Study of Wave Polarizer using Wave Concept Iteraive Method

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ABSTRACT: *This work will deal with the study of quasi square with a reference to the rigorous method iterative on wave's transverses. Reformulation of the Wave Concept Iterative Method is reformulated to integrated numerical polarizer, for principal argument stabilize of method.*

Keywords: Quasi-optical, Polarizes, WCIP

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1. Introduction

The techniques of combining quasi-optical power have been developed to resolve the limitation of the power components to the solid state [1]. They were applied to the oscillators [2], the amplifiers [3] and the converters frequency [4]. These techniques also allow the development of new tools for designing these types of circuits, and therefore this knowledge was transferred to the microwave circuit designers. In spatial power combiners quasi-optical, transmitters and receivers are positioned at suitable distance elements amplifiers so they can function as reinforces modes propagations. The technique of spatial power generally combines the use of a focusing system [5]. This focusing system has the function wave formulation and a fast efficient mode transformation [12] to calculate the electromagnetic field on the circuit plane. A multiple reflection procedure is established which is started using initial conditions and stopped once the convergence is achieved [12.13]. In order to generate the iterative process, two related operators are used. The first one noted S_Ω describes in spatial domain all the sub-domains of the circuit plane whereas the second called Γ defined in spectral domain and it can elate the waves in the spectral domain [9, 10]. The circuit plane is meshed into small cells; on each cell, the electromagnetic field satisfies the appropriate boundary condition. With these two operators, we establish two equations respectively in the spatial and spectral domain [8]. In these equations we are defined $\vec{A}_i$ as incident waves, $\vec{B}_i$ as scattered waves $\vec{B}_i$ and $\vec{A}_0$ as the incident source waves [14].

$$\begin{pmatrix} \vec{B}_1 \\ \vec{B}_2 \end{pmatrix} = S_\Omega \begin{pmatrix} \vec{A}_1 \\ \vec{A}_2 \end{pmatrix} \tag{1}$$

$$\begin{pmatrix} \vec{A}_1 \\ \vec{A}_2 \end{pmatrix} = \Gamma \begin{pmatrix} \vec{B}_1 \\ \vec{B}_2 \end{pmatrix} + \begin{pmatrix} \vec{A}_0 \\ 0 \end{pmatrix} \tag{2}$$

As shown on figure (1), the incident waves A_i and the scattering waves B_i are given in terms of the transverse electric E_{Ti} and magnetic fields H_{Ti} at the circuit interface (Ω). This leads to the following set of equations:

$$\begin{cases} A_i = \dfrac{\sqrt{y_{0i}}}{2}\left(E_{Ti} + \dfrac{1}{y_{0i}}\,(H_{Ti} \wedge n)\right) \\ B_i = \dfrac{\sqrt{y_{0i}}}{2}\left(E_{Ti} + \dfrac{1}{y_{0i}}\,(H_{Ti} \wedge n)\right) \end{cases} \quad (3)$$

y_{0i} is an intrinsic admittance characterizing the medium, *i* denotes the two mediums beside Ω (i =1 and 2), it can be defined as: $y_{0i} = \sqrt{\dfrac{\varepsilon_0 \varepsilon_{ri}}{\mu}}$ in which ε_0, μ_0 and ε_{ri} are respectively the permittivity and permeability of the vaccum and of the medium '*i*'. *n* is the outward vector normal to the interface.

The surface current density is introuced as being $J_{Ti} = H_{Ti} \wedge n$

According to equation (3), the boundary conditions can be expressed in terms of waves: On the metal:

$$\left\{ \begin{vmatrix} B_1 \\ B_2' \end{vmatrix} = [S_M] \begin{vmatrix} A_1 \\ A_1' \end{vmatrix} \right\}_{x,y}, \ [S_M] = \begin{vmatrix} -1 & 0 \\ 0 & -1 \end{vmatrix} \quad (4)$$

