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The EBG Structure With a Forest Carbon Nanotubes Analysed By Iterative Method WCIP

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Abstract-**This study is dedicated to analysis of electromagnetic bandgap circuits based on the carbon nanotubes often called EBG structure. The WCIP iterative method based on the concept of wave introduces a new process related to incident wave and the reflected wave by diffraction operators defined in the spectral and spatial domain.**

The method has the advantage of simplicity since it does not involve basic functions and neither matrix inversions, like other methods of calculation.

In this work, we used the WCIP method, to analysis a forest of carbon nanotubes to characterize the EBG structure that operates as a bandstop to remove unwanted electromagnetic waves in a certain frequency range.

***Keywords*— carbon nanotube, EBG Structure, WCIP method**

I. INTRODUCTION

In 1991, the researcher Iijma discovered carbon nanotubes (CNTs) that have since been the subject of an intensive research [1]. Seen their exceptional intrinsic properties, they become very interesting in many fields of science and technology, especially in the electronic domain.

Their remarkable structure, their electrical and mechanical properties have attracted much interest in their application for nanoelectronics components,their one-dimensional (1D) character and the nature of their carbon atoms makes them very sensitive to the charge, chemical properties allow advanced chemical functionalization, and their mechanical properties make them compatible with most substrates, for all these qualitities , here comes the iterative method WCIP for modeling of a forest of carbon nanotubes applied as viaholes for micrometric structure.

II. STUDY OF THE CARBON NANOTUBES IN THE TERAHERTZ FREQUENCIES

Carbon nanotubes (CNTs) have been of great interest for use as electronic devices such as field emission sources [2], transistors [3] and nanotransmission lines [4] due to their conductivity metal and exceptional mobility.

Since the discovery of the antenna made of carbon nanotubes in 2004 [5], the interest to nanoantennes, has increased steadily Furthermore, vertically aligned carbon nanotubes are extremely attractive for applications in nano-antenna THz and other nanoelectronic devices. Implementation of THz devices based on carbon nanotubes would also lay the basis for a super-fast quantum electronics.

The electromagnetic bandgap structures have attracted much attention in recent years for promising application in the fields of microelectronics and communications. The main characteristic of EBG structures is to act as a device band stop to remove undesirable electromagnetic waves in a certain frequency range.

In this context, we have chosen to work principally on an electromagnetic bandgap structure formed with metal holes, which are carbon nanotubes métallique ''chair''.

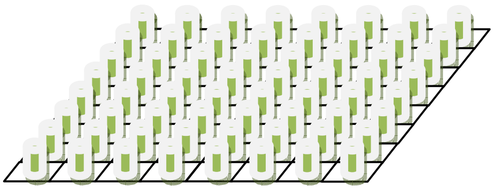


Fig.1 A periodic structure of carbon nanotube in Thz application

A. Geometric characteristics:

The graphene sheet is a tructure consisting of carbon atoms arranged in a hexagonal mesh, as the winding of this sheet, the carbon nanotube thus produced single wall is a cylinder that its structure is determined by the pair of integers (n, m) defining features a characteristic vector $\overrightarrow{C_h}$ called chiral vector, divided into two unit vectors of the crystal system $\overrightarrow{a_1}$ *et* $\overrightarrow{a_2}$ separated by an angle of 60°.

$$\overrightarrow{C_h} = n\overrightarrow{a_1} + m\overrightarrow{a_2} \quad avec \quad 0 \leq \ m \leq n \tag{1}$$

The carbon nanotube may be also defined in terms of diameter d and angle θ using chiral indices Hamada, by the following equations [6], [7]:

$$d_t = \frac{C_h}{\pi} = a_{c-c}\frac{\sqrt{3}\sqrt{(n^2+nm+m^2)}}{\pi} \tag{2}$$

$$\theta = arctan\left(\frac{m\sqrt{3}}{(m+2n)}\right) \tag{3}$$

The distance between two atoms is a_{c-c}=1.42A°. Like the carbon nanotubes are cylindrical their modeling is an inductance L given by the following formula [8] Fig-2:

