EXCITATION OF A CORRUGATED DIELECTRIC ROD

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The excitation of a corrugated dielectric rod has been theoretically studied for a magnetic ring source. The launching efficiency of the magnetic ring source has been determined for various combinations of the structure parameters and also for different values of ϵr_2 which is the effective dielectric constant of the corrugated region, and is given by $\epsilon r_2 = \left[\frac{s + t\sqrt{\epsilon r_1}}{s + t}\right]^2$.

INTRODUCTION

THEORETICAL and experimental study of the surface wave and radiation properties of a corrugated dielectric rod excited in a symmetric TM mode has been carried out extensively by Shankara and Chatterjee (1972 *a, b, c;* 1973). However, the launching efficiency of the magnetic ring source has not been considered so far for the corrugated rods. The object of this paper is to present the results of the theoretical investigations on the launching efficiency of a magnetic ring source, to launch a TM symmetric mode on the circular cylindrical corrugated dielectric rod waveguide. The method of approach is the usual Contour Integration method, using the Saddle Point technique.

FIELD COMPONENTS

The field components outside the corrugated dielectric rod is given by (Shankara & Chatterjee, 1972*a*)

$$\begin{aligned} E_z &= AH_0^{(1)}(k\rho)\exp(-j\beta z) \\ H_\phi &= A\frac{j\omega}{\beta} H_1^{(\pi)}(k\rho)\exp(-j\beta z) \\ E_\rho &= A\frac{j\beta}{k} H_1^{(1)}(k\rho)\exp(-j\beta z) \end{aligned} \qquad \ldots(1)$$

where $k^2 = \omega^2\mu_0\epsilon_0 - \beta^2$, k is the radial propagation constant and β is the axial phase constant.

The structure is excited by a magnetic ring source, which is obtained by applying a voltage $Ve^{j\omega t}$ across an infinitesimally narrow circular slot of radius c, cut in a perfectly conducting screen in the plane $z = 0$ (Fig. 1).

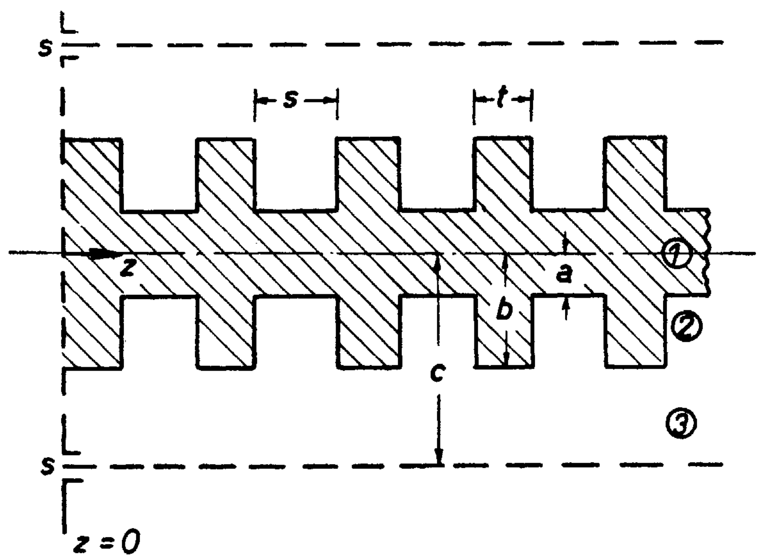

FIG. 1. Corrugated dielectric rod excited by a magnetic ring source. (1), (2) and (3) represent regions 1, 2 and 3 respectively, s — slot in the perfectly conducting sheet.