On the dielectric:

$$\left\{ \begin{vmatrix} B_1 \\ B_2 \end{vmatrix} = [S_D] \begin{vmatrix} A_1 \\ A_2 \end{vmatrix} \right\}_{x,y} \quad (5)$$

$$[S_D] = \begin{bmatrix} \dfrac{1-n_{12}}{1+n_{12}} & \dfrac{2n_{12}}{1+n_{12}} \\ \dfrac{2n_{12}}{1+n_{12}} & \dfrac{1-n_{12}}{1+n_{12}} \end{bmatrix} \text{ Where } n_{12} = \frac{y_{01}}{y_{02}}$$

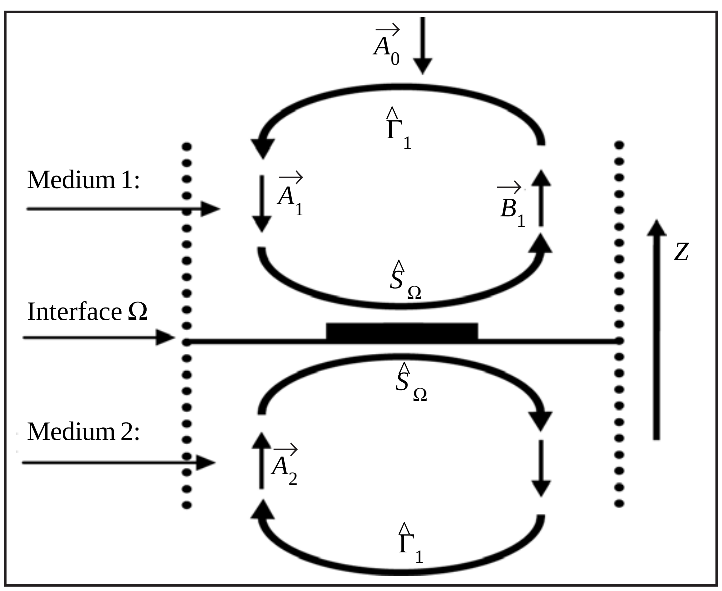

Figure 1. Definition of waves for the single-layer structure

3. General structure presentation

Figure (2) present the general structure under studied. It consists of three layers circuit. The medium one is the circuit under studied whereas the two others are the polarizer’s. The two polarizer’s are useful to isolate and guide the waves into desired direction. An ideal polarizer Ox doesn’t disturb or attenuate the Ex component and it will be produce the total reflection of Oy component of the electric field. The same analysis can be established for the Oy ideal polarizer.

