Realization of a Dual Transmission Band Conjugate Omega Shaped Metamaterial

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Abstract

In this article we propose a new conjugate omega shaped structure for realization of left hand material. This new metamaterial (MTM) is designed and simulated using CST MWS. The effective permittivity & permeability are extracted from the transmission & reflection data obtained by normal incident on the purposed structure. It is shown the purposed MTM exhibits DNG material property and negative refractive index in dual transmission band with wider band in frequency ranges from 3.35-6.37GHz and 12.53-16.7GHZ. The conjugate omegas structures are pseudo-chiral in nature, where both electric magnetic polarization are due to induced electric and magnetic fields.

Keywords – *MTM, refractive index, Ω shaped, electromagnetic propagation.*

1. Introduction

Metamaterials have been widely explored in recent years due to their intriguing and exotic electromagnetic properties. The idea of metamaterial (MTM) started with the Veselago’s proposal in 1967 [1]. Veselago proposed a new type of material which has simultaneously negative permittivity and permeability and he showed the general electromagnetic properties of such material. The theoretically formed a lossless MTM and presented the extraordinary properties of this material which is not found in nature. Then, Pendry and his coworkers illustrated their studies about the negative permittivity and the negative permeability as in [2] and [3]. They declared that an array of metallic wires can be constructed to obtain negative permittivity in 1996 [2] and a metallization of split rings can be manufactured for negative permeability in 1999 [3]. Later than, Smith and his colleagues demonstrated a new MTM that shows simultaneously negative permittivity and permeability and carried out microwave experiments to test its unusual properties in 2000 [4].

The first experiment showing negative refraction was performed using a metamaterial consisting of a two-dimensional array of repeated unit cells of copper strips and split ring resonators in 2001 by Shelby et. al. [5]. Several theoretical and experimental works have been studied by researchers on MTMs and their potential applications. The design of MTM based on shape and geometry is the most interesting work among the others [6-9]. Especially, the design of split rings is very important to construct a new type of MTMs. Numerous types of different ring and ring-like structures such as circular, square, Ω-shaped, U-shaped, S-shaped and others are used to create new MTMs.

Omega media are of special interest due to their interesting EM properties. Omega structures were firstly proposed by Saadoun and Engheta [10, 11]. These types of structures are composite EM materials with a proper combination of Ω-shaped metallic inclusions in a host dielectric medium. These metamaterial could be regarded as bi-anisotropic or pseudo-chiral media [10]. Electric and magnetic polarizations are induced by both electric and magnetic fields in bi-anisotropic media.

Here in this paper we have investigated a new design & systematic studied of transmission properties of conjugate omega shaped MTM.

Our realization of Ω media was based on conjugate Ω-like MTM patterns and repeated periodic array MTM pattern. Simulation results show that this configuration has better performance in terms of transmission band and BW

Omega MTM structure is well known for its single band DNG behavior but our purposed conjugate MTM structure operates in dual transmission band and both are wider and in both bands negative refractive index, DNG property for effective permittivity and effective permeability were observed

2. Metamaterial Unit Cell Design

The unit cell of purposed conjugate Ω structure is shown in figure1.The basic unit cell consists of back-to-back conjugate omega inclusions. The parameters given in the figure 1were r=1mm, R=1.4mm, W=0.4mm, g=0.4mm, L_1=1.8mm, L_2= 1.6mm, L= 4mm & g=0.4mm.Conjugate omega inclusions were copper that were deposited on FR4 substrate. The dielectric constant of FR4 substrate was chosen 4.4 with thickness was 1.6.

The back-to- back configuration suppress the magneto-electric response according to the basic idea developed in broadside coupled SRR The core of the pattern is responsible for a magnetic dipole through current loops via an H-field excitation along z axis. The two arms of the omega patterns are responsible for the electric response when the electric field is polarized along the y-axis.

We arranged purposed MTM units periodically with 2 unit cells in x-, y- direction. The spacing between two unit cells was 5mm maintained.