The source of excitation consists of the superposed magnetic ring sources of current

$$Im = \frac{V}{\pi}\ \delta\,(\rho - c)\ \exp\,(-j\beta z). \qquad \ldots(2)$$

The field components Ez_1 and Ez_2 in the regions 2 and 3 are given by

$$\left.\begin{aligned} Ez_1 &= [A_1 H_0^{(1)}\,(k\rho) + A_2 H_0^{(2)}\,(k\rho)\,]\ \exp\,(-j\beta z),\ (b \leqslant \rho \leqslant c) \\ &\text{and} \\ Ez_2 &= A_3 H_0^{(1)}\,(k\rho)\ \exp\ (-j\beta z),\ (\rho > c) \end{aligned}\right\} \ldots(3)$$

The components $E_{\phi 1}$, $E_{\phi 2}$, $H_{\phi 1}$, and $H_{\phi 2}$ can be obtained from eqns. (3). The wave in Region 2 is a standing wave, while that in Region 3 represents

(*i*) outward travelling wave when $k < 0$, real,
(*ii*) inward travelling wave when $k > 0$, real and
(*iii*) evanescent wave when $k > 0$, imaginary

Applying the conditions of continuity of H_ϕ and discontinuity of E_z across the magnetic current sheet, and matching the surface impedance at $\rho = b$, the excitation constants have been determined. The field excited by the annular slot is hence given by

$$H_{\phi 1} = \frac{V\omega\epsilon c}{4}\int_{-\infty}^{\infty} H_1^{(1)}\,(kc)\,[\,RH_1^{(1)}\,(k\rho) + H_1^{(2)}\,(k\rho)\,]\ \exp\,(-j\beta z)\ d\beta,$$

$$(b \leqslant \rho \leqslant c)$$

and

$$H = \frac{V \omega \epsilon c}{4} \int_{-\infty}^{\infty} H_1^{(1)} (k\rho) [R H_1^{(1)} (kc) + H_1^{(s)} (kc)] \exp(-j\beta z) \, d\beta, \qquad (\rho \geqslant c) \qquad \ldots(4)$$

where

$$R = \frac{jk H_0^{(2)} (kb) - Z_s \omega\epsilon H_1^{(3)} (kb)}{Z_s \omega\epsilon H_1^{(1)} (kb)_1 - jk H_0^{(3)} (kb)}$$

Z_s being the surface impedance at $\rho = b$.

Evaluation of the Infinite Integral

The infinite integral (4) is evaluated using contour integration. Since the integrand is a two-valued function of β (k possesses two values for each β), we have a branch-cut in the β-plane, (with the branch points at $\beta = \pm k_0$) to make the function single valued in the β-plane. Also, since the integrands converge when $Im\ k > 0$, the contour of integration should be in that sheet of β-plane for which $Im\ k > 0$.

The contour of integration in the β-plane consists of a semicircular path C_s (see Fig. 2) with radius tending to ∞, a branch-cut C_b and the paths enclosing the poles C_p. The integral vanishes on C_s for $z > 0$. Hence, the only contributions are from the branch-cut integral, which represents the radiation field, and the residues contributed by the enclosed surface wave poles.

