CORRECTION OF IMPERFECT ABSORBING BOUNDARY CONDITIONS IN FD-TD

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ABSTRACT

In the Finite Differences in the Time Domain (FD-TD) technique the knowledge of the field is often unnecessary, as that of the scattering parameter suffices. We introduce a very simple method to correct Absorbing Boundary Condition (ABC) errors in the scattering parameter evaluation arising from any ABC, however imperfect: this method allows universal use of any one simple ABC for any transmission media, therefore facilitating the development of general purpose codes. The technique is based on the evaluation of the reflection coefficient due to the absorbing boundary condition in the time-domain and a subsequent correction in the frequency domain. Hence, it is independent of the kind of line and applicable to microstrip, classical waveguide or any other transmission media. The technique can also be applied to any kind of ABC.

INTRODUCTION

ABC's produce some errors due to the non ideal truncations and in the last years many efforts have been directed towards eliminating them. In the analysis and design of devices, knowledge of the scattering parameter is sufficient in order to describe the components, whereas field knowledge is often unnecessary.
We analyze the complete circuit model of the overall structure including the incident line, the line containing discontinuities, the separation plane and the ABC. We evaluate first the reflection coefficients of the absorbing planes due to the imperfect ABC by analysing a known element, i.e. a section of line. This computation uses a reduced structure and is carried out at the beginning as a "de-embedding" of the FD-TD working geometry. The data are stored and recalled in the subsequent FD-TD analysis where we use those reflection coefficients in order to correct the scattering parameter of the unknown element. In [1] we analyzed a simplified geometry: a two port structure with identical lines of the same length. We now analyze a structure with different lines at the ports.
The correction is very easy to implement involving few computer resources. The technique performs very well in presence of simple ABC's like, as example, Mur of first order. Because of its simplicity and flexibility, it can be included in a general purpose CAD, removing the constraint of more complex ABC's.

METHOD DESCRIPTION

In [1] we analyzed the separation of the reflected field from the total field. At the separation plane the electric or magnetic fields are added or subtracted in the lower line in order to excite the right part of the geometry while leaving only the reflected field in the left part. Figure 1 shows the

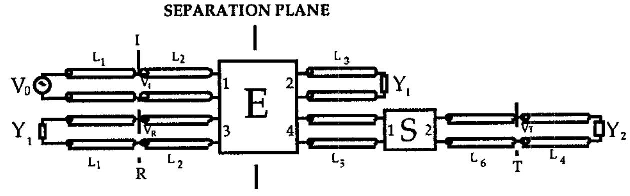

Fig. 1. The E-matrix effect the separation between the reflected, total and incident field. S is a scattering matrix known or unknown. When $Y_1 \neq Y_2$ input and output lines differ.

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equivalent circuit of the two lines effecting the separation. The **E**-matrix assumes the form

$$\mathbf{E} = \begin{vmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{vmatrix}$$

We excite the incident line with a sinusoidally modulated pulse and produce the responses V_I, V_R and V_T by FD-TD analysis. A Fast Fourier Transform (FFT) translates those voltages into the frequency domain and the circuit of figure 1 is easily solved twice in the frequency domain.

In the first step we evaluate the unknown Y-elements by analyzing a known section of line. The normalized Y-value can be obtained correctly in two separate ways by considering V_T/V_I or V_R/V_I. The two cases give equally good results: we obtain a third order linear equation with three solutions, only one being acceptable.

As a second step, we solve the circuit of figure 1 with the computed Y-admittances by evaluating and correcting the S-parameters for any unknown element.

When the input and the output lines differ, no symmetry exists and Phase(S_{11}) ≠ Phase(S_{22}). In order to evaluate the full S-matrix we need two FD-TD simulations, the first feeding port 1 and the second feeding port 2. By combining the two, we obtain the uncorrected S-matrix.

