SMALL SIZE RECTANGULAR MICROSTRIP PATCH ANTENNA WITH METAMATERIAL

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ABSTRACT

The purpose of this work is to design a smaller size rectangular mircostrip patch antenna. In this work, a smaller size patch antenna designed using metamaterial. In the work, antenna's resonate frequency is 1.815 GHz, normally designing a rectangular mircostrip patch antenna at this frequency required more space but with the help of metamaterial minimize the size of patch and also base structure of the antenna. The designed antenna is fit when required less size antenna, at 1.815 GHz frequency.

Keywords: Nicolson-Ross-Weir, Rectangular Mircostrip Patch Antenna, Metamaterial

I. INTRODUCTION

Left handed metamaterial is an artificial materials. It is firstly proposed by Victor Georgievich Veselagoin 1967[1]. Metamaterial has exceptional properties because of negative permittivity and negative permeability[2][3]. Due these properties, this is called left handed metamaterial. Because of these properties, the metamaterial is capable to improve the properties of microstrip patch antenna.

Rectangular mircostrip patch antenna is easy to designed and it consists a flat rectangular sheet of metal, which is set on a bigger sheet of metal known as a ground plane. In designing microstrip antennas, a number of substrate can be used. In this work FR-4 lossy substrate is used. This substrate is situated between smaller sheet of metal and larger sheet of metal.

Computer Simulation Technology - Micro Wave Simulator (CST- MWS) has been used for every part of the designing & simulation and also used MS Excel Software for verifying the double negative properties of the used metamaterial cover.

II. FORMULAE AND DESIGNING

For the designing of patch of Microstrip patch antenna some formulae are used, which are given below.

Desired Formulae [4][5]:

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,

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

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

In the work patch of antenna designed on FR4 lossy substrate, which have thickness h = 1.6mm and ε_r = 4.3 at 50Ω matching impedance. Size of ground and FR4 lossy substrate is same and it have width = 80mm and length = 80mm. Physical parameter of RMPA at operating frequency 1.815GHz shown in figure 1.

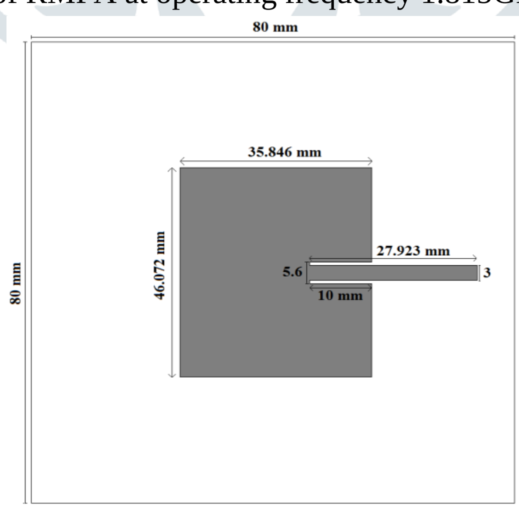

Fig. 1: *Dimention of rectangular Microstrip patch antenna (all dimensions in mm).*

Now, the suggested metamaterial cover is put on designed antenna at a height of 1.6mm from designed antenna. Structure of metamaterial has five squares and one rectangle. All six rectangle have one hole at own edge. Dimensions and physical view of metamaterial structure is shown below figure 2.

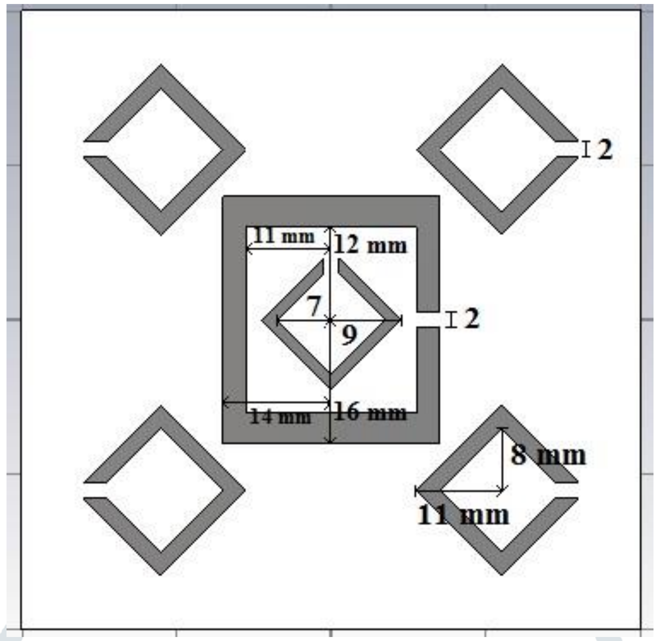

Fig. 2: *Dimensional view of the metamaterial cover (all dimensions in mm).*

After simulation of designed RMPA in transient mode at tuned frequency 1.815 GHz. Figure 3 is showing the Return loss (RL) of the antenna.

