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COMPACT SIZE OF RECTANGULAR MICROSTRIP PATCH ANTENNA USING LEFT HANDED META MATERIAL

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A narrow band micro strip patch antenna with four cocentric circular Rings" shaped metamaterial cover is proposed at a height of 3.2mm from the ground plane. The antenna along with the proposed metamaterial cover is designed to resonate at 2.31GHz frequency (in S-Band). Proposed metamaterial cover significantly reduces the return loss and increases the gain of the antenna in comparison to conventional rectangular microstrip patch antenna alone. After that, the antenna design with the planned metamaterial cover, due to the cover the antenna is start resonating at 1.548 GHz frequency. For designing an antenna at resonating frequency 1.548 GHz is required more space than the design. In the design, the antenna design along with the metamaterial cover which has some special properties so the antenna is minimize in the size and also reduce the return loss and increases the efficiency of the antenna. The purpose of this work is to design a compact and efficient antenna with metamaterial cover.

Keywords- *Left-Handed Metamaterial (LH MTM), Nicolson-Ross-Weir (NRW), Rectangular Flat Panel Antenna (RFPA), Return loss (RL)*

1. Introduction

Metamaterials were first introduced by Veselago [1] with a negative electric permittivity and a negative magnetic permeability. Metamaterial can be defined as a new class of ordered composites that exhibits exceptional properties not readily observed in nature. In general, metamaterials are artificial, manmade structures not found in nature. Its permittivity & permeability both are negative [1] so it is also called Double Negative Material (DNG). Firstly meta-material introduced by Victor Georgievich Veselago[1] in 1967.

DNG has few unique and special properties due to negative values of permittivity (ε) and permeability(μ) [5][8] of the structure itself like negative refractive index and backward wave propagation. With these properties, the DNG will be mainly used to focus on the radiation of the antenna. DNG play main role for increasing gain, cut down the antenna size, adjust bandwidth and also find its application in filtering the unwanted signals.

Microstrip antenna is most popular antenna due to its low profile, lightweighted, easy to fabricate and inexpensive properties but it have some drawbacks like poor efficiency, high return loss which are removed by using DNG. DNG improve the performance of micro strip antenna.

Computer Simulation Technology (CST-MWS) Software has been used for all the simulation and designing. Double negative property of proposed antenna is verified by MS Excel Software has been used for verifying the double negative properties of the proposed DNG cover.CST microwave studio using transient solver [8], and spectrum analyzer in frequency range 0 to 3 GHz.

2. Formulation And Designing

The Microstrip antenna parameters are calculated from the formulae given below.

Desired Parametric Analysis Calculations [2][3]:

Width (W):

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

Effective dielectric constant**:**

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

The actual length of the Patch (L):

$$L = L_{eff} - 2\Delta L \qquad (3)$$

Where,

$$Leff = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}} \qquad (4)$$

Calculation of Length Extension:

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)} \qquad (5)$$

Where,
c = free space velocity of light,
ε_r = Dielectric constant of substrate,
f_r = Resonating frequency,
ε_{reff} = Effective dielectric constant,
h = Height of dielectric substrate,
W = Width of patch,
L = Length of patch and
ΔL = Effective Length

Conventional Micro strip antenna etched on FR-4 lossy substrate of dielectric constant ε_r = 4.3 and thickness h = 1.6 mm at 50Ω matching impedance. Dimension of ground and lossy substrate is same and it is 90 X 90 mm^2. All parameter of rectangular micro strip antenna for resonating frequency 2.3 GHz are shown in fig. 1 and all parameters in millimeter (mm). These parameters are calculated with the help of above formula

