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Device Electromagnetic Characterization of GaAs MESFET Transistor.

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ABSTRACT

In this paper, an electromagnetic study of MESFET transistor based on iterative method is presented. This method is generating the relationship between the incident and reflected waves from the planar circuits. The WCIP method is developed from the fast modal transform algorithm.

INTRODUCTION

The MESFET or GaAs FET as it is also called is a high performance form of field effect transistor that is used mainly for high performance microwave applications and in semiconductor RF amplifiers. The abbreviation MESFET stands for MEtal-Semiconductor Field Effect Transistor. GaAs FET standars for Gallium Arsenide, the substance from wich this FET or field effect transistor is made. The GaAs FET or MESFET shares many features with the standard junction FET or JFET, although the MESFET is able to offer superior performance, especially in the region of RF microwave operation, especially for use within RF amplifiers. [1]

In this paper, an iterative method is applied to active circuit, it consist in successive reflection between the circuit plan and its two sides. It also has an alternative behavior between space and spectral domains. In addition the discontinuity plan is divided into cells and characterized by scattering operator matrix depending on the boundary conditions. [2]

This analysis is applied to calculate the S parameters of rectangular waveguide including a MESFET transistor.

THE ITERATIVE METHOD WCIP

The principle of the iterative method Wave Concept Iterative Process has been described in several studies [3, 4].

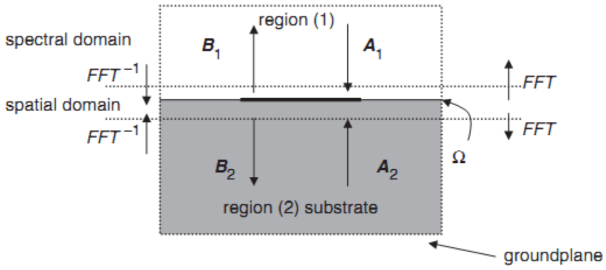


Figure 1: The principle of the iterative process [5]

It leads to the following set of equations:

$$A_i=(E_i+Z_{0i}*J_i)/2\sqrt{Z_{0i}}. \qquad (1)$$

$$B_i=(E_i-Z_{0i}*J_i)/2\sqrt{Z_{0i}}. \qquad (2)$$

Where:
J_i: the current density.
A_i: the incidents waves.
B_i: the reflection waves.
Z_{0i}: the characteristic impedance of the medium. i=(1.2)
By use –Equations (1), (2) the integral equation:

$$J_i=\hat{Y}*E_i \qquad (3)$$

Can be rewritten in the spectral domain by:

$$B_i=\Gamma*A_i \qquad (4)$$

The reflection operator Γ is related to the admittance operator by the following expression:

$$\Gamma=(1-Z_0*\hat{Y})/\ (1+Z_0*\hat{Y}) \qquad (5)$$

The boundary and continuity conditions in each spatial sub domains of Ω are expressed by:

$$A_i=\hat{S}.B_i+A_{0i} \qquad (6)$$

The diffraction operator $\hat{S}$ is related to the metal, dielectric, and source sub domains by applying the boundary conditions to the equation (7) [6]

APPLCATION OF THE WCIP TO THE MESFET

The analysis structure is composed of a rectangular waveguide closed from both sides. As described in Fig. 2, the discontinuity plane Ω is divided into cells and includes four sub domains: isolated, metal, source and MESFET transistor. The dimensions of the electromagnetic structure are a=b=25mm and the substrate characteristics are epsr=4.73 and thickness of 1.47 mm. We simulate this structure with 32*32 resolutions.