In the first step we evaluate the unknown

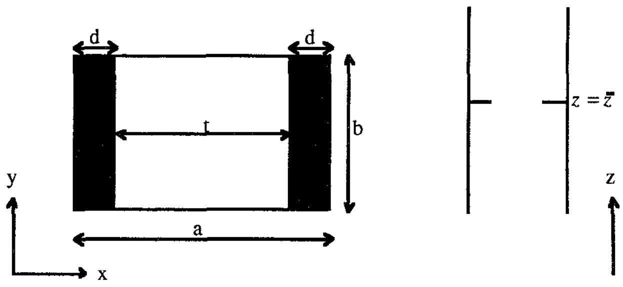

Fig 3. Geometry of the inductive septum in a rectangular waveguide: a=22.86 mm, b=10.16 mm, t=19.05 mm or t=7.62 mm, d=1.905 mm, $\bar{z}$= 94.5mm. FD-TD parameters: Δx=0.381 mm, Δy=0.363 mm, Δz=0.375 mm, Δt=1.25 ps.

elements: Y_1 and Y_2 by using two short FD-TD simulations. In the a second step, in order to correct the S-parameters for any unknown element, we need all uncorrected S-value arising from the two FD-TD simulations of the structure.

RESULTS

In order to test the method we analyze and correct a considerable residual reflection arising from terminating a waveguide by means of the first order Mur's ABC [2]. Correction improves the performance by about 50 dB as shown in figure 2.

First we analyze tthe problem of a thin inductive septum in rectangular waveguide shown in figure 3. The analytical solution is easy available by variational analysis.

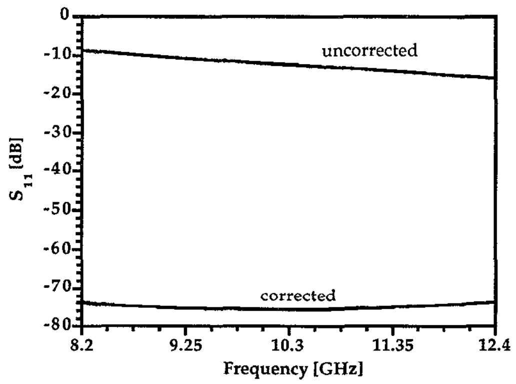

Fig. 2. Corrected and uncorrected magnitude of S_{11} for a lines of length = 7.5 mm; waveguide sides: 22.86 x 10.16 mm.

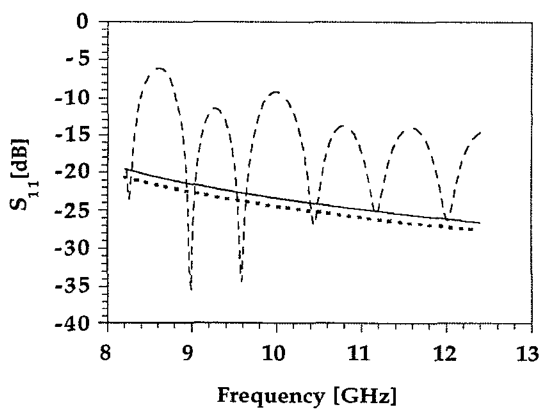

Fig. 4. Inductive septum with t=19.05 mm. Magnitude of S_{11} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to variational analysis.

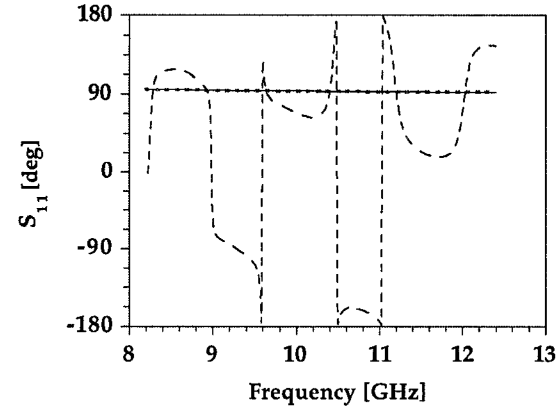

Fig. 5. Inductive septum with t=19.05 mm. Phase of S_{11} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to variational analysis.

Figures 4 and 5 compare the reflection magnitudes and phases respectively in the case of t=19.05 mm. Figures 6 and 7 compare the magnitudes and phases in the case of t=7.62 mm. We then analyze the H-plane junction between two rectangular guides shown in figure 8 and we compare the results with [3].

