Analysis of multilayer amplifier structure by an efficient iterative technique

Alexandre Serres[1], Georgina K. F. Serres[1], Glauco Fontgallant[1], Raimundo C. S. Freire[1] and Henri Baudrand[2]
[1] Department of Electrical Engineering
University of Campina Grande, Campina Grande, PB 58429-900, BRASIL
alexandreserres@dee.ufcg.edu.br, georginafreitas@ee.ufcg.edu.br, fontgalland@dee.ufcg.edu.br,
freire@dee.ufcg.edu.br
[2] LAPLACE-GRE, 2 rue Camichel 31071, Toulouse CEDEX, France
henri.baudrand@laplace.univ-tlse.fr

***Abstract*—A new compact microwave amplifier structure using an iterative technique based on the wave concept (WCIP) is presented. This new multilayer structure is composed of five planar interfaces with microstrip lines. The technique used to model this structure provides a mixed resolution in modal and spatial domain taking the best advantage of each resolution domain and lower computation time. The purpose of this work is to demonstrate that a near field amplification technique is possible and the WCIP is suitable to electromagnetic analysis of this kind of structure.**

***Index Terms*— Microwave amplifier, Iterative methods, Electromagnetic analysis.**

I. INTRODUCTION

The manufacturing of miniaturized hybrid microwave integrated circuits (MHMICs) is performed either by using the multilayer LTCC or HTCC (low or high temperature cofired ceramic) technology [1]. The use of multilayer circuits makes microwaves circuits more compact and the design more flexible [2]. For applications in the millimeter-length bands, new methods for the conception of these circuits have been developed, and others perfected, in order to meet requirements such as cost, performance and complexity. These methods allow the integration of different functions on the different planar surfaces among the dielectric layers on which the active and passive elements are deposited using several techniques. This article presents an efficient technique based on the Wave Concept Iterative Procedure (WCIP) for solving continuity conditions in terms of waves rather than in terms of tangential electric and magnetic field to analyze a compact microwave amplifier structure. This method is not conditioned by the complexity of the circuit design and was proved to be particularly interesting for planar circuit [3].

In the work reported herein the analysis and simulation of a strucuture with five interfaces were caried out as represented in Fig. 1.

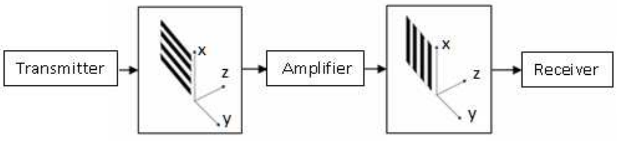

Fig. 1. Block diagram of the amplifier structure

Section II provides the formulation used with the WCIP. Simulations and results are presented in section III. Finally, conclusions are included in section IV.

II. FORMULATION OF THE WCIP

The usually used WCIP scheme is very simple. Two operators relating incident and reflected waves in the spatial domain and in the modal domain governs the iterative procedure. It can be represented through two equations:

$$\vec{A} = S\vec{B} + \vec{A}_0 \tag{1}$$

$$\vec{B} = \Gamma\vec{A} \tag{2}$$

where A_0 is the local source of the circuit.

When the wave concept is extended for multilayer structures, a new relationship formulation between waves is introduced for the transformation between two adjacent interfaces [4]. The boundary conditions on the interfaces are represented by a diffraction operator, S, defined in spatial domain. In the homogeneous media, the wave propagations between interfaces are represented by a transfer matrix, T, and on the extremities of the circuit (top and bottom) by a reflection operator, Γ, both defined in modal domain.

The structure under study is composed of five interfaces, a transmitter and receiver, an amplifier and two polarizers positioned perpendicularly. Using the wave concept, the interfaces of the polarizers can be substituted by virtual interfaces. For example, an ideal polarizer O_x does not disturb or attenuate the propagation of the E_x electric field and produces a total reflection of the E_y electric field and it, it is easy to express E_y in terms of waves:

$$E_{iy} = \sqrt{Z_{0i}}\left(A_{iy} - B_{iy}\right) \tag{3}$$

To satisfy the boundary conditions, $E_{iy} = 0$, the relationship between the incident and reflected waves becomes:

$$A_{iy} = -B_{iy} \tag{4}$$

As a result the polarizers can be expressed directly into the modal domain that avoids the discretization in the spatial domain. Therefore the structure is composed of three physical interfaces. For the amplifier interface modeling, it is used an auxiliary feed method. This method allows the electromagnetic modeling of structure composed of passive elements (P) and active element as represented in Fig. 2.

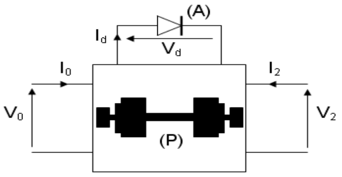

Fig. 2. Example of active circuit

The first step of the method is the electromagnetic analysis of the passive structure substituting the active element by an auxiliary feed as shown in Fig. 3. (a).

