IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)
ISSN(E): 2321-8843; ISSN(P): 2347-4599
Vol. 2, Issue 10, Oct 2014, 39-46

ACCRETION IN PARAMETERS OF RECTANGULAR MICROSTRIP PATCH ANTENNA WITH METAMATERIAL

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ABSTRACT

Rectangular microstrip patch antenna is low profile, light weighted and easy to fabricate, but it also have some drawbacks like low efficiency, high return loss, low directivity etc. In this paper, metamaterial structure have been incorporated on patch antenna for improving the parameters of microstrip patch antenna. Metamaterial has few unique and unusual properties due to negative values of permittivity and permeability, with these properties; the Metamaterial will be mainly used to focus on the radiation of the patch antenna and improved parameters of patch antenna. The suggested microstrip patch antenna along with metamaterial cover provides the better response in comparison to patch antenna alone. In this work, the bandwidth of directional device has become twice and the return loss reduced more than one by two times of previous one.

KEYWORDS: Rectangular Microstrip Patch Antenna (RMPA), Metamaterial (MTM), Permittivity and Permeability, Nicolson-Ross-Weir (NRW)

INTRODUCTION

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.

A microstrip patch antenna is also known as flat panel directional device which can be mounted on a flat surface. It consists of a flat rectangular sheet or patch of metal, mounted over a dielectric substrate and ground. The concept of microstrip patch antenna was introduced in 1953[2] but it became popular in 1970. These antennas are having various properties like low volume, inexpensive etc. so it is used in high performance aircraft, missile application, satellite etc.

Desired Formulae for Calculation

Width of the Patch (W):

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

Effective dielectric constant:

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

The actual length of the Patch (L):

$$L = L_{eff} - 2\,\Delta L \tag{3}$$

Where,

$$L_{eff} = \frac{C}{2\,f_r\sqrt{\varepsilon_{eff}}} \tag{4}$$

Calculation of Length Extension:

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

Where,

C = Velocity of light in free space,

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

After calculation, the value of patch width is 43.67 mm and the value of patch length is 33.948 mm for operating frequency 2.058 GHz. The Rectangular Microstrip Patch Antenna (RMPA) is fabricated on FR4 lossy substrate of thickness h = 1.6 mm, and dielectric constant

ε_r =4.3

Designing and Simulation

Process of simulation and designing of RMPA are performed in Computer Simulation Technology (CST) Software.

Designing of Microstrip Patch Antenna

After the calculation of patch width and length, antenna designed in this work, the area of ground and FR-4 lossy substrate is same and it is 90 X 60 mm^2. All parameters of lone RMPA for resonating frequency 2.058 GHz are shown in figure 1.

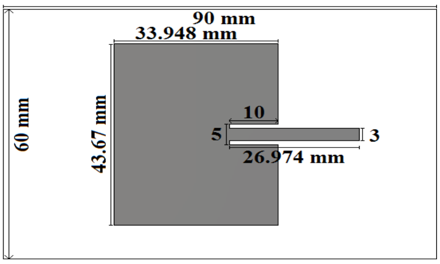

Figure 1: Dimensional View of RMPA at 2.058 GHZ (All Dimensions in mm)

Simulated Result after Designing RMPA

The return loss is an important parameter in antenna system analysis. In S-parameter, it indicates by S_{11}. Initially, the impedance bandwidth [17] of the RMPA is 36.6 MHz and the Return Loss is -14 dB, as shown in figure 2.

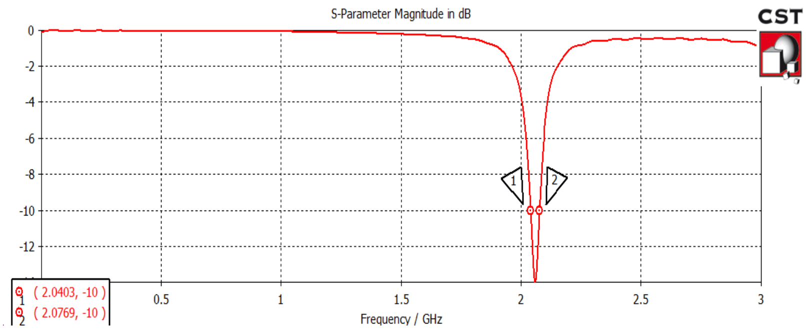

Figure 2: Simulated Result of RMPA Showing Return Loss of -14 dB and BW of 36.6 MHz

Radiation pattern defined the power radiated or received by antenna in a function of the angular position and radial distance from the antenna and Efficiency is used to expresses the ratio of the total power radiated by antenna to the net power accepted by antenna from the connected transmitter. The Radiation Pattern of the RMPA at operating frequency 2.058 GHz is shown in figure 3.