Figures 9 and 10 show real and imaginary parts respectively of the normalized admittances of the two guides dues to the non ideal first order Mur's ABC's.

Figure 11 reports the $|S_{11}|$, expressed in dB, for the uncorrected case, the corrected case and [3]. Figure 12 and 13 report the amplitudes and phases of S_{21}. The accuracy of the method is

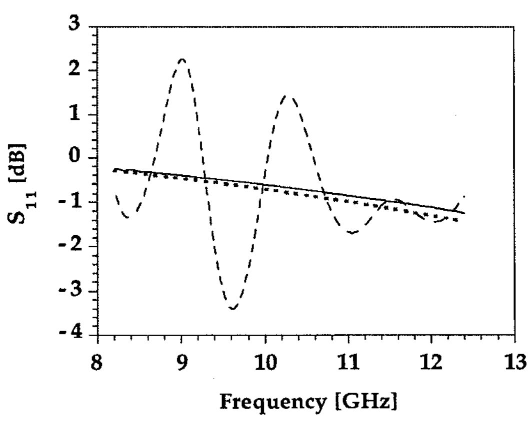

Fig. 6. Inductive septum with t=7.62 mm. Magnitude of S_{11} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to variational analysis.

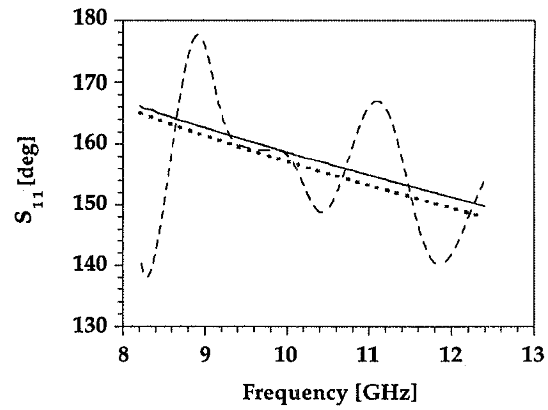

Fig. 7. Inductive septum whit t=7.62 mm. Phase of S_{11} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to variational analysis.

such as to reproduce the results of [3] and the corrected results very well indeed. Figure 14 also reports the percentage error computed as

$$\text{Error\%} = \frac{|S_{21}[3]| - |S_{21}[\text{corrected}]|}{|S_{21}[3]|} 100$$

REFERENCES

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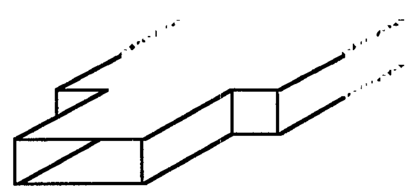

Fig. 8. H-plane junction between two rectangular guides: the shorter side is 10.16 mm long and the longer ones are 22.86 mm and 19.05 mm.

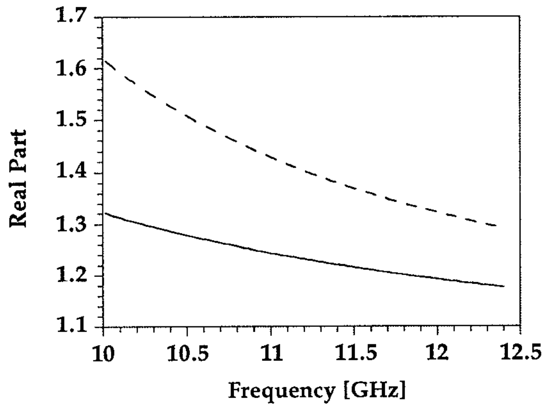

Fig. 9. Real part of normalized admittances for a 22.86 x 10.16 mm rectangular waveguide (continuous line) and 19.05 x 10.16 mm rectangular waveguide (dashed line).

