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TRANSVERSE RESONANCE ANALYSIS OF FINLINE DISCONTINUITIES*

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ABSTRACT

A transverse resonance technique is used to compute the resonant frequencies of a finline resonator containing the discontinuity to be analyzed. From this, the parameters of the equivalent circuit of the discontinuity are evaluated as functions of frequency and geometry of the structure.

INTRODUCTION

Finlines are now recognized as a valuable technology of millimeter wave integrated circuits. While many theoretical works have been done concerning the analysis and characterization of uniform finline structures [1,2], a relatively small number of analyses of finline discontinuities have been developed [3,4].

This paper presents a new method of analysis which can be used for characterizing both uniform finlines and finline discontinuities. The method consists of computing the resonant frequencies of a resonator obtained by short circuiting a finline section containing the discontinuity to be analyzed. The computation of the resonant frequencies is based on a transverse analysis technique. The EM field is expanded in terms of LSM and LSE modes of the rectangular waveguide housing. With respect to other approaches based on the field expansion in terms of finlines modes [3,4], the present one has the advantage of a notable reduction of the computing time. In this paper, we apply the new method to the step discontinuity in the finline, though the method itself can be applied to a number of other discontinuities.

Characterization of the Discontinuity

As will be shown next, the characterization of a finline discontinuity can be reduced to the evaluation of the resonant frequencies of a resonator obtained by inserting two shorting planes at some distances from the discontinuity. The structure so obtained is shown in Fig. 1.

As long as the frequency is such that only dominant modes can propagate in the two finline sections and higher order modes excited at the discontinuity have negligible amplitudes at the shortening planes, the discontinuity can be modeled as a two-port network, and the resonant structure has the equivalent circuit in Fig. 2.

In terms of the Z-parameters of the discontinuity, the resonance condition is

$$(Z_{11} + Z_1)(Z_{22} + Z_2) - Z_{12}^2 = 0 \qquad (1)$$

where

$$Z_i = jZ_{oi} \tan(\beta_i \ell_i) \qquad i = 1,2$$

Z_{oi} are the characteristic impedances of the i-th finline, β_i the corresponding phase constant.

If three different pairs of ℓ_1, ℓ_2 are known which give rise to the same resonant frequency ω_r, eq. (1) allows the evaluation of the three impedance parameters of the discontinuity of $\omega = \omega_r$.

If the two finlines are identical, i.e., the discontinuity is absent, then $\beta_1 = \beta_2 = \beta$, and (1) is easily reduced to $\beta(\omega_1) = \pi/\ell$ with $\ell = \ell_1 + \ell_2$. In other words, the knowledge of the length ℓ corresponding to the resonant frequency ω_r allow the evaluation of the finline phase constant at $\omega = \omega_r$.

Computation of the Resonant Frequencies

In the case of bilateral finlines, a magnetic wall can be inserted at $x = 0$, so that only one half of the structure ($x \geq 0$) has to be analyzed. In the following, we shall refer to this case, the extension to the unilateral case being straightforward.

The EM fields in the dielectric slab ($0 \leq x \leq s/2$) and in the air region ($s/2 \leq x \leq a/2$) can be expanded in terms of TE and TM components with respect to the x-direction (or LSM and LSE components). For instance, the transverse (with respect to x) components of the E-field $0 \leq x \leq s/2$ can be expressed as follows:

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$$\underline{E}_t = \Sigma_m \Sigma_n [A_{mn} \hat{x} x \nabla_t \psi_{mn} + \frac{\gamma_{mn}}{j\omega\varepsilon_o\varepsilon_r} \beta_{mn} \nabla_t \phi_{mn}] \cos\gamma_{mn} x \qquad (2)$$

where ψ_{mn}, ϕ_{mn} are the TE and TM potentials of a rectangular waveguide with inner dimensions $\ell = \ell_1 + \ell_2$ and b,

$$\gamma_{mn}^2 = \beta_o^2 \varepsilon_r - (\frac{m\pi}{\ell})^2 - (\frac{n\pi}{b})^2$$

Expression (2) is such that the boundary condition at x = 0 is already satisfied.

