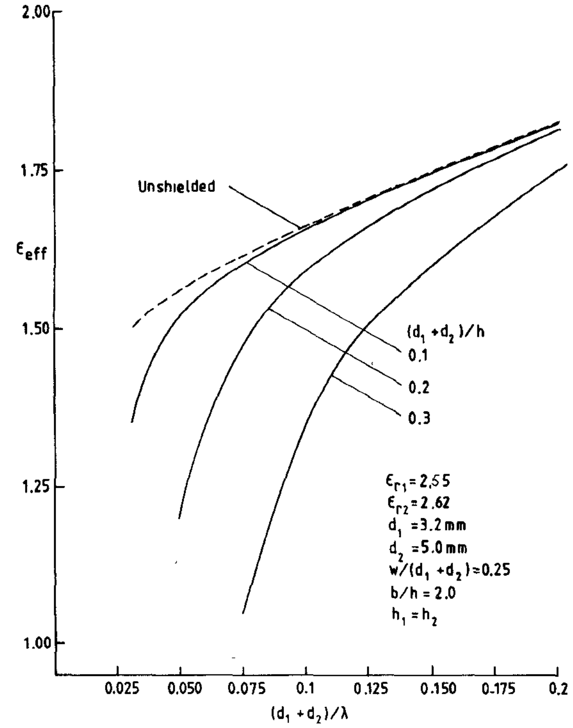

Fig. 6. The effect of shielding on the effective dielectric constant ϵ_{eff}.

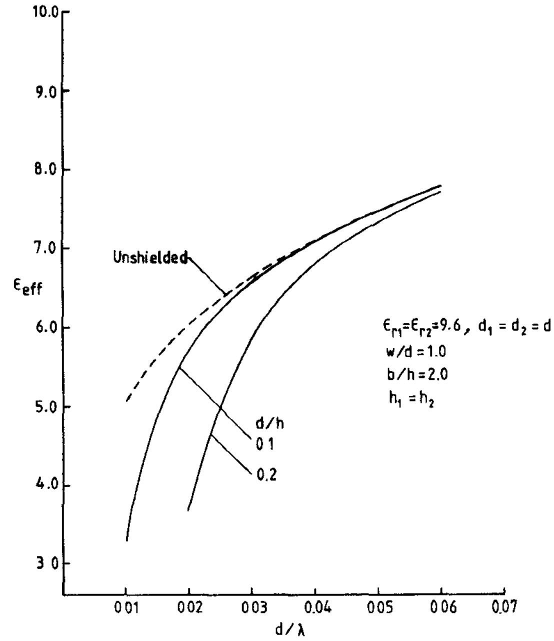

Fig. 7. The effect of shielding on the effective dielectric constant ϵ_{eff}.

observed between the unshielded case and for the case when the normalized height is equal to 0.1. This is expected since the effect of the conducting enclosure diminishes with increasing frequency.

V. Conclusion

Briefly, the paper presents an analysis of shielded slot line a) on a double layer dielectric substrate, and b) sandwiched between two dielectric substrates. The computed results illustrate the dispersion and characteristic impedance of the two structures. The effect of shielding on the dispersion, characteristic impedance and effective dielectric constant are also illustrated. These results should find extensive application in the design and fabrication of MIC components.

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Open-End Discontinuity in Shielded Microstrip Circuits

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***Abstract*—This short paper gives closed-form expressions for the open-end discontinuity in shielded microstrip circuits. These expressions consider the effect of dispersion at very high frequencies and are based on the results obtained earlier for the stripline configuration. The test of validity of these expressions is performed by comparison with the limit case of the unshielded microstrip.**

I. Introduction

A set of closed-form expressions was derived [1] for the computer-aided design of shielded microstrip circuits with zero strip thickness. In this configuration, the circuit performance can be controlled by adjusting the shield heights ratio. These expressions were for the calculation of the capacitances, characteristic imped-

