DESIGN AND DEVELOPMENT OF DOUBLE NEGATIVE METAMATERIAL ANTENNA FOR WIDEBAND APPLICATIONS

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***Abstract*— recently, lots of research has been done for artificial material or metamaterials whose property does not exists in nature but can be designed using metallic and dielectric structure to show properties like negative refractive index (NRI). Metamaterials find lots of applications in antenna design like low permittivity substrate to reduce the size of antenna, superstrate structure to increase the gain, and bandwidth of antennas, and also used for design of compact antennas for different applications but with main constraints of impedance bandwidth. The scope of this work is to design and simulate a novel structure having simultaneous negative permittivity and permeability so called double negative (DNG) metamaterial or left handed material. The complex permittivity, permeability and refractive index are determined from simulated Scattering parameters using direct retrieval method. Simulations of DNG structure are carried out using HFSS. The proposed DNG is then employed as a superstrate of MPA which reduces the surface waves and edge diffracted waves of an antenna and therefore reduces its losses.**

Keywords—Double Negative, Left-Handed, Metamaterial, Negative Permeability and Negative Permittivity, Negative Refractive Index

I. INTRODUCTION

Electromagnetic metamaterials were first investigated by the Russian physicist Victor Veslago [1]. Recently, there is a great interest from electromagnetic waves community in investigating metamaterial structures. Specifically, a great interest has been paid on studying the characteristics of using these artificially constructed metamaterials in possible RF/microwave circuit applications. The studies show that these materials have unique electromagnetic properties at microwave frequency bands, which are not found using conventional materials. Metamaterials are unnatural materials which can be only engineered and shows properties such as negative permeability and negative permittivity. It can be analyzed that metamaterials provide wide bandwidth coverage with low profile structure. The s-parameter matrix was analyzed to determine the effective permittivity and permeability. At frequencies where both the recovered real parts of ε and μ are simultaneously negative, the real part of the index of refraction is also found to be negative. 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. The DNG materials have a number of applications in microwave engineering.

II. ANTENNA DESIGN

Fig. 1 shows the proposed metamaterial antenna design. Fig. 2 shows the evolution of the proposed antenna.

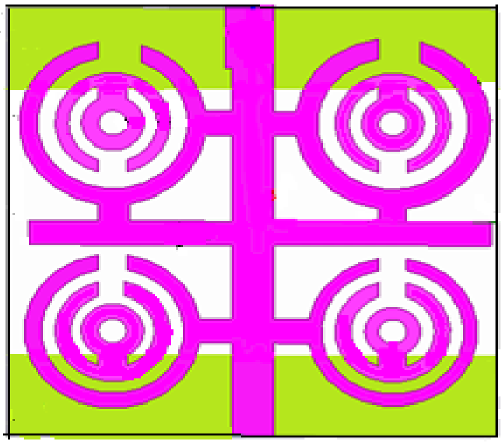
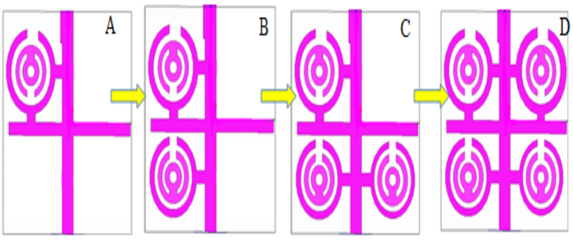


Fig.1:- The layout of the initial design of antenna



(a) (b) (c) (d)

Fig. 2:-Evolution of the proposed antenna

The geometry and the dimensions of the proposed antenna as shown in configuration "D". The proposed antenna is fabricated on a low cost FR4 substrate with dielectric constant εr = 4.4 as shown in Fig. 3. The thickness h of the substrate is 1.6 mm. The dimensions of the proposed antenna, after due optimization, are listed in Table 1.

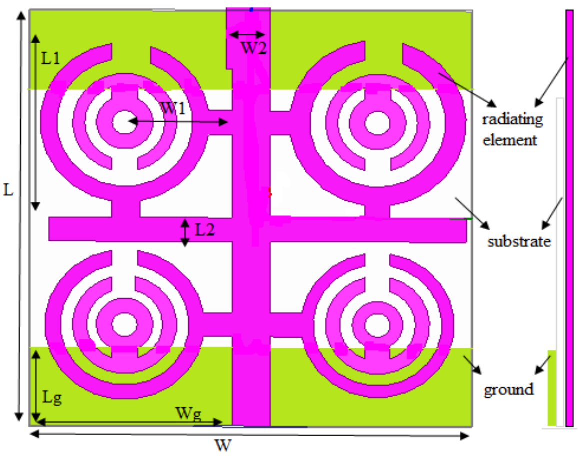


Fig. 3:-Geometry of Proposed Antenna Configuration

Table 1:-Dimensions of the proposed antenna illustrated in Fig. 3

Parameters	L	W	L1	L2	Lg	Wg	W1	W2	R1	R2	R3
Dimensions	9.5	9.5	5	2.5	2	4.5	3	1	1	2	3

III. RESULTS AND DISCUSSION

All the simulations have been carried out by an improved parameter retrieval method based on ansoft High Frequency Structure Simulator (HFSS). Figure 4 shows the simulated S parameter.

