CHARACTERISTICS OF MODIFIED SLOTLINE CONFIGURATIONS

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ABSTRACT:

Studies on the performances of modified slotline configurations: 1) a dual slotline and 2) a dielectric loaded conductor-backed slotline, are presented based on a full-wave spectral-domain analysis. The spectral moment method analysis is outlined, and results on propagation constant and characteristic impedance of example geometries are discussed. It is shown, that unlike an unloaded conductor-backed slotline, a conductor-backed slotline with a suitable dielectric loading on top or an even mode dual-slotline can be safely used without power leakage to the parallel plate mode.

INTRODUCTION:

Slotlines on the ground plane of a dielectric substrate have long been studied and used in microwave printed circuit applications [1,2]. A conductor-backed slotline would be useful, but it suffers from potential problem of leakage due to coupling to the parallel plate mode [3,4]. However, as pointed out in [4], such problem of leakage can be avoided by loading the slotline by a moderately high dielectric constant substrate on top (see Fig.1). The dielectric loading increases the slotline propagation constant above that of the parallel plate mode, which as discussed in [3,4], eliminates the leakage. Another useful variation of a slotline geometry is a dual slotline etched on the two sides of a substrate and excited with an even mode slotline field distribution (see Fig.2). Unlike the conductor-backed slotline this dual slotline geometry does not couple to the parallel plate mode, and can be useful with or without a dielectric loading.

In this paper we present analytical results for the modified slotline geometries investigating some of their characteristic features. The analysis used is outlined, with emphasis on the discussion of characteristic results.

ANALYSIS:

The modified slotline geometries are analyzed using a full-wave spectral domain moment method solution. Green's functions for a general multilayered geometry [5] that account for the equivalent magnetic currents (or slot field) of the slotline are used with a Galerkin testing procedure. An equivalent magnetic current formulation is suitable to model the slot electric fields, and are expanded using a set of basis with proper square-root singularity of the transverse electric field component at the slot edges. Using the symmetry of the electric fields across the two slots of the dual slotline, an equivalent magnetic wall is placed inbetween to simplify the analysis. Impedances were obtained using a rigorous power-voltage method, where the power was computed using the transverse electric and magnetic fields across the cross section, and voltage is the integral of the electric field across the slot. Fig.1 and Fig.2 show the field configurations of a loaded conductor-backed slotline and an unloaded dual slotline respectively, which were computed from the equvalent magnetic current (or, slot field) distribution using suitable Green's functions by perfoming spectral inverse integrals. Field profiles across the cross-section provide useful information on propagation mode, and as discussed with the conductor-backed slotline such field computations are effectively used to identify the 'onset of leakage' to the parallel plate mode

RESULTS:

CONDUCTOR-BACKED SLOTLINE: For the loaded conductor-backed slotline configuration, as mentioned before, the dielectric loading is the deciding factor if the parallel plate mode can be excited. Fig.3a shows the variation of effective dielectric constant [$=(k_e/k_o)^2$] with the cover substrate thickness, and the corresponding variation of the characteristic impedance is shown in Fig.3b. As it is clear from Fig.3a, the effective dielectric constants are larger than the dielectric constant of the parallel plate structure, which insures no leakage to the parallel plate mode [3,4]. However, As Fig.3b shows the characteristic impedance drops sharply with decrease in the cover thickness (also, with decrease in frequency) to small values. This low value of characteristic impedance is indicative of onset of leakage, and transition from the bound to a unbound (leaky) mode. The corresponding field spreading of a loaded conductor backed slotline as compared to that of a regular bound slotline mode (no conductor backing) is shown in Fig.4. Fig.4 clearly shows considerable field spreading of the conductor backed slotline as frequency decreases. Similar effect is also seen as the cover thickness or dielectric constant decreases, or also as the

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parallel plate thickness decreases. It is interesting to note that for the conductor backed slotline the coupling to parallel plate mode becomes more severe as the frequency decreases, which is unlike other layered geometries where the substrate mode coupling increases with increase in frequency. This field spreading, which is associated with more propagating power for the same slot field explains the drop in corresponding characteristic impedances.

It should be noted here that such field spreading, or the sharp drop of impedance or propagation constant characteristics at the onset of coupling to the parallel plate mode are predicted due to the full-wave nature of the analysis and would not be detected by quasi-static analysis approaches.

Using such studies on field spreading and/or impedance variation in the transition of onset of leakage, a suitable set of parameters for a conductor backed slotline can be chosen in order to operate safely away from the leakage effects. For example, for the parameters of curve 1 of Fig.3b, a value of the cover substrate thickness greater than about 0.5mm would be desirable.

DUAL_SLOTLINE: A dual-slotline with slots on both conducting walls of a parallel plate structure is useful for feeding dual-tapered slot antennas [6,7], and can be excited via a stripline to dual-slotline transition. Such a transition is in principle similar to the microstrip-to-slotline transition of [3] where the microstrip line and the slotline are replaced by a stripline and a dual-slotline respectively. A dual slotline can have two modes of operation, either with the same (even mode), or oppositely (odd mode) directed electric field across the two slots. The odd mode of excitation of the two slots is equivalent to a conductor backed slotline with half the parallel plate thickness (by imaging). So it suffers from the same problems discussed in the last section that can be obercome by proper dielectric loading. On the other hand the even mode dual slotline does not excite the parallel plate mode. Qualitatively, the parallel plate mode excitations of the two slots mutually interact to cancel with a net result of complete absence of the parallel plate power excitation. Fig.2 shows the electric field configuration of the even mode dual slotline. From the symmetry of the electric field, always the electric field path integral from one ground plane to another is zero, which excludes any possibility of parallel plate mode excitation.

The effective dielectric constant, ε_{eff}, and the characteristic impedance of a dual-slotline defined as $|V|^2/P$, where P is the total propagating power, and V is the voltage across each slot, are compared in Fig.5a,b with those of a slotline with the same substrate for two values of substrate thicknesses. The ε_{eff} values are close to those of the respective slotlines. If no coupling between the two slots could be assumed as a first order approximation, from the definations of characteristic impedances of a dual slotline and a slotline, in Fig.5 the characteristic impedances of the dual slotlines should be expected to be about one half of that of the respective slotlines. But as the results show, this does not seem to be the case for the present set of dimensions, which implies significant mutual coupling effects. The ratio between the characteristic impedances of the dual-slotline and the corresponding slotline is closer to two for smaller values of slot widths, which is due to the lower magnitudes of coupling between the more localized fields of these small slots.

REFERENCES:

[1] S. B. Cohn, "Slotline on a Dielectric Substrate," IEEE Tran. on MTT, pp.768-778, October 1969.

[2] J. B. Knorr, "Slotline Transitions," IEEE Tran. on MTT, pp-548-554, May 1974.

[3] H. Sigesawa, M. Tsuji and A. A. Oliner, "Conductor Backed Sloline and Coplanar Waveguide: Dangers and Fullwave Analyses," IEEE MTT-S Digest, pp.199-202, 1988.

[4] N. K. Das and D. M. Pozar, "Full-Wave Spectral-Domain Computation of Material, Radiation and Guided Wave Losses in Infinite Multilayer Printed Transmission Lines," IEEE Tran. on MTT, January 1991, to appear.

[5] N. K. Das and D. M. Pozar, "A Generalized Spectral Domain Green's Function for Multilayer Dielectric Substrates with Applications to Multilayer Transmission Lines," IEEE Tran. on MTT, pp.326-335, March 1987.

[6] D. H. Schaubert, "Endfire Tapered Slot Antenna Characteristics," Proceedings on 6th International Conference on Antennas and Propagation, Part I, pp.432-436, April 1989.

[7] K. S. Yngvesson, et al., "Endfire Tapered Slot Antennas on Dielectric Substrates," IEEE Tran. on Antennas and Propagations, pp.1392-1400, December 1985.

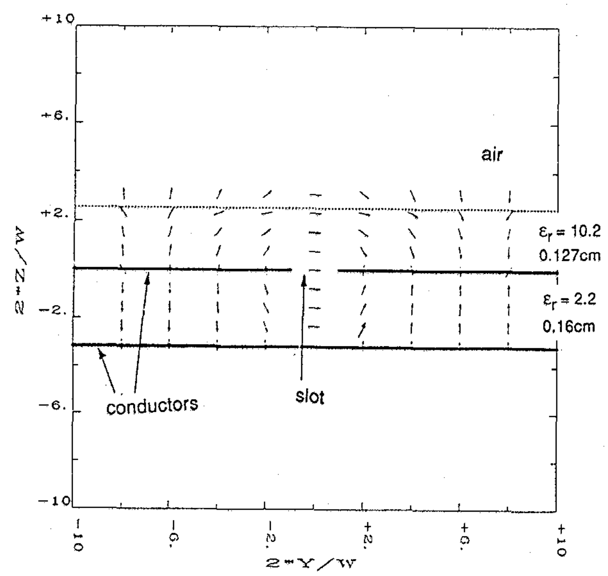

Fig. 1. Electric field lines of a loaded conductor backed slotline. Slotwidth = 0.1cm, frequency = 10GHz.

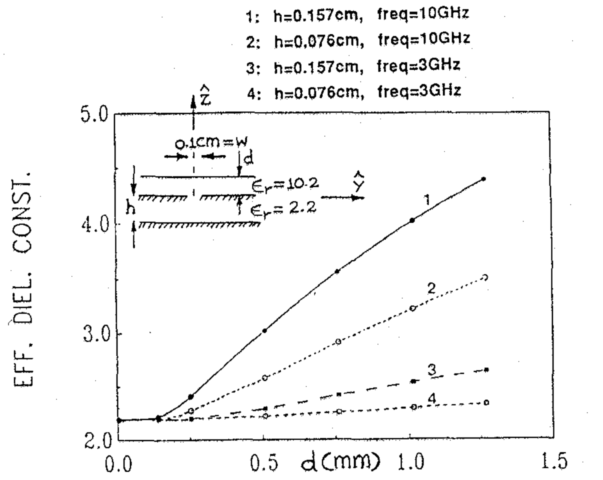

Fig. 3a. Effective dielectric constants of conductor backed slotlines with a dielectric loading to avoid leakage to the parallel plate mode.

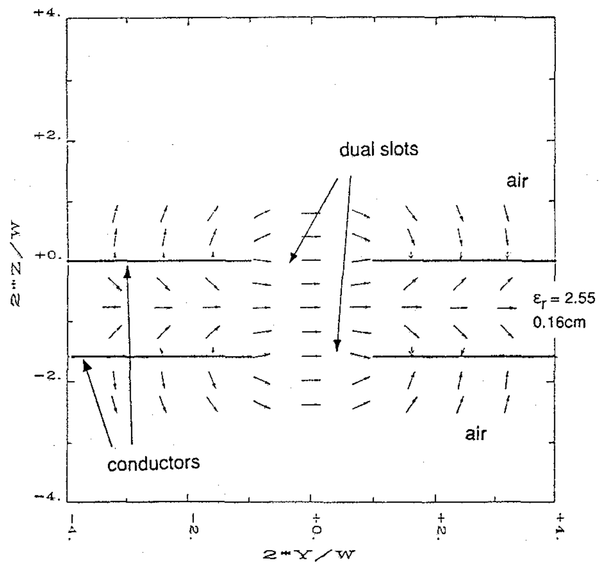

Fig. 2. Electric field lines of an even mode dual slotline. Slotwidth = 0.2cm, frequency = 3.0GHz,

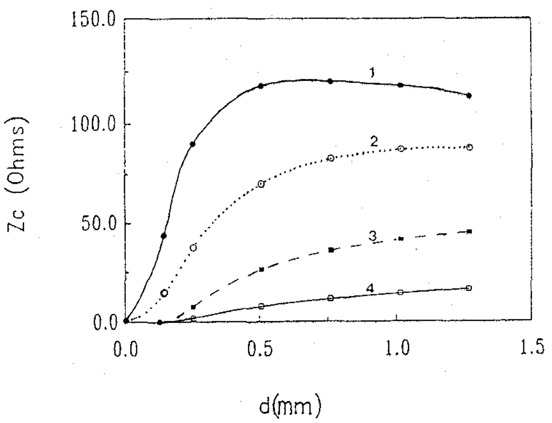

Fig. 3b. Characteristic impedances, Zc, for the geometries of Fig. 3a.

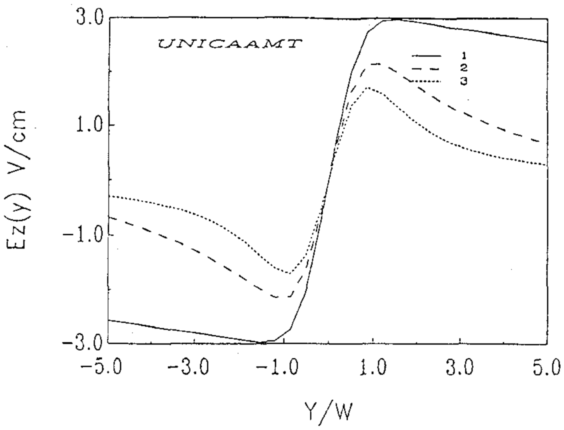

Fig.4. Comparison of field profile spreading of loaded conductor backed slotlines of Fig.2 at different frequencies (curves 1 and 2: cover: εr=10.2, 0.127cm, parallel plate: εr=2.2, h=.157cm) with that of a regular slotline (curve 3: εr=2.55, h=.157cm). Frequency: curves 1) 3GHz, 2)10GHz, & 3) 3GHz.

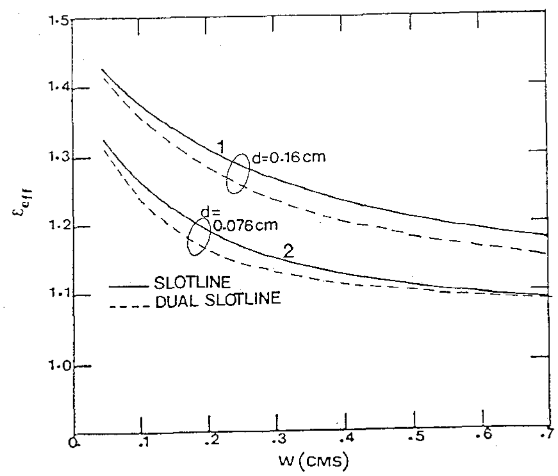

Fig.5a

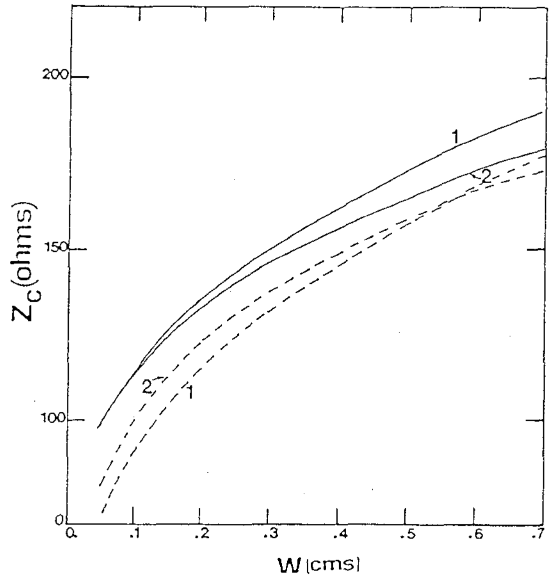

Fig. 5b.

Fig.5. Comparison of a) effective dielectric constants, b) characteristic impedance, of the dual slotline of Fig.2 with that of a slotline with the same substrate thickness, d. Slotwidth = w, frequency = 3.0GHz.