The transverse EM field components inside the slot (x = s/2) can be expressed in terms of a suitable set of orthogonal basis function. In the present analysis, we expanded the transverse EM field inside the slot in terms of the modes of a waveguide having a stepped cross section corresponding to the slot geometry (Fig. 1b).

The boundary conditions at x = s/2 lead finally to a homogeneous system of equations in the expansion coefficients of the EM field inside the slots. The condition for non-trivial solutions constitutes the characteristic equation of the structure. This equation may be regarded as a real function of ω, ℓ_1, ℓ_2 equated to zero.

Computed Results

The present method has been first tested for computing the propagation characteristics of uniform finlines.

Fig. 3 shows a comparison between the frequency behavior of the effective permittivity $\varepsilon_{eff} = (\beta/\beta_o)^2$ computed by the present method and by the spectral domain approach. The agreement is quite satisfactory.

Fig. 4 shows the resonant frequency of the finline resonator of Fig. 1 as a function of the total length $\ell = \ell_1 + \ell_2$, with the ratio ℓ_2/ℓ_1 as a parameter. From these data used in the procedure outlined in Section 2, the normalized reactance parameters $X_{11} - X_{12}$, $X_{22} - X_{12}$, X_{12} of the equivalent T-network of the discontinuity have been computed. The results are shown in Fig. 5.

Finally, Fig. 6 shows the computed scattering parameters of a unilateral finline discontinuity compared with those computed by Schmidt using the mode matching procedure [5].

CONCLUSIONS

A new method of analysis has been used for characterizing uniform finlines as well as finline step discontinuities. The results obtained are in good agreement with available data.

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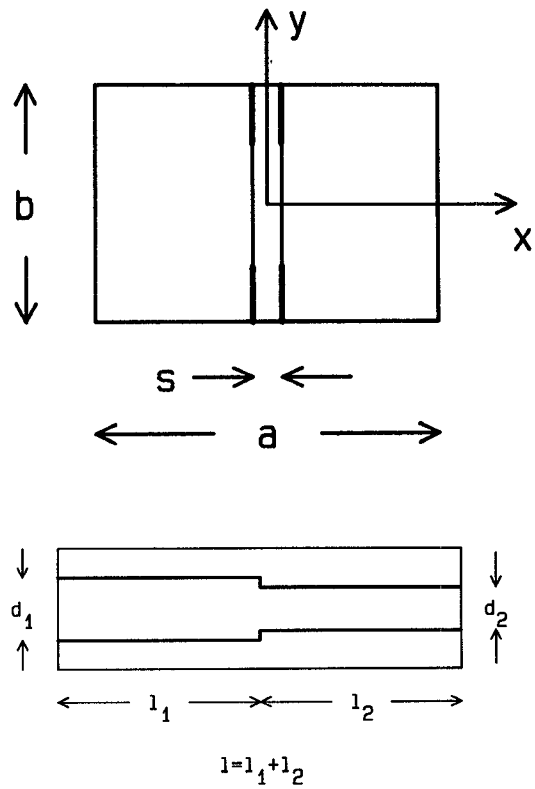

Fig. 1 Transverse and longitudinal cross sections of a finline discontinuity in a shorted cavity