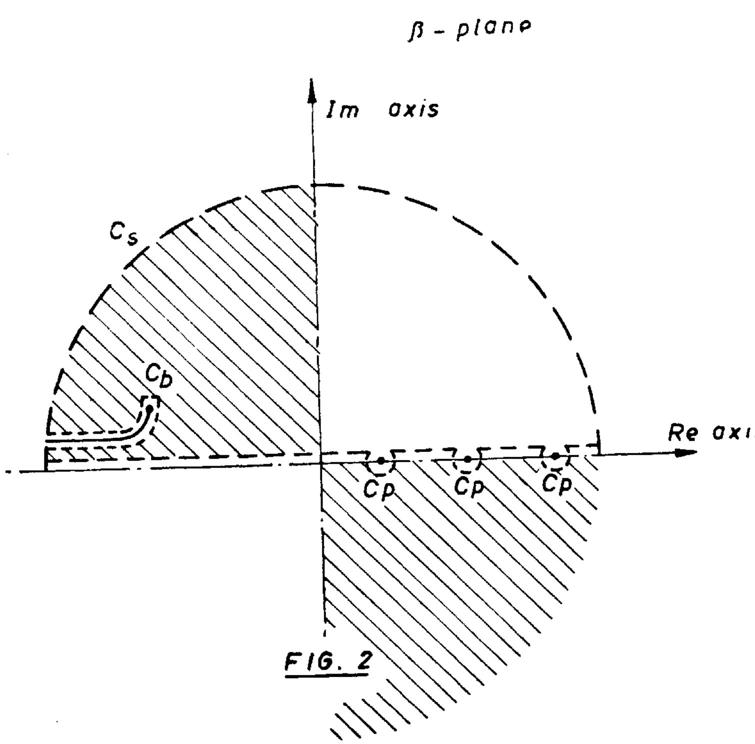

Fig. 2. Contour of Integration in the β-plane. In the crosshatche region, $Im\ k > 0$.

Surface Wave and Radiated Power

The surface wave field is given by the residues of the poles of the integrand. The total power carried by the surface wave is given by

$$P_s = 2\pi V^2 \frac{\omega\epsilon}{\beta}\left(\frac{c}{b}\right)^2 \frac{K_1^2(k'c)}{f(k'b)} \qquad \ldots(5)$$

where $f(k'b) = K_0^2(k'b) - K_1^2(k'b) + \frac{2}{k'b} K_0(k'b) K_1(k'b)$,

where K_0 and K_1 are modified Bessel Functions and $k = jk'$ is the root of the characteristic equation for the corrugated dielectric rod (Shankara & Chatterjee, 1973).

The radiated power P_r is evaluated using the Saddle Point technique, and is given by

$$P_r = \frac{Z_0\pi}{V\epsilon}\left(\frac{Vc\omega\epsilon}{2}\right)^2 \int_{\theta=0}^{\pi/2} |F(\theta)|^2 \sin\theta \, d\theta, \qquad \ldots(6)$$

where Z_0 is the free space impedance,

$$F(\theta) = H_1^{(2)}(-k_0 c \sin\theta) + R_\epsilon H_1^{(2)}(-k_0 c \sin\theta)$$

$$R_\epsilon = \frac{jk_0 \sin\theta \, H_0^{(2)}(-bk_0 \sin\theta) - Z_s\omega\epsilon \, H_1^{(2)}(-bk_0 \sin\theta)}{Z_s\omega\epsilon \, H_1^{(1)}(-bk_0 \sin\theta) - jk_0 \sin\theta \, H_0^{(1)}(-bk_0 \sin\theta)}$$

Launching Efficiency

The launching efficiency η is given by

$$\eta = \frac{P_s}{P_r + P_s} \qquad \ldots(7)$$

Numerical Evaluation

The launching efficiency η has been determined for varying ϵ_{r_2} for the value of $\epsilon_{r_1} = 2.56$ (perspex) for different combinations of a and b. The results are presented in Fig. 3. The normalised radiated power P_r for particular values of a and b (which have been used in the investigations of Shankara & Chatterjee, 1973) has been determined and the results are shown in Fig. 4 [1 to 7], for varying c/b. The launching efficiency corresponding to each of these seven structures has been presented in Fig. 4 (8).

Discussion

It can be seen from Figs. 3 and 4 that :—

(*i*) The launching efficiency η decreases as the ratio b/a decreases and a increases. η is maximum when b/a is the largest and a is the smallest, and is not very much affected by the variation in ϵ_{r_2} for these values of a and b.