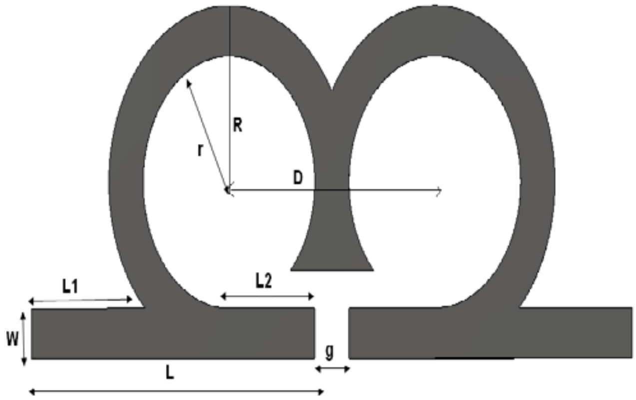


Figure 1. Conjugate Ω shaped MTM unit cell

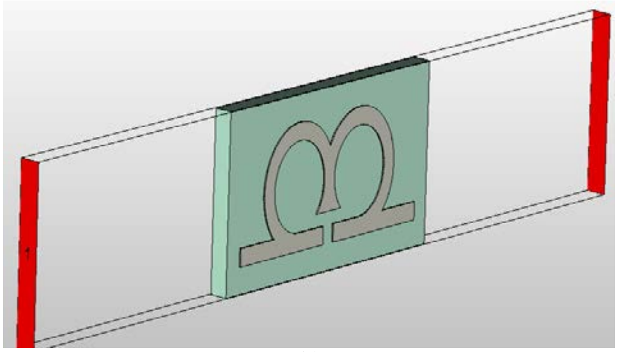
3. Simulation of Metamaterial

The design and simulation of purposed LHM was executed using CST MWS EM tool. The boundary conditions of MTM unit cell and periodic array of MTM were displayed in figure 2 & 3.

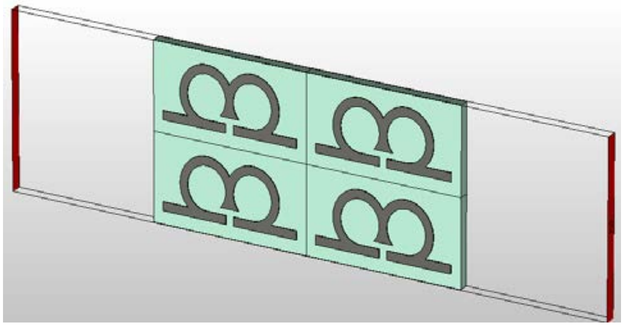
A two waveguide ports were set on x-axis, perfect electric conductor (PEC) & perfect magnetic (PMC) boundary condition was set on y- & z-axis respectively, The incident field propagating along x direction, with E & H field along y & z direction respectively.

A transient domain solver is used to simulate the MTM construction in CST MWS.A tetrahedral mesh was chosen and the density was set up 10 steps per wavelength using advance volume method to obtain good accuracy in the simulation. The samples are simulated in the frequency ranges 0-20 GHz to to obtain the S parameters.

The S parameters that were obtained from simulation were exported to MATLAB. There are several methods to verify the different characteristics of material from S parameter. In this work a modified Nicolson-Ross weir technique was used to attain the effective medium parameters, refraction index and wave impedance. From S parameter as [6] [8] [12-13]



(a)



(b)

Figure 2. Boundary condition of (a)unit cell (b) periodic array

4. Result & Discussion

In figure 3 simulated results of transmission and reflection characteristic of MTM unit cell is shown. The dip in the phase of S_{11} indicates the presence of negative regions which were observed at 3.6&15.25 GHz.

In figure 4 and 5 the effective medium parameters of the unit cell and periodic array of four MTM cells are shown. In this figure, the real and imaginary parts of wave impedance, refractive index, permittivity and permeability are also illustrated.

