iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** VII **Month of publication:** July 2015

DOI:

www.ijraset.com
IC Value: 13.98

Volume 3 Issue VII, July 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

A L-Band "Rectangular Shape Inside a Pentagon" Metamaterial Structure for Microwave Application

Suprabhat Vishwakarma[1], Bimal garg[2]
[1]*Student*, [2]*Associate Professor*
Electronics Department, Mitsgwalior (m.p.) India.

Abstract--In this paper a design of L-band (1GHZ-2GHZ) rectangular microstrip patch antenna integrated with "rectangular shape inside a pentagon" metamaterial structure attached at the height of 3.276mm from the ground plane. It is demonstrated that the application of the media with a negative refractive index, negative permeability and negative permittivity. Furthermore the return loss is improved by the inclusion of the metamaterial structure reaching -28.426db compared with -12.73db achieved by the original patch antenna structure alone. Main focus in this design process is to reduce the size and return loss of the patch antenna. In this paper, we will improve the property of RMPA. In which proposed metamaterial structure, reduce the size of antenna by shifting the lowest dip to a frequency other than the operative frequency i.e. 1.035GHZ. The sizes is being reduced to 85% and also reduce the return loss from -12.73db to -28.426db. The proposed antenna is designed by using CST(computer simulation technology software) MICROWAVE STUDIO. This proposed design has low profile, small size, low loss, easy to fabricate and better directivity as compared to the simple rectangular patch.
Keywords--left handed metamaterial (LHM), rectangular microstrip transceiver (RMT), double negative metamaterial(DNG), impedance bandwidth,return loss, Nicolson-ross-weir(NRW).

I. INTRODUCTION

In modern wireless communication system, the microstrip patch antennas are commonly used in the wireless devices. Because, microstrip patch antenna has been very popular due to many advantages, like low profile and cost, light Weight and small size [1]. These attractive features made patch antenna more applicable in many noticeable communication systems. However, it suffers from the many problems like impedance bandwidth, return loss, gain , directivity and the parameter of the antenna. To reduce these typeof problems, we will use the technique to improve these parameters. One parameter is size of the Antenna that can also be improved. This particular idea has the benefit of cost reduction and enhancing the system reliability. Intensive research has been carried out to develop the size reduction techniques of the patch antenna. The reduction of size of antenna, wide bandwidth and low profile antenna are in great demand for commercial applications. Several researchers have been trying from years to reduce the size of antenna. Recently, metamaterial based structure, originally proposed by Pendry, has opened the door to new design strategies. To overcome rectangular microstrip antenna drawbacks Victor Veselago (1968) Engheta [2][3][4] and Ziolkowski (2006) introduced the theoretical concepts on metamaterial. In the theory of metamaterial, which exhibit negative permittivity and permeability [2], also known as media with a negative refractive index or left handed material. The unusual properties of the Metamaterials [5] [6] are utilized here in a Microstrip Patch Antenna at operating frequency in order to achieve a more efficient antenna. In this type of material "the phase Velocity would be parallel to the direction of pointing vector". Some applications for Metamaterial Antennas are communication, space GPS, satellites, space vehicle navigation, and airplanes.

II. DESIGN METHODOLOGY

The RMT parameters are calculated from the formulae given below [7].

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$L = L_{eff} - 2\Delta L \quad (2)$$

$$L_{eff} = \frac{C}{2\ f_r\ \sqrt{\varepsilon_{eff}}} \quad (3)$$

Volume 3 Issue VII, July 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

$$\frac{\Delta L}{h} = \frac{0.412\left(\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)\right)}{\left(\varepsilon_{eff-0.258}\left(\frac{W}{h} + 0.8\right)\right)} \quad (4)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + \frac{12\,h}{w}}}\right) \quad (5)$$

Where

ε_{eff} = Effective dielectric constant.
ε_r = Dielectric constant of substrate.
h = Height of the dielectric substrate.
W = Width of patch.
L = Length of the patch.
ΔL =Effective length.
f_r = Resonating frequency.

After dimension calculation design work has been done. Perfect electric conductor (PEC) was used to make the patch antenna over the ground which also having the same material with substrate of dielectric constant 4.3 between patch and ground. RMPA at 2.691GHZ frequency is shown in fig. 1. The height of the patch from the ground plane is 1.6 mm and the thickness of the ground plane and the patch is 0.038mm.