$$L = \frac{\mu_0}{2\pi}\left[h.\ln\left(\frac{h+\sqrt{r^2+h^2}}{r}\right) + \frac{3}{2}\left(r - \sqrt{r^2+h^2}\right)\right] \tag{4}$$

r:radius of carbon nanotube
h:length of carbon nanotube

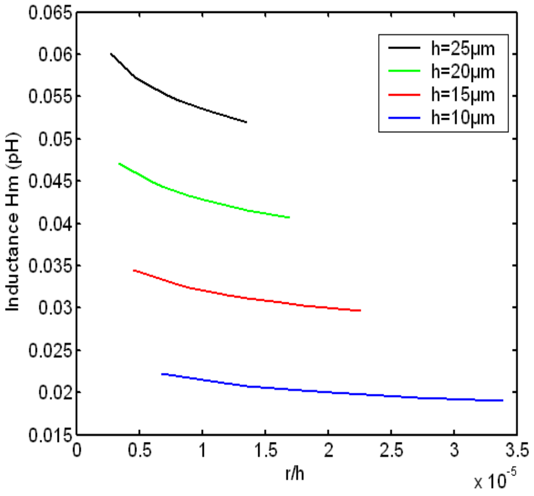


Fig.2 The inductance depending on the length of the metallic nanotube

B. Theory of iterative method

The iterative method denoted "WCIP" (Wave Concept Iterative Process) is an integral method based on the concept of wave for solving electromagnetic scattering problems and analysis of planar circuits.

It appeals to the Fast Fourier Transform Mode (FMT). This method depends on the manipulation of incident and reflected waves instead of electromagnetic field [9], [10].

Thus, the method defines two operators, in space domain and in the spectral domain.

WCIP method uses easy equations to solve with the integral method.

I. ANALYSIS OF CARBON NANOTUBES STRUCTURE WITH THE WCIP METHOD

The Electromagnetic Bandgap Structures (EBG) are periodic cells that have evolved primarily in the optical domain by the name of photonic bandgap structures (PBG) in the late 1980 [11], [12].

These periodic structures have very interesting features that make them very promising candidates for a number of applications [13] As the propagation of electromagnetic waves in some frequency bands and prohibit them in other bands known as the bandgap.

This structure can be represented by two unit cells one with metallic carbon nanotube like via hole and the other empty.

The concept of wave is introduced by writing the electric field E and current density J in the expression of the incident and reflected wave that leads to the following equations:

$$A = \frac{1}{2\sqrt{Z_0}}(E + Z_0 J) \tag{5}$$

$$B = \frac{1}{2\sqrt{Z_0}}(E - Z_0 J) \tag{6}$$

$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$ is the characteristic impedance of vacuum

The iterative process is to establish a recurrent relationship between incident wave (A) and reflected wave (B) .

By using (5) and (6), the integral equation $\vec{J} = \hat{Y}\vec{E}$ can be rewritten in the spectral domain by:

$$\tilde{B}_{p,q} = \Gamma_{(p,q)}\tilde{A}_{(p,q)} \tag{7}$$

Where $\Gamma_{(p,q)}$ is the diffraction operator in the spectral domain.

Boundary conditions and continuity of electromagnetic fields in each sub-space fields of S are expressed by an equation inside:

$$A_{(i,j)} = S_{(i,j)} B_{(i,j)} + A_{0(i,j)} \tag{8}$$

$$S_{(i,j)} = \frac{Z_{CNT} + Z_O}{Z_{CNT} - Z_O} \tag{9}$$

The source term $A_{0(i,j)}$ is added to specify which via hole is excited, S is the spatial diffraction operator describing the boundary conditions on the surface of discontinuity Ω.

This interface (Ω) is divided into cells and can include sub-domains: dielectric (D), metal (M) and source (S).

Z_{CNT} is the impedance of carbon nanotubes depending on the inductance L

$$(\Delta_T + k_0^2)E = jw\mu_0 J \tag{10}$$

J: Current density in the via hole centered
w: angular frequency.
$k_0 = W/c$: Wave number in vacuum.
c : celerity.

Δ_T : Laplace operator along x and y.
μ_0 : vacuum Permeability.

By solving equation (8) it can have an expression of the electric field$E$.