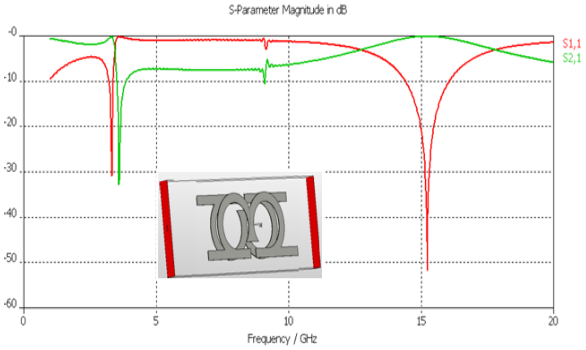


Figure 3. Transmission & reflection characterstic curve of MTM unit cell

S parameters, wave impedance & refractive index, dispersive material properties are plotted are plotted in the range of 0−20 GHz to observe the negative region.

For passive materials, real part of the wave impedance and imaginary part of the refractive index must be greater than zero. The wave impedance and refractive index satisfy this condition for our configuration.

In MTM unit cell, the real value of refractive index was negative from 3.35-6.37GHz and from 12.53-16.7 GHz. The real value of the permittivity of MTM unit cell lies in the negative band from 3.35 -3.45 GHz and 12.5-16.7.The real part of permeability of the MTM unit cell lies in the negative band from 3.56-6.37 and 13.5-14.2 GHz. Thus it can be said that negative permeability has wider frequency band in 1st band where as permittivity has wider band in the 2nd frequency band for MTM unit cell.

In periodic MTM array the frequency of resonance, refractive index, permittivity and permeability band shift a little to right side of the original band .Since the structure of the structure is increased, the resonance occurred at higher wavelength.

The conjugate omegas structures are pseudo-chiral in nature, where both electric magnetic polarization are due to induced electric and magnetic fields. The electric resonance is due to the capacitive coupling at the gap and magnetic resonance is due to the inductive coupling in the split ring.

With a series of simulations, we used the field monitor facility of CST to calculate the electric field & surface current density within the Ω unit cell. It is seen that the current at the edge of region of the MTM around the gap is crucial for resonance. In figure 5, the arrows indicate the direction and size of the surface current density. The induced surface current density is in circular form and it is weak at the gap. This gives insight into the manner in which MTM resonate at dual transmission bands.

5. Conclusion

We have studied a new metamaterial design from the unit cell of the conjugate omega structure. Then retrieved effective material parameters are computed using S parameter. The dip in the phase of S is observed for the design of metamaterial and the negative region is indicated. The DNG property is shown by the simultaneous negative permittivity and permeability and negative refractive index from the transmission and reflection data of the MTM structure at dual transmission band with wider BW in the studied frequency band. The frequency range of metamaterial is different depending on the. The design is implemented by using CST MWS electromagnetic simulation.