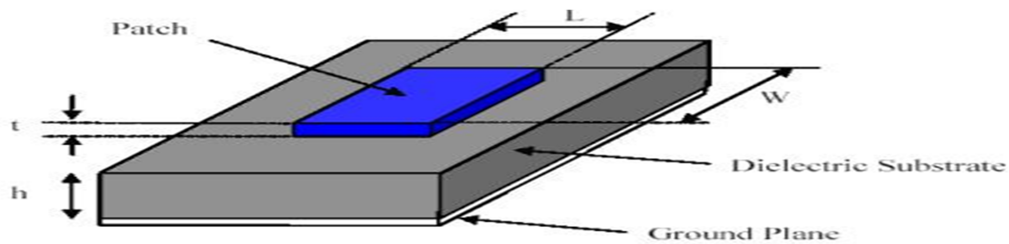


Fig .1: General block diagram of rectangular patch

The parameters are analysed and implied in designing of microstrip patch antenna in computer simulation technology software (CST-MWS) . where the width of feed 4mm, at which the port will be attached. The position of the port is (x=25mm, y=0 ,z=0 to1.676mm

Parameters	Dimensions	Unit
Dielecric constant of FR-4 (lossy)(ε_r)	4.3	-
Loss tangent($\tan\partial$)	0.025	-
Thickness of FR-4 (lossy) (h)	1.6	mm
Operating frequency	2.691	GHZ
Length(L)	26	mm
Width(W)	34	mm
Cut width	6	mm
Cut depth	8	mm
Path length	20	mm
Width of feed	4	mm

Table.1: Dimension of the rectangular patch.

Volume 3 Issue VII, July 2015
ISSN: 2321-9653

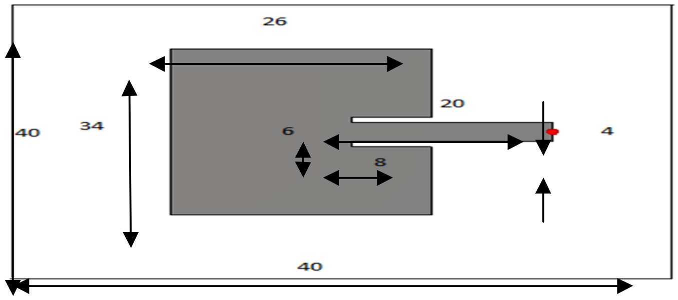


Fig.2: Simulated Rectangular microstrip patch antenna (all parameters in mm).

The simualtion result of the rectangular patch without metamaterial structure shown in fig.2 (all parameters in mm). The return loss characteristic of RMPA at 2.691 GHZ have been studied in fig.3 below. The relative narrow bandwidth of rectangular microstrip patch antenna is 54.8 MHZ and the return loss of 12.73db Exhibited for conventional RMPA.

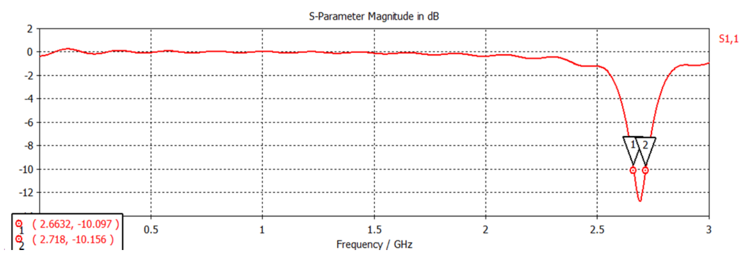


Fig.3: Simulation of return loss S11 of reactangular microstrip antenna.

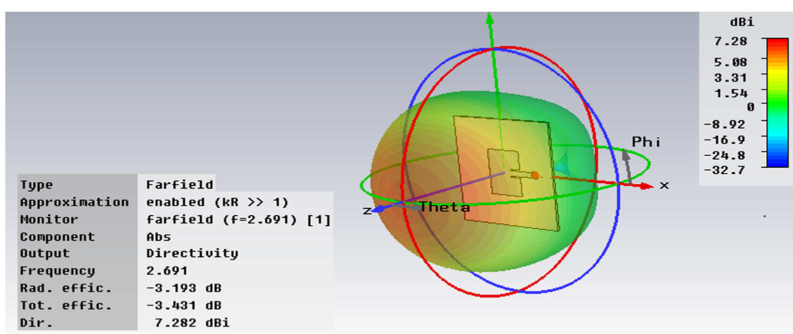


Fig.4: 3D radiation pattern of rectangular microstrip patch antenna

Fig.4 shows , 3D radiation pattern together with azimuth and elevation plane definition. Azimuth angle is denoted by "theta" and angle of elevation is denoted by "phi". Azimuth angle is the angle between reference direction (north direction) and a point, at which our antenna will be placed in the ground plane and elevation angle is the angle between ground plane axis and tilted axis of the antenna.

