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Double Negative Metamaterial of Copper Split Ring and Graphite Materials

Authors

Muhammad Waqas[1], Zeeshan Akbar[2], Muhammad Abid Saeed[3]
Shahid Alam[4], Muhammad Junaid Khan[5]

[1]Department of Electrical Engineering,
Sarhad University of Science and Information Technology
Email: engr_waqasjan@hotmail.com

[2]Department of Electrical Engineering
Sarhad University of Science and Information Technology
Email: zeak.mohmand@gmail.com

[3]Department of Electrical Engineering
Sarhad University of Science and Information Technology
Email: m.abidsaeed@yahoo.com

[4]Department of Electrical Engineering
Sarhad University of Science and Information Technology
Email:afr.shd@gmail.com

[5]Department of Communication Engineering
University of Oulu, Finland
Email: amjaykay_s@yahoo.com

Abstract
The work of this paper is to design and simulate a novel rectangular split ring and graphite wire structured having simultaneous negative permittivity and permeability so called double negative metamaterial or left handed material. The DNG structure consists of four rectangular split ring resonators on one side of dielectric medium and a couple of graphite wires on other side. The complex permittivity, permeability, impedance and refractive index are determined from simulated Scattering parameters using direct retrieval method. Simulations of DNG structure are carried out using CST MWS. MATLAB is used for verification of negative values of structure's parameter.
Keywords: Double negative left handed material, Negative Permittivity, Negative Permeability, Negative Refractive Index, Negative impedance, Split Ring Resonators.

INTRODUCTION

Metamaterials are artificial material having numerous potential applications in science, technology and medicine which have been receiving increased attention recently. These novel artificial materials are first predicted by V. Veselago but the experimental verification did not occur until several decades [1]. Later several researchers studied the characteristics and applications of SRR based left handed material (LHM) for experimental verification. Double negative materials do not exist in nature but such material is physically realizable by making composite structure in which the propagation of

electromagnetic waves are possible [2]. To achieve negative permittivity and permeability, rectangular split ring resonators are used on one side of a dielectric medium while a couple of graphite wires on other side. These SRR gives negative permittivity and wires gives negative permeability. Furthermore negative refractive index and impedance are also achieved from respective structure. The DNG structure has been simulated in CST microwave studio 2011 software and scattering parameters are extracted to calculate negative values of permittivity, permeability, impedance and refractive index using direct retrieval method [3 - 5].

The DNG materials have a number of applications in microwave engineering [6]. For metamaterials, it is implied that are concerned in their response to electromagnetic fields. The most frequently application of DNG is to use it as a substrate or superstrate for antenna to improve its directivity and gain [7-9]. Other applications such as metamaterials-cloaking is one of the magical application of metamaterial. Perfect lenses and near field imaging is also the attractive ideas of metamaterial [6].

METHODOLOGY

For double negative structure using CST Microwave studio four rectangular split rings of copper having different length and same width are used on dielectric medium (substrate) and four graphite wires of same length and width are used on other side of dielectric medium. The substrate used here is glass having a dielectric of 4.82 and the thickness of substrate is 1mm. The structure of DNG front view (Rectangular SRR) and back view (wires) are shown in Figure.1 and Figure.2 respectively. For convenience, parameters of rectangular split ring, wires and substrate are summarized respectively in Table I.
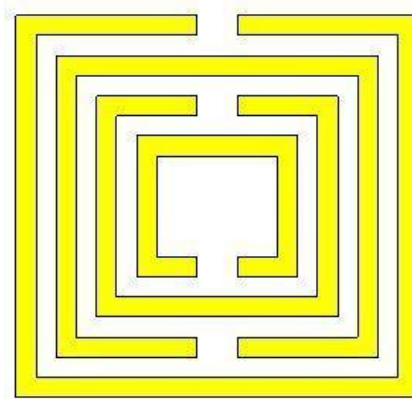

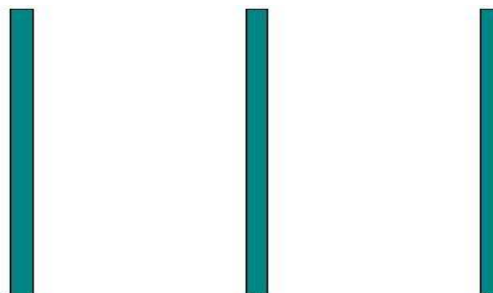Figure.1: Rectangular SRR (Front View)

Figure.2: Wires (back view)

Table I: Parameters of DNG Structure (All dimensions are in mm)