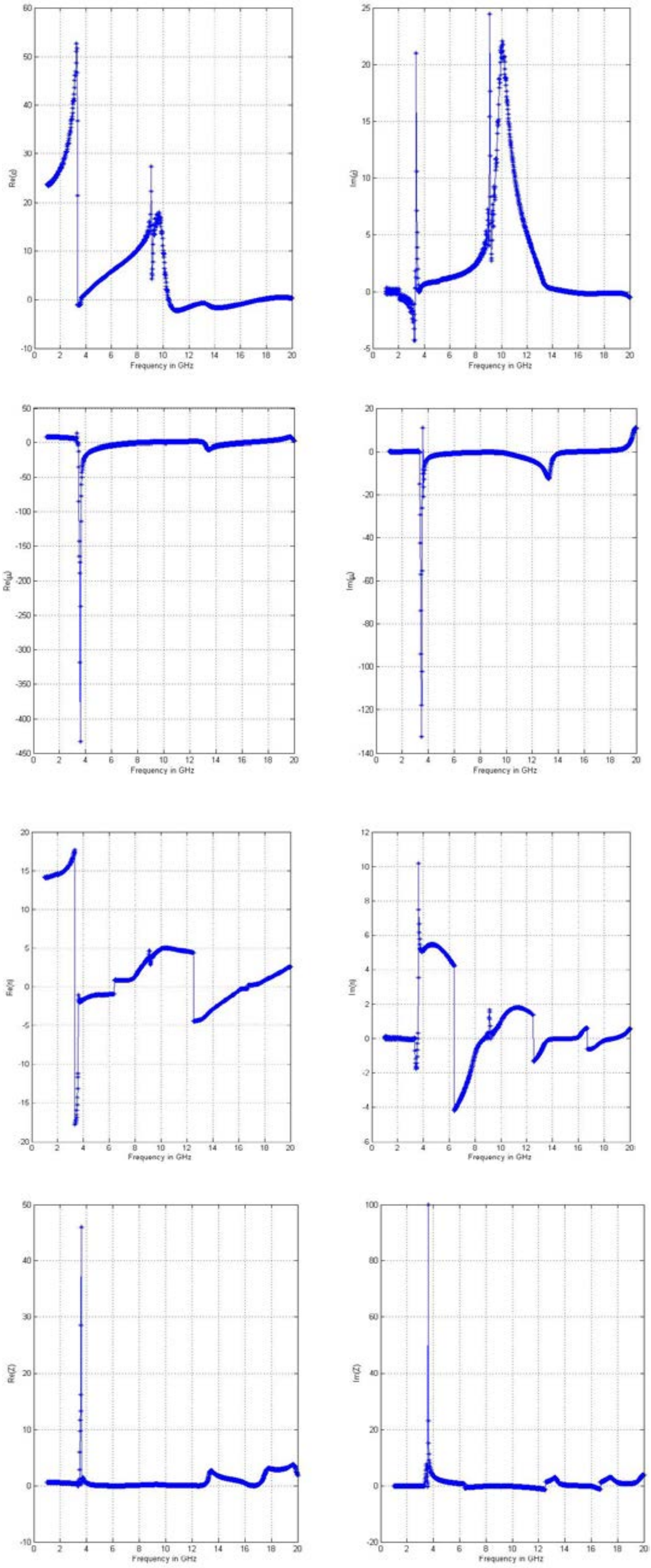


Figure 4. Effective medium paramter of MTM unit cell (a) permitivity, (b) permiablity, (c)refractive index,(d) wave impedance

