DESIGN AN ARTIFICIAL MAGNETIC CONDUCTOR (AMC) UNIT CELL USING FREQUENCY SELECTIVE SURFACE (FSS)

تصميم وحدة خلية موصل مغناطيسي اصطناعي (FSS) باستخدام التردد الانتقائي للسطح

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Abstract:

One class of metamaterial types, artificial magnetic conductor unit cell is present.

The proposed unit cell is allocated to be as a backed to an antenna work at 2.45 GHz frequency which is used for WLAN and Bluetooth Application and based on frequency selective surface (FSS) structure.

The achieved results show that the proposed structure has a good reflection coefficient magnitude (in phase) (nearly zero) in the aimed frequency.

Keywords—*Metamaterial, artificial magnetic conductor(AMC), frequency selective surface(FSS).*

I. Introduction

Recently, Metamaterial has spawned a considerable research interest due to their unique properties that is not found in the nature. The term “metamaterial” had been originally employed to describe any artificial (engineered) structure possessing effective electromagnetic properties not encountered among natural materials [1].

One of the Metamaterial types which is concerned in this work is the artificial magnetic conductor (AMC). The AMC is an artificial

Material designed in a special manner to exhibit the perfect magnetic conductor behavior which is not existent in the nature. The attracted feature of AMC (in phase reflection) releases us from the condition of switching the antenna by (λ/4) from the substrate to obtain aimed results which make the overall size of the antenna is compact.

The Perfect Electric Conductor (PEC) exhibits 180° phase shift while Perfect Magnetic Conductor(PMC), which doesn't exist in the nature with a reflection phase of 0°. The reflection phase of AMC varies from -180° to +180° with frequency. When it is between -90 to +90 the image currents are more in phase than out of phase. It means that in a certain frequency band, AMC behave as PMC. This in phase reflection behavior enables low profile antenna design using AMC as ground plane [2].

On the other hand a frequency selective surface (FSS) is *a* spatial electromagnetic filter, which is defined as a one or two dimensional periodic array of patch elements or aperture elements etched on a dielectric substrate is used with ground plane to design AMC unit cell [3].

In this paper a Jerusalem Cross shape (JC) is used to design AMC unit cell structure (JC-AMC) that operate in 2.45 GHz frequency, a (JC-AMC) in[3] used with vacuum as a substrate and the resonant frequency was at 5.56GHz. and in [4] is used (ring + cross) structure to design AMC with paper substrate and the resonant frequency was at 5 GHz. The mathematical model analysis shows the calculation of the important parameters (fr, Zs, BW) in section III. following the algorithms were based in [5]. The simulation of the proposed structure is done by using computer simulation technology (CST). The achieved results are analyzed and discussed in section III.

II. THE MOTIVATION OF USE JC-AMC STRUCTURE INTEGRATED WITH AN ANTENNA.

a- obtaining an ultra low profile design by reduce the distance between the antenna and the ground plane(not need to the condition of > λ/4) as shown in the Figs. (1, 2, 3) [6]:

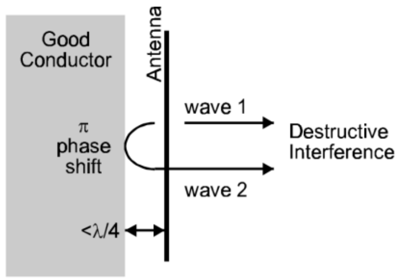

Fig. 1. An antenna lying flat against a ground plane

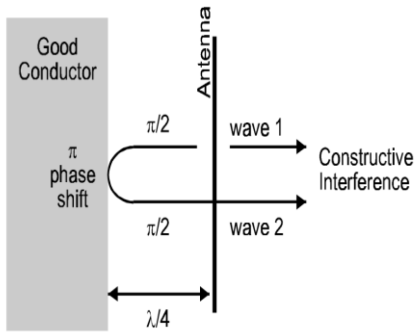

Fig. 2. An antenna separated by 1/4 wavelength from the ground plane

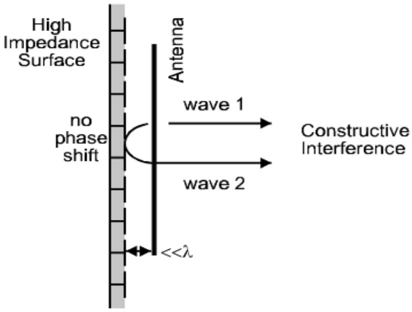

Fig. 3. A flush-mounted dipole on AMC ground plane

b- reducing the SAR value which it is the main consider for the antenna used near human body[4].

c- The AMC ground plane is utilized to eliminate the impedance mismatch and frequency shift caused by the human tissues proximity.