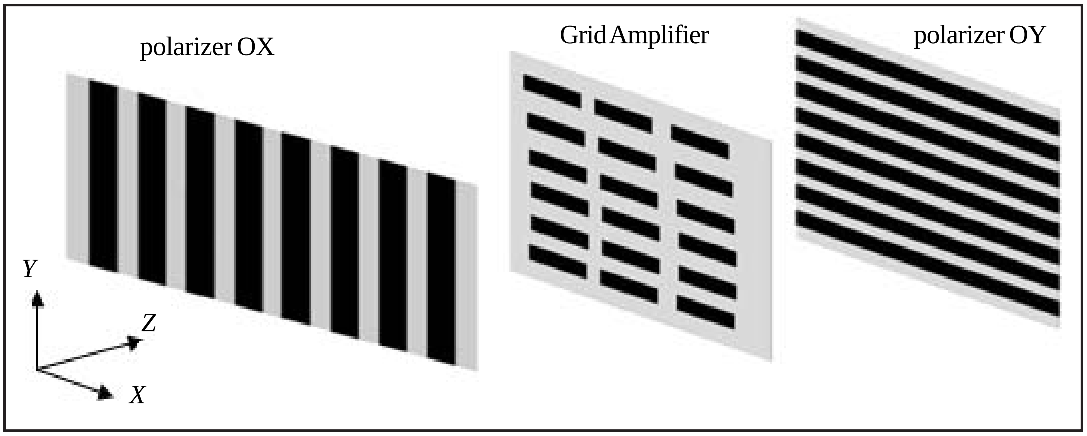

Figure 2. Block diagram of an amplifier with polarizer

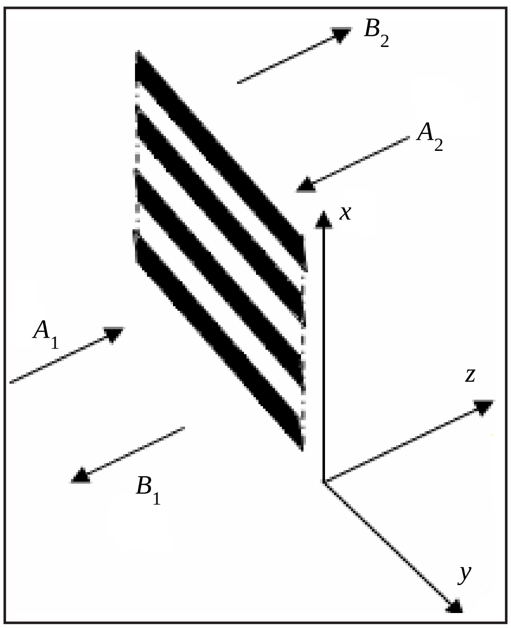

Figure 3. Polarizer OX

In Equation (1) is shown a possible relationship between the electric field and the incident waves and reflected. The field Ey can be written as

$$E_{iy} = Z_{0i} (A_{iy} + B_{iy}) \qquad (6)$$

Where *i* represents the medium and Z_{0i} the impedance of the medium. To satisfy the boundary condition on the component propagating the field along *Ox*, $E_{iy} = 0$, the condition applies to the field space: $A_{iy} = -B_{iy}$

Figure 3 is shown the physical interface representing a polarizer *Ox* real. When the incidence of the waves, the endless pairs of the metal tracks Throughout *Oy* form a distributed capacitance to *Ox* and the induced current on metal tracks generate an inductance distributed on each track in *Oy*.

$$\begin{bmatrix} A_{1x} \\ A_{1y} \\ A_{2x} \\ A_{2y} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} B_{1x} \\ B_{1y} \\ B_{2x} \\ B_{2y} \end{bmatrix}$$

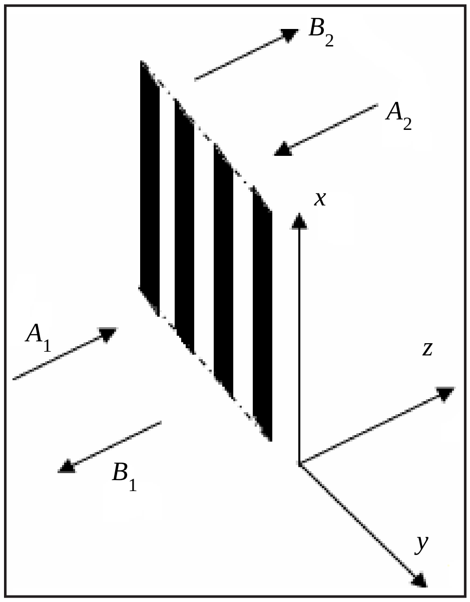

Figure 4. Polarizer *OY*

$$\begin{bmatrix} A_{1x} \\ A_{1y} \\ A_{2x} \\ A_{2y} \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} B_{1x} \\ B_{1y} \\ B_{2x} \\ B_{2y} \end{bmatrix}$$

Characteristic matrix of the polarizer

The pair permits to go from spatial domain to the spectral domain and back to the spatial domain [11]. The use of the FMT requires that the spatial and spectral fields should be discrete. In the space fields this discretization is carried out by a grid in small rectangular areas (pixels) of the interface Ω. Electromagnetic value and the incidental and the reflected waves are represented by matrices whose dimensions depend on the density of grid of this interface.