The unit cell of the structure described above is isolated, bounded by periodic walls and has a carbon nanotube at its center.

A scalar function $F_{\alpha\beta pq}$ corresponding to the modes waveguide square periodic with dimensions dxd is envisaged.

$$F_{\alpha\beta pq}(x,y) = \frac{1}{D} e^{j(\alpha x+\beta y)} e^{\frac{j2\pi px}{D}} e^{\frac{j2\pi qy}{D}} \tag{11}$$

The boundary conditions on the holes are separately processed by means of the spatial operator defined above.

B. Results and Discussion: The indications concerning the structure studied are presented in fig-1.We have chosen to simulate in first place the structure formed by a minimum number of carbon nanotubes (NXN = 8X8).

The results coincide perfectly with those of other authors [14], we have not described these results in this paper.

Then We have worked with a structure presenting a large number of metallic carbon nanotubes, we took the number of CNT NXN=16X16,the diameter d=50 nm,the length h=18 µm and the other dimensions of structure are a=b=10µm.

We achieved our results for a frequency range that lies between the terahertz and near infrared.

In Figure-3 we got the response of a stopband filter which presents a resonance has 8.35Thz which provides a wavelength 35.96µm therefore λ / 2 = 17.92 microns which corresponds to the length of carbon nanotube.

The figure-4 shows the distribution of the current density and the electric field for different values of frequencies.

In Figure Fig-4 (a) we have the distribution of the current density and the electric field at frequency f = 8.3 THz represents the resonant frequency.

In Figure Fig-4 (b) and Fig-4 (c) we presented the distribution of current density and electric field in the frequency f = 16.5 Thz, which is none other than the anti-resonance and for f = 20Thz.

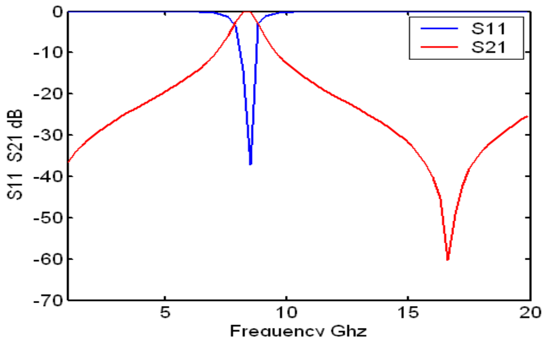
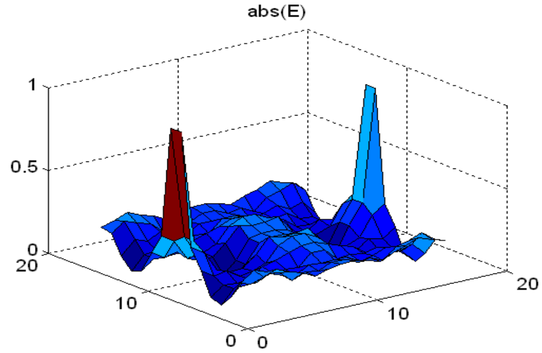


Fig.3 Scattering parameters S11 and S21



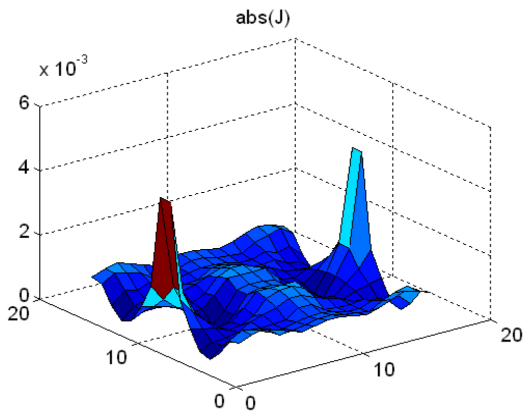


Fig-4(a)

