Proceedings of Engineering & Technology (PET)
pp.191-197

Analysis of concentric rectangular metallic rings FSS characterized by band enhancement and resonant frequencies tuning using WCIP method

Manel AOUISSI
University of Batna/Department of electronics, Batna, Algeria
LMSE laboratory, El Anasser, Bordj Bou-Arréridj/
Algeria
§Correspondence author: Email: aouissimnl@gmail.com

Abstract:

In this work we present a characterization of a frequency selective surface based on concentric rectangular metallic rings. The aim of this study is to end with an FSS structure allowing band enhancement and resonant frequencies tuning.

The WCIP method is applied to the analysis of FSS based on concentric square rings FSS. The principle of the WCIP method is to connect between the incident waves and the waves reflected in the mediums around discontinuities by expressing the reflection in the modal domain and the diffraction in the spatial domain. The transition between these two domains is achieved through the use of a Fast Modal Transformation FMT and its reverse transformation FMT^{-1}. The iterative process is stopped once the convergence of the physical parameters is observed.

The presence of two concentric metallic rings provides two stop bands at resonant frequencies adjusted by the circumference length of each ring. Another way of tuning independently the FSS resonant frequencies is observed when a gap is inserted in each square ring. The variation in the gaps dimensions is inversely proportional to the corresponding resonant frequency of the FSS.

The obtained WCIP results are the transmission coefficient, the current density, the electric field and the input impedance. The WCIP results are compared to the literature results and a good agreement is observed.

Keywords— frequency selective surfaces (FSS), wave concept iterative procedure (WCIP), Fast modal transform, periodic walls .

I. INTRODUCTION

Frequency selective surface (FSS) structures can be used in radar satellite, microwave ovens, optical communication, radio astronomy, amateur radio, radar, Satellite Communication and mobile communication. For the analysis of the FSS problem was carried out using many methods. Such as method of moments and method of the finite element or. All require an important computing time and are limited in their applications.

To avoid this problem, we analyze a FSS structure by the iterative method WCIP (wave concept iterative procedure). Based on the concept of wave will be presented. It allows the resolution of electromagnetic problem of diffraction and the analysis of the planar circuits of arbitrary form multi-layer dielectric deposited on dielectric layers isotropic / anisotropic. [1]

The principle of this method simple and effective is to connect between the incidental waves and the waves reflected in the mediums around discontinuities by expressing the reflection in the modal domain and diffraction in the Spatial Domain. The transition between two domains is done through a Fast Modal Transformation FMT and its reverse transformation FMT^{-1}. The iterative process is stopped with convergence of the physical parameters is observed. The originality of this method is double. Its facility of application because of the absence of functions of test and its fast computing time

In this context we develop the Iterative Method for the study of the electromagnetic coupling between two concentric rectangular metallic rings of the FSS. Another way will discuss how the tuning each resonant frequencies independently.

The characterization the structure provides two stop bands at resonant frequencies adjusted by the circumference length of the FSS and by electromagnetic coupling between the lengths. For the corroboration of the observations the WCIP results are validated with literature results and a good agreement is observed.

II. THEORY: WCIP FORMULATION

The general Frequency Selective Surface structure (FSS) is depicted in Figure 1. The circuit interface is constituted of two sub domains: metal and dielectric. It is deposed on homogeneous dielectric substrate with thickness h and permittivity εr [2].
We consider the printed circuit,

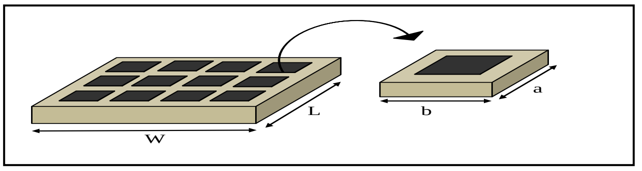


Fig. 1. Periodic structure (FSS) with unit cell.

WCIP method is based on the full wave transverse wave formulation and the on collection of information at the interfaces. A multiple reflection procedure is started using initial conditions and stopped once convergence which is achieved. Two related operators incidental waves and

ISSN: 2356-5608

scattered waves in the spatial domain and in the spectral domain governs the iterative procedure. They are: the scatting operator SΩ and the reflection Γ[3].