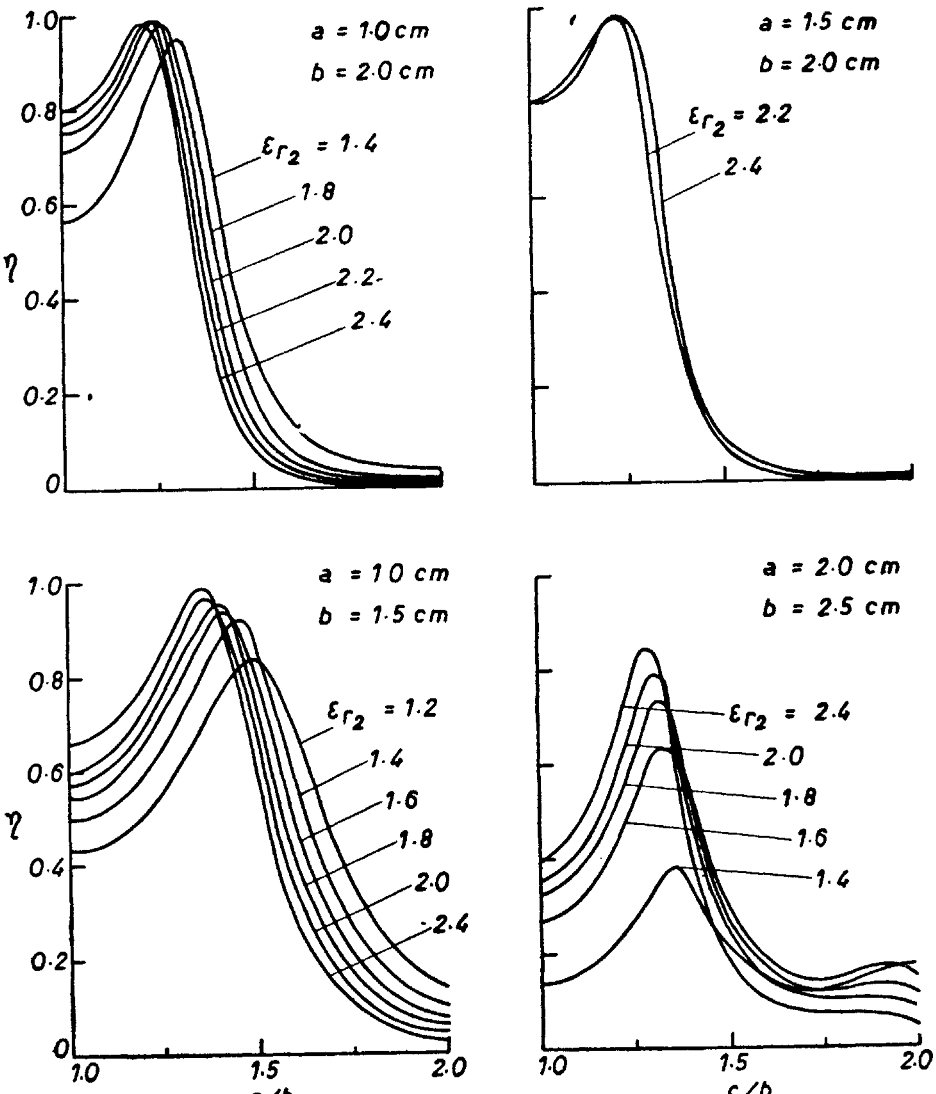

FIG. 3. Launching efficiency as a function of c/b and ϵ_{r_2}. $\epsilon_{r_1} = 2.56$.

(*ii*) η increases as the effective dielectric constant ϵ_{r_2} of the region 2 increases. Since ϵ_{r_2} is given by $\left[\frac{s+\sqrt{\epsilon_{r_1}}\,t}{s+t}\right]^2$, s and t can be so adjusted as to give the largest possible ϵ_{r_2}.

(*iii*) η is affected by the ratio c/b. There is a maximum value of η for each combination of a, b, s and t, at a particular value of c/b. However, the maximum value itself depends on the parameters a and b.

It was also found that when $a = 1.5$ cm and $b = 2.0$ cm, the guide does not support a surface wave for values of ϵ_{r_2} less than 2.2.