Parameters of DNG	Values
Length of each wire	23
Width of each wire	1
Length and Width radius of ring 1	8 & 0.5
Length and Width radius of ring 2	11 & 0.5
Length and Width radius of ring 3	15 & 0.5
Length and Width radius of ring 4	19 & 0.5
Dielectric of substrate	4.82
Thickness of substrate (glass)	1
Gap of each rings	2

Several techniques have been used to get negative permittivity and permeability from the simulated complex value of S-parameter. Nicolson Ross Weir equations is one of the most repeated method to find negative values of permittivity and permeability [10]-[13]. Another method used Drude model and Lorentz model made some assumptions about negative permittivity and permeability [2], [14]. Among these and all other methods a direct retrieval method is used in this work which is more convenient and simple [3].

The suggested DNG Metamaterial model is configuring between two waveguide ports at the left and right of Y-Axis. The wave is excited from positive Y-axis (Port 1) towards negative Y-axis (Port 2) to calculate complex S11 (Transmission/reflection of port 1 to 1) and complex S21 (Transmission/ Reflection of port 1 to 2) parameters. The X-Plane is defined as a Perfect Electric Boundary (PEB) while Z-plane is defined as a Perfect Magnetic boundary (PMB). Simulated DNG structure between two waveguide ports is shown in Figure.3.
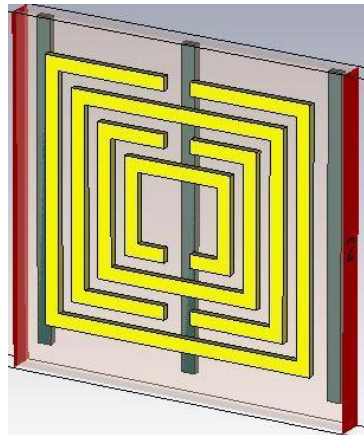

Figure.3: DNG structure between two waveguide ports

Transmission/Reflection method is used in order to obtain S-parameters from corresponding structure. The real and imaginary values of scattering parameters are then

Permittivity and permeability of a material are given by [3] :

$$\varepsilon = {}^{n}/_{z} \qquad (1)$$

and

$$\mu = nz \qquad (2)$$

where,

$$n = \frac{1}{kd}\ cos^{-1}[\frac{1}{2S_{21}}\ (1 - S_{11}^2 + S_{21}^2)] \qquad (3)$$

and

$$z = \sqrt{\frac{(\ 1 + S_{11})^2 - S_{21}^2}{(\ 1 - S_{11})^2 - S_{21}^2}} \qquad (4)$$

SIMULATED RESULTS AND DISCUSSION

Scattering parameter is the key term for extracting negative permittivity and permeability. The complex scattering parameters S11, S12, S21 & S22 are extracted

exported to MATLAB to obtained negative values using permittivity and permeability equations.