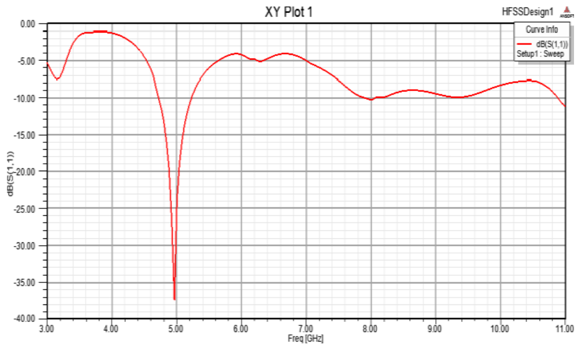


Fig 4:- The simulated return loss of metamaterial antenna at 7GHz

It is evaluated for 3GHz -11GHz.It is observed that the proposed antenna shows a -10 dB impedance bandwidth from 4.7 – 5.1 GHz i.e.0.4GHz. The minimum value of S(1,1) is found to be -37.5 dB at 4.9 GHz.Here With extracted s-parameter matrix, value of refractive index n and wave impedance z was calculated using the following equations (1) and (2)

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

$$Z = \sqrt{\frac{(1+S_{11})^2 - S_{21}^{2}}{(1-S_{11})^2 - S_{21}^{2}}} \text{ ------ } \quad (2)$$

The value of effective permittivity ε and effective permeability µ then may be computed as

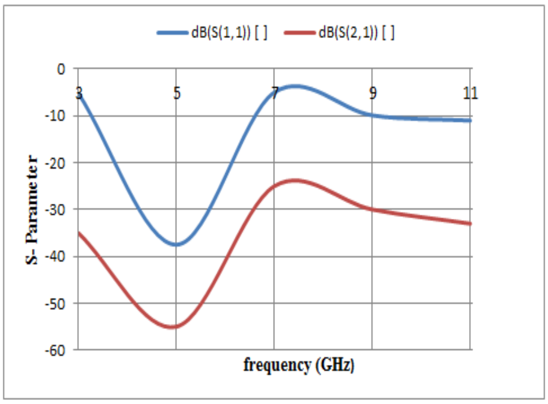
$$\epsilon_{eff} = \frac{n}{z} \text{ And } \mu_{eff} = n * Z \text{ -----} \quad (3)$$

The condition Im{n} ≥ 0 fix the choice for sign of '*n*'. Similarly the condition Re{z}≥0 fixes the choice for sign of 'z'.An improved parameter retrieval method is as follows:

$$n = \frac{\ln\left(\frac{S_{21}}{1 - S_{11}\left(\frac{Z-1}{Z+1}\right)}\right)}{ikd} \text{ -----} \quad (4)$$

After calculating *n* and *z*, the value of effective permittivity and effective permeability was computed and the graphs of refractive index versus frequency are drawn using excel sheet.

Fig 5 shows the graph of S parameter at intrinsic variation of 7GHz and fig. 6 shows the electric field distributions for 5GHz, 7GHz and 9GHz. Fig 7 shows the radiations patterns for near field and far fields for the proposed antenna. It is evaluated for 3GHz -11GHz.It is observed that



the proposed antenna shows a -10 dB impedance bandwidth from 4.7 – 5.1 GHz i.e.0.4GHz. The minimum value of S(1,1) is found to be -37.5 dB at 4.9 GHz. Here With extracted s-parameter matrix, value of refractive index n and wave impedance z was calculated using the following equations (1) and (2)

Fig 5:- The simulated S parameter of Two port antenna at 7 GHz.

$$n = \frac{1}{kd}\cos^{-1}\left[\frac{1}{2S_{21}}\left(1 - S_{11}{}^{2} + S_{21}{}^{2}\right)\right] \quad \text{----(1)}$$

$$Z = \sqrt{\frac{(1+S_{11})^2 - S_{21}{}^2}{(1-S_{11})^2 - S_{21}{}^2}} \quad \text{------} \qquad (2)$$

The value of effective permittivity ε and effective permeability µ then may be computed as