Polarizer can be inserted in the spectral absorption unwanted waves which stipulates a new formulation. The first passage is from the spatial domain to the spectral domain by FFT in 2D, second a modal projection [12] FMT. Modal basis chosen there are described extensively in [13] and [14]. The 2D periodic wall and the bases functions are exponential. There are described in [15]. In the above equation, we have included the excitation wave $A_{00} = \begin{vmatrix} A_{ox} \\ A_{oy} \end{vmatrix}$. A_{00} is defined in the spectral domain and has the following expression: For TE polarization:

$$\begin{cases} A_{0x} = \dfrac{1}{2\sqrt{Z_{oi}}} \dfrac{N_y}{\sqrt{|N_x|^2 + |N_y|^2}} \dfrac{1}{\sqrt{ab}} e^{-j(\beta_x x + \beta_y y)} \\ A_{0y} = \dfrac{1}{2\sqrt{Z_{oi}}} \dfrac{N_x}{\sqrt{|N_x|^2 + |N_y|^2}} \dfrac{1}{\sqrt{ab}} e^{-j(\beta_x x + \beta_y y)} \end{cases} \quad (7)$$

Where $N_x = (\frac{2m\pi}{A} + \frac{2p\pi}{a})$ and $N_y = (\frac{2n\pi}{B} + \frac{2p\pi}{b})$

And the constant of propagation becomes:

$$\gamma_{mn} = \sqrt{(\frac{2m\pi}{A} + \frac{2p\pi}{a})^2 + (\frac{2n\pi}{B} + \frac{2q\pi}{a})^2 - K_0^2 \varepsilon_{ri}}$$

$$\begin{bmatrix} A_{mn}^{TE} \\ A_{mn}^{TM} \end{bmatrix} = \mathrm{FMT} \begin{bmatrix} A_x(x,y) \\ A_y(x,y) \end{bmatrix} = \begin{bmatrix} \beta_y & -\beta_x \\ \beta_x & \beta_y \end{bmatrix} \mathrm{FFT}_{2D} \begin{bmatrix} A_x(x,y) \\ A_y(x,y) \end{bmatrix}$$

Using FMT / FMT^{-1} for passing characteristic matrix from the spatial domain to the modal domain.

$$\left[FMT \begin{bmatrix} A_{1x} \\ A_{1y} \\ A_{2x} \\ A_{2y} \end{bmatrix} \right] = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \left[FMT^{-1} \begin{bmatrix} B_{1x} \\ B_{1y} \\ B_{2x} \\ B_{2y} \end{bmatrix} \right] \quad (8)$$

$$\left[FMT \begin{bmatrix} A_{1mn}^{TM} \\ A_{1mn}^{TM} \\ A_{2mn}^{TM} \\ A_{2mn}^{TM} \end{bmatrix} \right] = \begin{bmatrix} P\begin{bmatrix} 0 & 0 \\ 0 & -1 \end{bmatrix} & P\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \\ P\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} & P\begin{bmatrix} 0 & 0 \\ 0 & -1 \end{bmatrix} \end{bmatrix} \left[FMT^{-1} \begin{bmatrix} B_{1x} \\ B_{1y} \\ B_{2x} \\ B_{2y} \end{bmatrix} \right] \quad (9)$$

$$\left[\begin{bmatrix} A_{1mn}^{TE} \\ A_{1mn}^{TM} \\ A_{2mn}^{TE} \\ A_{2mn}^{TM} \end{bmatrix} \right] = \begin{bmatrix} P\begin{bmatrix} 0 & 0 \\ 0 & -1 \end{bmatrix} P^{-1} & P\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} P^{-1} \\ P\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} P^{-1} & P\begin{bmatrix} 0 & 0 \\ 0 & -1 \end{bmatrix} P^{-1} \end{bmatrix} \left[\begin{bmatrix} B_{1mn}^{TE} \\ B_{1mn}^{TM} \\ B_{2mn}^{TE} \\ B_{2mn}^{TM} \end{bmatrix} \right] \quad (10)$$

Combining the equations we determine characteristic matrix of the modal domain for the polarizer *OX*.