from CST Microwave studio. The structure resonates within the given range of frequency as shown in the following Figures. Figure.4 and Figure.5 show the reflection graphs and Figure.6 and Figure.7 shows the transmission graphs
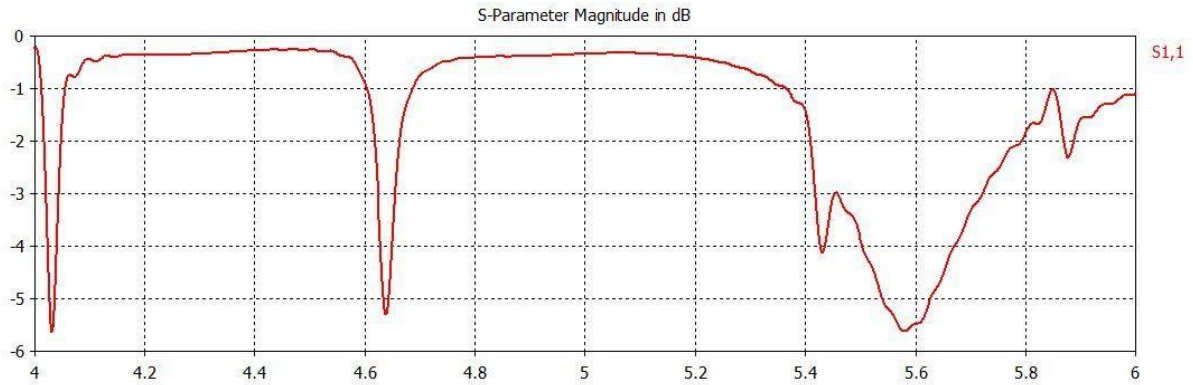
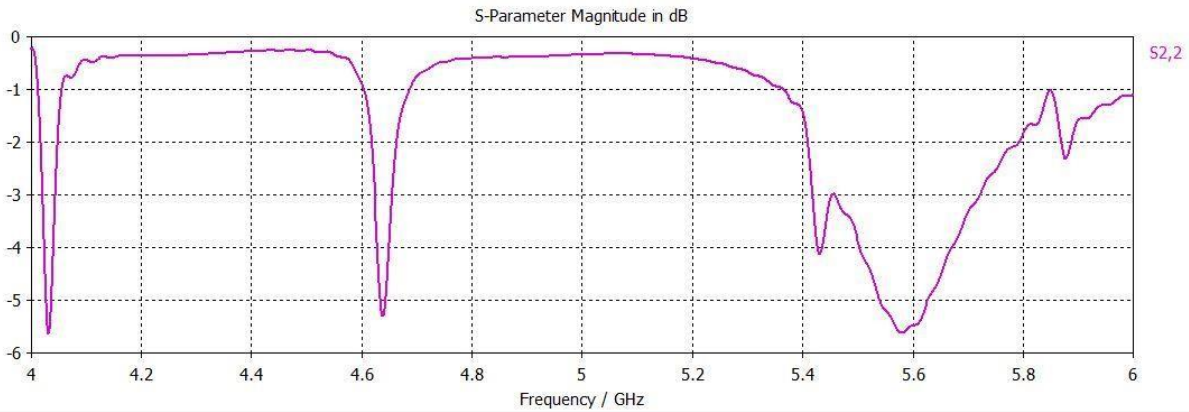Figure.4: S11-parameter (frequency/GHz)
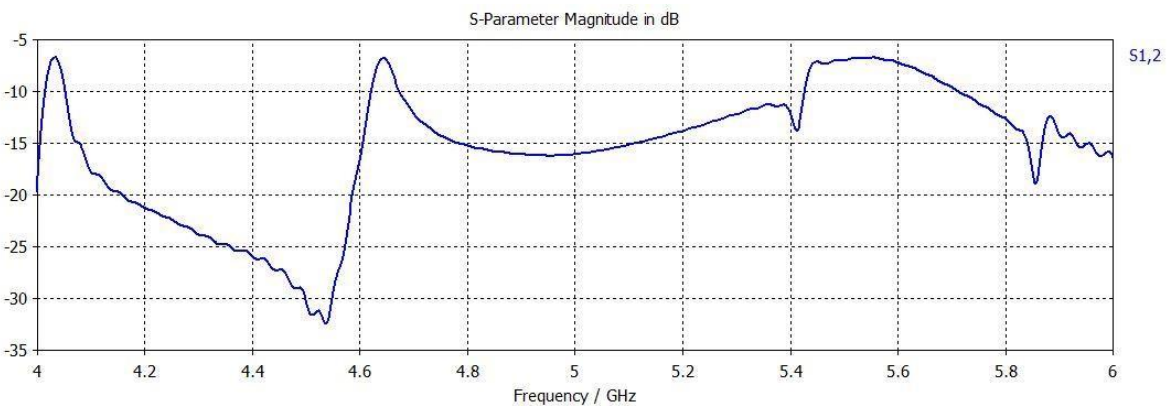

Figure.5: S22-parameter (frequency/GHz)

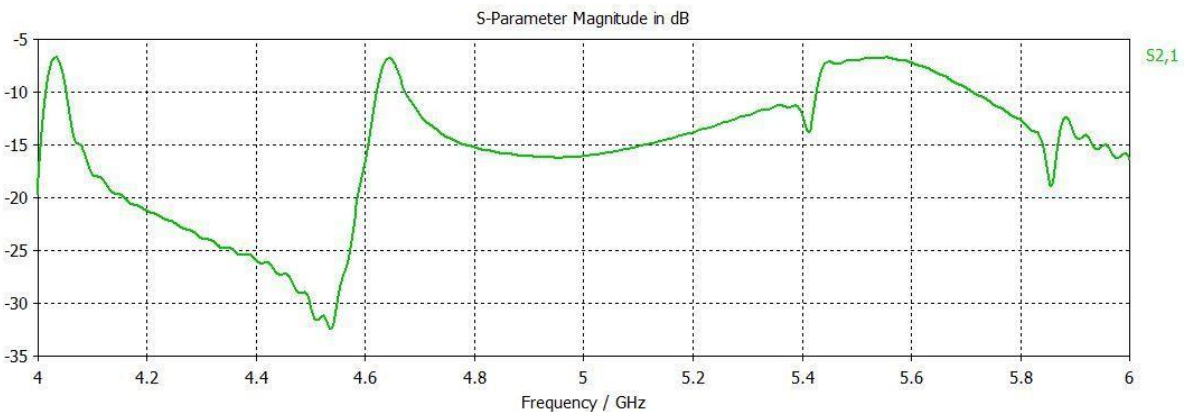Figure.6: S12-parameter (frequency/GHz)