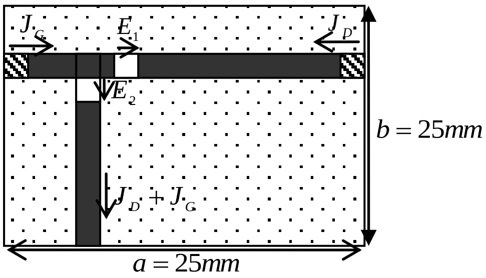


Figure 2: The discontinuity plane Ω

$$V_{gs}=V_1=E_2d \qquad (7.a)$$

$$V_{ds}=V_2=(E_2+E_1)*d \qquad (7.b)$$

$$I_{ds}=(2J_1+J_2)*c \qquad (8.a)$$

$$I_{gs}==J_2*c \qquad (8.b)$$

The electrical tension and intensity have related by the admittance parameters with the following experience:

$$\begin{bmatrix} I_{gs} \\ I_{ds} \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_{gs} \\ V_{ds} \end{bmatrix} \qquad (9)$$

Applying the equations (7.a), (7.b), (8.a) and (8.b) in the equation (9), where d=c, the electrical fields and density can be written in the following form:

$$\begin{bmatrix} J_1 \\ J_2 \end{bmatrix} = \begin{bmatrix} Y_{21}-Y_{11} & Y_{21}+Y_{22}-Y_{11}-Y_{12} \\ Y_{22} & Y_{22}+Y_{21} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} \qquad (10)$$

Where:

$$Y_{11}=I_{gs}/V_{gs}]V_{ds=0},\ Y_{12}=I_{gs}/V_{ds}]V_{gs=0},\ Y_{21}=I_{ds}/V_{gs}]V_{ds=0},\ Y_{22}=I_{ds}/V_{ds}]V_{gs=0}, \qquad (11)$$

The admittance parameter of the MESFET transistor is defined by the intrinsic model. The equivalent circuit of the MESFET is shown in Fig.3.

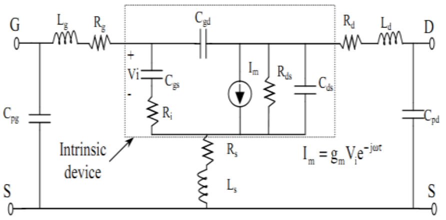


Figure 3: The equivalent circuit of the MESFET transistor. [7]

$$Y_{11}=(j*\omega*C_{gs}/1+j*\omega*R_i*C_{gs})+(j*\omega*C_{gd})$$

$$Y_{21}=(g_m*e^{-j*\omega*t}/1+j*\omega*R_i*C_{gs})-(j*\omega*C_{gd})$$

$$Y_{12}=-j*\omega*C_{gd}$$

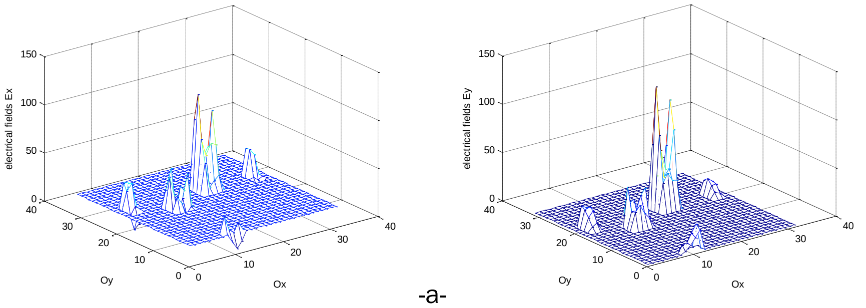
$$Y_{22}=g_{ds}+j*\omega*(C_{ds}+C_{gd})$$

The candidate MESFET model parameters are presented with the following values:
C_{gs}=504Ff, R_i=0.5Ω, C_{gd}=31.41fF, g_m=62.52ms, τ=2.32ms, g_{ds}=1.067ms, C_{ds}=51.39fF

THE RESULTES OF SIMULATION

The boundary conditions and the continuities equation

The boundary conditions to the sub domains have verified with the graphics of fig.4.



-a- -b-

Figure 4: The electrical fields to the sub domains: metal, dielectric, source and transistor.

Convergence of the WCIP

The determination of the discontinuity's characteristics requires a convergence study, Fig. 5 shows that, the modulus of the transmission coefficients converge (90 trial functions with 300), and the Zin converge with 50 functions .