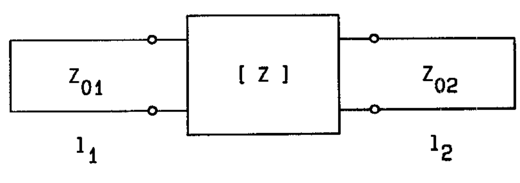

Fig. 2 Equivalent circuit of Fig. 1

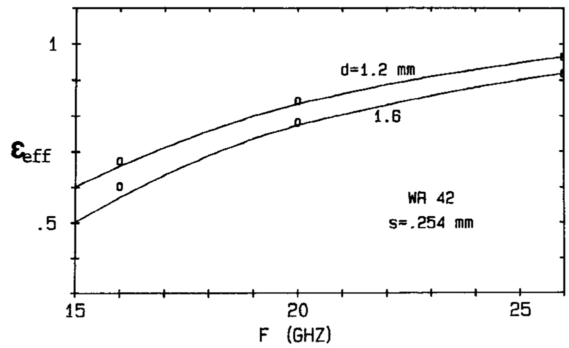

Fig. 3 Effective permittivity vs. frequency of a uniform fin line

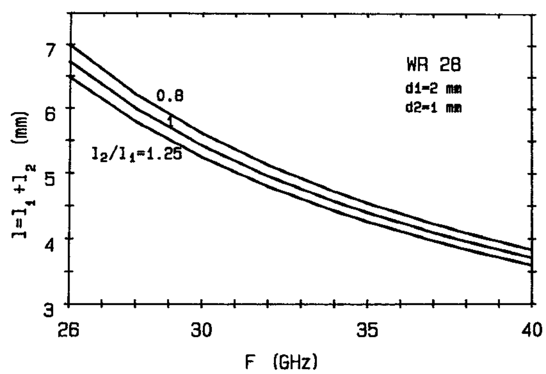

Fig. 4 Resonant frequency of the structure in Fig. 1

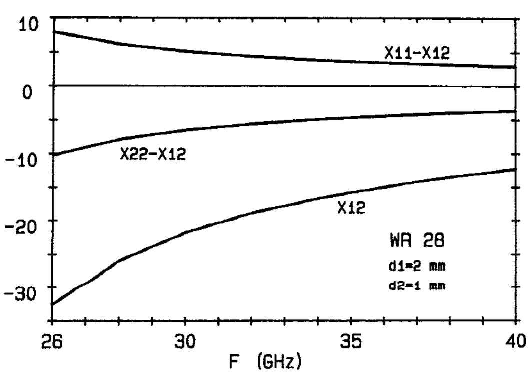

Fig. 5 Reactance parameters of the T-equivalent network of the fin line step discontinuity

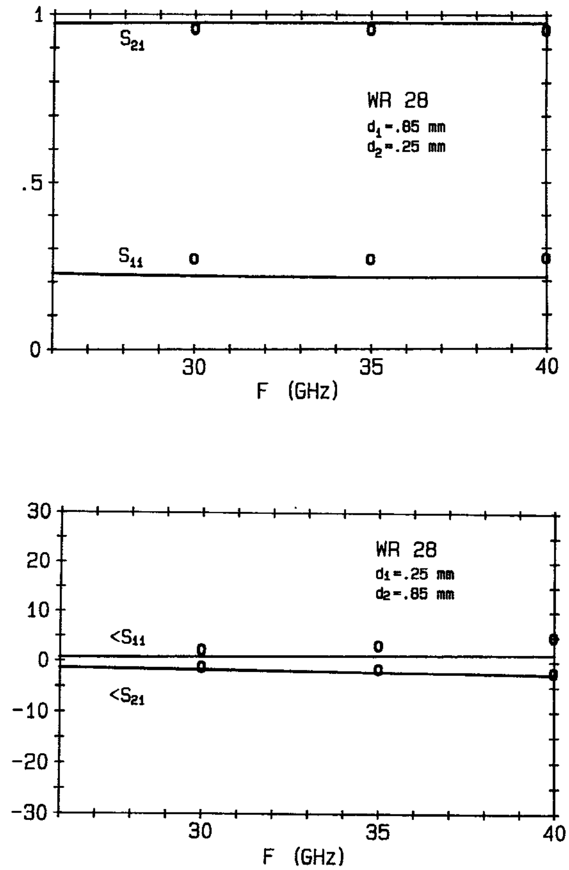

Fig. 6 S-parameters (magnitude and phase) of the step discontinuity