REDUCTION IN THE SIZE OF RECTANGULAR MICROSTRIP PATCH ANTENNA

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Abstract - *In the era of nanotechnology, size is matter. For such purpose, the design is focused on reduce the size of rectangular microstrip patch antenna. In the design, firstly design a patch antenna at resonating frequency 2.4 GHz. 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.*

Key Words: Metamaterial (MTM), Nicolson-Ross-Weir (NRW), Rectangular Microstrip Patch Antenna (RMPA), Return loss (RL)

1. INTRODUCTION

Rectangular Microstrip Pacth Antenna (RMPA) is popular antenna due to its low profile, lightweighted, easy to fabricate and conformable to planar and nonplanar surfaces. The idea of a microstrip antenna can be traced to 1953. Microstrip antennas consist a very thin metallic strip (patch) placed on a dielectric substrate above a ground plane[2].

Metamaterial is an artificial materials (not found in nature) which is firstly theoretically introduced by Victor Georgievich Veselago[1] in 1967. Metamaterial has unique properties such as negative values of permittivity and permeability[5][8], negative refractive index, backward wave propagation etc. Due to these properties, the metamaterial is used to ameliorate the antenna. Metamaterial is also used in various application other than the ameliorate the antenna.

Computer Simulation Technology (CST-MWS) 2010 Software has been used for all the simulation and designing. CST Microwave Studio is ultimate software to simulate the design, as this software is desirable for a 3D platform in simulating a full wave simulation. After obtaining the S-parameters from the software, they were exported to Microsoft Excel to calculate the effective values of permittivity and permeability by utilizing the Nicolson-Ross-Weir (NRW) Approach. Hence MS Excel Software has been used for verifying the double negative properties of the planned metamaterial cover.

2. FORMULATION AND DESIGNING

The Rectangular flat panel 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,

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \qquad (4)$$

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

The Rectangular Microstrip Patch Antenna (RMPA) is fabricated on FR-4 (lossy) material of dielectric constant ε_r = 4.3 and thickness h = 1.6 mm at 50Ω matching impedance. In the design, the area of ground and the area FR-4 lossy material is same and it is 100 X 100 mm^2. All parameters of RMPA at resonating frequency 2.4 GHz are shown in figure 1 and all parameters are shown in millimeter (mm).

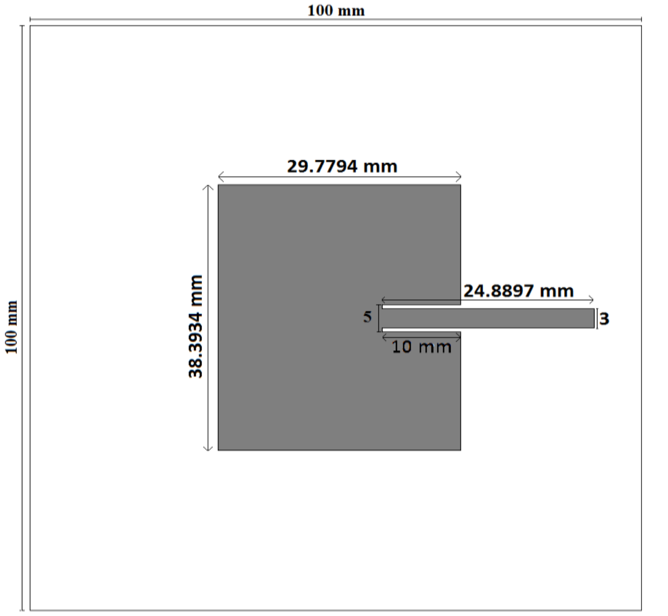

Fig -1: Rectangular Microstrip Patch Antenna at 2.4 GHz (all dimensions in mm)

The figured RMPA is simulated in CST-MWS software at the operating frequency (2.4GHz). After simulation, return loss of antenna is shown in figure 2. It is denoted as S_{11} in two port network. Figure 2 shows the return loss approximately -16 dB and bandwidth of 42.4 MHz.

