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Design of a Metamaterial Dual Band Absorber

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***Abstract*—this paper presents a split-ring resonator (SRR) which is a metamaterial microwave absorber structure. The structure is simulated in CST solver that giving rise to almost unity absorption at X band. Combining two different SRRs with two dielectric layers, at vertical direction, makes an expansion of the bandwidth of metamaterial become possible. According to the SRRs dual band absorbing achieved but the main advantage of the proposed absorber is that can effectively absorb most of the incident power in x-polarization (97%) and y-polarization (96%). In addition the proposed structure can be effective in different oblique incident waves. Changing the angle (θ) of incident of wave vector up to 60 which decays 7% of the absorption (90%) and changing the angle (φ) of incident of wave vector up to 60 which only decays 2% of the absorption (95%). These properties together cause the structure extremely effective in stealth technology for X band for the application of battlefield and airborne radar.**

Keywords-metamaterial; absorber; X band; SRR; bandwidth

I. INTRODUCTION

Metamaterials are artificial electromagnetic composites consisting of periodic structural units much smaller than the wavelength of the incident radiation [1]. Because of some attractive properties of metamaterials structures that natural materials don't have, several potential applications for these materials in invisible cloak [2], perfect lens [3], and highly directive antennas [4] have been found. In almost every technologically relevant spectral range from radio wave, microwave, THz, MIR (mid-infrared), NIR (near-infrared), to the near optical frequency. EM microwave absorber [5] is one of the major applications of metamaterials which has several uses in different frequency ranges such as solar cell in infrared frequencies, reduction of Radar Cross Section in stealth technology in gigahertz domain and thermal detector at terahertz regime [6]. In this paper, an SRR driven bandwidth enhanced metamaterial absorber has been proposed based on double resonance [7]. First, we have presented a single band metamaterial resonator, where absorption takes place at 9.7 GHz. After analyzing the structure combining SRRs with two different frequency resonance, at vertical direction, makes an expansion of the bandwidth of metamaterial become possible, which gives two distinct absorption peaks. Then the dimensions of the array structure are optimized to bring the peaks closer which exhibits a full width at half maximum (FWHM) of 5.35% around 8.07 GHz and at second band FWHM of 7.16% around 11.45 GHz for normal incidence with X-polarization.

II. UNIT CELL OF METAMATERIAL COMPOSED OF TWO DIFFERENT SRRS AT VERTICAL DIRECTION

The unit cell of the metamaterial composed of two different SRRs that are shown in figure 1. The unit cell of the metamaterial is simulated by using the commercial software CST Microwave Studio, which is a 3D time domain finite-integration solver.

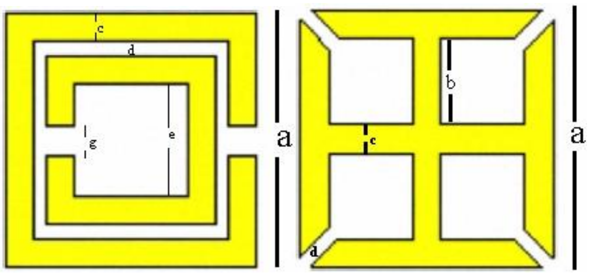

Figure 1. Structures of SRR A (right), B (left)

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III. Design

The proposed metamaterial structure consists of two conductive copper layers (conductivity of $5.8*10^7$ S/m) separated by a lossy dielectric substrate FR-4 (relative permittivity ε_r = 4.9 and dielectric loss $tan\delta$ = 0.025) as shown in figure 2. After analyzing many structures, two different structures have been taken and combined at vertical direction which gives two distinct resonant peaks. These peaks expressing the power loss according to the resonance that lead us to the final absorption.