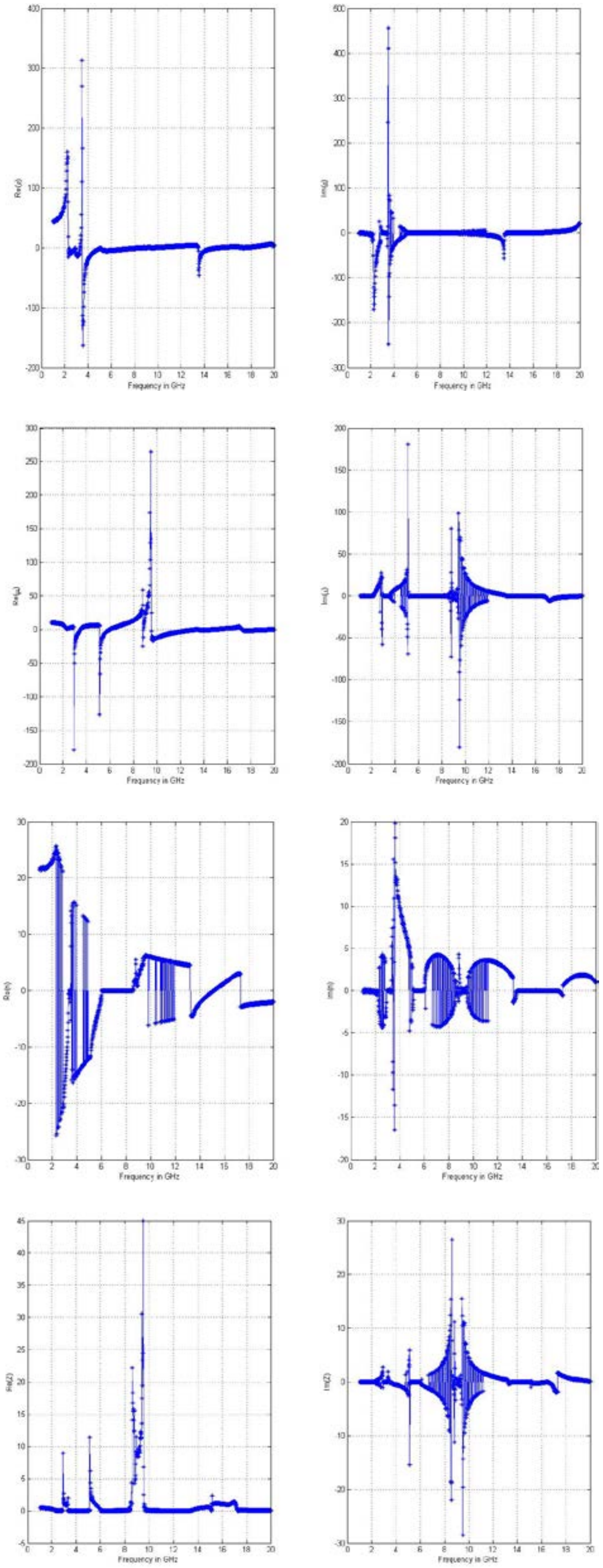
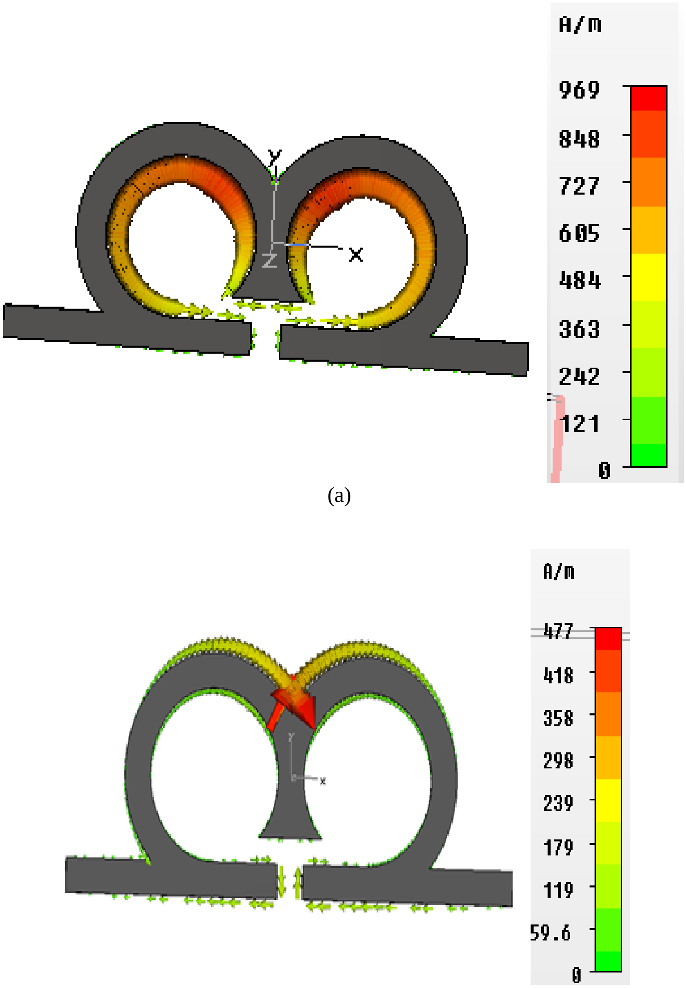


Figure 5. Effective medium paramterof (2 × 2) periodic array MTM (a) permitivity, (b permiablity), (c)refractive index,(d) wave impedance



(a)

(b)

Figure 6. Surface current density at (a) 3.7 GHz & (b) 15.4GHz

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