Figure.7: S21-parameter (frequency/GHz)

The complex values of these parameters are than exported to MATLAB and using previous equations of direct retrieval method, the graphs of negative permittivity and permeability versus frequency are obtained. These graphs provided verified results of a negative behavior of such .

periodic structure. It confirmed that proposed structure is double negative material. Negative permittivity and permeability graphs are shown in Figure.8 and Figure.9 respectively
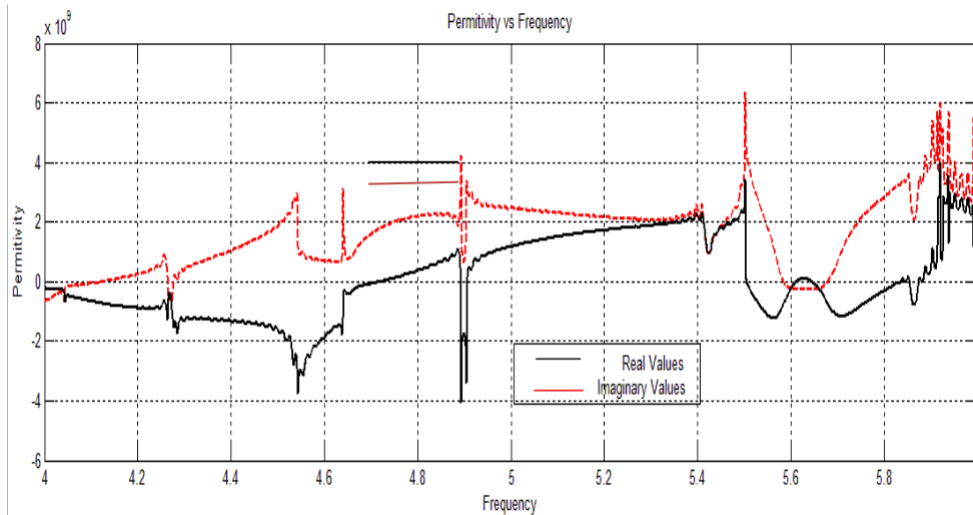

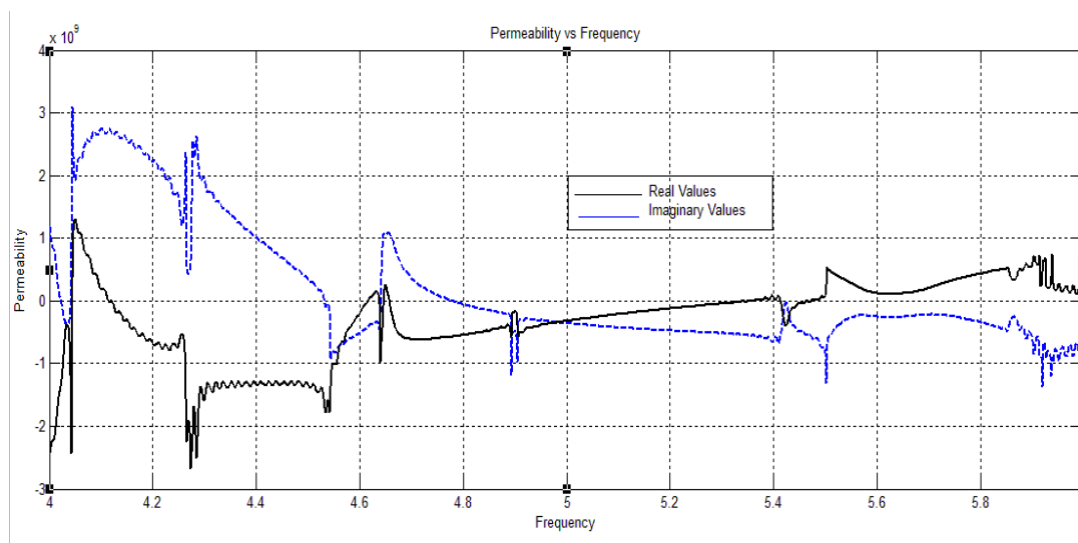Figure.8: Proposed DNG permittivity vs frequency

Figure.9: Negative permeability vs frequency

Negative refracitve index and impedance are also found from the MATLAB software using the same direct retrieval method as shown in Figure.10 and Figure.11. range.