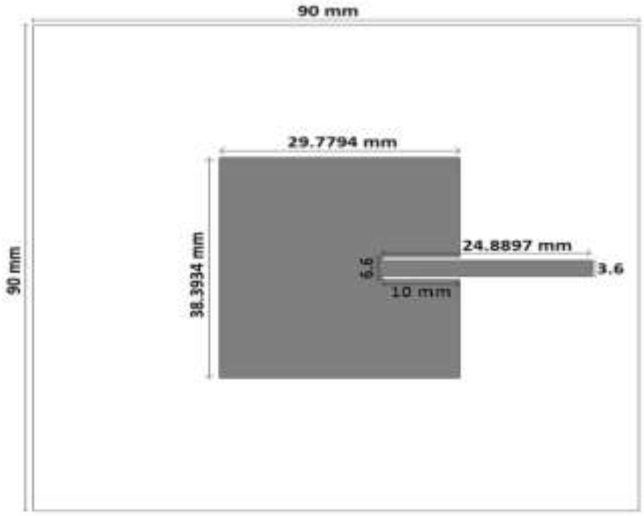

Fig. 1: Micro strip antenna at 2.3 GHz (all dimensions in mm).

Above Design is simulated in CST-MWS software in transient mode at the operating frequency. After simulation, return loss of antenna is shown in fig. 2. Return loss defines the antenna's absorption of the fed power over the total power fed. It is also known as S11 parameter in two port network.

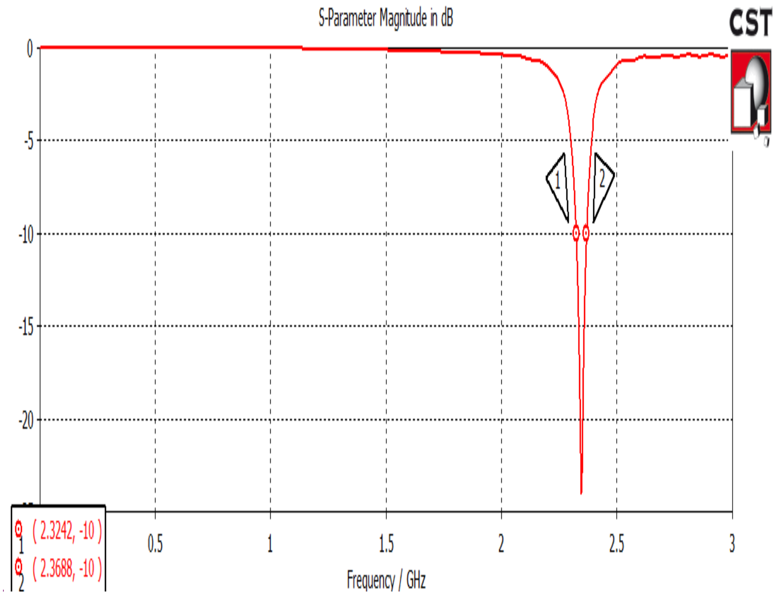

Fig. 2: Simulated result of rectangular flat panel antenna showing Return Loss of -24 dB.

After simulation,return loss is -24db which is shown in fig 2 and radiation pattern of the antenna is shown in fig. 3 which also shows gain of 4.457dB.

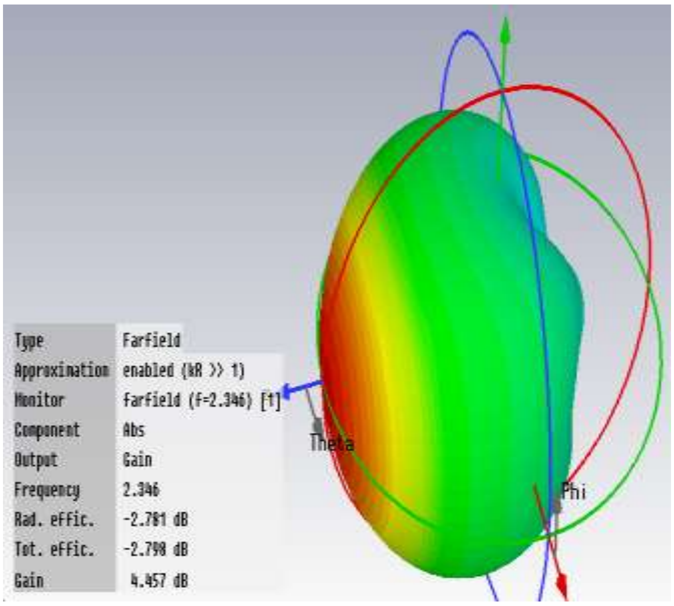

Fig. 3: Radiation Pattern of Microstrip antenna showing Gain

After designing & simulating the micro strip antenna, Proposed meta material design is placed on the micro strip antenna at a height of 1.6 mm from the designed antenna. The design of material cover consists of four octagons, four circles and a square. Dimensions of all the circles are the same and all octagons also have the same dimensions as shown in fig.4.