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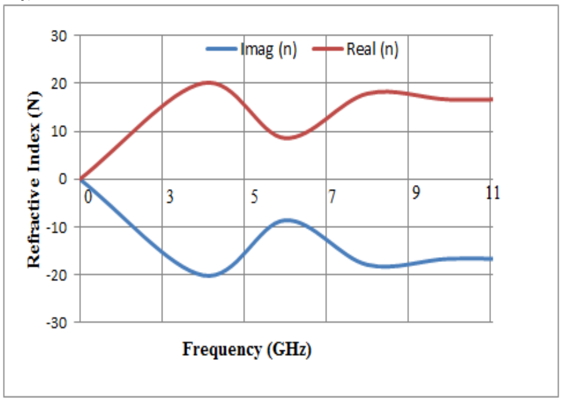

Fig 6:- Real and imaginary values of refractive index

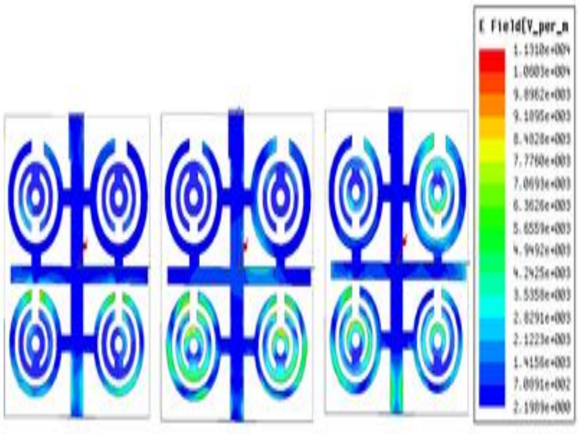

Fig 7:- Simulated results of the electric field distributions for the proposed antenna at 5GHz, 7GHz and 9 GHz

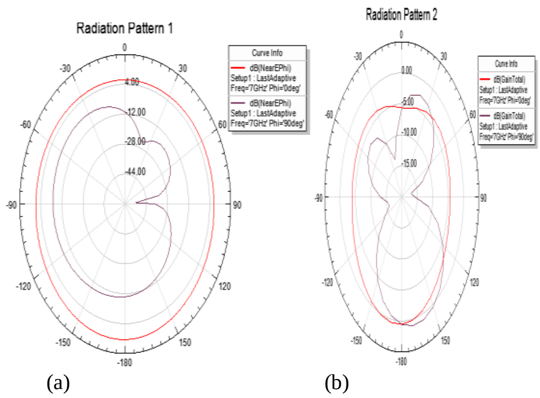

Fig 8:- Simulated radiation pattern of the proposed antenna at 7 GHz (a) near field (b) Far field.

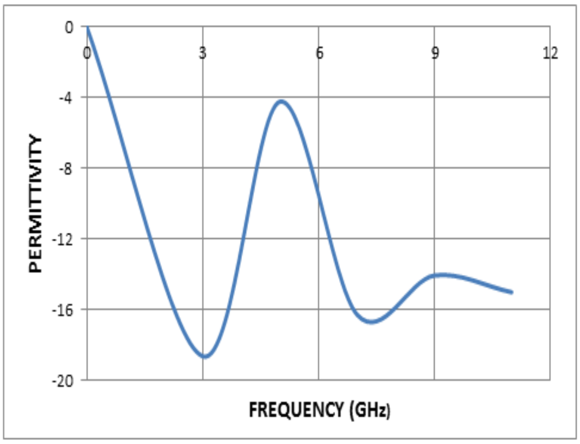

Fig 9:- Permittivity Vs frequency

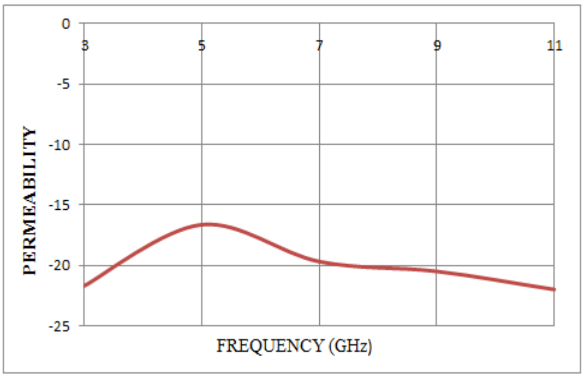

Fig 10:- Extracted negative permeability characteristics of the proposed wideband antenna

IV. CONCLUSION

A compact metamaterial antenna fed by a microstrip line is designed and simulated.Metamaterial design must satisfies the four parameters i) Negative refractive index ii) wave impedance iii) Negative permittivity iv) Negative permeability. The proposed designs are satsifying all four parameters.Negative values of permittivity and permeability are obtained from transmission reflection using improved parameter retrieval method. Negative parameters are obtained at different operating frequency which is the finest option for selection of respective metamaterial structure.It exhibits the property of negative index of refraction at wide-band. Results obtained using HFSS are verified by coding formulae for refractive index, effective permittivity and effective permeability.

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