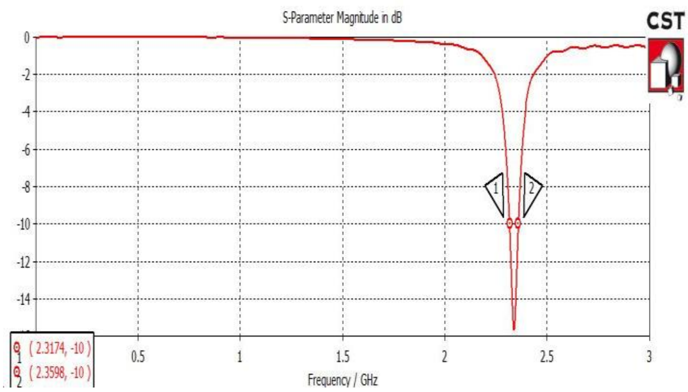

Fig -2: Simulated result of Rectangular Microstrip Patch Antenna showing Return Loss of -16 dB

After simulation, radiation pattern of the antenna is shown in figure 3, which shows directivity 7.237 dBi and total efficiency 29.12%. The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna.

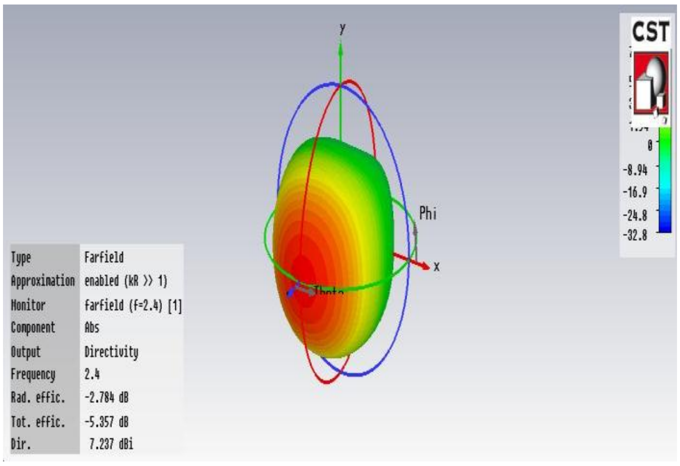

Fig -3: Radiation Pattern of Rectangular Microstrip Patch Antenna showing directivity and total efficiency

After designing & simulating the RMPA, the planned metamaterial cover is placed above the patch of rectangular microstrip patch antenna. The design of metamaterial cover consists of four circles and four octagons. Dimensions of all the circles are the same and all octagons also have the same dimensions. The circles and octagons are symmetric to each other. Planned cover is shown in figure 4.

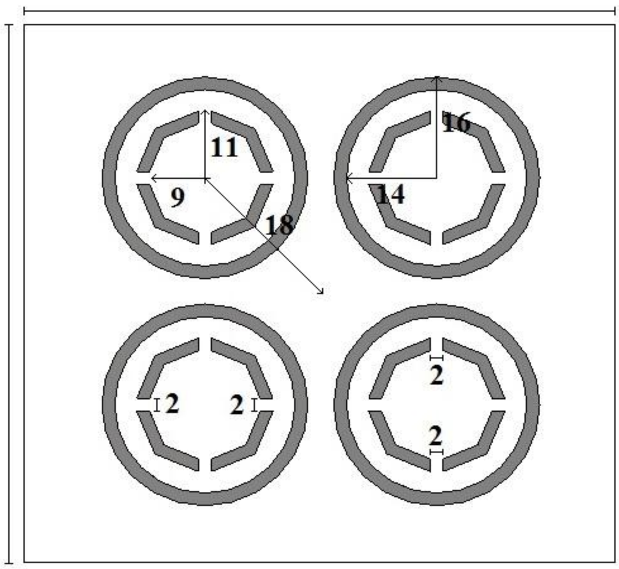

Fig -4: Planned cover of Metamaterial (all dimensions in mm)

Now, the planned metamaterial cover 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 S_{11} and S_{21} 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).