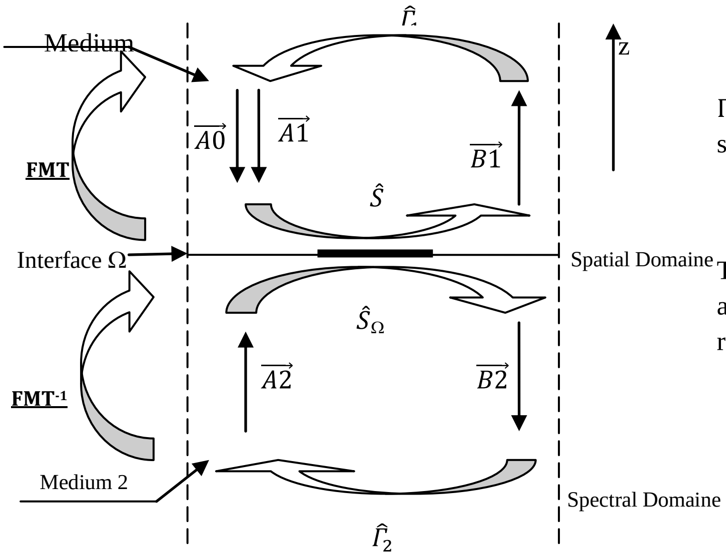


Fig. 2. Iterative process

Introduced to express the boundary conditions on the interface Ω (Figure 2).

The incident waves A_i and the scattered waves B_i are calculated from the tangential electric and magnetic fields E_i and H_i as [4]

$$\vec{A}_i = \frac{1}{2\sqrt{Z_{0i}}}\left(\vec{E}_{Ti} + Z_{0i}\vec{J}_i\right) \quad (1)$$

$$\vec{B}_i = \frac{1}{2\sqrt{Z_{0i}}}\left(\vec{E}_{Ti} - Z_{0i}\vec{J}_i\right) \quad (2)$$

Where i indicates the medium 1or2 corresponding to a given interface **Ω**. Z_{0i} is the characteristic impedance of the same medium i and J_i being the surface current density vector given as:

$$\vec{J}_i = \vec{H}_{Ti} \wedge \vec{n} \quad (3)$$

With n being the outward vector normal to the interface. Thus [5], the tangential electric and magnetic fields can be calculated from:

$$E_i = \sqrt{Z_{0i}}(A_i + B_i) \quad (4)$$

$$J_i = (1/\sqrt{Z_{0i}})(A_i - B_i) \quad (5)$$

The scattered waves are related to the incident waves as:

$$\begin{pmatrix} B_1 \\ B_2 \end{pmatrix} = \widehat{S_\Omega}\begin{pmatrix} A_1 \\ A_2 \end{pmatrix} \quad (6)$$

S_Ω is a scattering operator defines in the spatial and it accounts for the boundary conditions. The scattered waves B_i will be reflecting to generate the incident waves for the next iteration but after adding the incident source waves A_0

$$\begin{pmatrix} A_1 \\ A_2 \end{pmatrix} = \Gamma_i\begin{pmatrix} B_1 \\ B_2 \end{pmatrix} + \begin{pmatrix} A_0 \\ 0 \end{pmatrix} \quad (7)$$

Γ_i Being the reflection operator and it is defined in the spectral domain.

A. Scattering operator $\widehat{S_\Omega}$ Determination

Two domains characterizing the interface Ω of a loaded FSS are: the dielectric domain and the metal domain. They can be represented using Heaviside unit steps as:

$$H_D = \begin{cases} 1 & on\ the\ dielectric \\ 0 & otherwise \end{cases} \quad (8)$$

$$H_M = \begin{cases} 1 & on\ the\ metal \\ 0 & otherwise \end{cases} \quad (9)$$

The metal domain scattering operator S_M is given

$$\left[\widehat{S_M}\right] = \begin{vmatrix} -H_M & 0 \\ 0 & -H_M \end{vmatrix} \quad (10)$$