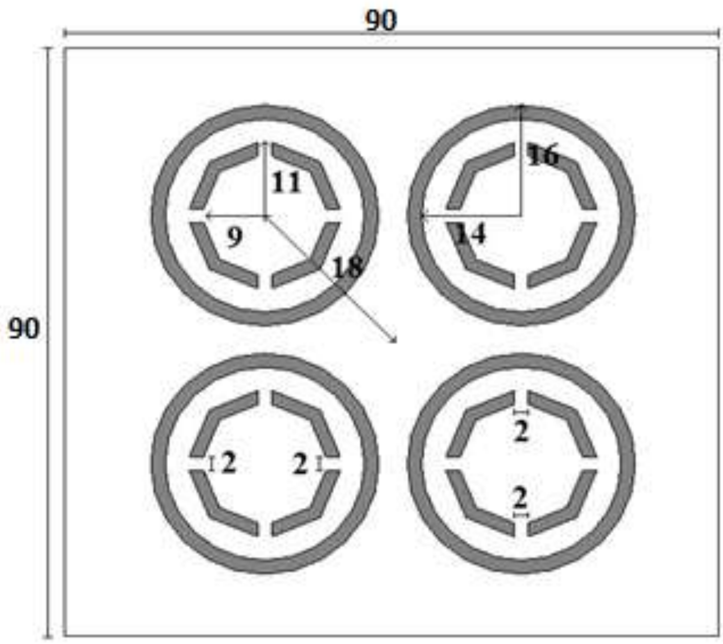

Fig. 4: Dimensional view of the Proposed meta material (all dimensions in mm).

The suggested material cover design is placed between the two waveguide ports [17] at the left & the right of X-Axis as shown in figure 5, in order to calculate S11 and S21 parameters[11][16]. The excitation of the signal was done from the left side to the right side of the structure assuming the surrounding was air. Y-Plane was defined as Perfect Electric Boundary (PEB) and Z-Plane was defined as Perfect Magnetic Boundary (PMB). Subsequently, the wave was excited from the negative X-axis (Port 1) towards the positive X-axis (Port 2).

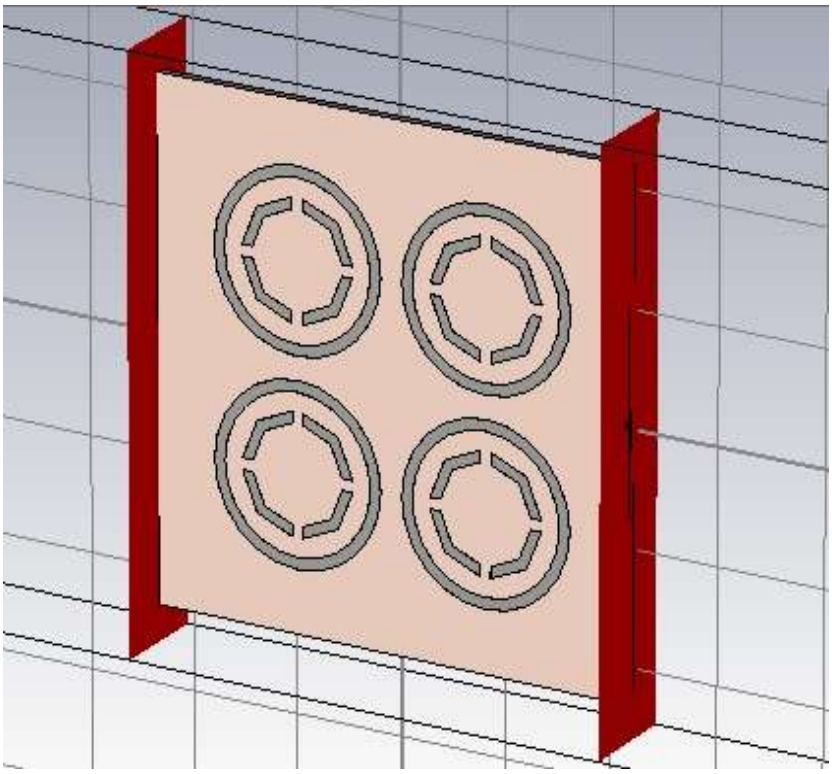

Fig. 5: Proposed Metamaterial Structure placed between the two Waveguide Ports at the left & right of the X-axis.