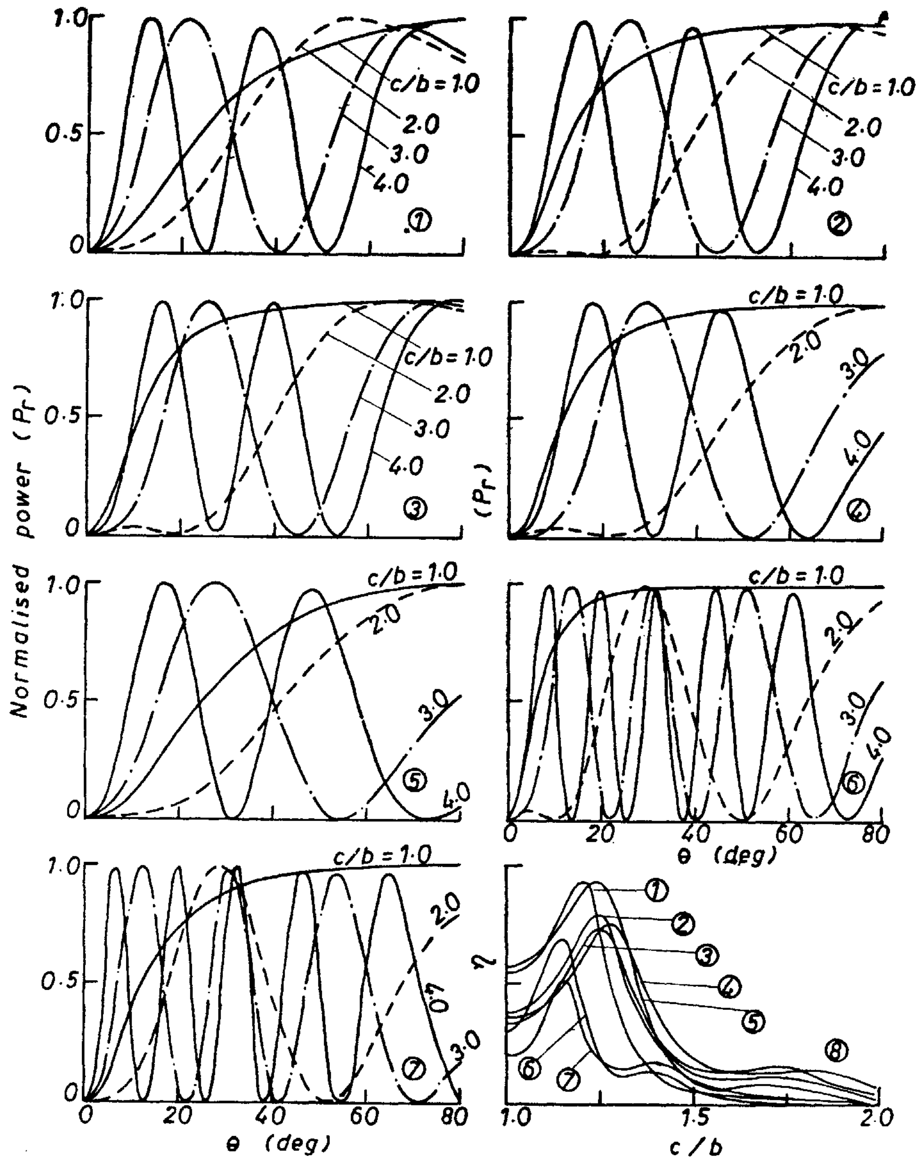

FIG. 4. Normalised radiated power and launching efficiency as functions of c/b.

	a(cms)	b(cms)	s(cms)	t(cms)
(1)	0.9525	1.5875	0.2	0.15875
(2)	0.9525	1.5875	1.0	0.15875
(3)	0.9525	1.5875	1.4	0.15875
(4)	0.9525	1.4288	1.0	0.15875
(5)	1.27	1.3	0.5	0.3175
(6)	1.27	3.0	0.5	0.3175
(7)	2.2225	2.8575	1.0	0.15875

CONCLUSIONS

The parameters *a* and *b* can be adjusted in such a way as to give a launching efficiency of more than 95 per cent for an optimum value of c/b. This confirms the conclusion experimentally arrived at by Shankara and Chatterjee (1973).

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