Thus the dielectric domain scattering operator S_D can be given terms of the dielectric generator H_D as

$$\left[\widehat{\boldsymbol{S_D}}\right] = \begin{vmatrix} \frac{1-N^2}{1+N^2}H_D & \frac{2N}{1+N^2}H_D \\ \frac{2N}{1+N^2}H_D & -\frac{1-N^2}{1+N^2}H_D \end{vmatrix} \quad (11)$$

Then the total scattering operator SΩ is given as

$$S_\Omega = S_D + S_M \quad (12)$$

B. Reflection Operator Determination

The reflection coefficient in the spectral domain is given by

$$\begin{cases} \Gamma i_{mn}^{TE} = \frac{1-Z_{0i}\ Yi_{mn}^{TE}}{1+Z_{0i}\ Yi_{mn}^{TE}} \\ \Gamma i_{mn}^{TM} = \frac{1-Z_{0i}\ Yi_{mn}^{TM}}{1+Z_{0i}\ Yi_{mn}^{TM}} \end{cases} \quad (13)$$

W

here Y is the admittance of the mn mode at the medium i and α stands for the mode TE or TM, when no closing ends exist y can be calculated by

$$Yi_{mn}^{TM} = \frac{j\omega\varepsilon_0\varepsilon_{ri}}{\gamma_{mn}^{(i)}} \quad (14)$$

$$Yi_{mn}^{TE} = \frac{\gamma_{mn}^{(i)}}{j\omega\mu_0} \quad (15)$$

$\gamma_{mn}^{(i)}$ Being the propagation constant of the medium i it is given by

$$\gamma_{mn}^{(i)} = \sqrt{(\frac{2\pi m}{a})^2 + (\frac{2\pi n}{b})^2 - k_0^2 \varepsilon_{ri}} \qquad (16)$$

ε_{ri} is permittivity of the medium i and μ_0 is permeability of the vacuum.

C. *Fast Modal Transform FMT*

The modes are decoupled in the domain of mode where each mode is characterized by its own reflection coefficient, the need to pass to spectral domain is necessary. To enable this operation, a transform known as the Fast Modal Transform FMT defined and to go back to spatial domain, FMT^{-1} is will be used.

The FMT/FMT^{-1} pair permits to go from spatial domain to the spectral domain and back to the spatial domain; it is summarized in the following two equations

$$FMT\left(\begin{vmatrix} E_x(x,y) \\ E_y(x,y) \end{vmatrix}\right) = \begin{vmatrix} B_{mn}^{TE} \\ B_{mn}^{TE} \end{vmatrix} = \begin{vmatrix} K_{ymn} & -K_{xmn} \\ K_{xmn} & K_{ymn} \end{vmatrix} FFT2\left(\begin{vmatrix} E_x(x,y) \\ E_y(x,y) \end{vmatrix}\right) \qquad (17)$$

$$FMT^{-1}\begin{vmatrix} B_{mn}^{TE} \\ B_{mn}^{TE} \end{vmatrix} = \left(\begin{vmatrix} E_x(x,y) \\ E_y(x,y) \end{vmatrix}\right) = FFT2\left(\begin{vmatrix} K_{ymn} & K_{xmn} \\ -K_{xmn} & K_{ymn} \end{vmatrix}\begin{vmatrix} E_x(x,y) \\ E_y(x,y) \end{vmatrix}\right) \qquad (18)$$

III. SIMULATION RESULTS

The WCIP method is applied to the concentric rectangular metallic rings FSS we consider at first the structure of Figure 3. The interface of the FSS unit cell is divided into 60x60 pixels with dimensions of thickness h = 0.021mm, ε_r=3, and the iterative procedure is stopped after 300 iteration. The presence of two concentric metallic rings provides two stop bands

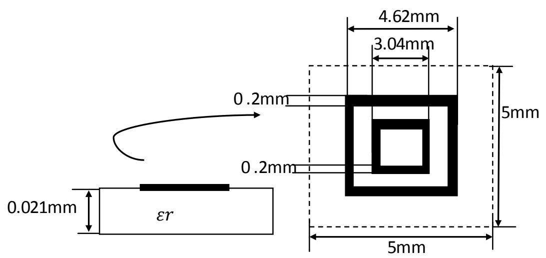


Fig. 3. Geometry of unit cell

Depicted in Figures 4 is transmitted power versus frequency for the two concentric metallic. The results demonstrated a very good agreement between literature and WCIP simulations, illustrating the accuracy of the proposed WCIP method.

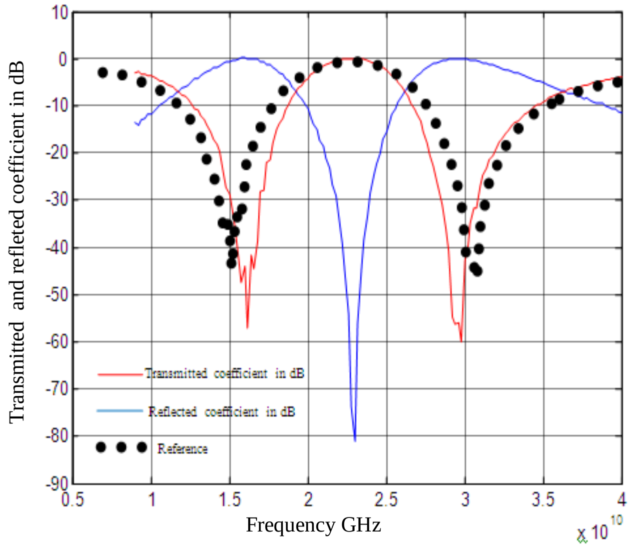


Fig. 4. Variation of the Transmitted power versus frequency.

Figures 6 and figure 8 show the obtained transmission coefficient using WCIP method is characterized by dual resonances frequencies adjusted independently is observed when a gap is inserted in each square ring. The variation in the gaps dimensions is inversely proportional to the corresponding resonant frequency of the FSS.

The transmission coefficient is versus of the operating frequency. The WCIP results are successfully

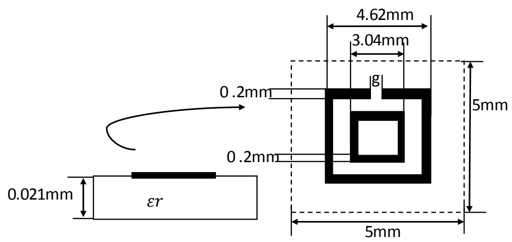


Fig. 5. Geometry of unit cell

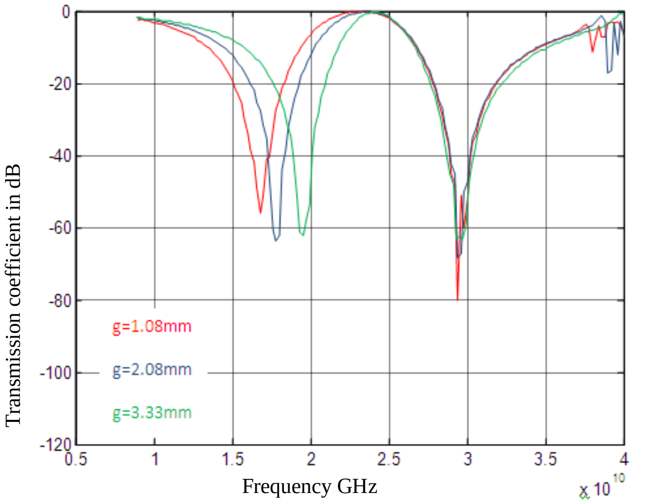


Fig. 6. Variation of the transmission power and the reflected power versus frequency.

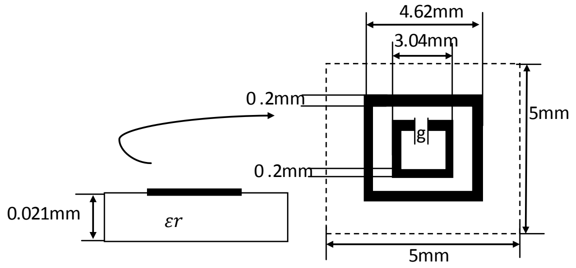


Fig. 7. Geometry of unit cell

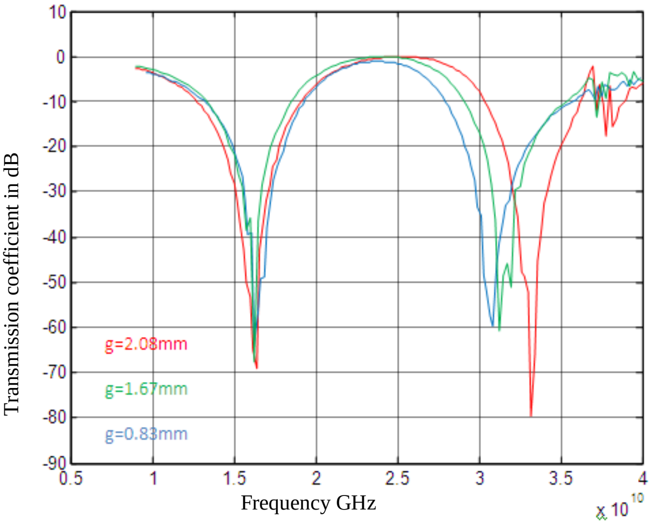


Fig. 8. Variation of the transmission power versus frequency.

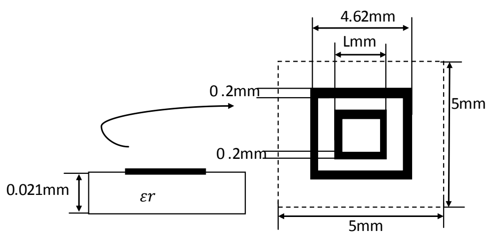


Fig. 9. Geometry of unit cell

Figure 10 represents the transmitted power versus frequency for a FSS is caractrised of resonant frequencies adjusted by the circumference length of concentric ring.

An increase in the dimension of the length of the concentric metallic ring observed the displacement of the single resonnance. This offers bandwidth and enhanced band. The WCIP results are in a good agreement.

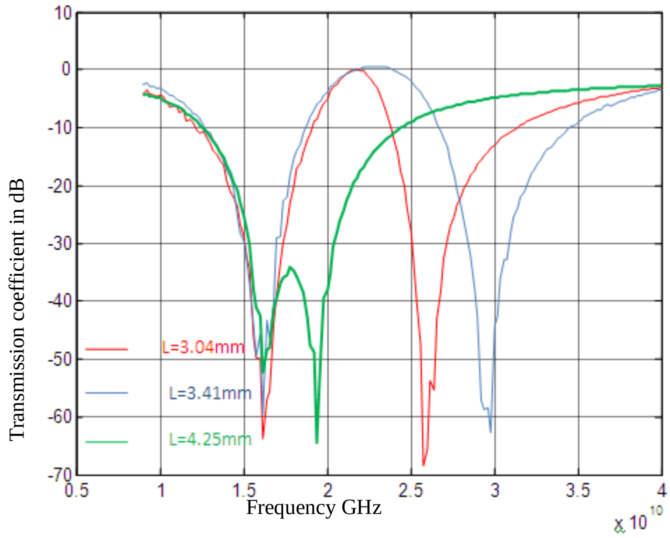
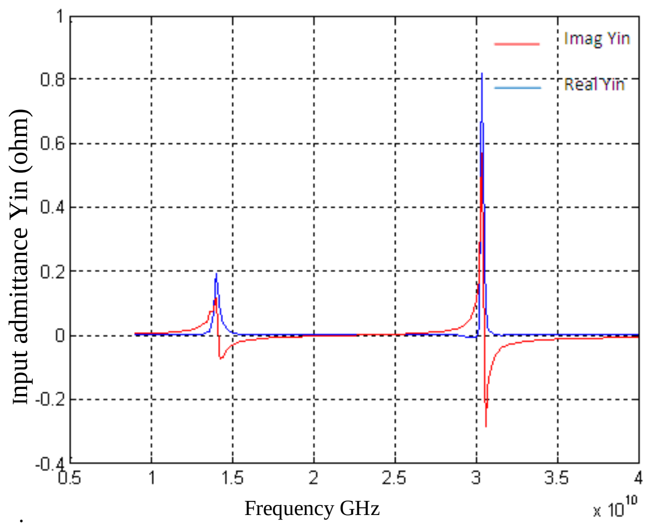


Fig. 10. Variation of the transmission power versus frequency.

Figure 11 shows the variation of the input admittance of the structure of figure 3 as a function of the operating frequency.



.

Fig. 11. Variation of the transmission power and the reflected power versus frequency.

A. *Study of the convergence*

The curve in Figure 12 shows that the convergence of the admittance (Yin) is reached fairly quickly, in less than 200 iterations.

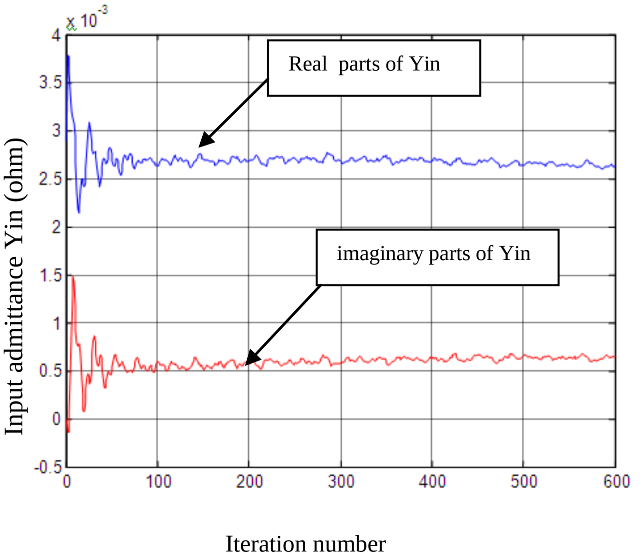


Fig. 12. Convergence of admittance (Yin) versus number of iterations

The 3D representations the distribution of electric fields in Figure 13 and figure 15, current densities in Figure 14 and figure 16 in the interface plane with concentric rectangular metallic rings FSS. Those show that the boundary conditions are satisfied in all sub-domains, the sum of current densities is zero on the dielectric and electric fields is concentrated on the edges of the metal

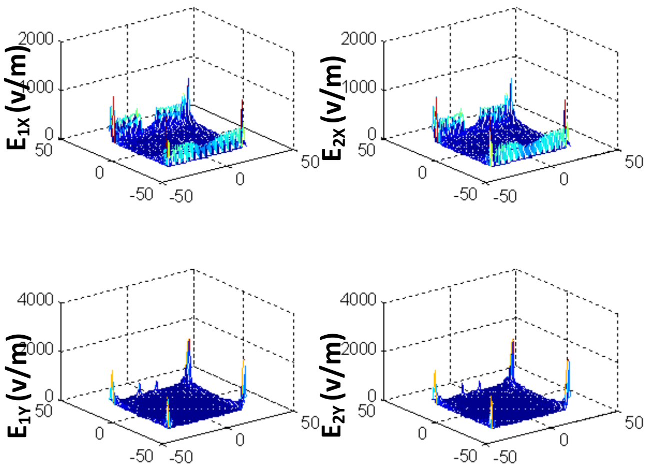


Fig.13. Distribution of the electric field | E | V/m in terms of the interface at 15GHz

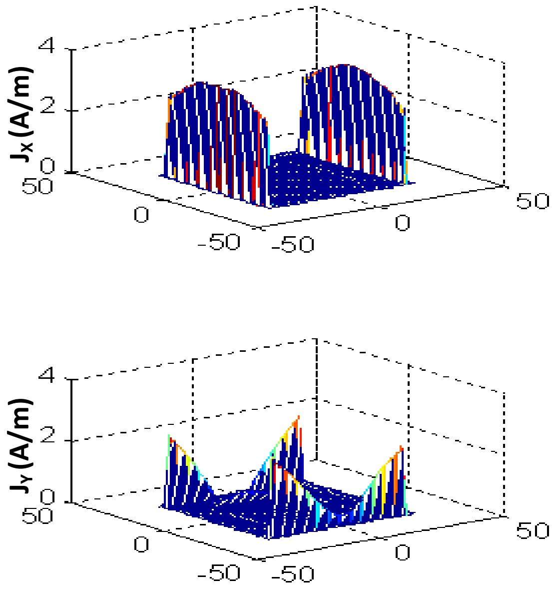


Fig.14. Distribution of the electric current density | J | in Ampere/m in terms of the interface at 15GHz

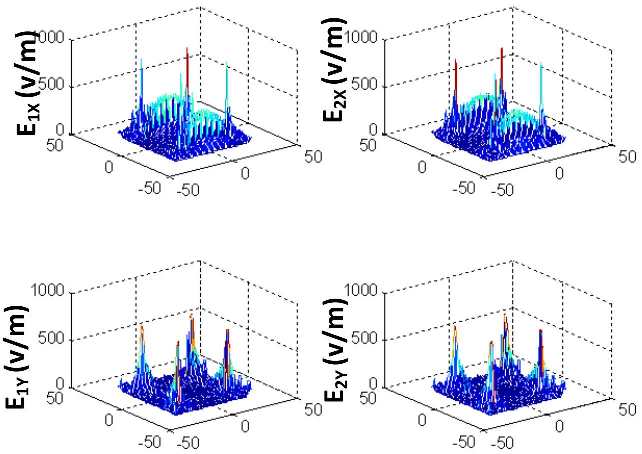


Fig.15. Distribution of the electric field | E | V/m in terms of the interface at 30GHz

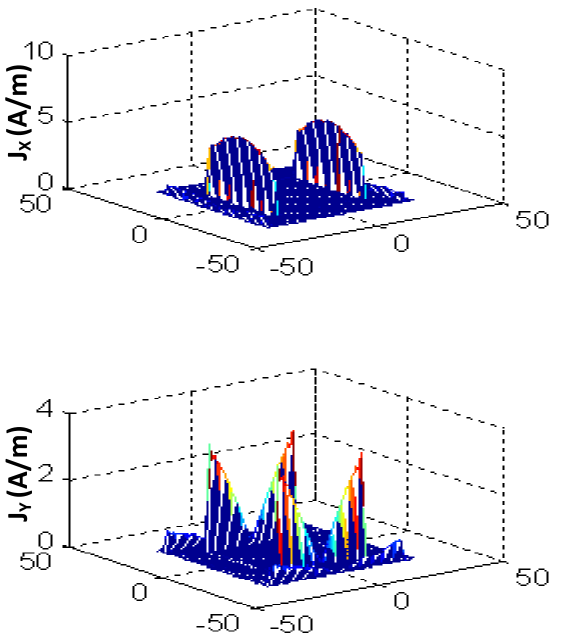


Fig.16. Distribution of the electric current density | J | in Ampere/m in terms of the interface at 30GHz

IV. CONCLUSION

This paper is present the analysis of a frequency selective surface based on two concentric metallic rings provides two stop bands at resonant frequencies adjusted by the iterative method WCIP (wave concept iterative procedure). Is used to analyze the different the variation in the gaps dimensions is inversely proportional to the corresponding resonant frequency of the FSS. Furthermore, this iterative method provides faster convergence as compared to integral methods, such as the method of moments, and the finite element method, because the large amount of memory space

In this paper, we successfully demonstrate an efficient method for the analysis of concentric metallic rings was presented. The results are the transmission coefficient, the current density, the electric field and the Convergence of admittance (Yin) versus number of iterations.

The results demonstrated a very good agreement between literature and WCIP simulations, illustrating the accuracy of the proposed WCIP method.

References

[1] M. Titaouine, A. Gomes Neto, H. Baudrand and F. Djahli, "Analysis of Frequency Selective Surface on Isotropic/Anisotropic Layers Using WCIP Method", ETRI journal, Vol. 29, No. 1, February 2007, pp. 36-44.

[2] D. M. Pozar, Microwave Engineering, John Wiley and Sons, Inc., 1998.

[3] M. Titaouine, A. Gomes Neto, H. Baudrand and F. Djahli "Determination of Metallic Ring FSS Scattering Characteristics Using WCIP Method" Microwave and Optical Technology Letters / Vol. 50. No, 5,May 2008

[4] M.titaouine,N.Raveau,A.Gomes Neto and H.Baudrand "Dual-Baand and Enhanced Band FSS Charactrization Using WCIP Method" Vol. 52, No, 4,april 2010

[5] C. Balanis, Advanced Engineering Electromagnetic, John Wiley and Sons, Inc., 1989.