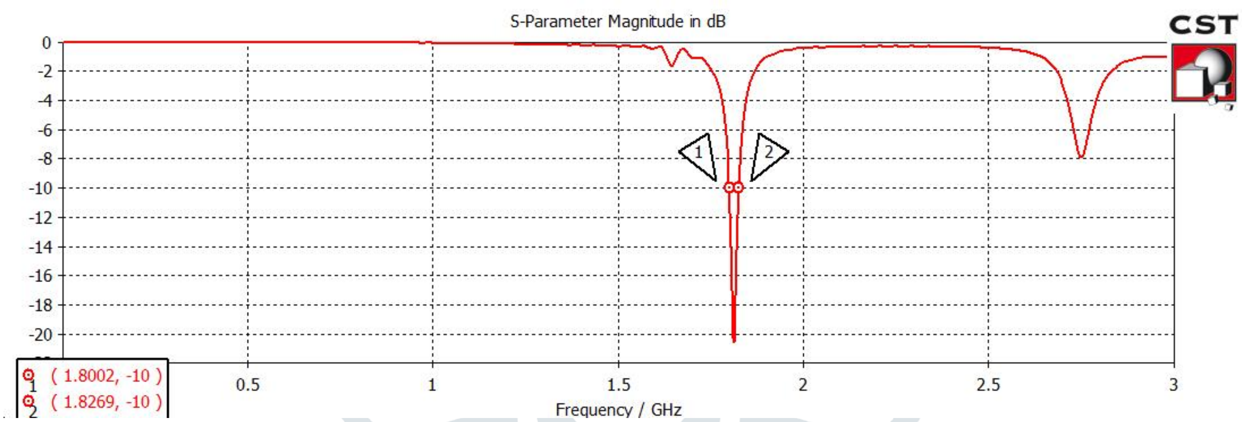

Fig. 3: *Simulated result of the RMPA showing Return Loss of -20dB.*

Pattern of the radiation of designed antenna is shown in figure 4, which shows total efficiency of 54.51% and directivity of 6.668 dBi. Pattern of radiation is defined as the power of the antenna receives or transmits as a form of function of the angular position and radial distance from the antenna.

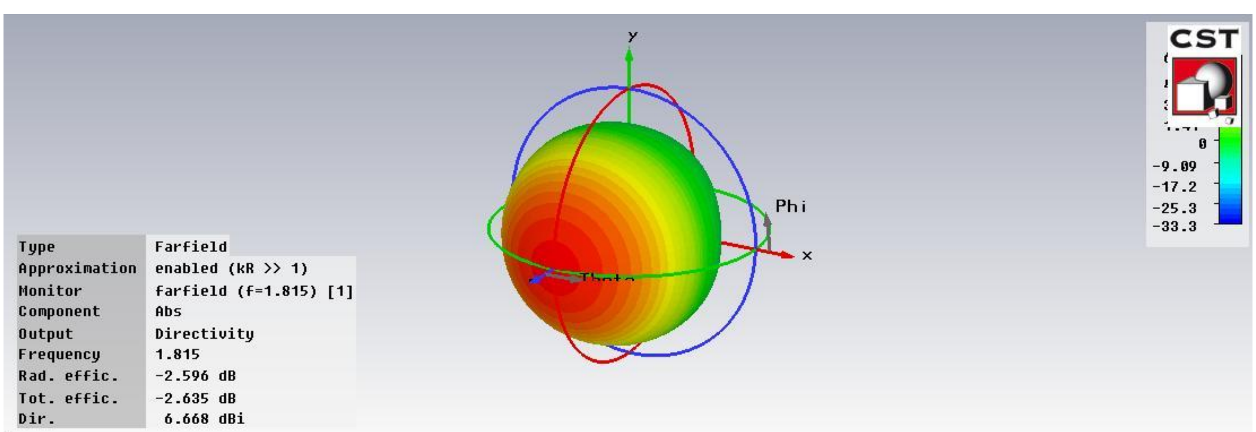

Fig. 4: *Radiation Pattern of the RMPA directivity & total efficiency*

To determine the parameters S_{11} and S_{21}[6], The metamaterial cover is now located between the left and right waveguide ports of the X-axis. The signal excitation was carried out from the left side of the device to the right, given the nearby area was air. Y- Plane has been define as a Perfect Electric Boundary and a Perfect Magnetic Boundary has been defined as Z-Plane.