III. NICOLSON-ROSS-WEIR (NRW) APPROACH

Fig.5 shows that The proposed metamaterial structure is placed between the two waveguide ports[8] at the left and right of the X-Axis in order to calculate the S11 and S21 parameters so as to prove that the proposed structure possess Double NegativeMetamaterial properties. Where Y-Plane was defined as Perfect Electric Boundary (PEB) and Z-Plane was defined as the Perfect Magnetic Boundary (PMB). In this Nicolson-Ross-Weir (NRW) technique has been used to obtain the values of permittivity and permeability as this is a very popular technique to convert S-parameters due to the fact that this technique provides easy as well as effective formulation and calculation. (PEB) and (PMB) both in wave guide, which creates internal environment of waveguide. The simulated S-Parameters are then exported to Microsoft Excel Program for verifying the Double-Negative properties of the

Volume 3 Issue VII, July 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

proposed metamaterial structure.

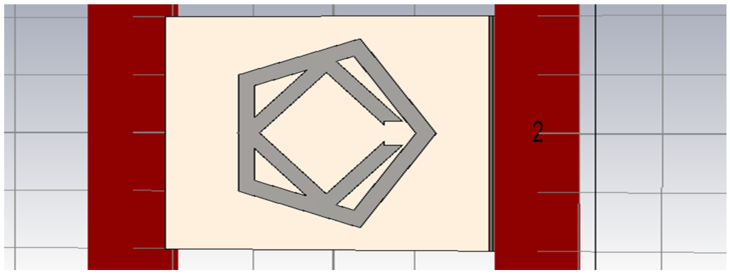


Fig.5: Proposed metamaterial structure between the two port waveguide.

The simulated result after the implementation of the metamaterial over the rectangular microstrip patch antenna at the height of 3.276mm from the ground plane enhance the property of the RMPA alone and reduces the size of the antenna by shifting the lowest dip to a frequency other than the operative frequency i.e. at 1.035GHZ.

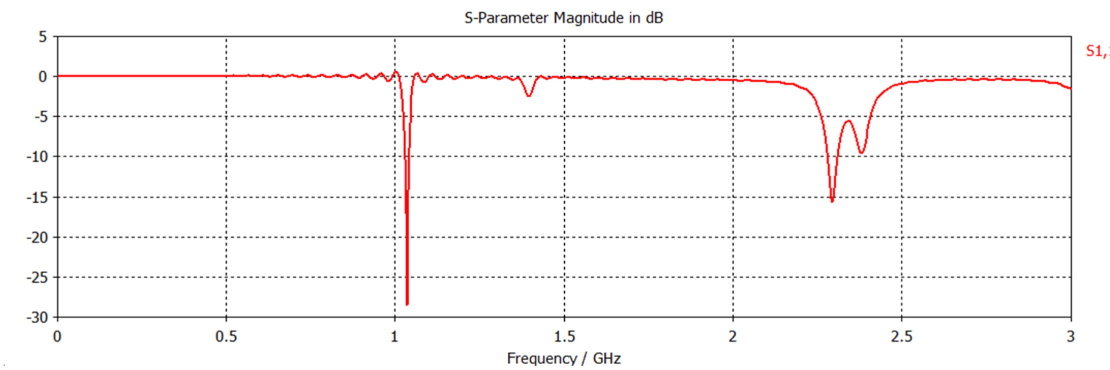


Fig.6: Simulated result is showing the return loss of -28.426db .

