac{1}{j\omega\mu_o r}p(\frac{\pi}{a})\sin p\theta.[AJ_p(k_{r1}r)+BN_p(k_{r1}r)]$$

$$\bar{H}_x = \frac{1}{j\omega\mu_o}k_{r1}^2\cos\frac{\pi}{a}\cos p\theta.[AJ_p(k_{r1}r)+BN_p(k_{r1}r)]$$

In the axial region

$$E_r^+ = \frac{C}{r}p\cos\frac{\pi}{a}x\sin p\theta\, H^{(2)}_{p(k_r r)}$$

$$E_\theta^+ = Ck_r\cos\frac{\pi}{a}x\cos p\theta\, H^{(2)'}_{p(k_r r)}$$

$$E_x^+ = 0$$

$$H_r^+ = \frac{-Ck_r}{j\omega\mu_o}(\frac{\pi}{a})\sin\frac{\pi}{a}x\cos p\theta\, H^{(2)'}_{p(k_r r)} \qquad (3)$$

$$H_\theta^+ = \frac{C}{j\omega\mu_o r}(\frac{\pi}{a})p\sin\frac{\pi}{a}x\sin p\theta\, H^{(2)}_{p(k_r r)}$$

$$H_x^+ = \frac{C}{j\omega\mu_o}k_r^2\cos\frac{\pi}{a}\cos p\theta\, H^{(2)}_{p(k_r r)}$$

where A, B and C are constants and

$$k_{r1} = \sqrt{\epsilon_r k_o^2 - (\pi/a)^2}$$

The characteristic equation for the separation constant p can be formulated by applying appropriate boundary conditions. This equation is derived as -

$$\frac{J_p(x_1)N_p'(x_2) - J_p'(x_2)N_p(x_1)}{J_p'(x_1)N_p'(x_2) - J_p'(x_2)N_p'(x_1)} = \frac{k_{r1}}{k_r} \frac{H_p^{(2)}\left(k_r \frac{b_1}{2\,\mathrm{Sin}\,\alpha_1}\right)}{H_p^{(2)'}\left(k_r \frac{b_1}{2\mathrm{Sin}\alpha_1}\right)} \quad (4)$$

where $x_1 = k_{r1} \frac{b_1}{2\mathrm{Sin}\alpha_1}$

$x_2 = k_{r1} \frac{b_o}{2\mathrm{Sin}\alpha_o}$

and the prime indicates differentiation with respect to the argument. This equation is solved graphically for HE11 mode for particular values of $\epsilon_r, \alpha_o, \alpha_1$ and δ. With the assumption of quadratic phase variation of the horn aperture field, the radiated far field in the H-plane ($\emptyset$=0), by Vector diffraction formula|2|, for HE_{11} mode is given by

$$E_\emptyset = C' k_r \frac{e^{-jk_o r}}{r} R \left(1 + \frac{k_r}{k} \mathrm{Cos}\theta \frac{\mathrm{Sinp}\alpha_1}{p}\right) \cdot \frac{\sqrt{\lambda_g R}}{2} \left[M\left\{c(v_1) - c(v_2) - j(s(v_1) - s(v_2)\right\} + N\left\{c(v_3) - c(v_4) - j(s(v_3) - s(v_4)\right\}\right] \quad (5)$$

where

$$\binom{M}{N} = e^{\frac{j\pi}{\lambda_g} R \left(\frac{1}{a} \pm \frac{2\mathrm{Sin}\theta}{\lambda_g}\right)^2}$$

$$\binom{v_1}{v_2} = \frac{1}{\sqrt{2}} \left| \frac{a}{\sqrt{\lambda_g R}} \pm \sqrt{\lambda_g R}\left(\frac{1}{a} + \frac{2\,\mathrm{Sin}\theta}{\lambda_g}\right) \right| \quad (6)$$

$$\binom{v_2}{v_3} = \frac{1}{\sqrt{2}} \left| \frac{a}{\sqrt{\lambda_g R}} \pm \sqrt{\lambda_g R}\left(\frac{1}{a} - \frac{2\,\mathrm{Sin}\theta}{\lambda_g}\right) \right|$$

R being the horn axial length.

The on-axis gain of the dielectric coated E-plane sectoral horn is obtained as

$$G(0,0) = \frac{16\pi R^2 \lambda_g^2 \left(1 + \frac{\lambda}{\lambda_g}\right)^2}{\lambda^3 a(\alpha_o + \mathrm{Sin}2p\alpha_o)} \frac{\mathrm{Sin}^2 p\alpha_1}{p^2} \cdot \left\{(c(u_1) - c(u_2))^2 + (s(u_1) - s(u_2))^2\right\}$$

where

$$\binom{u_1}{u_2} = 1/\sqrt{2}\left[\frac{a}{\sqrt{\lambda_g R}} \pm \frac{\sqrt{\lambda_g R}}{a}\right] \quad (7)$$

