Rigorous Approach of the Planar Circuit

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Abstract- In this paper, a new Rigorous approach of a wave iterative method, this method is applied to active circuits. It consists in successive reflections between the circuit plan and its two sides. It also has an alternative behavior between space and spectral domains. In addition, the discontinuity plane is divided into cells and characterized by a scattering operator matrix depending on the boundary conditions. In the present study, we introduce a new technique based on the wave concept combined with the 2D-FFT algorithm (fast modal transformation FMT). Consequently, a high computational speed can be achieved. [1]

I. INTRODUCTION

Planar and stratified circuits are characterized by one or several planes containing thin metallic circuits including active elements, air bridges, and lines and so on. Between these planes, the dielectric medium is most often homogenous and the problem is referred as two-dimensional. The more suitable methods for the simulation of these circuits are based on an integral formulation solved with a method of moments although some other three dimensional approaches are successfully used. [2]

The full wave methods are mostly used as electromagnetic field can be known at any point. An integral formulation permits these methods to be adapted to study some particular structures, among these methods are:

- *The least squares method* this is easy to develop, but the numerical treatment requires an important means when the studied circuit has a complex geometry. [3]
- *The mode-matching method* this consists of determining all the modes at both sides' discontinuity without taking it into consideration. This method is ideal when we can determine and know numerically all the modes. On the contrary, when the determination of the proper modes cannot be done numerically, the mode-matching method becomes difficult to bring into operation and requires significant computing time. [4]
- *The source method* this uses an excitation on the plane of the circuit and is easy to formulate, since the solution of the problem is obtained by solving a deterministic system. Thus, the iterations needed to solve homogenous systems, in the Eigen value methods, are avoided. The numerical solution is based the verification of the boundary conditions. The source current density is described by an arbitrary function. The solution of the system will give a model of the current density on all the circuit with the help of appropriate trial functions.[5]

In this paper, a new iterative method is applied to active circuits. It consists in successive reflections between the circuit plan and its two sides. It also has an alternative behavior between space and spectral domains. In addition, the discontinuity plane is divided into cells and characterized by a scattering operator matrix depending on the boundary conditions. In the present study, we introduce a new technique based on the wave concept combined with the 2D-FFT algorithm (fast modal transformation FMT). Consequently, a high computational speed can be achieved. [5]

II. THEORETICAL FORMULATION OF THE WAVE CONCEPT ITERATIVE PROCEDURE (W.C.I.P)

II.1 Definition of the waves

Contrary to the electromagnetic fields, the waves are defined with regard to a chosen surface which should be closed or leaning on the boundaries of the domain Ω where the fields are defined. Saying that the waves are S-related means that the change in S changes the waves.

Let M a point, n the normal unitary vector on S, E and H the tangential electric and magnetic fields on S. the waves A and B are defined as:

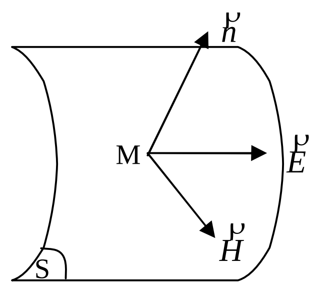


Figure 1. Definition of the S-related waves.

$$A = \frac{1}{2\sqrt{Z_0}}\left(E + Z_0 H \wedge n\right)$$
$$B = \frac{1}{2\sqrt{Z_0}}\left(E - Z_0 H \wedge n\right) \quad (1)$$

A and B are two tangential vectors on S and Z_0 an arbitrary impedance.

With the usual definition of the $J = H \wedge n$ (2)

$$A = \frac{1}{2\sqrt{Z_0}}\left(E + Z_0 J\right)$$
$$B = \frac{1}{2\sqrt{Z_0}}\left(E - Z_0 J\right) \qquad (3) \quad [1]$$

II.2 Method formulation

The equivalent circuits previously characterized for the electrical and magnetic tangential fields lead to two scattering operators that relate the incident and reflected waves.

Figure 2- iterative process.

The spectral scattering operator $\hat{\Gamma}$ is deduced from the admittance operator $\hat{Y}$ in $J = YE$ and the wave's definition in (3)

$$\hat{\Gamma} = \left(1 - Z_0\hat{Y}\right)\left(1 + Z_0\hat{Y}\right)^{-1} \qquad (4)$$

Where $\hat{\Gamma}$ relates the incident and the reflected waves in the spectral domain;

$$B = \hat{\Gamma}A \qquad (5)$$

The space scattering operator $\hat{S}$ is deduced from the equivalent circuits on each sub-domain of S. the boundary conditions expressed for field in:

$$\begin{aligned} &E_1 = E_2 && \text{on the metal} \\ &E_1 = E_2,\ J_1 + J_2 = 0 && \text{on the dielectric} \\ &E_1 = E_0 - Z_s J_0 && \text{on the source} \end{aligned} \qquad (6)$$

are simply transposed to waves.