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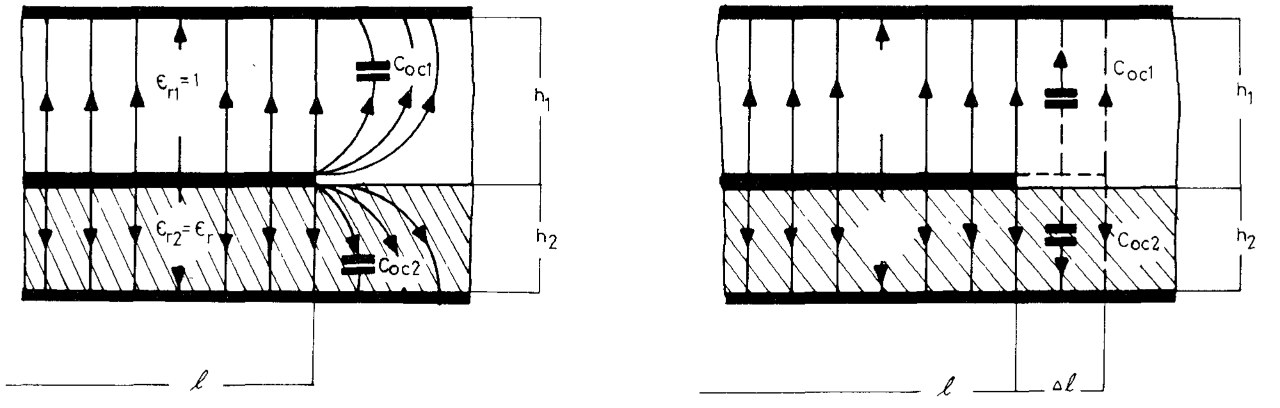
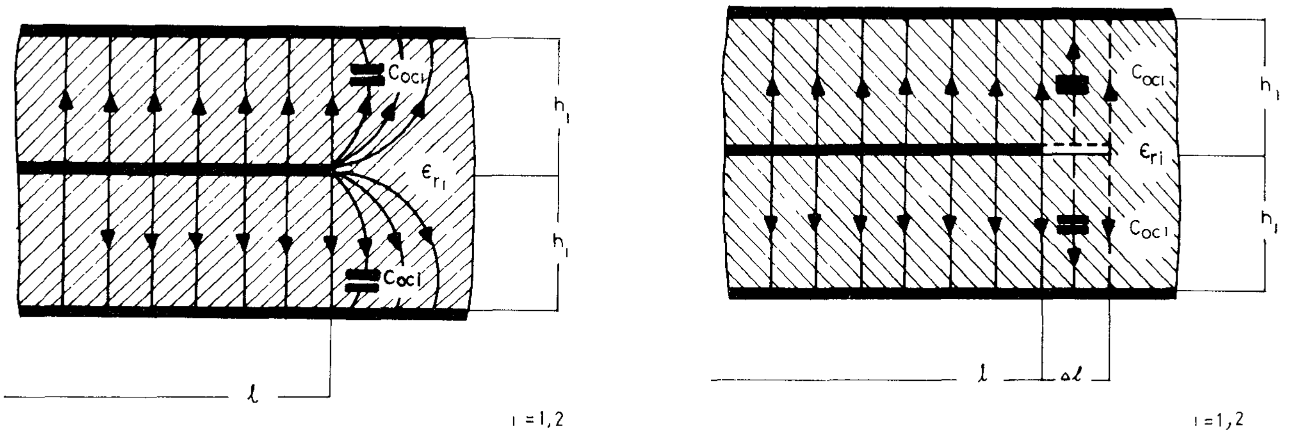


(a) (b)

Fig. 1. (a) The open-end capacitances of the shielded microstrip line. (b) The apparent additional length of the open end of the shielded microstrip.



(a) (b)

Fig. 2. (a) The open-end capacitances of the corresponding stripline (b) The apparent additional length of the open end of the corresponding stripline.

ances, and effective dielectric constants for the single and coupled shielded microstrips. This short paper gives closed-form expressions for the open-end discontinuity which occurs frequently in a number of circuits such as resonators, matching stubs, and parallel-coupled filters. The approach used here is based on dividing the total fringe capacitance at the end of the line into air and dielectric capacitances which are calculated using the expression for the additional line length for an open-end discontinuity in the corresponding stripline [2].