Experimental Results and Discussions

The narrow walls of an E-plane sectoral horn of R=6.7 cm, b=5.8 cm, a=2.5 cm and $\alpha_o = 19^o$ was coated with bakelite (ϵ_r=3.55) for an angular thickness of $2^o(\alpha_1 = 17^o)$. Observations were made for the horn excited in HE_{11} mode at a frequency of 8.86 GHz. Analytical results of the radiation pattern are verified by good agreement with experimental results in fig.2. Experiments were repeated with paraffin wax (ϵ_r=2.25) spheres of diameter 4 cm, 6 cm and 9 cm placed off-set 5 at minimum input VSWR position in front of the horn aperture. (The sphere off-set position were found to lie between 1 and 1.4 cm from the horn aperture for the 3 sphere sizes tested. The input VSWR for the off-set spheres respectively were found to be 1.2, 1.15 and 1.1. The radiation patterns with off-set placed spheres are presented in fig.(3). In fig.(4) is depicted the gain (experimental) of the sphere loaded dielectric coated E-plane horn as a function of the sphere dimension in wave lengths.

From the results, it is concluded that the dielectric coated E-plane sectoral horns have significantly increased directivity at the cost of slightly increased sidelobelevels. The radiation characteristics of the coated E-plane sectoral horn can be further improved with greater directivity increased on-axis gain and reduced sidelobe levels by loading the horn with off-set placed dielectric spheres.

References

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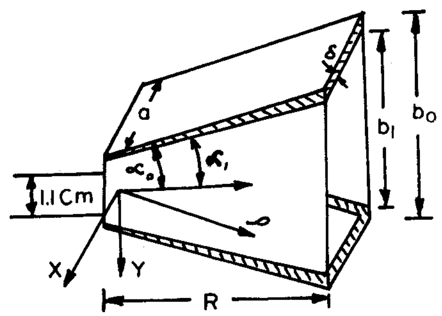

$\alpha_o = 19°$, $\alpha_1 = 17°$, R = 6.7cm, b_o = 5.8cm
b_1 = 5.2cm, a = 2.5cm, δ = 3mm

FIG.1 DIELECTRIC COATED E-PLANE SECTORAL HORN.

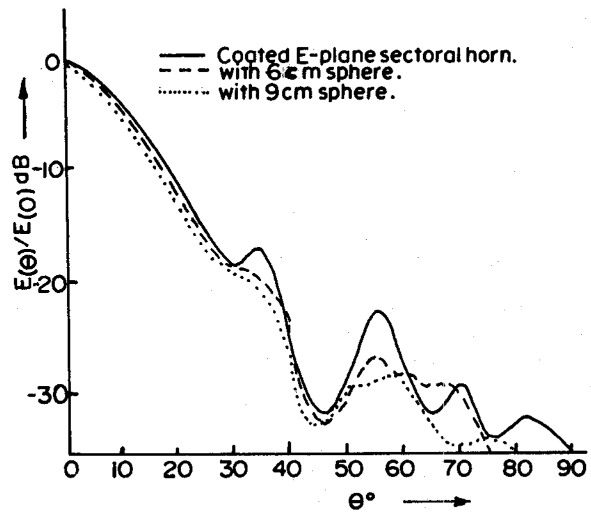

FIG.3 RADIATION PATTERN FOR DIELECTRIC SPHERE LOADED DIELECTRIC COATED E-PLANE SECTORAL HORN.

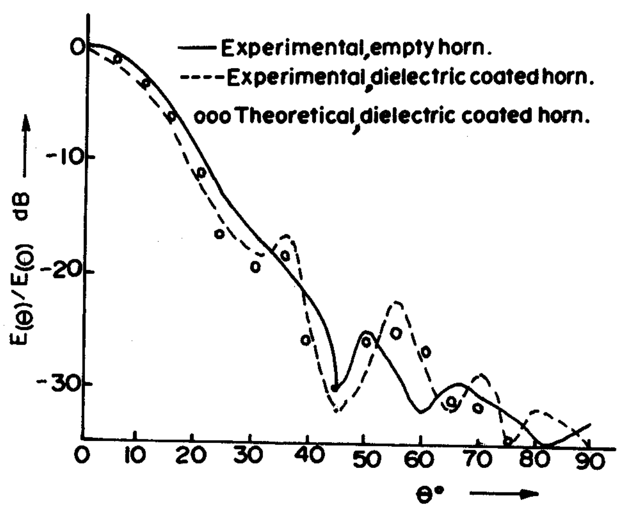

FIG.2 RADIATION PATTERN FOR DIELECTRIC COATED E-PLANE SECTORAL HORN.

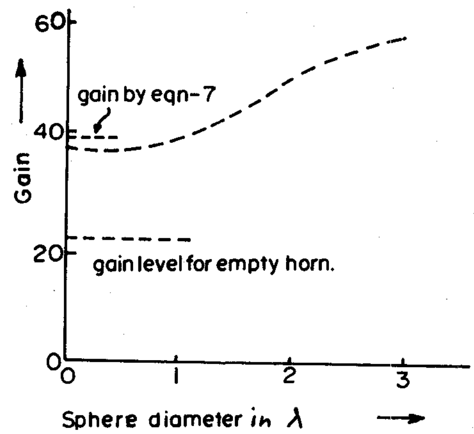

FIG.4 GAIN Vs SPHERE DIAMETER FOR SPHERE LOADED DIELECTRIC COATED E-PLANE SECTORAL HORN.