COUPLING BETWEEN A DIELECTRIC IMAGE GUIDE AND A DIELECTRIC RESONATOR.

F. FARZANEH - P. GUILLON- Y. GARAULT

L.C.O.M. L.A. CNRS 356
UER Sciences 123 av. A. Thomas
F. 87060 LIMOGES Cedex.

SUMMARY

Since many years dielectric guides have been used to realize microwave components {1} at millimeter wave frequencies.

In this frequency band, the coupling of dielectric resonators with such guides will permit to obtain integrated dielectric components like filters or oscillators.

This paper presents the study of the coupling between a dielectric image guide and the $TE_{0\gamma\delta}$ cylindrical dielectric resonator mode. A lumped equivalent circuit is given and the coupling coefficient between the guide and the resonator is evaluated. Experimental and theoretical results are also presented.

. Dielectric resonator

To evaluate respectively the E.M. fields, the resonant frequencies and the quality factor of the dipolar $TE_{0\gamma\delta}$ dielectric mode we use the 3rd order approximation defined in {2}, {3}, in which we suppose that all the dielectric interfaces are imperfect magnetic walls (fig.1). With this assumption, the expressions of the longitudinal magnetic components of $TE_{0\gamma\delta}$ mode in each zone have been evaluated and H_r and E_θ components are deduced from those by using Maxwell equations.

Writing boundary conditions at dielectric interfaces, we obtain two eigenvalues equations which are solved simultaneously to obtain the resonant frequencies of the $TE_{0\gamma\delta}$ dielectric resonator mode.

$$k_r \frac{J_o(k_r a)}{J_r(k_r a)} = - k_a \frac{K_o(k_a a)}{K_1(k_a a)} \qquad (1)$$

$$2\,\beta h = q\pi + 2 \tan^{-1} \frac{\alpha_a}{\beta}$$

J_o, K_o are respectively Bessel functions of first kind and modified Bessel function of second kind.

With :
$$k_r^2 = \frac{\omega^2}{C^2}\varepsilon_r - \beta^2 = \frac{\omega^2}{C^2} + \alpha_a^2$$
$$k_a^2 = \beta^2 - \left(\frac{\omega}{C}\right)^2$$

. Dielectric image guide (fig.2){4}

We have solved Helmolhtz equation to obtain the expressions of the EH_{11} mode components of the guide.

C_p the tangential components are deduced from longitudinal one's per using Maxwell equations.

Using the effective permittivity (ε_{re}) method, we have find the eigenvalue equation (2) which permits to deduce the propagation constant β_g as a function of the dielectric guide dimensions (fig.2)

$$a\,k_x = \frac{m\pi}{2} - \tan^{-1}\frac{k_x}{K_x^{o}}$$
$$b\,k_y = \frac{n\pi}{2} - \tan^{-1}\frac{k_y}{\varepsilon_r k_y^{o}} \qquad (2)$$

m, n mode orders

$$k_x^{o2} = (\varepsilon_{r_e} - 1)\,k_o^2 - k_x^2$$
$$K_y^{o2} = (\varepsilon_r - 1)\,k_o^2 - k_y^2$$
$$\varepsilon_{r_e} = \varepsilon_r - (k_y/k_o)^2\,;\quad k^2 - \beta_g^2 = k_x^2 + k_y^2$$
$$k_o^2 - \beta_g^2 = k_x^2 - k_y^{o2}$$

For this dielectric guide we have defined the characteristic impedance Z_c by (3)

$$Z_c = \frac{2\overline{P}}{I_z^2} \qquad (3)$$

where
$$\overline{P} = \int_0^{\infty}\int_{-\infty}^{+\infty} (E_x H_y - E_y H_x)\,dx\,dy$$
$$I_z = 2\int_0^{+\infty} \vec{a}_y \times \vec{H}_x \,dx$$

. Coupling between a dielectric image guide and a dielectric resonator.

To use them in the millimeter frequencies band as filters or in oscillators it is necessary to couple the dielectric guide and the dielectric resonator.