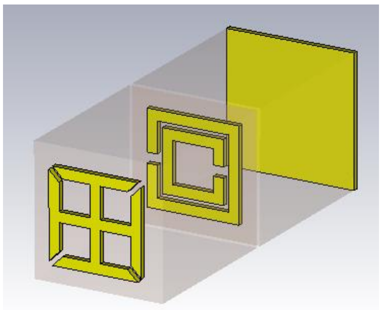

Figure 2. The unit cell composed of two different SRRs

TABLE I. DIMESIONS OF THE UNIT CELL

Table Head	Table Column Head					
	a	*b*	*c*	*d*	*e*	*g*
A	*7.2*	*2.4*	*.8*	*.4*	*	*
B	*7.2*	*	*.8*	*.4*	*3.2*	*.8*

In the simulations, the waveguide ports are set on the upper and lower surfaces of the unit cell, and a pair of perfect electric conductor (PEC) and perfect magnetic conductor (PMC) boundary conditions is set on the lateral faces. The incident X band electromagnetic wave spectrum is selected. To better the comprehension of the physical insight and by using the CST simulation, the distribution of the power loss densities at the peak absorption frequency of the metamaterial absorber, are shown in figure 3, and figure 4.

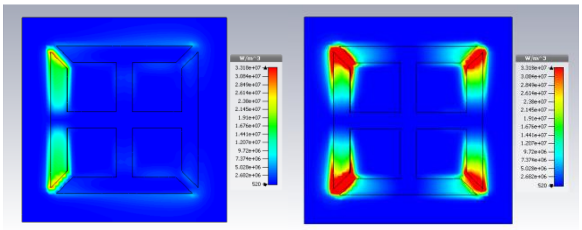

Figure 3. Ohmic loss of single band structure at two different resonance frequencies (left (8.02 GHz), (right 11.31 GHz))

As shown in figure 3 this structure is responsible for absorption at 11.31 GHz and as shown in figure 4 this structure is responsible for absorption at 8.02 GHz.

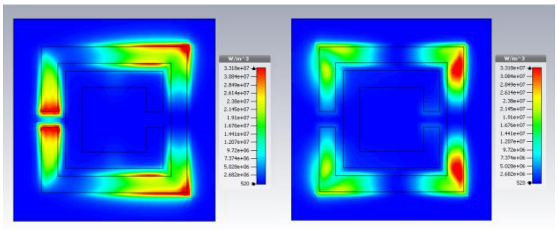

Figure 4. Ohmic loss of single band structure at two different resonance frequency (left (8.02 GHz), (right 11.31 GHz))

When a wave is incident on the interface of two media, the absorbance in the second medium can be expressed as in (1), where A(ω), $|S_{11}|^2$ and $|S_{21}|^2$ are the absorbance, reflected power and transmitted power respectively at an angular frequency ω.

$$A(\omega) = 1-|S_{11}|^2-|S_{21}|^2. \qquad (1)$$

Since the structure is completely copper backed, $|S_{21}|$ = 0 and thus (1) is reduced to

$$A(\omega) = 1-|S_{11}|^2, \qquad (2)$$

As you see power is lost in dual band so for designing an absorber from this SRR the dimensions of the structure are optimized to bring the peaks closer and another dielectric layer added to the unit cell also the last conductive layer is completely grounded. These improvements giving rise to the absorption peak in a very satisfying way. First absorption band resonates at 8.07 GHz with 550 MHz bandwidth with Max absorption of 99.70% and second absorption band resonate at 11.35 GHz with 850 MHz with Max absorption of 99.68%.