III. THE MODEL ANALYSIS AND THE SIMULATION OF THE PROPOSED STRUCTURE.

There are several types of FSS as shown in Fig. 4 which can be used to design AMC[3] :

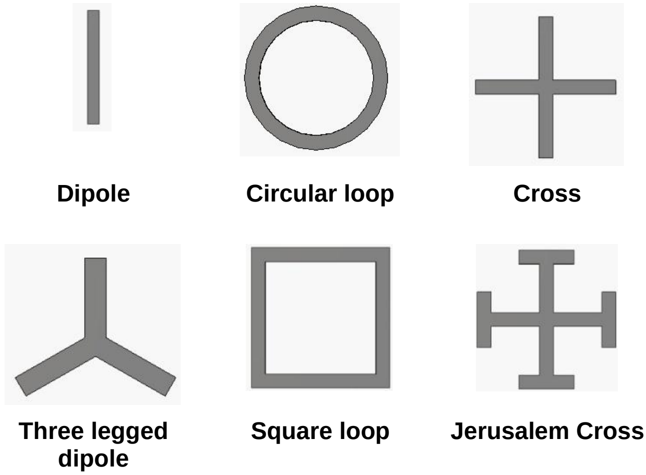

Fig. 4. Unit cells of FSS element geometries.

A. THE MODEL ANALYSIS:

The proposed structure and the equivalent circuit of the Jerusalem Cross shape (JC) based AMC is depicted in the Fig. 5 below:

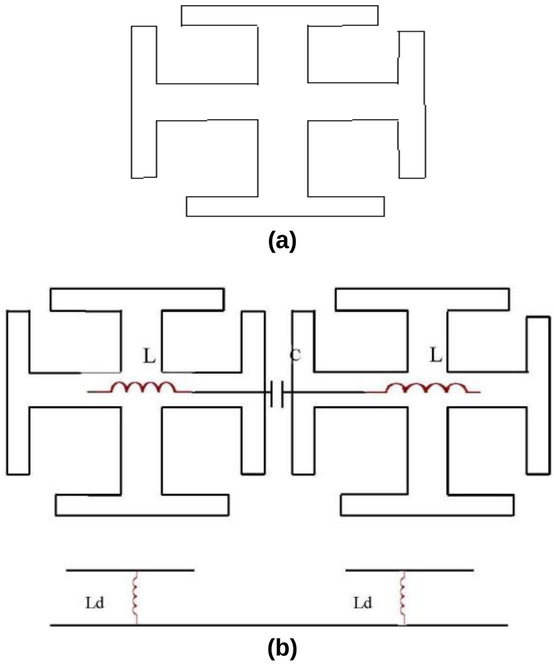

Fig. *5*. (a)the JC-AMC structure (b) the equivalent circuit of JC-AMC

The surface impedance is given as [5]:

$$Z_S = E_t / H_t \quad \text{---------------(1)}$$

$$Zs(\omega)=Zg \,//\, Zd=j\omega L_d \frac{1-W^2LgCg}{1-w^2(Lg+Ld)Cg} \quad \text{------------(2)}$$

where Zg is the FSS grid impedance, Zd is the impedance of the grounded dielectric slab and Lg, Ld, Cg are the grid inductance, dielectric slab inductance and grid capacitance, respectively.

The resonant frequency is:

$$f_r = \frac{1}{2\pi\sqrt{(Lg+Ld)Cg}} \quad \text{----------------(3)}$$

and the bandwidth is obtain as [6]:

$$BW = \frac{\pi}{8\eta}\sqrt{\frac{Ld+Lg}{Cg}}\; X \left(\frac{Ld}{Ld+Lg}\right)^2 \quad \text{----------(4)}$$

The reflection phase of a surface with impedance Zs[6] :

$$\Phi = \text{Im}\left\{\ln\left(\frac{Z_s-\eta}{Z_s+\eta}\right)\right\} \quad \text{---------------(5)}$$

where η is the characteristic impedance=120π .

When Zs is low, the reflection phase is ± π . When Zs is very high, the reflection phase is zero. The phase crosses through ± π /2 when Zs is equal in magnitude to the impedance of free space[6].

Since, the AMC feature is limited in the a certain resonant frequency. The mathematical calculation is very important to accurate the resonant frequency. The value of the bandwidth is also important to know the region of the AMC working.

B. THE SIMULATION OF THE PROPOSED STRUCTURE:

In this design used a (25.6 mm X 23.6 mm) rogers ultralam substrate with thickness 1.45 mm with epsilon 2.5 and tangent loss 0.0019, the conductor was perfect electric conductor (PEC).

The dimension of the proposed structure is as shown in the Fig. 6 and the dimensions of the elements are listed in Table 1.