These graphs showed negative values of refractive index and impedance in the given frequency
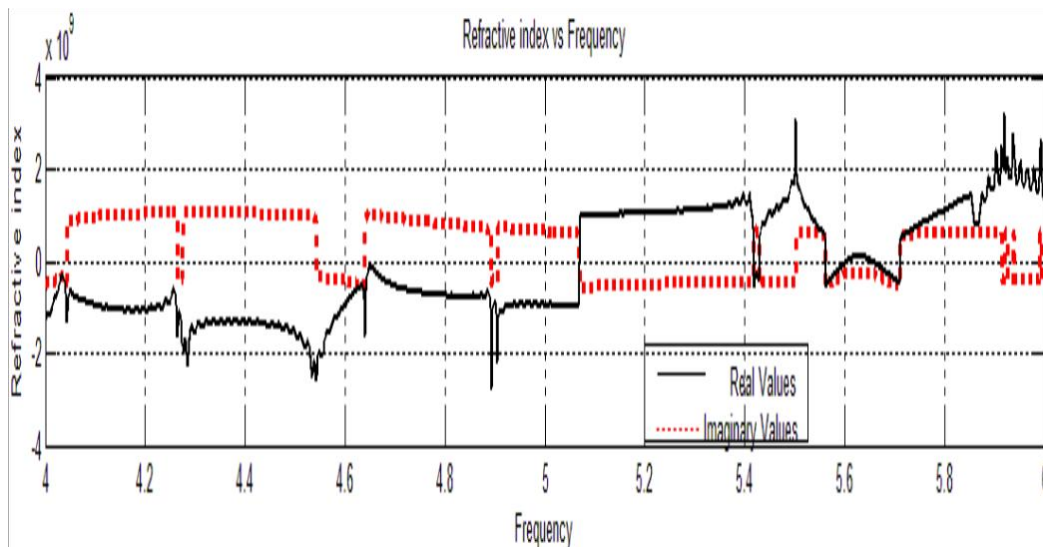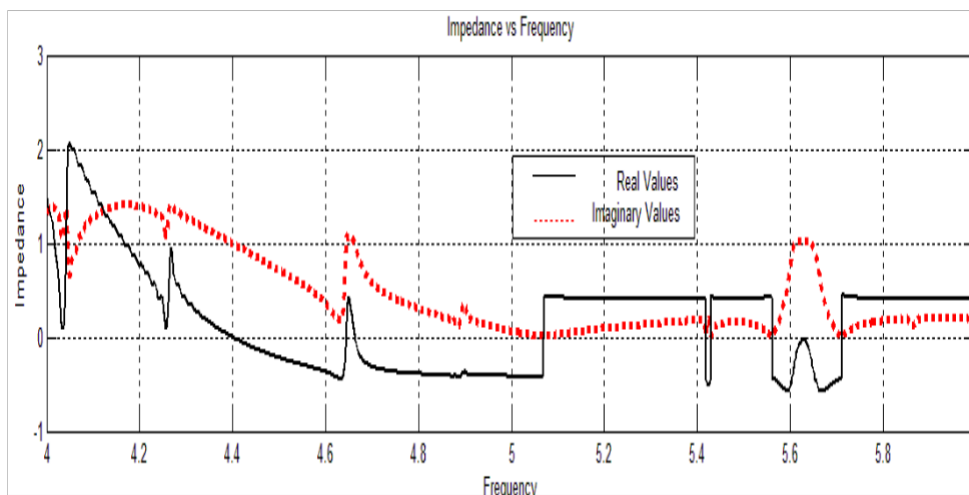
Figure.10: Negative Refractive Index vs frequency

Figure.11: Negative Impedance vs frequency

CONCLUSION

All the simulations are successfully done using CST MWS while the negative values of refractive index, imepedance, permittivity and permeability are fruitfully obtained using MATLAB from transmission reflection method using direct retrieval technique. Negative paremters are obtained at different operating frequency which is the finest option for the selection of respective DNG structure. The simulated structure possesses simultenous negative permittivity and permeability at different frequency range having left handed properties and hence called LHM or DNG. Further amendments in this structure can give favorite values of constitutive parameters for desired frequency ranges. DNG metamaterial structures can be of great importance where negative refractive index, enhanced gain and radiation characteristics are need at specific range of frequency. The structure is widely used for the improvement of diverse antenna's parameters.

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