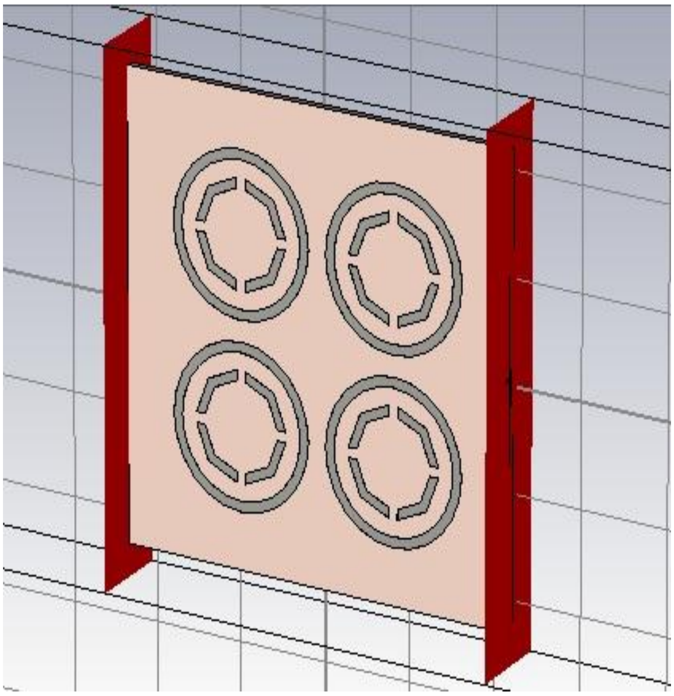

Fig -5: Planned metamaterial cover placed between the two Waveguide Port

The obtained value of S_{11} and S_{21} parameters was in complex form, which are 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]:

$$\mu_r = \frac{2.c(1-v_2)}{\omega.d.i(1+v_2)} \quad (6)$$

$$\varepsilon_r = \mu_r + \frac{2.S_{11}.c.i}{\omega.d} \quad (7)$$

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,
v_1 = Voltage Maxima, and
v_2 = Voltage Minima.

The values of permittivity (ε) and permeability (μ) were calculated by using above equations 6 and 7. Figure 6 and 7 shows that the planned metamaterial cover possesses negative values of permittivity & permeability at the resonating frequency.

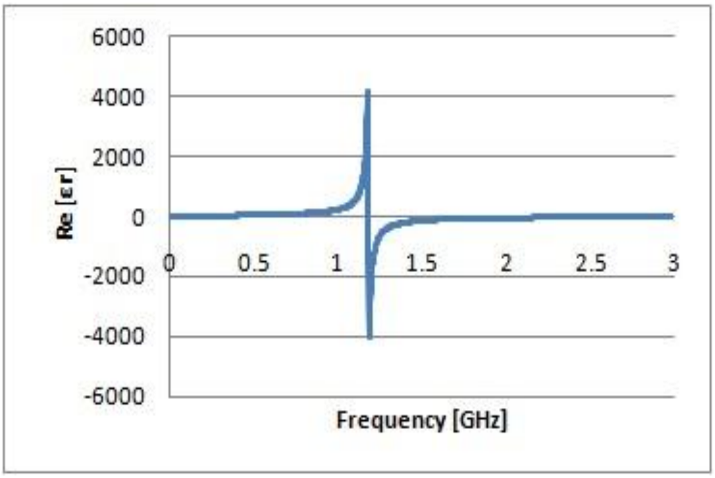

Fig -6: Permittivity versus Frequency Graph obtained from Microsoft Excel Software.