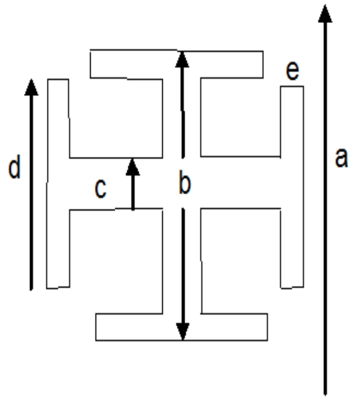

Fig. *6*. the dimension of the proposed structure

Table. 1. Dimensions and values of the design

The Dimensions	Value (mm)
a	25.6
b	23.6
c	4
d	6
e	3
h	1.45

The CST simulator is used to achieve the proposed structure The results show that the structure has a good reflection coefficient at 2.45 (nearly equal to zero in term of phase) with bandwidth (1.1376 GHz) for the range (+90 to -90) which make it a good candidate to be a backed for an antenna operate in the 2.45 GHz and as shown in Fig. 7.

In some other considerable work such as that published in [4], [7]. the results aim to be more accurate by consider the reflection coefficient angle (+45 to -45). For this criterion we have a bandwidth = 458 MHz and this insure the feature of the structure for working at 2.45 GHz.

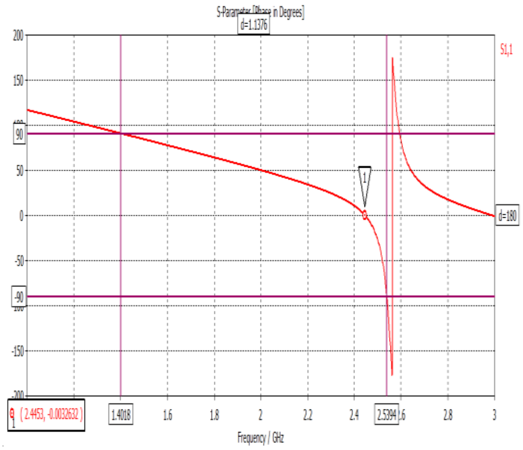

Fig. 7. the reflection coefficient of the proposed antenna.

IV. CONCLUSIONS

This paper presents and simulates a structure of AMC based on one type of FFS (JC) that can be integrated with an antenna operate at 2.45 GHz .

A nearly zero reflection coefficient (in phase) at 2.45 GHz with bandwidth = 1.1376 GHz is obtained.

The results shown a good identical between the theoretical and The simulation.

The impedance surface (Zs) should be very large to have zero reflection coefficient in the desired frequency and the Tangential magnetic field be equal to zero.

by comparing the value of tangential magnetic field obtain by simulation at 2.45 GHz which must be equal to zero (no radiation) because the reflection coefficient nearly equal to zero and its value into another frequency value (at 1 GHz for example, reflection coefficient not equal to zero). Also it is found that the *tangential* magnetic field actually have radiation at 1 GHz and not have radiation at 2.45 GHz which vitrify The mathematical calculation and as shown in Figs. (8,9).

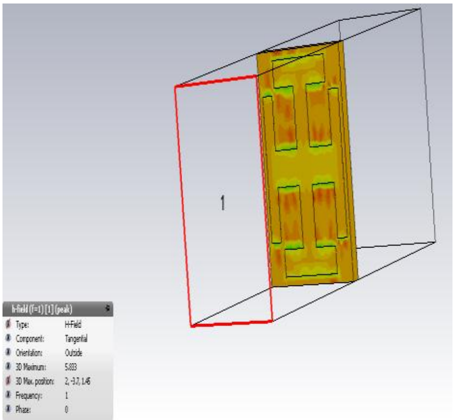

Fig. 8. the tangential magnetic field at 1 GHz

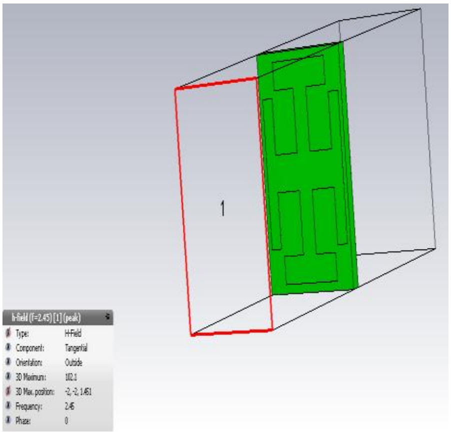

Fig. 9. the tangential magnetic field at 2.45 GHz

الخلاصة:

أحد أنواع المادة الافتراضية الاصطناعية تم استخدامها في تصميم وحدة خلية موصل مغناطيسي. ان وحدة الخلية المقترحة هذه تم تخصيصها للعمل مع هوائي يعمل على تردد مقداره ٢.٤٥ غيغاهرتز والذي يستخدم في تطبيقات البلوتوث وكذلك مع شبكات اللاسلكية المحلية (WLAN) وترتكز على التردد الانتقائي لسطح الهيكل (FSS). وتشير النتائج التي تحققت أن معامل الانعكاس للنموذج المقترح ذات قيمه جيده (للطور) (تقريبا صفر) باتجاه قيمة التردد المطلوب.

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