Acting on the $TE_{0\gamma\delta}$ mode the dielectric resonator can be assimilated to a magnetic dipole and we couple it to the dielectric guide by orienting the resonator axis perpendicular to the guide propagation axis (fig. 3). Let be L_r, C_r, R_r the equivalent circuit parameters of the resonator and L_g the equivalent self inductance of the guide.

0149-645X/84/0000-0187 $01.00 © 1984 IEEE

In figure 4 we present the lumped equivalent circuit between the guide and the resonator. L_m is the mutual inductance which characterizes the magnetic coupling.

At resonant frequency the input impedance Z_{in} calculated in the coupline plane verifies :

$$Z_{in} = Q_o \omega_o \frac{L_m^2}{L_r} \qquad (4)$$

Q_o : unloaded quality factor of the dielectric resonator.

The induced voltage in the dielectric guide by the current I_r flowing in the dielectric resonator is :

$$\Delta V = j \omega L_m \quad I_r \qquad (5)$$

This voltage can also be obtained by the magnetic flux (between the guide and the resonator) defined by

$$\Delta V = j\omega \mu_o C \iint \vec{H}_r . \vec{dS} \qquad (6)$$

C is a coefficient which takes into account the disalignement between the magnetic field line H_r of the $TE_{0\gamma\delta}$ resonator mode and that of the dielectric guide H_g. C is defined by (7)

$$C = \frac{\int_S H_r H_g^* dS}{\int H_r H_r^* dS \int H_g H_g^* dS} \qquad (7)$$

S is a sectionnal plane.

We have drawn in fig.5 the curves which give the C variations as a function of the distance S between the dielectric guide and the resonator.

From (4), (5), (6), we obtain :

$$Z_{in} = Q_o \omega_o \frac{\mu_o^2 C^2 (\int_S \vec{H} \ \vec{dS})^2}{\varepsilon \int_V E^2 dV} \qquad (8)$$

The external quality factor Q_e defined by (9) has been evaluated as a function of the distance separing the guide and the resonator

$$Q_e = \frac{2Z_c Q_o}{Z_{in} + 2Z_c} \qquad (9)$$

Z_C and Z_{in} are respectively given by equations (3) and (8)

. Experimental results

A transition (acting at 10 GHz) between a metallic waveguide and the dielectric image guide has been realized using the parameters presented in (5) (6).

The characteristics measured of the transition are :

return loss > 25 db ; VSWR < 1.16 ;
insertion loss : 0,5 db.

Dielectric resonator characteristics :
diameter : 5 mm ; height : 3 mm ;
permittivity : 36.

Characteristics of dielectric guide :
permittivity ε_g = 2,54 ; width : 17 mm.

The experimental and theoretical variations of the external quality factor Q_e are presented in fig. 6 and 7 for different positions of the dielectric resonator.

CONCLUSION

These first results show that it will be interesting in the future to use simultaneously dielectric guide and dielectric resonator ; in particular to realize microwave integrated components in millimeter wave range.

REFERENCES

{1} E.A.MARCATILI : Dielectric rectangular waveguide and directional coupler for integrated optics.
B S T J Vol. 48 p. 2078 sept. 1969.

{2} T. ITOH - R. RUDOKAS : New method for computing the resonant frequencies of dielectric resonators.
IEEE Trans. Microwave Theory and Techniques vol. MTT-25 pp. 52-54 janv. 1973.

{3} P. GUILLON - Y. GARAULT : Accurate resonance frequencies of dielectric resonators.
IEEE Trans. Microwave Theory and Techniques vol. MTT-25 pp. 916-922 nov. 1977.

{4} K. KNOX - P. TOULIOS : Integrated circuits for millimeter through optical frequency range.
B S T J vol. 48 p. 495.

{5} T. TRINH - R. MITTRA : Coupling characteristics of planar dielectric waveguides of rectangular cross section.
IEEE Trans. on MTT vol. 29 n°9 sept. 1981

{6} T. TRINH - I.A.G. MALHERBE and R. MITTRA : A metal to dielectric waveguide transition with application to millimeter-wave integrated circuits.
IEEE MTT-S 1981 WASHINGTON D.C.