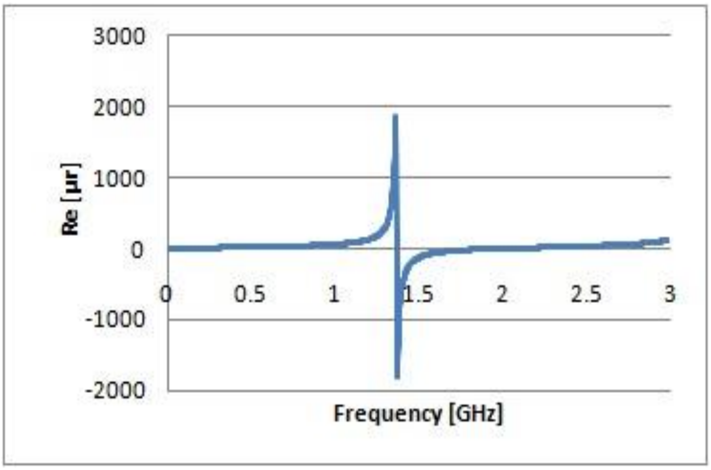

Fig -7: Permeability versus Frequency Graph obtained from Microsoft Excel Software

The simulated results of the RMPA along with planned metamaterial cover are shown in figure 8 and 9. It has been found that the size of antenna reduces significantly. The performance of antenna is also increased by increasing efficiency, reducing return loss. Figure 8 shows the return loss of RMPA along with metamaterial cover.

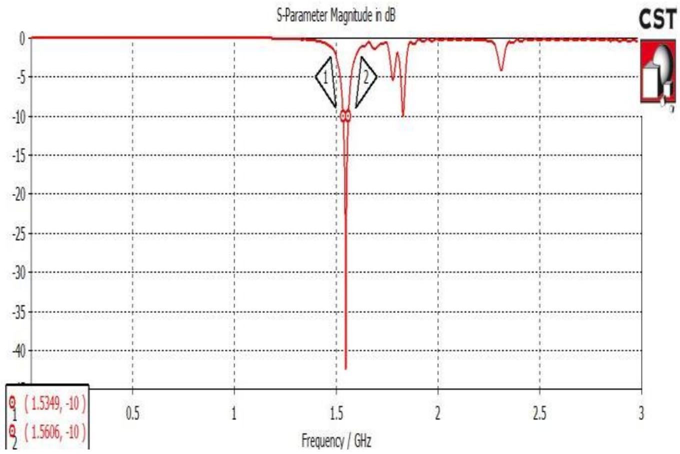

Fig -8: Simulated result of the RMPA along with metamaterial cover.

Figure 9 shows the radiation pattern of the RMPA along with planned cover. In the figure, it has been observed that the total efficiency is increased from 29.12% to 69.88%

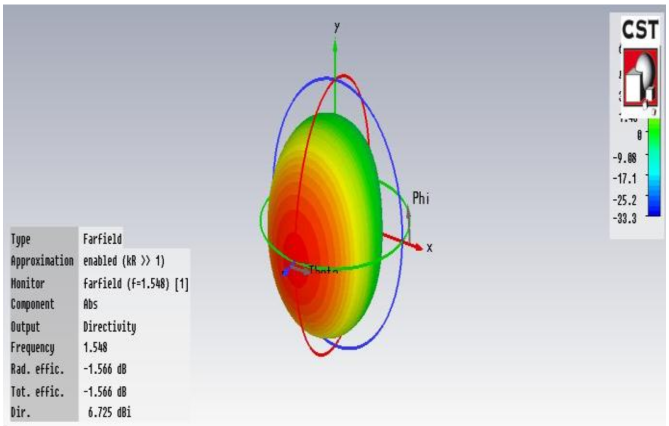

Fig -9: Radiation Pattern of the planned antenna showing directivity of 6.725 dBi & total efficiency of 69.88%.

3. CONCLUSIONS

As already discussed, the purpose of the paper provides a reduced size rectangular microstrip patch antenna. It is obtained with the help of metamaterial cover. It is also observed that metamaterial increases the performance of antenna by increasing efficiency, reducing the return loss etc. Finally found in the paper, a small size and an efficient rectangular microstrip patch antenna at operating frequency 1.548 GHz.

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