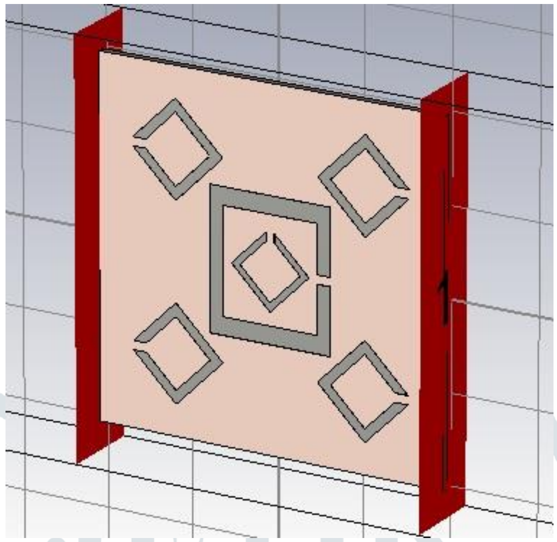

Fig. 5: *Designed metamaterial cover located between the two Waveguide Ports at the righht & left of the X-axis.*

The value of the parameters S_{11} and S_{21} is obtain in a complex form according to this procedure, These values are export to MS Excel software for dual negative properties verification of proposed metamaterial structure by NRW approach.

Following formulae are used to find the value of permeability and permittivity by NRW method [7][8]:

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

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

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

v_2 = Voltage Minima.

The permeability and permittivity values are finding by using Operating Frequency Range equations 6 & 7. Chart by figure 6 and figure 7 shows that the metamaterial cover has negative permeability and permittivity values at the tuned frequency.

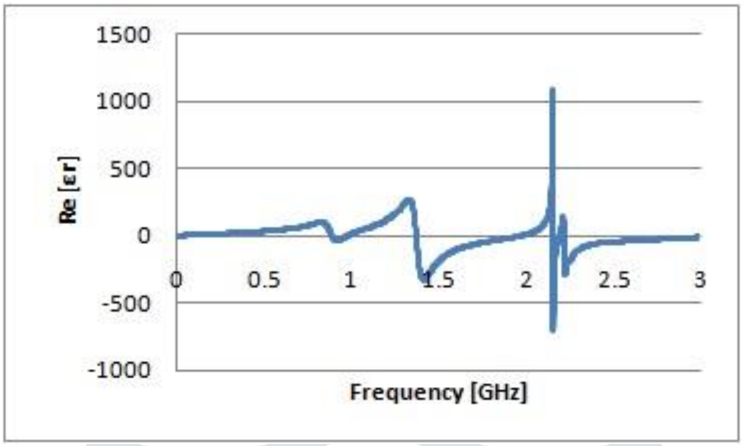

Fig. 6: *Permittivity Vs Frequency Graph.*

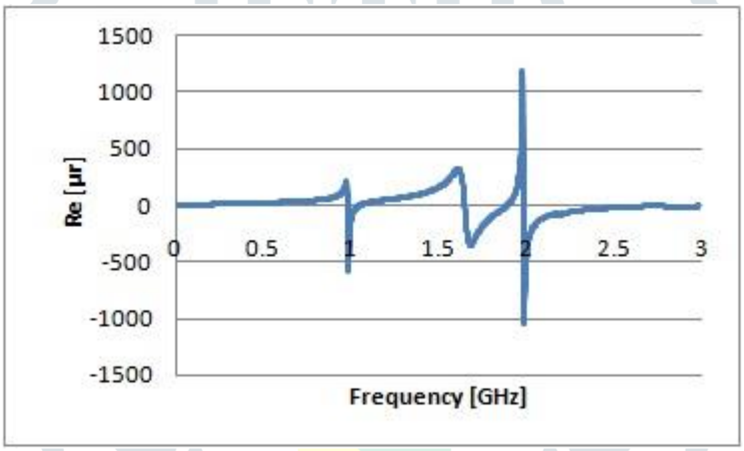

Fig. 7: *Permeability Vs Frequency Graph.*

The negative permittivity and permeability values for the operating frequency range 1.800-1.827 GHz are shown below in Table 1.

Table 1: Negative values of permittivity and permeability between operating frequency range

Frequency (GHz)	Real value of Permittivity Re (ε_r)	Real value of Permeability Re (μ_r)
1.800	-40.47825592	-99.0554163
1.806	-39.17853177	-92.2725816
1.812	-37.8257407	-85.3903918
1.818	-36.44228849	-78.4134796
1.824	-35.07479546	-71.5210824
1.827	-34.41042488	-68.1682156

Comparison between lone patch antenna dimension and patch antenna with metamaterial cover dimension is shown in table 2.

Table 2: Dimension of patch antenna and patch antenna with metamaterial

Parameter	Dimension of Lone Patch Antenna	Dimension of Patch Antenna with Metamaterial	Unit
Length (L)	39.552	35.846	mm
Width (W)	50.768	46.072	mm
Length of Ground plane & Substrate	110	80	mm
Width of Ground plane & Substrate	110	80	mm

III. CONCLUSION

The intention of the work is to provide a small size patch antenna for requiring applications. It is clearly prove by table 2 that the size of patch antenna is decreased. Finally, in this work found a small size antenna at operating frequency 1.815 GHz with -20 dB return loss, 6.668 dBi directivity and 54.51% total efficiency.

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