According to this approach, the value of S11 and S21 parameters were obtained in complex form, which are then exported to Microsoft Excel program for verifying the double-negative properties of the proposed material cover structure by using NRW approach.

Formulae for determining the value of permittivity & permeability using NRW approach [9][10][13]:

$$\mu_r = \frac{2.c(1 - v_2)}{\omega.d.i(1 + v_2)}$$

$$\varepsilon_r = \mu_r + \frac{2.S_{11}.c.i}{\omega.d}$$

Where,

$v_1 = S_{11} + S_{21}$

$v_2 = S_{21} - S_{11}$

ω = Frequency in Radian,

d = Thickness of the Substrate,

c = Speed of Light,

v1 = Voltage Maxima, and

v2 = Voltage Minima.

The values of permittivity (ε) and permeability (μ) are calculated by using equations 6 & 7 in the simulated frequency range. Graph in fig. 6 & 7 shows that the proposed material cover possesses negative values of permittivity & permeability at the resonating frequency.

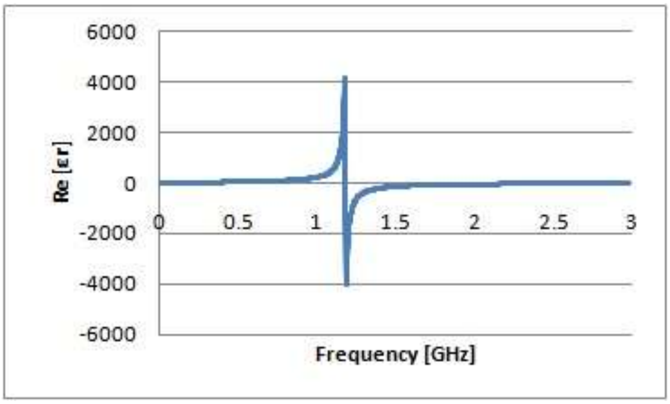

Fig. 6: Permittivity versus Frequency Graph obtained from Microsoft Excel Software.

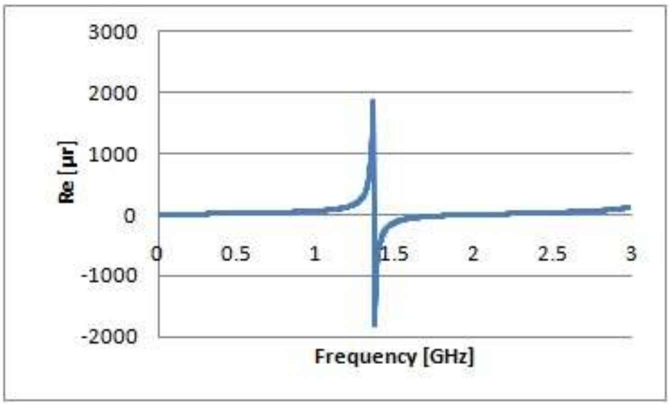

Fig. 7: Permeability versus Frequency Graph obtained from Microsoft Excel Software

Microstrip antenna integrated with suggested material cover at a height 3.2 mm from the ground plane is shown in fig. 8.

