NUMERICAL SIMULATION OF A VIRTUAL MATCHED LOAD FOR THE CHARACTERIZATION OF PLANAR DISCONTINUITIES

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ABSTRACT

A mixed technique, based on the association of the integral equations solved by the method of moments (Galerkin) to the theory of loaded scatterers, is shown to be useful for simulating virtual matched loads for characterizing planar discontinuities. The theory of loaded scatterers is used to include the effects of either localized or distributed loads through which the matching can be achieved. Moreover, when using this technique for shielded discontinuities, the scattering parameters are obtained from the knowledge of only current or electric field maxima and hence, the errors associated with the accurate determination of the current or the electric field minimum evaluation encountered in other existing techniques are avoided. A good agreement is reported between experimental and theoretical results for some simple and multilayer discontinuities.

INTRODUCTION

In using integral equation technique associated with the method of moments [1] for characterizing planar discontinuities, several numerical techniques has been developed for the extraction of the related scattering matrix parameters. Most of these techniques use the standing wave pattern of either the current or the electric field distribution to evaluate the SWR and the reflection coefficients. The evaluation of the scattering parameters is achieved by terminating the output ports by short circuit or open circuit at different planes [2], or by using even and odd excitations [3] which is valid only for symmetrical discontinuities. One of the main problems encountered with these techniques is the evaluation of the magnitude and position of the current or the electric field minimum especially for discontinuities having high reflection coefficients. Interpolating techniques which are often used for this purpose give rise to substantial phase errors.

In this paper, we propose to simulate numerically matched loads at the output ports of the general N port network to be characterized. Each matched load is achieved through the insertion of localized impedances at some line sections of the output ports. The association of these loads to the whole structure is carried out using the theory of loaded scatterers [4] for loaded metallic conductors. In this case a modified integral equation is then obtained.

Generally, these localized impedances provide, at once, an energy absorption and an inductive or capacitive compensation. The main advantage of this technique, with respect to other existing ones, is that the obtained standing wave pattern is rather smooth which leads to a more precise determination of the reflection coefficients and also to an accurate phase evaluation due to the elimination of the sharp minimum of either current or electric field distributions. Obviously, this technique is also able to characterize both symmetrical and asymmetrical discontinuities. For shielded discontinuities the scattering parameters are obtained from the determination of only the current maxima, which are usually more accurately determined even for high values of reflection coefficients. On the other hand, for open structures, this technique provides an estimation of the radiation and surface wave losses due to the discontinuity itself or due to the feeding line.

THEORY

Without loosing generality, we will treat the case of a microstrip discontinuity but the analysis is similar for other types of planar discontinuities. The general N port network configuration to be characterized is shown in figure 1. Firstly, the structure is assumed to be unloaded (i.e. without localized impedances) and hence, the boundary condition at the perfect metallic conductors can be written as :

$$\vec{n}(\vec{r}) \times \left[\vec{E}^{diff}(\vec{r}) + \vec{E}^{inc}(\vec{r}) \right] = 0$$

where $\vec{r}$ is the point position vector and $\vec{n}(\vec{r})$ is the unit vector normal to the conductor.

Using the well known method of moments, the structure is divided into a number of current cells each supports a current basis function [2]. The diffracted electric field can then be evaluated using these current functions.

Localized impedances are then assumed to be connected at the centers of the current cells as shown in figure 2. The new boundary condition equation for the loaded structure can be written now as :

$$\vec{n}(\vec{r}) \times \left[\left\{ \vec{E}^{diff}(\vec{r}) + Z_{load}(\vec{r})\, \vec{J}_s(\vec{r}) \right\} + \vec{E}^{inc}(\vec{r}) \right] = 0$$

The above equation is projected on the same set of basis functions and hence, it can be tranformed to a matrix equation having the form :

$$[\,[Z] + [Z_{load}]\,]\,[I] = [V]$$

where [Z] is the generalized impedance matrix for the unloaded structure, [Z_{load}] is a diagonal impedance matrix for the localized loads, [I] is the unknown current distribution vector and [V] is the excitation voltage vector.

The above matrix equation is similar to that obtained for the unloaded structure except for the generalized impedance matrix which is now modified diagonally by the localized loads. Solving this new matrix equation, the new current distribution for the loaded structure can be obtained.

Under good matching condition of all output ports j, the obtained reflection coefficient at the input port i is approximately equal to S_{ii}. Inserting this value in the energy conservation equation, for shielded discontinuities, the scattering parameters are then obtained from the values of only current maxima.