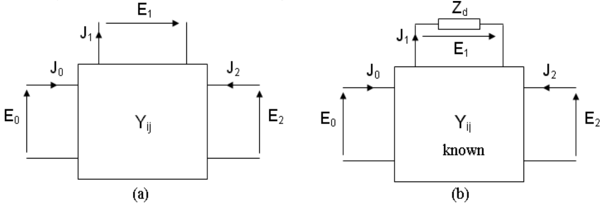

Fig. 3. (a) Passive structure analysis (b) Active structure analysis

The admittance matrix Y$_{ij}$ of the structure is determined using the WCIP. The second step consists in substituting the auxiliary feed by the electrical representation of the active element as illustrated in Fig. 3. (b), where Z$_d$ represents the impedance of a diode. Considering this active element as negative impedance:

$$J_1 = -\frac{E_1}{Z_d} \tag{5}$$

As a result, a new admittance matrix is calculated and the three-port circuit becomes a two-port circuit. From this admittance matrix of the amplifier structure, the coefficients of the equivalent scattering matrix are given as:

$$S_{11} = \frac{(1 - Z_c Y_{11Ampl})(1 - Z_c Y_{22Ampl}) + Z_c^2 Y_{12Ampl} Y_{21Ampl}}{(1 + Z_c Y_{11Ampl})(1 - Z_c Y_{22Ampl}) - Z_c^2 Y_{12Ampl} Y_{21Ampl}} \tag{6}$$

$$S_{11} = \frac{-2 Z_c Y_{21Ampl}}{(1 + Z_c Y_{11Ampl})(1 - Z_c Y_{22Ampl}) - Z_c^2 Y_{12Ampl} Y_{21Ampl}} \tag{7}$$

where Z$_c$ is a 50Ω characteristic impedance.

Finally, it is possible to express the boundary conditions in terms of waves on each cell of the structure under study.

III. SIMULATION RESULTS

In order to present and evaluate the performance of the proposed tools, a simulation of the amplifier structure was performed. Fig. 4 shows the multilayer structure with the physical interfaces used with the auxiliary feed method.

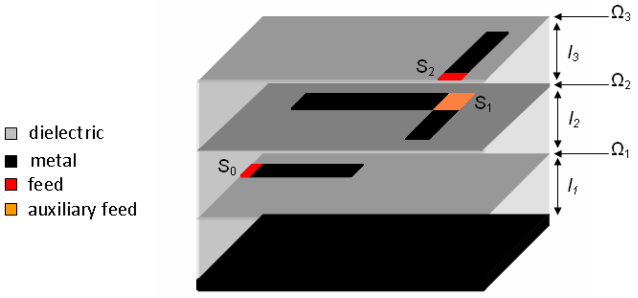

Fig. 4. 3-D view of the structure with auxiliary feed

On the first interface, the microstrip feed line has width of 2mm and length of 18mm. On the second interface the L-resonator has width of 4mm and length of 20mm. On the third interface, the microstrip line has the same dimensions as the first interface. Expressing the polarizers directly into the modal domain avoids the discretization in the spatial domain. Therefore, a time computational of 30% associated with these operations is released. The waveguide is 32mm wide and 32mm long, $\varepsilon_{r1} = \varepsilon_{r2} = \varepsilon_{r3} = 2.2$, $\varepsilon_{r4} = 1$ and $l_1 = l_2 = l_3 = 0.65$mm. A simulation of the proposed amplifier structure was conducted varying the negative impedance of the diode from -120Ω to -60Ω at a frequency of 5.6GHz. As seen in Fig.5, a gain of 13.4dB is obtained for negative impedance Z$_d$ of 80Ω

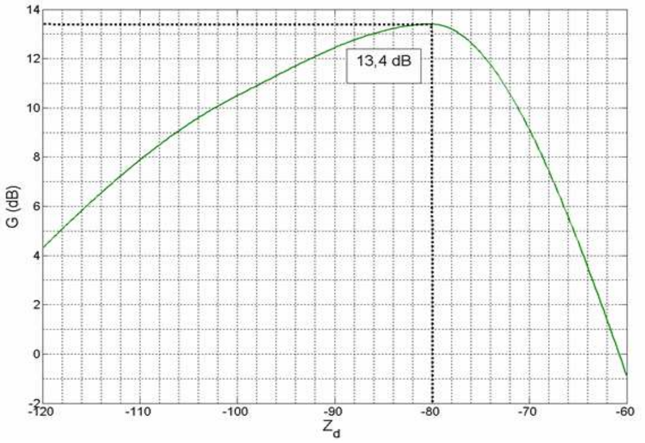

Fig. 5. Gain versus impedance of the amplifier structure

IV. CONCLUSION

In this paper, an implementation of the WCIP for a multilayer amplifier structure is presented. The obtained results show that the method herein formulated and computationally implemented is suitable to electromagnetic analysis. A very good result of 13.4 dB is obtained with a simple negative impedance model. The next step of this work is to substitute this impedance by a transistor model using the WCIP and the auxiliary feed method.

REFERENCES

[1] K-L. Wu; Y. Huang, "LTCC technology and its applications in high frequency front end modules," *6th International Symposium on Antennas, Propagation and EM Theory*, pp. 730-734, 28 Oct.-1 Nov. 2003.

[2] N. Militaru, G. Lojewski, M.G. Banciu, “Aperture Couplings in Multilayer Filtering Structures,” *International Symposium on Signals, Circuits ans Systems, ISSCS 2007*, vol. 2, pp. 1-4, 13 – 14 July 2007.

[3] A. Serres, G. Fontgalland, J.E.P. de Farias, H. Baudrand, “An Efficient Algorithm for Planar Circuits Design,” IEEE Transactions on Magnetics, vol.46, no.8, pp.3441-3444, Aug. 2010.

[4] A. Serres, G.K.F. Serres, G. Fontgalland, J.E.P. de Farias, H. Baudrand, “Analysis of multilayer circuits by an efficient iterative technique,” Microwave & Optoelectronics Conference (IMOC), 2011 SBMO/IEEE MTT-S International, pp.743-747, Oct. 29 2011-Nov. 1 2011.

.