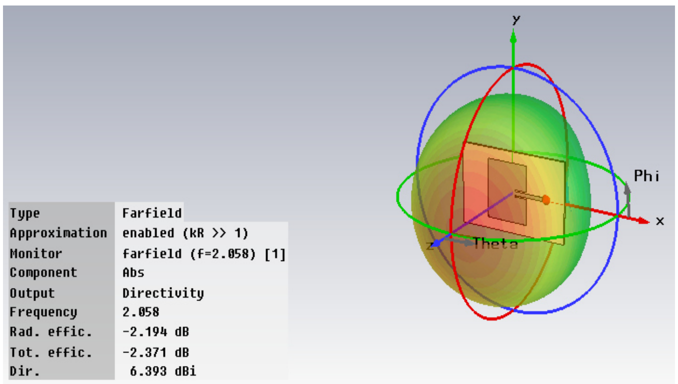

Figure 3: Radiation Pattern of RMPA Showing 76.29% Total Efficiency & 6.393 dBi Directivity

Designing of Metamaterial Cover on RMPA

After designing & simulating the lone RMPA, the suggested material cover is placed on the RMPA at a height of 1.6 mm from the designed antenna. The design of material cover has two circles and one octagon. Dimensions of circles and octagon are shown in figure. Suggested cover is shown in figure 4.

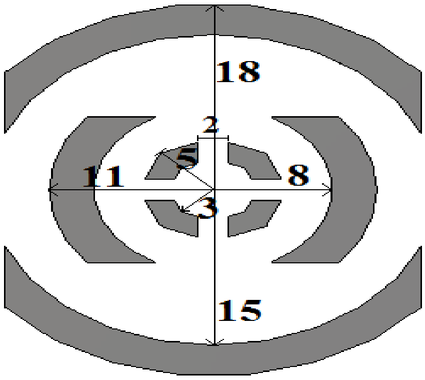

Figure 4: Dimensional View of the Suggested Cover (All Dimensions in mm)

Simulated Result after Placing Suggested Cover

When the proposed structure is incorporated with the RMPA, it shows the improved impedance bandwidth of 71.9 MHz and reduced return loss of -35 dB as shown in Figure 5.

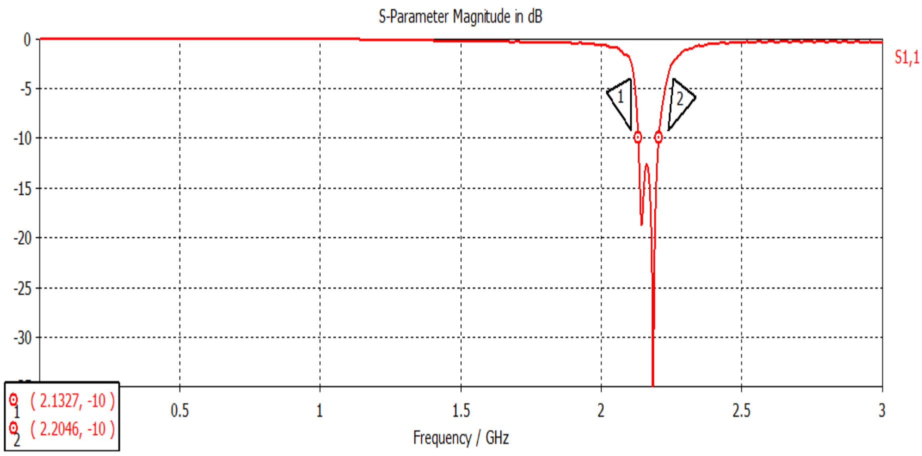

Figure 5: Simulated Result of the RMPA along with Suggested Material Cover Showing Return Loss of -35 dB and Bandwidth of 71.9 MHz

Figure 6 shows the radiation pattern of RMPA along with metamaterial cover at resonating frequency 2.184 and figure shows the directivity of 6.736 dBi and total efficiency of 75.62%.

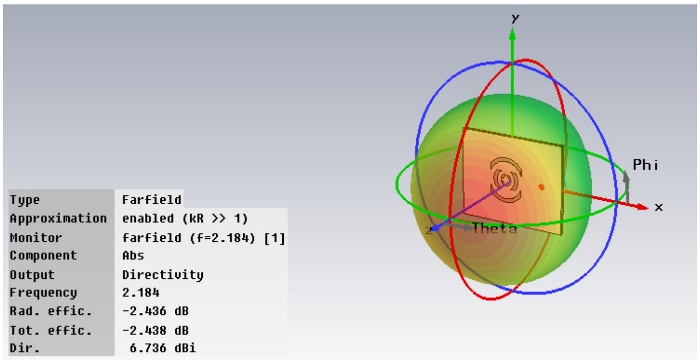

Figure 6: Radiation Pattern of the RMPA along with the Suggested Material Cover Showing Total Efficiency of 75.62% and the Directivity 6.736dBi

Nicolson-Ross-Weir (NRW) Approach

NRW approach is used for proving that the suggested material shows double negative property. By this approach, determined value of permittivity & permeability and verified that these are negative in a certain range of frequency. In this approach, two waveguide ports [17] are placed at the left & the right of suggested cover as shown in figure 7, in order to calculate S_{11} and S_{21} parameters [11][16]. The excitation of the signal is done from the left side to the right side of the structure assuming the surrounding is air. Y-Plane is defined as Perfect Electric Boundary (PEB) and Z-Plane is defined as Perfect Magnetic Boundary (PMB). Subsequently, the wave is excited from the negative X-axis (Port 1) towards the positive X-axis (Port 2).