RESULTS

The developed algorithm is applied on a microstrip line to simulate a wide band matched load. Figure 3 shows the obtained current distribution on a microstrip line of 50 Ω loaded by localized impedances at the last few current cells. A quasi stable variation is observed showing good matching termination. The obtained return loss of the simulated matched load on a 50 Ω line in both K_u and K_a bands is shown in figure 4 a and b respectively. The return loss is less than -30 dB all over these frequency bands. This matched load is then used as a termination for a two port multilayer discontinuity as shown in figure 5 (an overlay microstrip to multilayer microstrip colinear transition) commonly used in packaging technology. The transmission coefficient of this transition is determined directly and presented in figure 6. A wide band transition is reported without a significant insertion loss. As a comparison with other scattering parameters extraction techniques, the matched load technique is used to characterize a microstrip gap discontinuity where an excellent agreement is observed with other published data [5] as shown in figure 7.

CONCLUSION

A new scattering parameters extraction technique for the characterization of planar discontinuities is presented. It is a combination of the integral equations technique and the theory of loaded scatterers. A good virtual matched load is simulated using this technique which takes into account the dispersion characteristics of the guiding structure in order to achieve a wide band matching. The scattering parameters of any general N port network can be obtained directly using these virtual terminations. The main advantage of this technique is the elimination of the need of the determination of either a current or an electric field minimum which is difficult to be evaluated precisely when the ports are terminated with severe loading conditions. For shielded discontinuities the scattering parameters are determined only from current maxima. An excellent agreement is noticed between our theoretical results and other published ones.

REFERENCES

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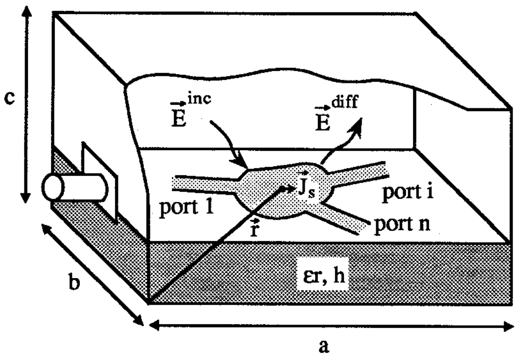

Fig. 1 : General shielded microstrip discontinuity configuration

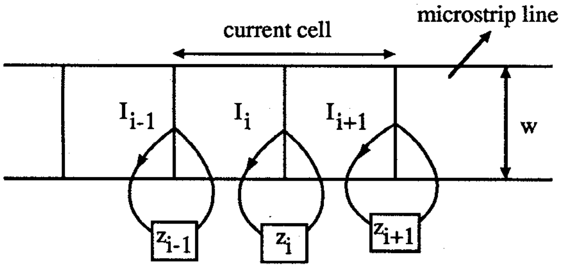

Fig. 2 : Localized impedances connected at current cells centers of some strip sections

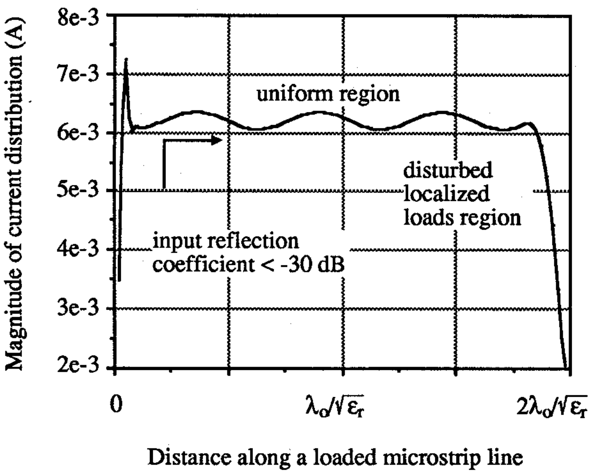

Fig. 3 : Current distribution along a microstrip line loaded by localized impedances (a=80 mm, b=7.112 mm, c=3.56 mm, εr=2.22, h=254 µm, w=0.75 mm, f=15 GHz)

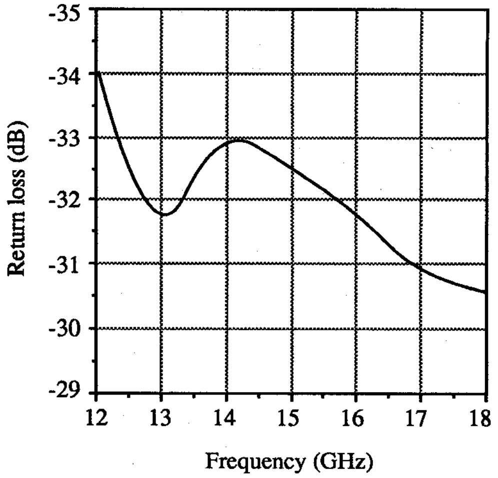

Fig. 4a : Variation of the return loss as a function of frequency in the Ku-band (a=80 mm, b=7.112 mm, c=3.56 mm, w=0.75 mm, h=254 µm, εr=2.22)