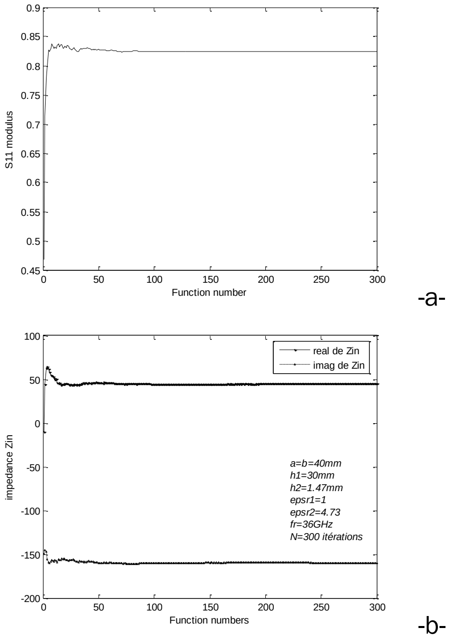


Figure 5: Convergence of WCIP –a- variation of S11 against number of functions. –b- variation of Zin against number of functions

The frequencies simulation

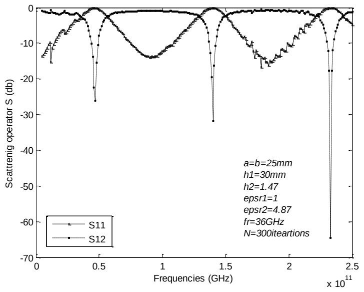


Figure 6: The diffraction operator S as a fuction of frequency

In the fig.6 the diffraction operator is ploted against frequency, this traces shows the schift in resonnant frequency f= “45 – 140 – 235 GHz”

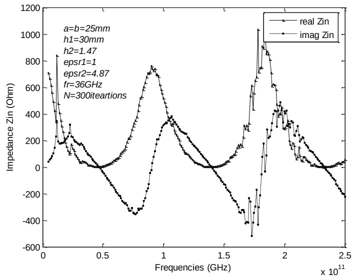


Figure 7: The impedance Zin as a function of frequency.

The traces of fig.7 is verified and comfirmed the resonnant frequency. After this simulation, we study the effect of the box characteristic on the diffraction opérateur values, from the following traces,

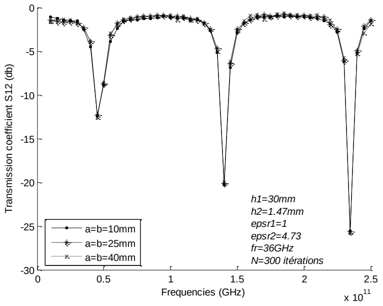


Figure 8: The transmission coefficient S12 as a function of frequency.

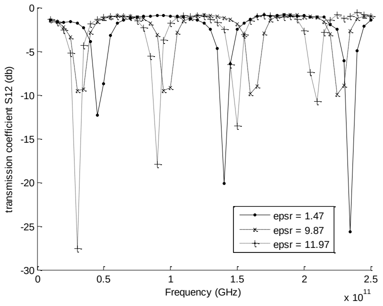


Figure 9: The transmission coefficient S12 as a function of frequency.

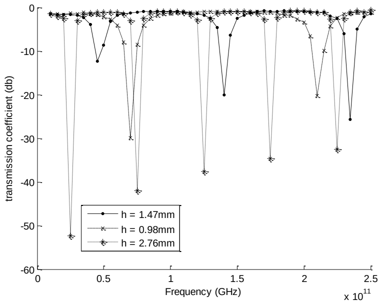


Figure 10: The transmission coefficient S12 as a function of frequency.

The previously figures determined the effect of the boxing characteristics of the transmission coefficient when the box size does not matter on the resonance frequency, but the material and the thikness of the dielectric substrate changes the values of the reflection coefficient and the resonance.

This change has been created from the composition and atomic structures of dielectric or semi conductor substrate, then we recall, the silicium is well suited for the diffraction and transmission of electromagnetic waves in the MESFET structures

CONCLUSION

This paper is performed the transmission of electromagnetic waves on MESFETs, and confirms that the WCIP method is also highly flexible and efficient for this type of electronic components

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