$\hat{S}$ relates the incident and reflected waves in the space domain

$$A = \hat{S}B \qquad (7)$$

Finally the integral formulation leads to a system based on (5) and (7) with a space localized wave source A_0

$$A = \hat{S}B + A_0$$
$$B = \hat{\Gamma}A \qquad (8)$$

The fast modal transform (FMT) assures wave transformation from the spatial to the spectral domain, and its inverse FMT^{-1} transformation back. The multiscale formulation requires a preliminary determination of the operator $\hat{S}$. [6]

III. PROBLEMS MODELING AND RESULTS

III.1 Iris in a metallic waveguide

To check the present approach we consider the structure illustrated in fig.3

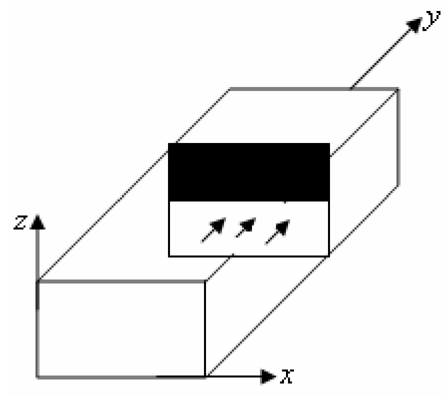
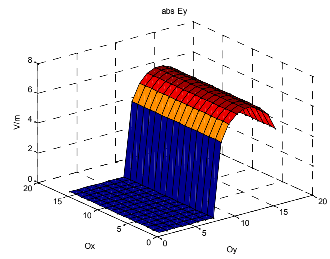
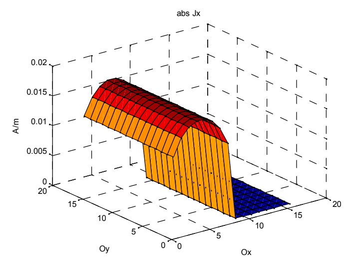


Figure 3- iris in a waveguide

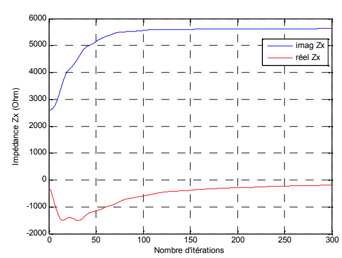
It consists of the iris in a metallic waveguide, the dimension of this structure are ------- and the substrate characteristics are ------- and thickness of ----mm

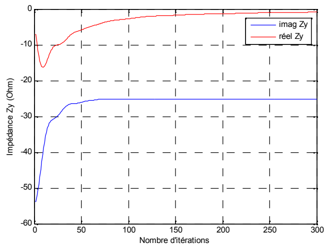


-a- the electric field



-b- the current density field





-c- – Convergence of the impedances Z_x and Z_y compared to the iteration count

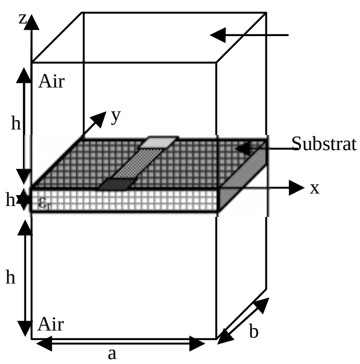
Figure 4- The diagrams resultants

In fig.4 –a-b-, the electric and the current density fields in the iris is represented, these fields have satisfy the boundary conditions on the sub-domains [metal-dielectric].

III.2 Application in planar circuit

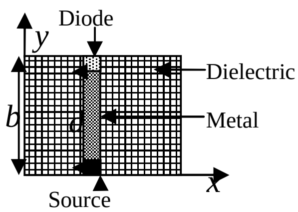
This analysis is applied to calculate the S parameters of a rectangular waveguide including a Gunn diode.

The source is not an incident wave but an excitation source displayed on the surface of the circuit.



-a-

Metal case



-b-

Figure 5- (a) typical planar circuit (b) discontinuity plane.

The discontinuity plane Ω is includes three sub-domains, isolated, metal, source and diode. The equivalent circuit of the Gunn diode Z_d is shown in fig.6. Moreover; in the discontinuity plane Ω, the relationship between the incident and reflected waves can be obtained by applying the following boundary conditions.

a. On the dielectric, the tangential magnetic field is zero and the electric field is continuous.
b. The tangential electric field is zero on the metal.
c. On the diode, the total electric field is continuous and is equal to Z_d multiplied by the total current in this region.

Let H_m , H_s , H_i , H_d the indicator functions of the metal, source; insolent, diode (equal to one on the considered medium, and zero elsewhere) and S_m , S_s , S_i , S_d the corresponding scattering matrix:

$$A = (S_m H_m + S_s H_s + S_i H_i + S_d H_d)B + A_0$$

$$B = \Gamma A$$

With $\hat{\Gamma}_i = \sum_n | f_n \rangle \Gamma_{in} \langle f_n |$

where $\hat{\Gamma}_{in} = \dfrac{1 - Z_0 Y_{in}}{1 + Z_0 Y_{in}} = \dfrac{Z_{in} - Z_0}{Z_{in} + Z_0}$

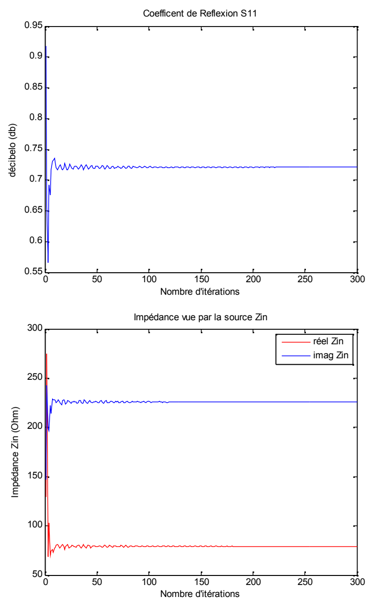


Figure 6 convergence of S_{11} and of Z_{in}

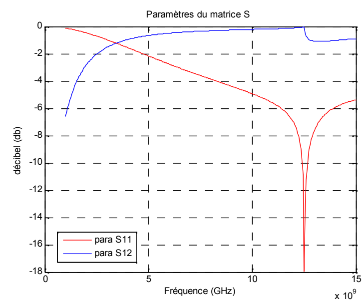


Figure 7

CONCLUSION

The principles and advantages of an iterative method based on a wave concept known as the wave concept iterative procedure are outlined, And give a good result.

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