$$\left[\begin{bmatrix} A_{1mn}^{TE} \\ A_{1mn}^{TM} \\ A_{2mn}^{TE} \\ A_{2mn}^{TM} \end{bmatrix} \right] = \begin{bmatrix} \beta_x^2 & \beta_x \beta_y & \beta_y^2 & -\beta_x \beta_y \\ -\beta_x \beta_y & -\beta_y & \beta_x \beta_y & -\beta_y^2 \\ \beta_y^2 & \beta_x \beta_y & \beta_x & \beta_x \beta_y \\ \beta_x \beta_y & -\beta_x^2 & -\beta_x \beta_y & -\beta_y^2 \end{bmatrix} \left[\begin{bmatrix} B_{1mn}^{TE} \\ B_{1mn}^{TM} \\ B_{2mn}^{TE} \\ B_{2mn}^{TM} \end{bmatrix} \right] \quad (11)$$

The same for characteristic matrix of the modal domain for the polarizer *OY*

$$\left[\begin{bmatrix} A_{1mn}^{TE} \\ A_{1mn}^{TM} \\ A_{2mn}^{TE} \\ A_{2mn}^{TM} \end{bmatrix} \right] = \begin{bmatrix} \beta_y^2 & \beta_x \beta_y & \beta_y \beta_y & -\beta_x \beta_y \\ -\beta_x \beta_y & \beta_x^2 & \beta_x^2 & -\beta_x^2 \\ \beta_x \beta_y & \beta_x \beta_y & -\beta_y^2 & \beta_x \beta_y \\ \beta_x^2 & -\beta_x \beta_y & -\beta_x \beta_y & -\beta_x \beta_y \end{bmatrix} \left[\begin{bmatrix} B_{1mn}^{TE} \\ B_{1mn}^{TM} \\ B_{2mn}^{TE} \\ B_{2mn}^{TM} \end{bmatrix} \right] \quad (12)$$

Where $P = \begin{bmatrix} \beta_y & -\beta_x \\ \beta_x & \beta_y \end{bmatrix}$ and $\begin{bmatrix} \beta_x \\ \beta_y \end{bmatrix} = \frac{\beta}{\sqrt{ab}} \begin{bmatrix} N_x \\ N_y \end{bmatrix}$

$$\beta = \frac{1}{\sqrt{(\frac{m}{A} + \frac{p}{a})^2 + (\frac{n}{B} + \frac{q}{b})^2}}$$