Fig.6 shows that the proposed metamaterialstructure reducethe return loss up to 123%.Three dimensional radiation pattern of rectangular microstrippatch antenna with proposed metamaterial structure is shown in below

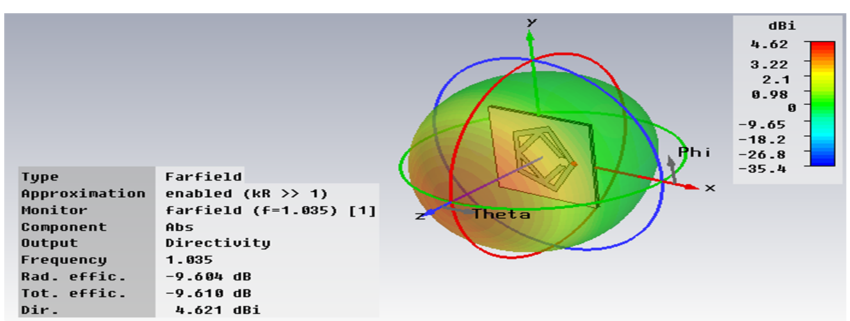


Fig.7: 3DRadiation pattern of RMPA with proposed metamaterial structure.

Fig.7 shows, 3D radiation pattern of RMPA with proposed metamaterial structure , in which no improvements in directivity and total efficiency parameter.

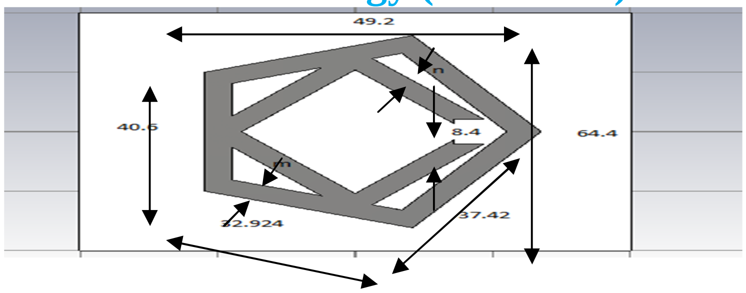


Fig.8: Rectangular microstrip patch antenna loaded with" rectangular shape inside a pentagon" metamaterial structure at the height of 3.276mm from the ground plane[m=4.384,n=5.2](all parameters in mm).

Equations used for calculating permittivity and permeabilityusing NRW approach [9][10][11].

$$\mu_r = \frac{2\,c\,(1 - v_2)}{\omega di\,(1 + v_2)} \qquad (1)$$

$$r = \frac{2\,c(1 - v_2)}{\omega di\,(1 + v_1)} \qquad (2)$$

$$V_2 = S_{21} - S_{11} \qquad (3)$$

$$V_1 = S_{11} - S_{21} \qquad (4)$$

Where
εr= Permittivity , μr= Permeability
c = Speed of Light, ω = Frequency in Radian
d = Thickness of the Substrate,
i = Imaginary coefficient.
V1=voltage maxima.
V2= voltage minima.
After the simulation in CST-MWS software the S11 and S21 parameter were exported to MS excel software for knowing the property of metamaterial. In MS Excel above equation is used to prove that it is metamaterial. The result of NRW approach, showing negative permeability and permittivity.

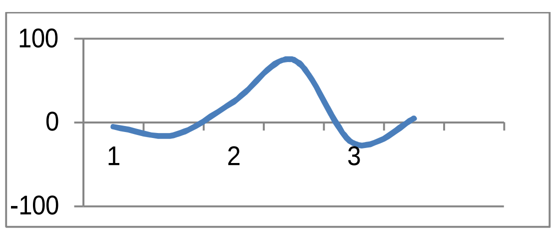


Fig.9: Permittivity versus frequency graph obtained from Excel software.

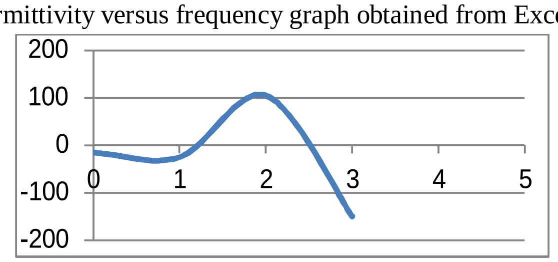


Fig.10: Permeability versus frequency graph obtained from Microsoft Excel software.

The negative value of permittivity and permeability by using MS-EXCEL software in the frequency range 1.00GHZ to 1.103GHZ range.