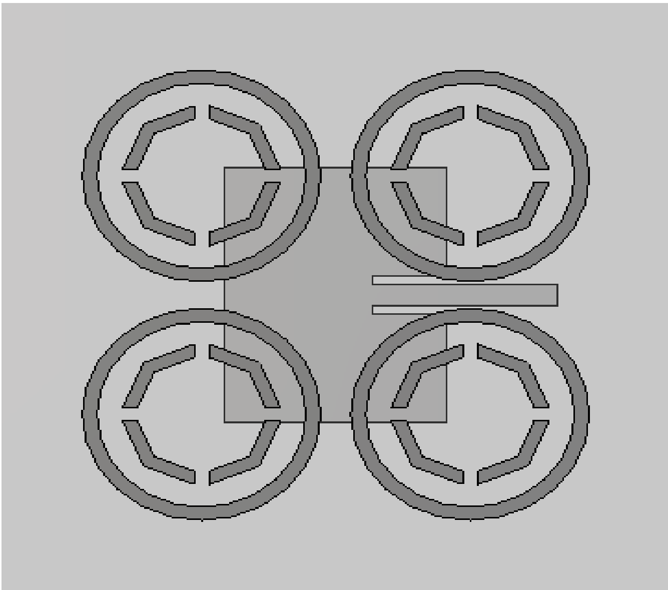

Fig. 8: Rectangular flat panel patch antenna along with material cover at a height of 3.2mm from the ground plane.

The simulated results of the RFPA along with suggested metamaterial cover are shown in figure 9 & 10. It has been found that the performance of suggested antenna is increased by increasing efficiency, reducing return loss etc. in comparison to RFPA alone. The size of antenna also reduces significantly. The return loss of RFPA along with suggested material cover is reduced by 19 dB, is shown in fig. 9.

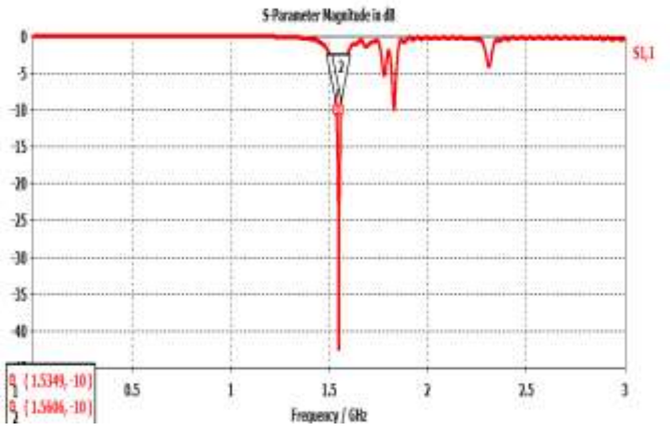

Fig. 9: Simulated result of the RFPA along with suggested material cover showing Return Loss of -43dB.

Fig. 10 shows the radiation pattern of the microstrip antenna along with metamaterial. It has been observed that the total efficiency [12] is increased from 52.5% to 73.19% and gain is improved from 4.457 to 5.589dB in comparison with Microstrip alone. Radiation pattern is defined as the power radiated (transmitted) or received by an antenna in a function of the angular position and radial distance from the antenna.

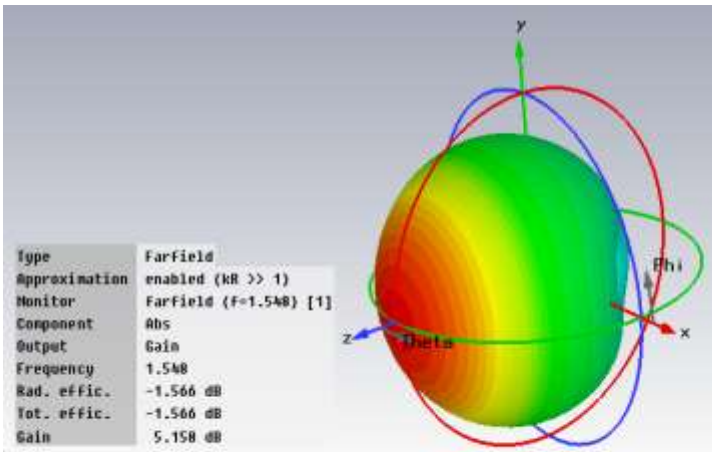

Fig. 10: Radiation Pattern of the microstrip antenna along with the metamaterial cover showing gain of 5.158

Conclusion

The Aim of this paper provides a reduced size Micro strip antenna for several microwave applications. It has been observed that Meta material improve the performance of antenna like increase gain and reduction in return loss etc. Finally Proposed structure gives advantage of small size, less power consumed and less cost antenna at operating frequency 1.572 GHz with 43 dB return loss and 5.158dB improved gain.

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