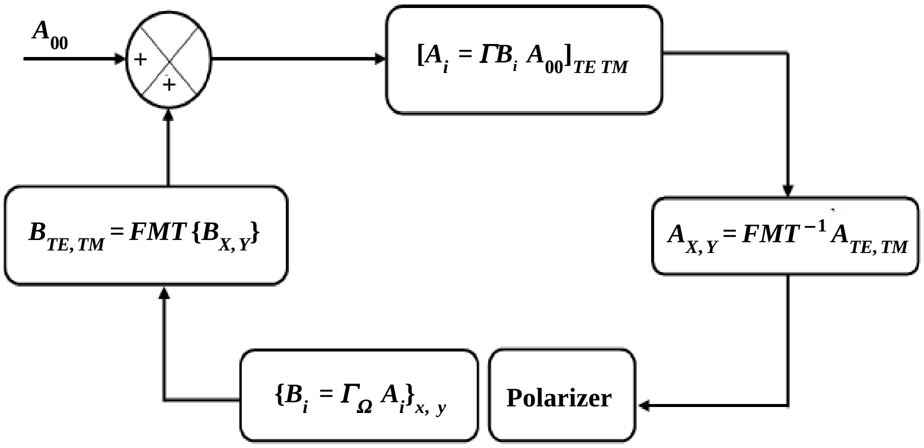

Figure 5. Flow chart summarizing the iterative method with polarizer

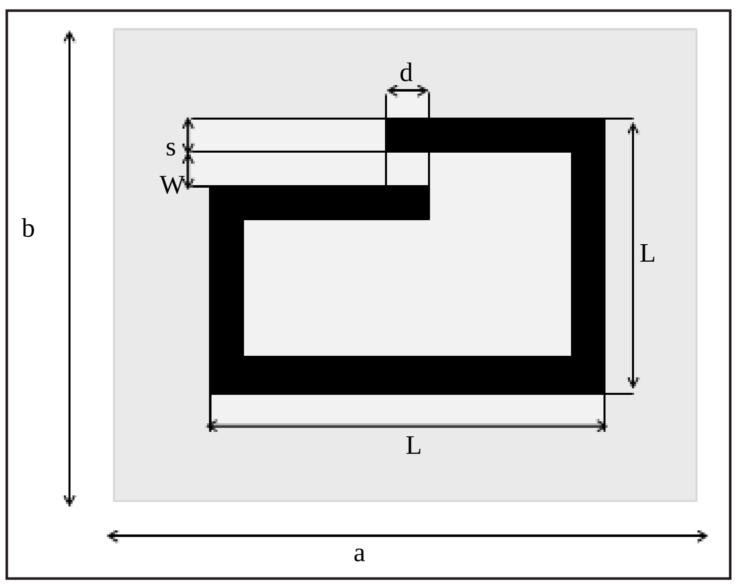

Figure 6. FSS unit cell geometry and dimensions

4. Application

We study the structure in Figure 5 presented by reference [15] which made measures and used iterative method for the simulation in which polarization is unique (polarization following (xo) or (oy)). In this work, we use a normally incident plane wave which is doubly polarized the required polarizer will fulfilled by a default polarizer.The results are WCIP botanies as the interface of the quasi-square open metallic ring FSS unit cell is meshed with a grid of 60 × 60 pixels, and the iterative process is stopped Effective 200 iterations.

FSSs of arrays with 10 ×10 unit cells the dimensions are a = 20 mm, L =10 mm, and w = s = 2 mm. d = 2mm,The quasi-square metallic rings of the FSS are made of copper and etched on a fiberglass (FR 4) substrate1 mm thick with a dielectric constant of 4 using printed circuit board (PCB) technology.