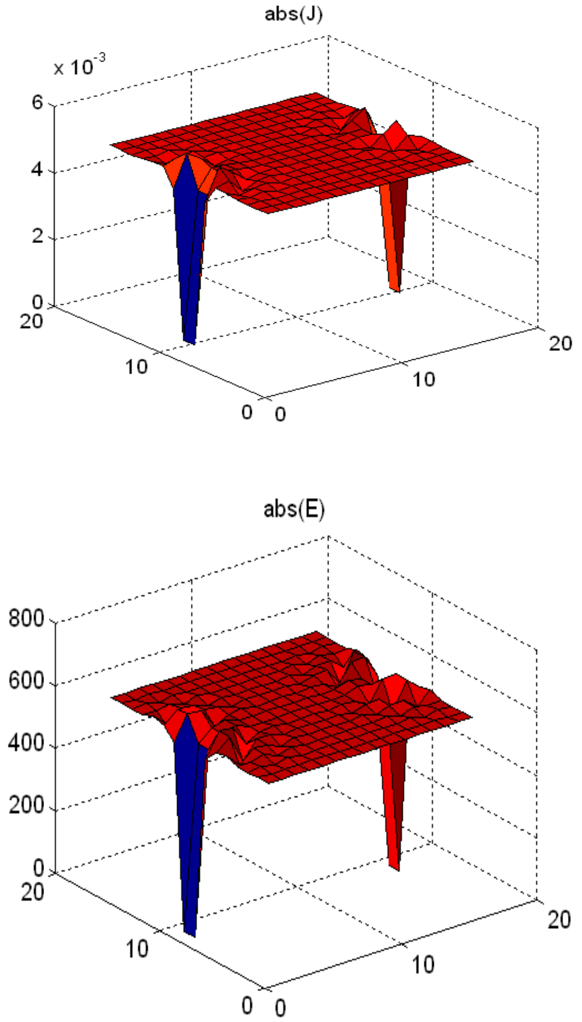


Fig-4(b)

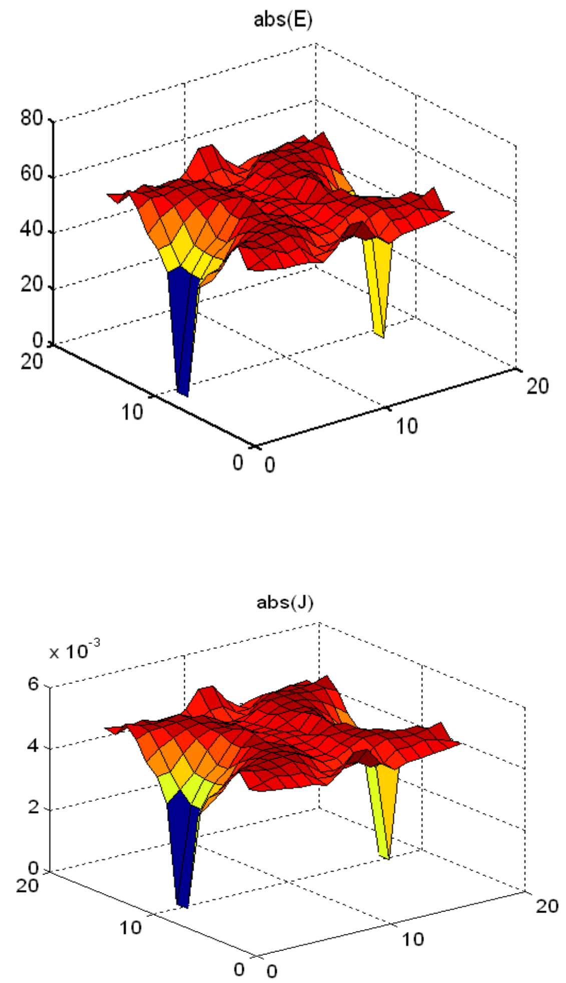


Fig-4 (c)

Fig.4 Current density and elictrical field distribution

IV CONCLUSION

In this article the EBG structure based on carbon nanotubes is characterized by an efficient numerical method based on wave concept iterative process (WCIP),mostly used for planar circuits. we showed that carbon nanotubes are the candidates promising for nanotransmission.

The simulation results obtained confirm that the parameters of the studied structure are filtering criteria in tera hertz frequencies and the carbon nanotubes can be useful for the realization of filters such as past band ,stop bands and many other applications in the domains of transmission.

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