Contribution to the Study of the Planar Circuits by a Hybrid Method (Iterative Method + FDTLM Method)

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Abstract: The new method of numerous simulations is considered as hybrid. It is based on concept of waves. With this method we can win a lot of times in the course of simulation and opening other perspectives in the circuit of microstrip study. This method is considered as combination between WCIP methods (Wave Concept Iterative Method) and FDTLM methods (Frequency Domain Transmission Line Matrix).

Key words: FDTLM, WCIP, hybrid method, microwave

INTRODUCTION

The conception of circuit constitutes a primordial stage and must be accomplished on short times that impose to simulator electromagnetic an optimal management of resources. In this sense a lot of studies were affected.

Consequently many methods were developed. The amelioration that can be exist between the tool and another that se translate in precision of results and the time of calculation then in the resolution of numerous equation. The iterative method[TRA 03],[GHA 01]is most quickly but we can apply only on structure make in two dimensions in the other side the FDTLM[JIN 95], [JIN 92a] is three-dimensional method it is slower than iterative method.

So we profit to advantages of iterative method and FDTLM method to formulate a hybrid method that will apply in every area.

1. Formulation of the Hybrid method

The analysis structure is composed by planar micro strip circuit enclosed in the metallic box (Figure 1). This structure is formed by interfaces $\Omega$ separating two dielectric mediums respectively region 1 with $\varepsilon_1$ as a permittivity and region 2 with $\varepsilon_2$ as a permittivity.

Figure 1. structure of simple layer circuit

If we model this structure only with FDTLM we will be obliged to discretize all region according to the three directions (x,y,z) [JOH87] and consequently we will use more memory and that will take much more time for simulation. If this structure is modelled only with WCIP, any inhomogenity according to the third dimension will not be modelled and consequently we will simulate a model that does not reflect reality. The hybrid method resolves this problem by applying the WCIP method in the homogeneous areas and the FDTLM method in the no homogeneous areas.

The application of the hybrid method on the structure represented in Fig.1 consists in studying the region 2 with FDTLM method and region 1 with WCIP method. Then, to make the coupling between these two methods on the level of the interface $\Omega$. 

- 1 -
The interface $\Omega$ is composed by the upper faces of the equivalent FDTLM symmetrical condensed nodes. In fact these higher faces of the FDTLM network represent the pixels used in WCIP.

**Figure 2. A node of the network FDTLM whose its higher face belongs to the interface $\Omega$**

We consider the incident and reflected waves of the upper faces of the symmetrical condensed nodes of the FDTLM. These waves are reformulated using the relationship:

$V^i$ and $Vr^i$ are respectively the incident and the reflected waves in x direction in FDTLM. [JIN 92c]

$V^v$ and $Vr^v$ are respectively the incident and the reflected waves in z direction in FDTLM. [JIN 92c]

$Ax$ and $Bx$ are respectively the incident and the reflected waves in the x direction in WCIP. [AZI 95]

$Az$ and $Bz$ are respectively the incident and the reflected waves in the z direction in WCIP. [AZI 95]

The relationship between waves A, B and Vi, Vr on the interface is given by:

$$
\begin{align*}
\begin{bmatrix}
V^i_x \\
V^r_x
\end{bmatrix} &= \begin{bmatrix}
\sqrt{Z_{01}} & 0 \\
0 & \sqrt{Z_{01}}
\end{bmatrix} \begin{bmatrix}
A_x \\
B_x
\end{bmatrix} \\
\begin{bmatrix}
V^i_z \\
V^r_z
\end{bmatrix} &= \begin{bmatrix}
\sqrt{Z_{01}} & 0 \\
0 & \sqrt{Z_{01}}
\end{bmatrix} \begin{bmatrix}
A_z \\
B_z
\end{bmatrix}
\end{align*}
$$

(1)

Zoi is the intrinsic impedance of the two middles. It is equal to: $Z_{oi} = \sqrt{\mu_0 / \epsilon_0 \epsilon_z}$.

The implementation of the global algorithm consists of establishing a recursive relationship between the waves in the two regions 1 and 2 treated respectively by FDTLM and WCIP, using the reflection operator in the spectral domain and the boundary conditions required on the interface plane for the WCIP, connection matrix[JIN 92b] and boundary conditions[BER 02], [PAS 00], [PAS 01] for the FDTLM.

The connection between the FDTLM and the iterative method is insured by a coupling matrix.

The global algorithm of the new approach is presented in Figure.3:

**Figure 3: Hybrid method algorithm**

2. Validation of the Hybrid method:

The second application is a demonstration of the speed of the hybrid method compared to the FDTLM method. By simulating the same structure with the two methods (FDTLM and hybrid method) and by comparing times of simulation of the two methods we will show the advantage brought by the hybrid method.

The second application considered consists of a multilayer structure [12]. The fig. 4 describes the layout of a two-port vertical transition with a while aperture formed on the plane between the upper and lower strips to provide a fed-through coupling between those two strips.

To demonstrate the efficiency of the proposed algorithm we have first simulated the structure using the FDTLM and in the second case the structure is simulated with the hybrid algorithm FDTLM-WCIP.
A computer program, with FORTRAN language, has been written to evaluate the S parameter matrix.

**Figure 4:** Layout of the proposed vertical transition of microstrip line with an electrically wide aperture

**Figure 5:** Top view of the proposed vertical transition

With:

\[
\epsilon_r^1 = \epsilon_r^2 = 10.2
\]

\[
h_1 = h_2 = 0.635\text{mm}
\]

\[
w_f = 0.60\text{mm}
\]

\[
w_a = 4.80\text{mm}
\]

\[
w_c = 1.80\text{mm}
\]

\[
L_a = 4.80
\]

**Figure 6:** Simulated reflected coefficient S11 using hybrid method

**Figure 7:** Simulated reflected coefficient S11 using FDTLLM method

Fig. 6 shows the results of the simulation using FDTLM.

Fig. 7 shows the results of the simulation using Hybrid method.

It is noticed that there is a good agreement between the calculated results and those obtained by simulation.

The table below gives us the time put by the FDTLM and the hybrid method in the simulation and the number of cells, to give an idea about the memory of the machine used by the two methods.

<table>
<thead>
<tr>
<th>Table 1: Comparison between the FDTLM solution and the Hybrid FDTLM-WCIP technique regarding the computational time for the structure illustrated in Fig 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proprieties of the Computer used for the simulation</strong></td>
</tr>
<tr>
<td>Pentium(R)4 CPU 3.20Ghz</td>
</tr>
<tr>
<td>Pentium(R)4 CPU 3.20Ghz</td>
</tr>
</tbody>
</table>

It is noted that our method is almost 6 times faster than the traditional method. This reduction of the computing time because of the reduction in the number of Tab-1 : Comparison between the FDTLM solution and the Hybrid FDTLM-WCIP technique.
regarding the computational time for the structure illustrated in Fig 9 cells is considered in the simulation of the structure.

\[
\frac{Time_{FDTLM}}{Time_{HYBRIE}} = 6.42
\]

(4)

3. Conclusion

It is estimated whereas we will solve many problems by using the hybrid method which will allow us to have much more facility in modelling of the structures and especially to make simulation with a minimum of time. We succeeded in formulating a three-dimensional and fast numerical method.

REFERENCES