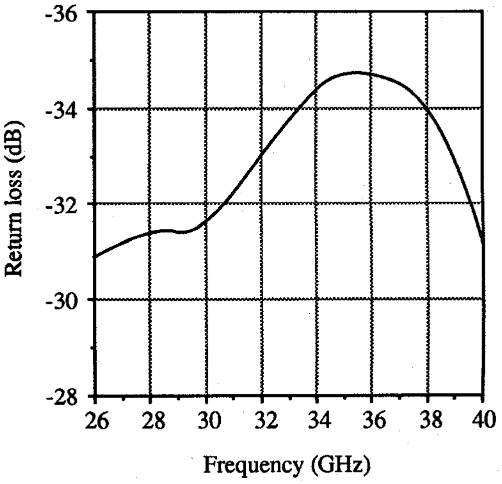

Fig. 4b : Variation of the return loss as a function of frequency in the Ka-band (a=40 mm, b=c=1.905 mm, w=h=635 µm, εr=9.7)

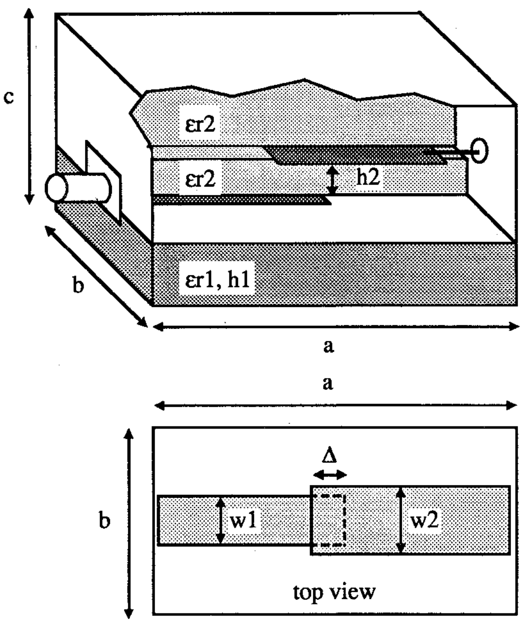

Fig. 5 : Overlay microstrip to multilayer microstrip 50Ω-50Ω colinear transition

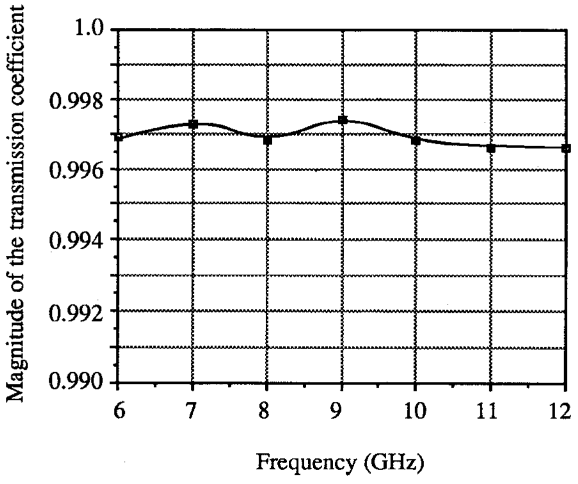

Fig. 6 : Variation of the transmission coefficient as a function of frequency for the transition of fig. 5 (a=80 mm, b=7.112 mm, c=3.56 mm, w1=520 μm, w2=550 μm, Δ=3.88 mm, h1=635 μm, h2=10 μm, εr1=9.55, εr2=2.6)

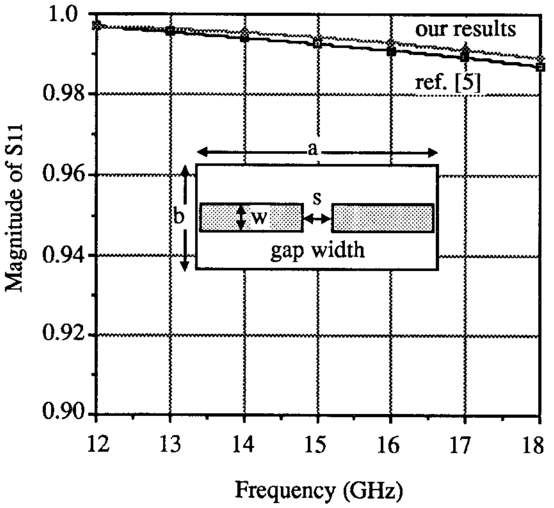

Fig. 7 : Comparison between our theoretical results obtained by the matched load technique and those published in ref. [5] for a microstrip gap discontinuity (a=80 mm, b=c=6.35 mm, w=h=0.635 mm, εr=9.7, gap width s=0.381 mm)