IV. RESULT

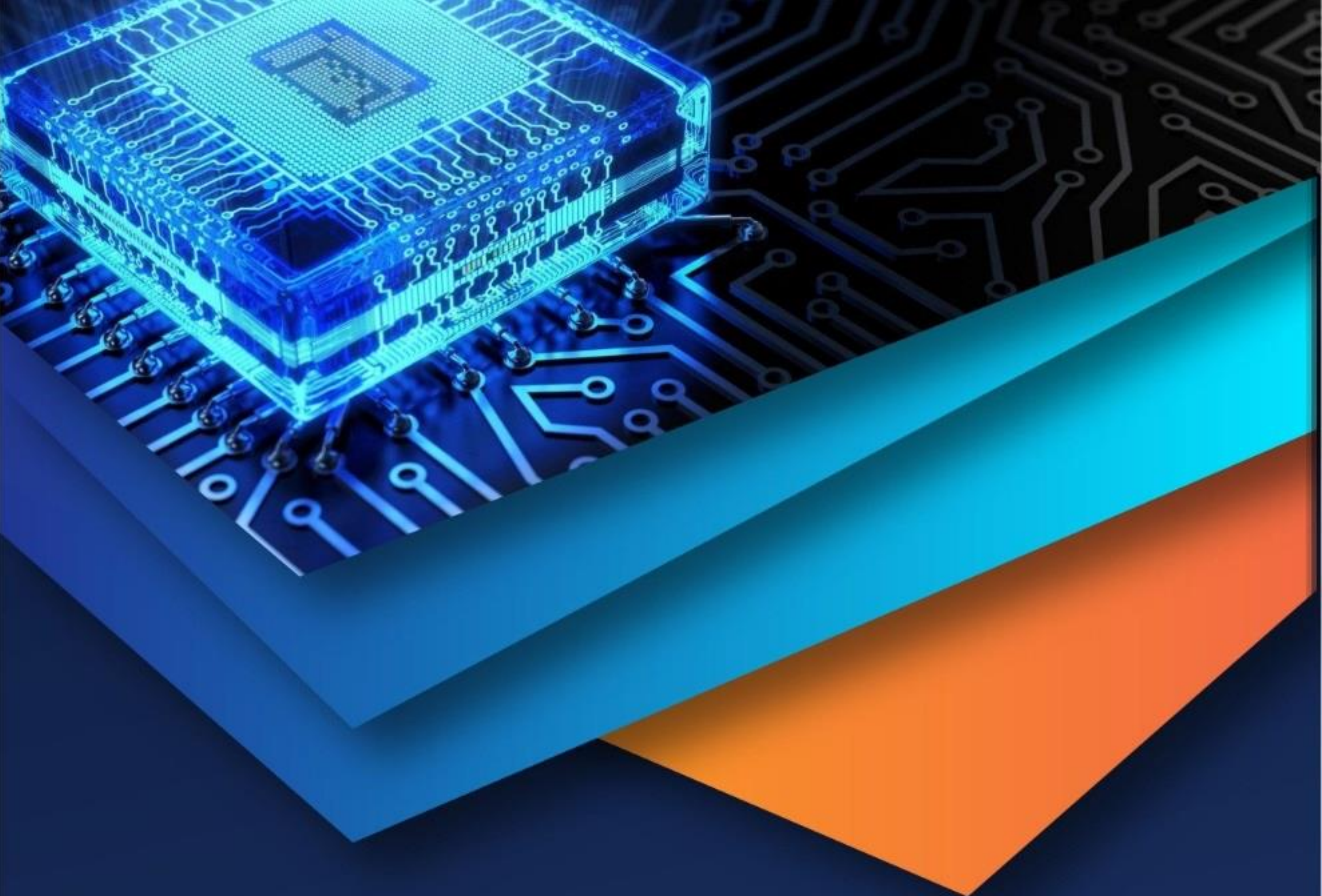
By emphasizing RMPA with" rectangular shape inside a pentagon" metamaterial structure of RMPA. The frequency on which it shows lowest return loss is -28.426db where the operating frequency is 1.035GHZ. the frequency at which size of the antenna will reduce is 1.035GHZ. It is possible by using rectangular patch antenna with metamaterial structure, and with the help of metamaterial structure ,we will not only achieve good size of the antenna but also it will provide low return loss and wide bandwidth characteristic of the antenna.

V. CONCLUSION

Authors, presented a new design methodology in this paper for creating highly improved rectangular microstrip transceiver, by adding a single layer that contains an "rectangular shape inside a pentagon" metamaterial structure. The proposed metamaterial structure at the height of 3.276 mm from the ground plane of the rectangular microstrip transceiver. Due to its small size , the antenna have many applications in communication system. Along with these improvements this the construction is simple, improved transceiver can be produced with little effort at low cost. On the basis of the simulation results it is observed that there is reduction in size of the RMT at the frequency of 1.035GHZ , return loss is reduced by 123% [12] and the size is being reduced to 85% by incorporating the proposed metamaterial structure. It is clearly observed that the return loss, size and gain has improved significantly by incorporating the structure satisfies Double Negative property within the simulated frequency range.

