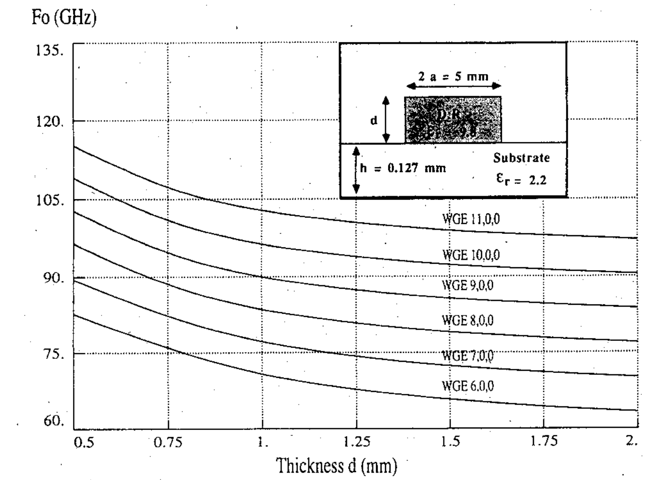

Fig. 5. Resonance frequency variations as a function of the resonator thickness for the WGE modes.

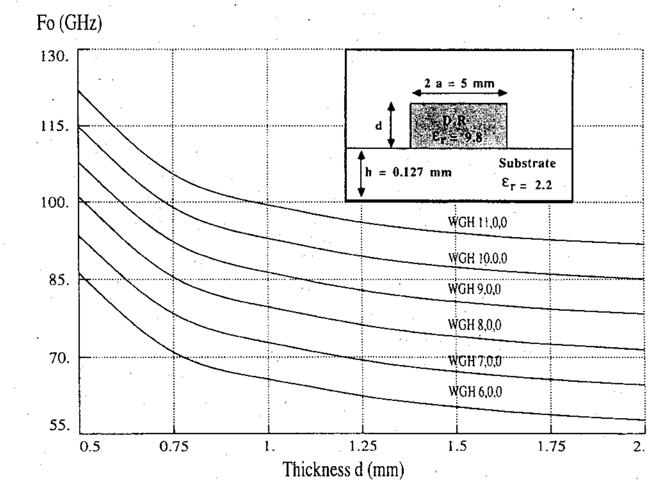

Fig. 6. Resonance frequency variations as a function of the resonator thickness for the WGH modes.

thickness. In this case, the resonator is placed on the same dielectric substrate as previously ($h = 0.127$ mm, $\epsilon_r = 2.2$).

These results confirm that the resonance frequency of WG modes depends on the thickness of the resonator in particular when this one is not too large.

Comments on "A Novel Method for Modeling Coupling Between Several Microstrip Lines in MIC'S and MMIC'S"

Eugenio Costamagna

In the above paper[1], the capabilities of a described four-port generalized coupling model (GCM) in analysing multiple coupled microstrip line circuits are deeply explored. The model is used to describe coupling between nonadjacent lines as well as adjacent ones, and interesting results are shown.

A rather similar method for modeling couplings in multiple line structures was described in [1], based on a different algorithm to compute line self-admittences in an indefinite admittance matrix scheme [2] for the overall circuit analysis. This method utilizes the equivalent circuit for asymmetric coupled pairs of lines in inhomogeneous dielectric described in [3], which generalizes the Zysman and Johnson's model for symmetric pairs [4], and completes the description in terms of decoupled transmission lines and congruence transformers and the time domain analysis of Chang [5]. The circuit parameters can be easily shown to be consistent with the full modal analysis provided by Tripathi [6], [7]; special cases have been examined by Speciale [8] and by Allen [9].

Routines based on this equivalent circuit and on the Zysman and Johnson's one have been implemented at Marconi Italiana in general purpose programs (see the short descriptions of the MARE and MIDFO programs in [10]), to perform accurate analysis and synthesis of microstrip and suspended substrate line devices in quasi-TEM wave propagation.

Although possible in principle, as shown by Swanson, we have not utilized these routines to describe couplings between nonadjacent lines, because their primary use concerned shielded structures, where nonadjacent lines were very weakly coupled. The interesting results now obtained by Swanson in applying the GCM to non adjacent lines encourage me to draw the reader's attention to a further type of model improvement, also described in [1], which introduces a building block concept in modeling multiple coupled line structures. In fact, segmenting the coupled lines as described in [1] allows to more precisely modeling, by the equivalent circuit in [3] or a similar four-port, the local coupling among various lines. Some results are given in [1], where the dramatic improvement in the analysis results which arises in some cases is illustrated by considering a three line microstrip circuit, for which exact reference parameter values can be provided from the Tripathi's [11] analytical description.

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Author's Reply[2]

Daniel G. Swanson, Jr.

I would like to thank Dr. Costamagna for calling my attention to the work in [1]. His method is an interesting generalization to the asymmetric coupled line case of an earlier work by Grayzel [2] for symmetric coupled lines. I would also like to emphasize some important differences between the method in [1] and [2] and the method described in my paper.

Only adjacent couplings are modeled in [1] and [2] by combining pairs of coupled lines. In [1] the correct self admittance for each line is obtained by dividing the appropriate admittance parameters by two. The same result is obtained in [2] by dividing the strip width in half before computing the admittance parameters. It may be possible to extend this technique to non-adjacent couplings by carefully modifying the self admittance terms as each additional coupling is added, but this has not been demonstrated.

In fact the key contribution of the GCM technique is that it deliberately avoids including the self admittance terms. In this way the GCM correctly accounts for coupling only and is thus independent of whether the strips are adjacent or non-adjacent. The meander line example in my paper used uncoupled single microstrip lines as the basic circuit with the GCM applied to model both adjacent and non-adjacent couplings. An equally valid approach would be to use the technique in [1] or [2] to model the basic circuit, which would include only adjacent couplings, and then use the GCM to increase the accuracy of the model by including non-adjacent couplings.

Finally, a statement has been made in [1], in the letter above and in many other published articles that non-adjacent couplings are not significant in enclosed microstrip circuits. I believe this position was developed in the past when the analytical tools to model non-adjacent couplings were not available, but it can no longer be supported today. The examples in my paper were designed to demonstrate the importance of non-adjacent couplings and the behavior of those circuits is essentially the same whether enclosed or unenclosed. Additional evidence for the importance of non-adjacent couplings in microstrip interdigital filters can be found in [3] and examples of the effects of non-adjacent couplings in MMIC design can be found in [4], [5].

The GCM can easily be applied on top of existing circuit descriptions to discover where non-adjacent couplings may be significant. A more accurate circuit description can then be developed using the multiple coupled line model (MCPL) in [6] or one of the new electromagnetic field solvers.

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