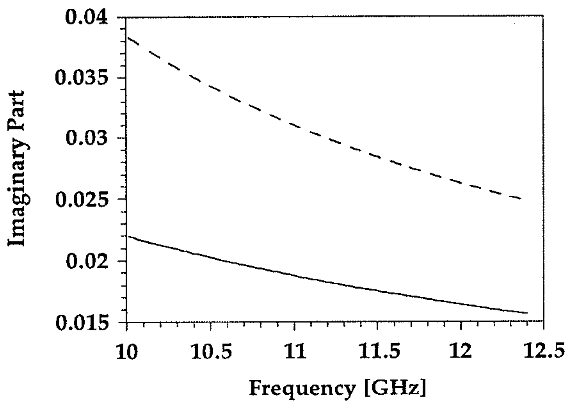

Fig. 10. Imaginary part of normalized admittances for a 22.86 x 10.16 mm rectangular waveguide (continuous line) and 19.05 x 10.16 mm rectangular waveguide (dashed line).

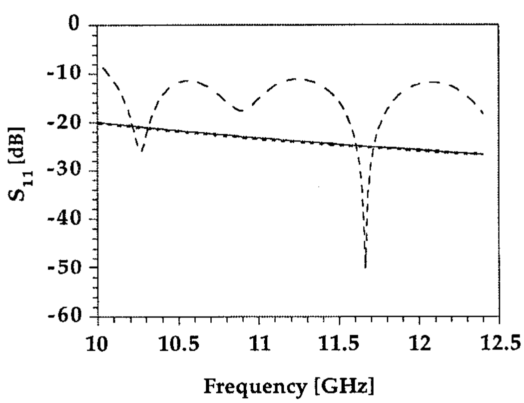

Fig. 11. Magnitude of S_{11} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to [3].

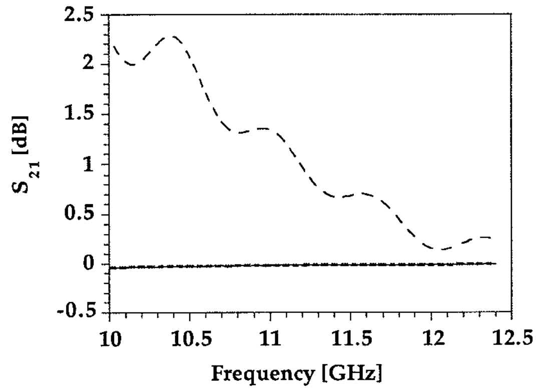

Fig. 12. Magnitude of S_{21} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to [3].

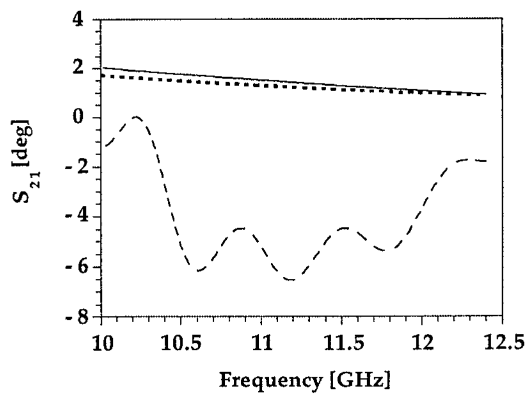

Fig. 13. Phase of S_{21} using first order Mur's ABC without correction (dashed line) and with correction (continuous line). Dotted line refers to [3].

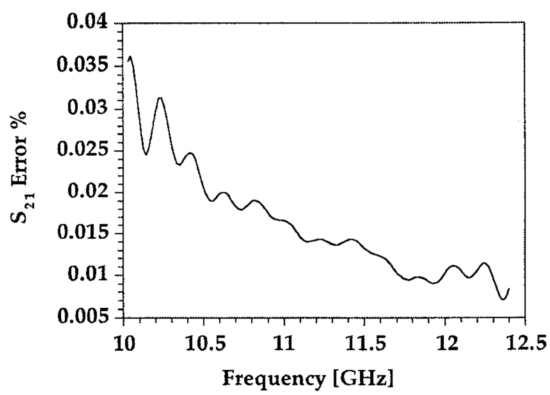

Fig. 14. Error (%) in the magnitude of S_{21} with correction: [3] gives the exact result.