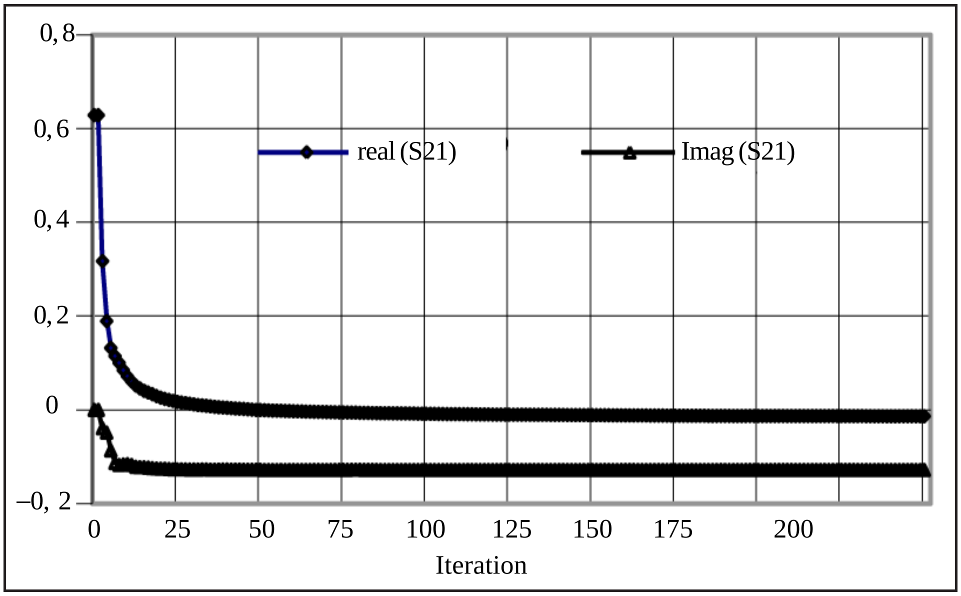

Figure 7. Real and imagine |S21| versus number of iteration in 11 GHz

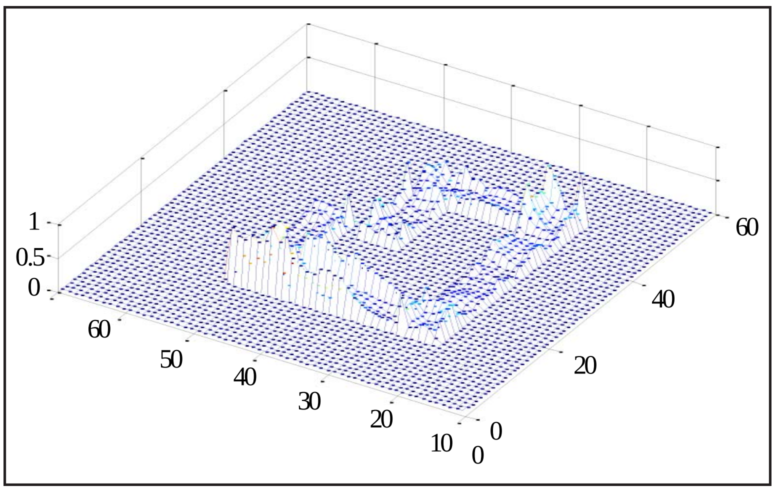

Figure 8. Surface current density | $\boldsymbol{J}_y$ | in 8 GHz (A/m)

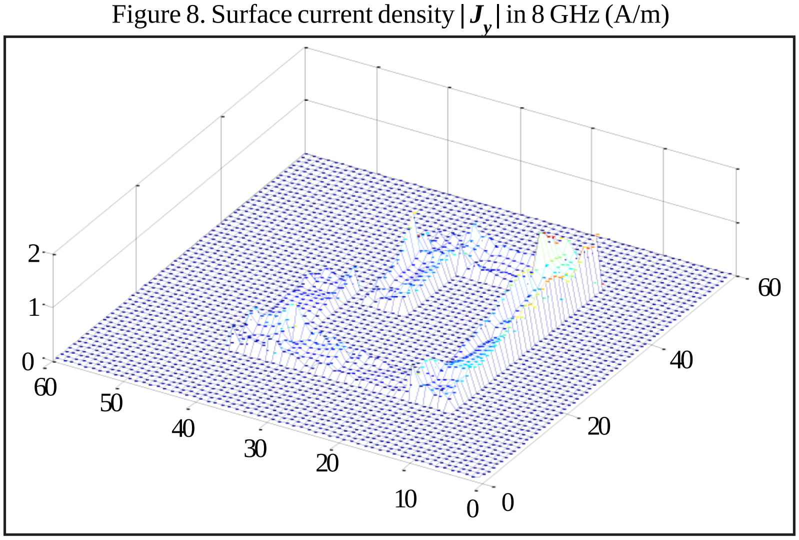

Figure 9. Surface current density | $\boldsymbol{J}_y$ | in 8 GHz (A/m)