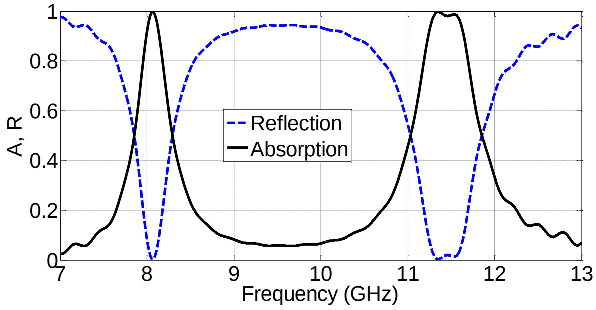

Figure 5. Absorption, reflection and cross wave with X-polarization

To confirm the polarization-independent feature of the proposed metamaterial absorber, the absorptive characteristic has been analyzed under normal incident plane waves with various lateral faces. The X-polarization electromagnetic wave is incident in figure 5. The next step is changing lateral faces, to test the ability of the metamaterial structure to face with Y-polarization incident wave. Figure 6 shows the simulation results of the metamaterial absorber with Y-polarization. First absorption band resonates at 9.26 GHz with 450 MHz bandwidth with Max absorption of 97.92% and second absorption band resonate at 11.58 GHz with 680 MHz with Max absorption of 96.54%.

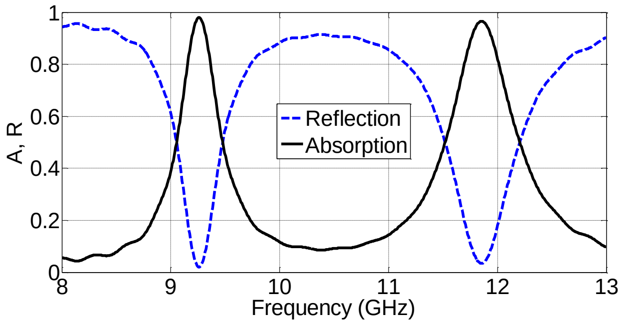

Figure 6. Absorption, reflection and cross wave with Y-polarization

The proposed unit cell metamaterial structure is highly absorptive with wide incident angle ranging from 0 to 60 for oblique incidence of electric field as well as for changing the angle (θ,ϕ) of incident of wave vector as shown in figure 7.

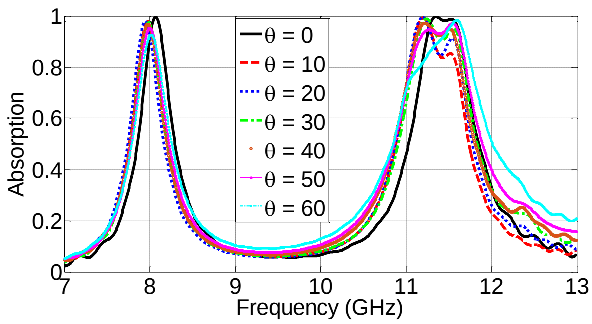

Figure 7. Oblique incidence (θ-variation) for variation of E-field at constant Phi (φ = 0) angle

It is observed from figure 7, 8 that as the incidence angles increase, the absorption bandwidth decreases slightly for both the low and high frequency absorption bands. For an incident angle of 60, the peak absorption drops to 90% at the low frequency absorption band and 95% at the high frequency absorption band. This can be explained by the fact that the incident magnetic field can no longer effectively induce resonant currents on the metallic patterns on the SRRs [8].

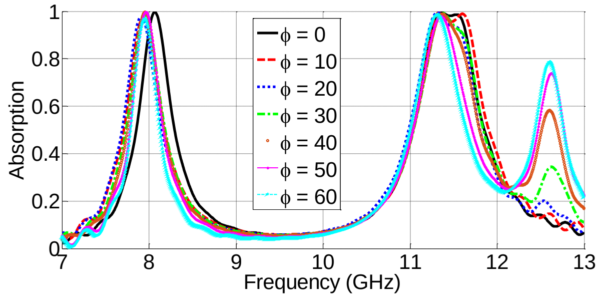

Figure 8. normal incidence for variation of E-field along Phi (φ) for constant Theta (θ = 0) angle

IV. CONCOLUTION

In this paper, we propose a unit cell SRR driven microwave absorber having a total thickness of 1.051mm (~λ/25). By optimizing the dimensions of the resonating structures, the absorption peaks are brought closer to achievement of dual band absorption with a FWHM of 7.16% around 11.45 GHz in second band. The unit cell structure, also gives above 90% absorbance for changing the angle (θ) of incident of wave vector up to 60 and above 95% absorbance for changing the angle (φ) of incident of wave vector up to 60.

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