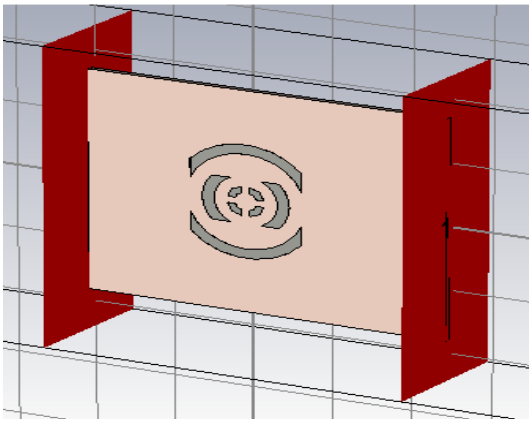

Figure 7: Suggested Material Cover Placed between the Two Waveguide Ports

According to this approach, the value of S_{11} and S_{21} parameters are 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][12]:

$$\mu_r = \frac{2\,C\,(1 - V_2)}{\omega\, d\, i\,(1 + V_2)} \tag{6}$$

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

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, and

V_2 = Voltage Minima.

The values of permittivity (ε_r) and permeability (μ_r) are calculated by using equations 6 & 7 in the simulated frequency range. Graph in figure 8 and figure 9 shows that the proposed material cover possesses negative values of permittivity & permeability respectively in the certain range of frequency.

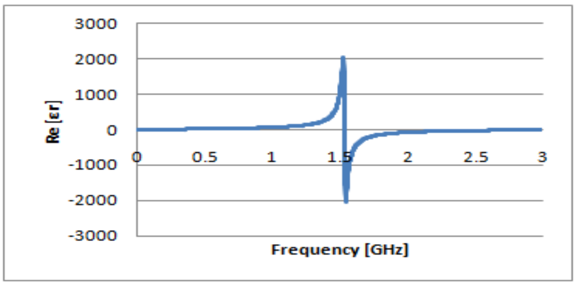

Figure 8: Permittivity versus Frequency Graph

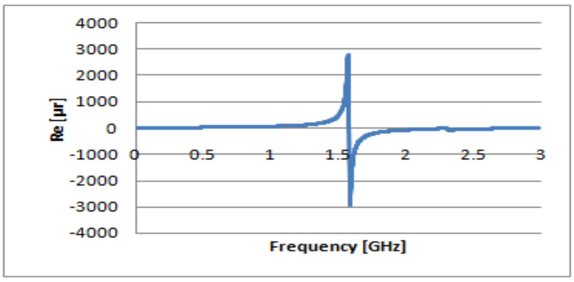

Figure 9: Permeability versus Frequency Graph

Tables generated for permittivity and permeability using MS-Excel software are too large, therefore table 1 and table 2 shows the negative values of permittivity and permeability only in frequency range 2.118 - 2.211 GHz.

Table 1: Negative Values of Permittivity at 2.118 - 2.211 GHz Frequency Range

Sample Point	Frequency (GHz)	Real value of Permittivity Re (ε_r)
710	2.118	-57.109
716	2.1359999	-54.868
722	2.1539998	-52.593
728	2.1719999	-50.115
734	2.1900001	-47.686
741	2.211	-45.014

Table 2: Negative Values of Permeability at 2.118 - 2.211 GHz Frequency Range

Sample Point	Frequency (GHz)	Real Value of Permeability Re (μ_r)
710	2.118	-54.113
716	2.1359999	-50.878
722	2.1539998	-46.763
728	2.1719999	-42.625
734	2.1900001	-39.111
741	2.211	-34.319

New Dimensions of RMPA

After placing the suggested cover on the RMPA at a height of 1.6 mm from the designed directional device, the dimensions of RMPA along with metamaterial are shown in table 3.

Table 3: Dimensions of RMPA along with Metamaterial

Parameters	Dimension of RMPA	New Dimension of Proposed RMPA	Unit
Panel Length	33.948	31.948	mm
Panel Width	43.670	37.270	mm
Cut Width	5	6	mm
Cut Depth	10	9	mm
Feed Length	26.974	24.974	mm
Width of Feed	3	3.4	mm
Area of Ground	90×60	90×70	mm^2

In this section, simulation results were presented. It is observed that the parameters of RMPA are improved after putting suggested cover. Figure 2 & 5 shows that the return loss of the proposed metamaterial structure is reduced by 21 dB and bandwidth increases by 35.3 MHz. Radiation Pattern in figure 3 and 6 shows that the directivity is slightly improved by 0.343 dBi. Figure 8 and figure 9 verifies double negative [11] properties of the proposed inspired metamaterial Structure.

CONCLUSIONS

The purpose of the work is to design a small size, power efficient and low cost antenna that can be used for wideband communication applications. In this work, it has been observed that the behavior of RMPA loaded with metamaterial structure at a height of 3.2 mm from the ground plane is better than lone RMPA. So RMPA loaded with metamaterial can be used in more communication application comparison to lone RMPA.

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