II. Calculation of the Open-End Discontinuity

The decomposition of the total fringe capacitance C_{oc} at the open-end of a shielded microstrip line into air and dielectric capacitances C_{oc1} and C_{oc2}, respectively, is shown in Fig. 1(a), while the apparent additional length Δl_{oc} is shown in Fig. 1(b). From Fig. 1(a), the capacitance C_{oc} may be written as

$$C_{oc}=C_{oc1}+C_{oc2}. \qquad (1)$$

C_{oc1} represents the capacitance due to the fringe field at the end of the line in the air region and is taken as half the total fringe capacitance at the end of a corresponding stripline with the same W but with the spacing between the ground planes being $2h_1$ and containing air as dielectric ($\epsilon_r=1$).

The capactiance C_{oc2} represents the fringe capacitance in the dielectric region and is calculated as in the case of C_{oc1}, but with the spacing between the two ground planes of the corresponding stripline being $2h_2$ and containing the dielectric material with dielectric constant $\epsilon_{r2}=\epsilon_r$. The striplines corresponding to our shielded microstrip are shown in Fig. 2.

The capacitances C_{oc1} and C_{oc2} are obtained using the empirical expressions that had been developed by Altschuler and Oliner [2] and are given by

$$C_{oci}=\frac{C_i}{k_i}\cot^{-1}\left[\frac{0.882+W/h_i}{0.220+W/h_i}\cot(0.441h_ik_i)\right], \qquad i=1,2 \quad (2)$$

where $k_i=2\pi/\lambda_i$, $\lambda_i=c/(f\sqrt{\epsilon_{ri}})$ with f and c as the frequency and the velocity in free space, respectively, and C_i is half the capacitance per unit length of the corresponding stripline. An accurate and simple expression for the capacitance C_i is available in [1]. The above expression considers the effect of disperssion at high frequencies and a simplified quasi-static expression that approximates (2) within 3 percent for $h_ik_i \leq 0.68$ is obtained [2]

$$C_{oci}=0.441h_iC_i\left[\frac{0.220+W/h_i}{+0.882+W/h_i}\right], \qquad i=1,2. \quad (3)$$

When the width of the line W is infinite, the value of the static fringe capacitance at the end of the corresponding striplines will be the same as that reported by Cohn [3] for the fringe capaci-