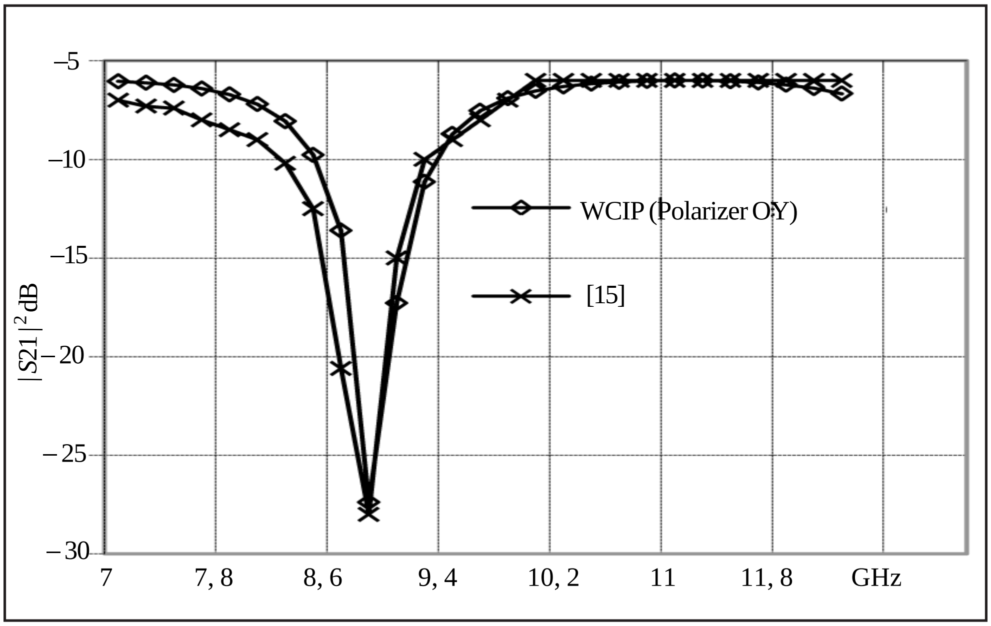

Figure 10. Transmission power versus frequency (Polarizer oy)

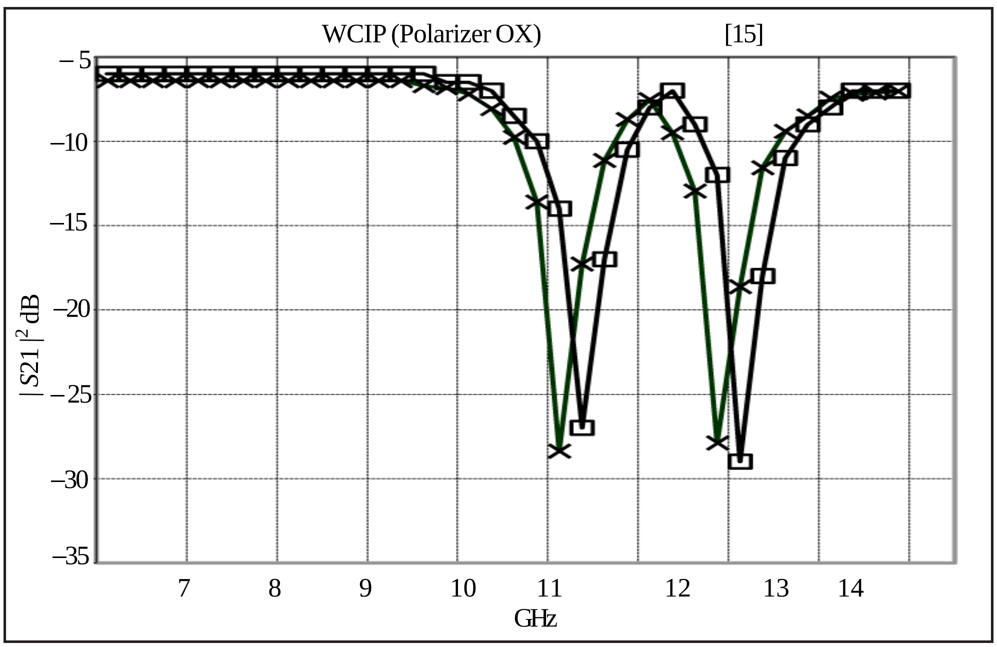

Figure 11. Transmission power versus frequency (Polarizer OX)

5. Conclusion

In this paper, a reformulation of the Wave Concept Iterative Method is reformulated to integrated numerical polarizer, the advantage the convergence of this approach concerning the polarizer allow to eliminate the unwanted wave with an efficient manner which allows to obtain the same result only with 200 iterations rather than convergence which was about 600 iterations.

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