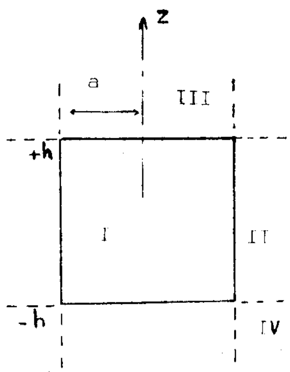

Fig.1 - cylindrical dielectric resonator.

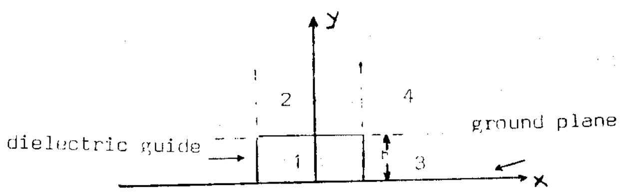

Fig.2 - dielectric image guide.

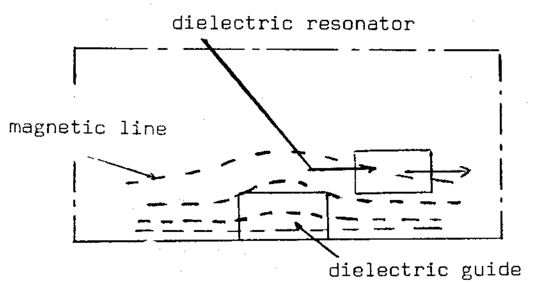

Fig.3 Coupling between a dielectric guide and a dielectric resonator.

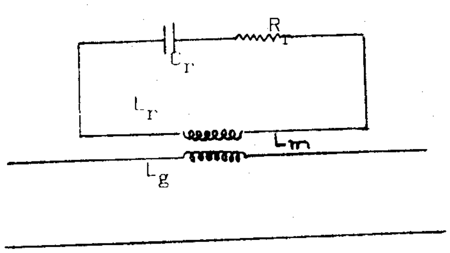

Fig.4 : lumped equivalent circuit.

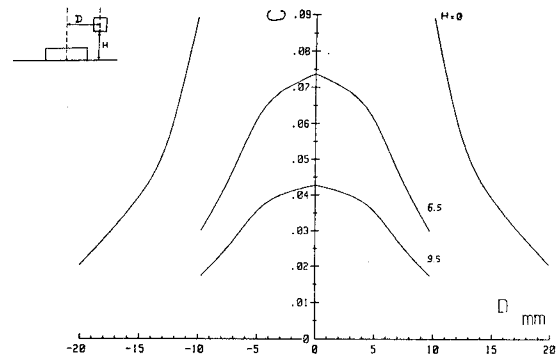

Fig.5 C variations.

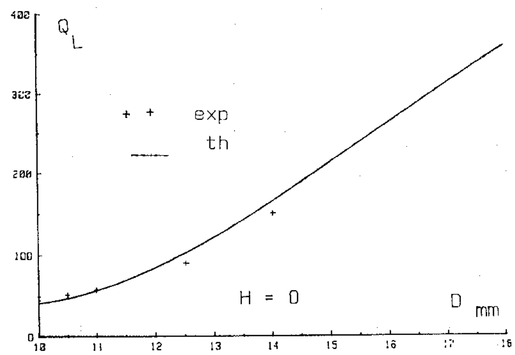

Fig. 6 loaded quality factor variations

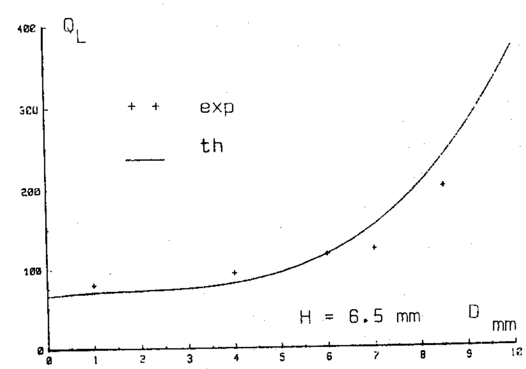

Fig. 7 loaded quality factor variations