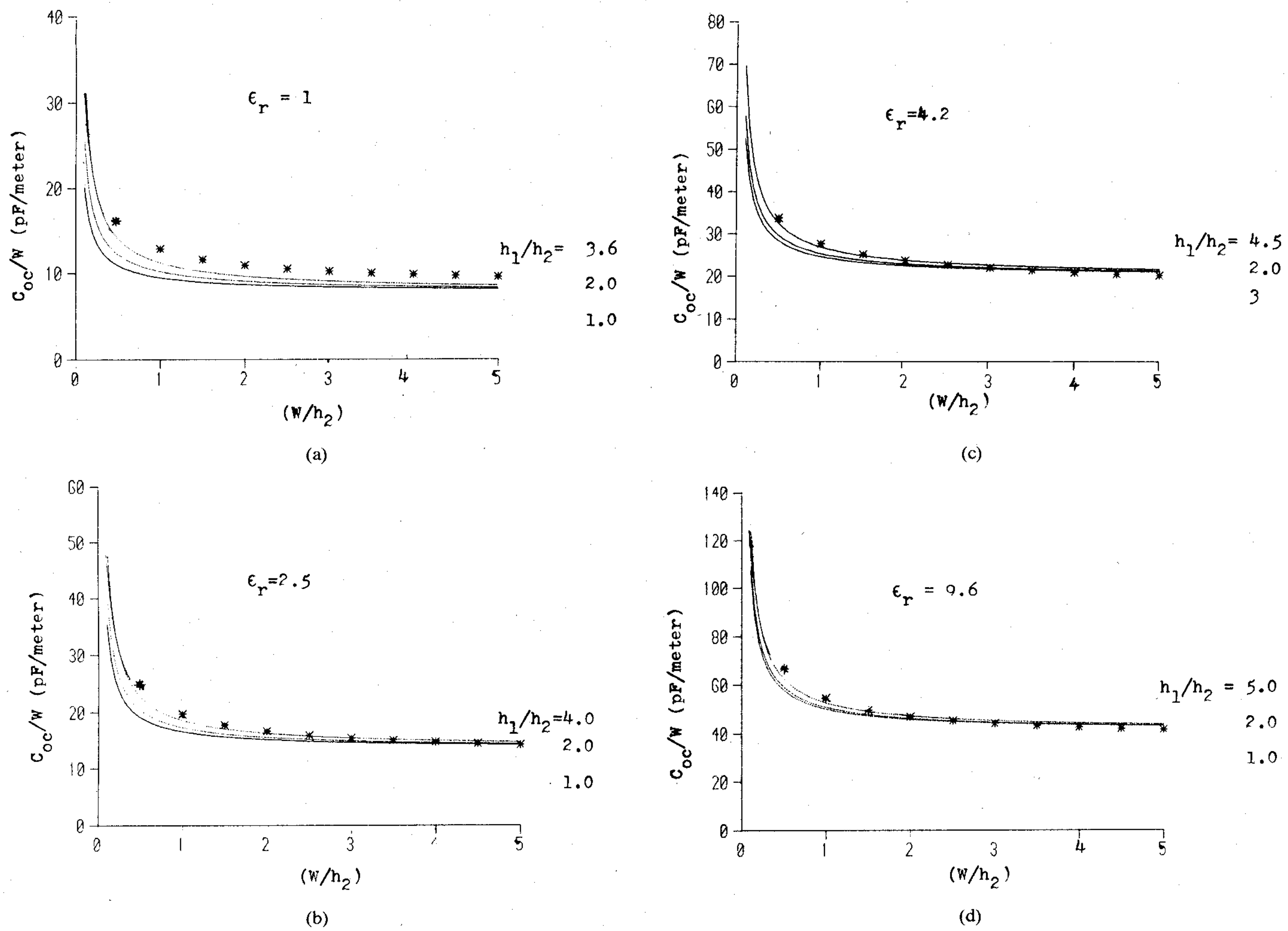


Fig. 3. (a) Open-end capacitance of shielded microstrip and the capacitance of the unshielded microstrip. * * *: obtained from [4]. (b) Open-end capacitance of shielded microstrip and the capacitance of the unshielded microstrip. * * *: obtained from [4]. (c) Open-end capacitance of shielded microstrip and the capacitance of the unshielded microstrip. * * *: obtained from [4]. (d) Open-end capacitance of shielded microstrip and the capacitance of the unshielded microstrip. * * *: obtained from [4].

tance for a semi-infinite plate between ground planes

$$C_{oci}=0.441h_iC_i, \qquad i=1,2. \tag{4}$$

The equivalent additional length Δl_{oc} for the open-end discontinuity in the shielded microstrip may be written as follows:

$$\frac{\Delta l_{oc}}{h_2}=\frac{C_{oc}}{h_2(C_1+C_2)}. \tag{5}$$

III. Results and Conclusion

The variation of the fringe capacitance at the end of the shilded microstrip with the width-to-height ratio W/h_2 and the shield heights ratio h_1/h_2 using (1) and (3) for various substrate dielectric materials with $\epsilon_r=1$, 2.5, 4.2, and 9.6 are shown in Fig. 3(a)–(d), respectively.

The results are compared with the limit case of the unshielded microstrip [4]. As the shield heights ratio h_1/h_2 increases, the values of the end fringe capacitance C_{oc} approach those of the unshielded microstrip.

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Extension of an Old Circulator Model

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***Abstract*—An old circulator model consists of an ideal circulator with parallel coupled resonant circuits. This paper determines the parameters of this model at frequencies different from the resonant one. As a conse-**

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