REFERENCES

[1] H. W., R. L. Haupt, and P. L. Werner, "Fractal antenna engineering: The theory and design of fractal antenna arrays," IEEE Antennas and Propagation Magazine, Vol. 41, No. 5, 37-59, 1999.
[2] V. G. Veselago"The electrodynamics of substances with simultaneously negative valueεandμ"Sov.Phys.Uspekekhy.10 (4), 509-514, 1968.
[3] J. B. Pendry, A. J. Holden, D. J. Robbins, W. J. Stewart, "magnetism from conductors and enhanced nonlinear phenomena" IEEE Trans. Micro Tech. vol.47 no.11, pp.2075-2081, Nov. 1999.
[4] D.R. Smith, W.J. Padilla, D.C. Vier, et al, "Composite medium with simultaneously negative permeability and permittivity", Phys Rev Lett 84, 4184–4187,May 2000.
[5] R.W. Ziolkowski, "Design fabricating and fabrication and testing of double negative Metamaterials," IEEE Transactions on Antennas and Propagation, vol.51, no.7, pp.1516-1529, July 2005.
[6] Wu, B-I, W. Wang, J. Pacheco, X. Chen, T. Grzegorczyk, and J.A. Kong, "A study of using Metamaterials as Antenna substrate to enhance gain," Progress in Electromagnetic Research, PIER 51, pp.295-328, 2005.
[7] A. Desired Parametric Analysis (Balanis, 1997; Stutzman and Thiele, 1998.
[8] Silvio Hrabar, GordanJankovic, BerislavZickovic, ZvonimirSipus, "Numerical and Experimental Investigation of Field Distribution in Waveguide Filled with Anisotropic Single Negative Metamaterial" .
[9] Ahmad A. Sulaiman, Ahmad S. Nasaruddin, "Bandwidth Enhancement in Patch Antenna by Metamaterial substrate", European Journal of scientific research, 2010.
[10] Huda A. Mazid, Mohammad Kamal A. Rahim, ThelasaMasri, "Left-handed Metamaterial design for Microstrip Antenna application", IEEE International RF and Microwave conference, 2008.
[11] H.A. Majid, M.K.A. Rahim and T. Marsi, "Microstrip Antenna gain enhancement using left-handed Metamaterial Structure" Progress in Electromagnetic Research M. Vol.8, pp.235-247, 2009.
[12] Richard R. Ziolkowski, "Double NegativeMetamaterial Design, Experiments and Applications", IEEE Transactions on Microwave Theory and Techniques, Vol.51, No. 7, July 2003.
[13] P. K. Singhal, BimalGarg, NitinAgrawal "A High Gain Rectangular Microstrip Patch Antenna Using "Different C Patterns" Metamaterial Design In L-Band",published in Advanced Computational Technique in Electromagnetics July 2012.
[14] P. K. Singhal, BimalGarg "A High Gain & Wide Band Rectangular Microstrip Patch Antenna Loaded With Interconnected SRR Metamaterial structure", published in International Journal of Engineering and Technology, August 2012.
[15] P. K. Singhal, BimalGarg "Design and Characterization of Compact Microstrip Patch Antenna Using "Split Ring" Shaped Metamaterial Structure" published in international journal of electrical and computer engineering, Vol.2, No.5, October 2012.
[16] Garg B, Saleem D (2013). Ameliorated RMPA using 'Squares surrounded by Hexadecagon' shaped Double Negative Metamaterial structure in Ultra High Frequency (UHF) Band. Amer. J. Eng. Sci. and Technol., Res. 1(1): 1-9.
[17] Garg B, Saleem D (2013b). A Highly Efficient & Directive Rectangular Microstrip Patch Transceiver Using Circular SRR Based Metamaterial Structure for Microwave and Wireless Communication Applications. Int. J. Information & Computation Technol., 3(9): 710-713.
[18] Garg B, Saleem D (2013c). Experimental Verification of Double Negative Property of LHM with Significant Improvement in Microstrip Transceiver Parameters in S Band. Int. J. Eng. Practical Res., 2(2): 64-70.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY