Microstrip Patch Antenna with Parameters Improvement Using "Symmetric Cylinder Shapes of Zero & Four Segments" Metamaterial Structure

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***Abstract*—In this work, a Rectangular microstrip patch antenna loaded with "Symmetric Cylinder Shapes of Zero & Four Segments" metamaterial structure is designed at a height 3.2 mm from the ground plane by using CST-MWS software. The resonance frequency of the designed antenna is 2.5GHz.The 10 dB impedance bandwidth of proposed antenna is 33.7MHz. The Return loss of the proposed antenna is reduced by 28dB .This antenna is small size, cheap, compact and easy to fabricate, and achieve good radiation characteristics with higher return loss. This antenna can have wide application in a great variety of wireless communication.Double-Negative properties of the proposed metamaterial structure have also been verified by using Nicolson-Ross-Weir Method (NRW).**

Keywords-Rectangular Microstrip Patch Antenna, Metamaterials, Bandwidth, Return Loss, NRW.

I. INTRODUCTION

In high-performance aircraft, spacecraft, satellite and missile applications, where size, weight, cost, performance, ease of installation, low profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications. To meet these requirements microstrip antenna can be used. These antennas are low profile, conformal to planar and non-planar Surfaces, simple and inexpensive to manufacturer using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with Monolithic Microwave Integrated Circuit (MMIC) designs.

The introduction of the so-called metamaterials [1] (MTMs), artificial materials which have engineered electromagnetic responses that are not readily available in nature, has provided an alternate design approach to obtain efficient electrically-small antenna (EESA)systems.

II. DESIGN AND SIMULATED RESULTS OF RMPA AND PROPOSED ANTENNA.

The Rectangular microstrip patch antenna parameters are calculated from the formulas given below [2-3].

Calculation of Width (W):

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

Where,
c = free space velocity of light
ε_r = Dielectric constant of substrate

Effective dielectric constant is calculated from**:**

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-}{2} \qquad (2)$$

The actual length of the Patch (L)

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

Where

$$\text{Leff} = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}}$$

Calculation of LengthExtension

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3}{(\varepsilon_{eff}-0.2} \qquad (4)$$

The parameters of rectangular microstrip patch antenna are specified in the Table1 and dimensional view is shown in figure 1.

TABLE 1: RECTANGULAR MICROSTRIPPATCH ANTENNA SPECIFICATIONS

parameters	**Dimensions**	**Unit**
Dielectric Constant (εr)	4.3	-
Loss Tangent (tan ∂)	0.02	-
Thickness (h)	1.6	mm
Operating Frequency	2.5	GHz
Length (L)	28.4656	mm
Width (W)	36.2822	mm
Cut Width	8	mm
Cut Depth	10	mm
Path Length	28.1411	mm
Width Of Feed	3.6	mm

The RMPA is designed using the calculated parameters shown in Table 1.

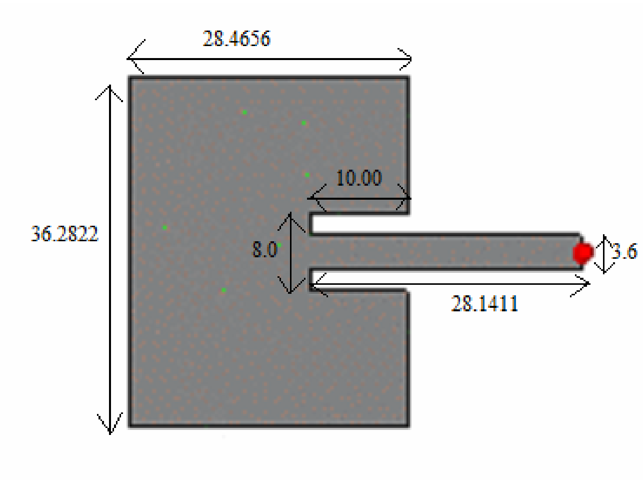

Figure 1: Rectangular patch antenna designed at 2.5GHz (All dimensions in mm).

The Simulated Results of Rectangular microstrip patch antenna is shown in figure 2 and 3.The CST-MWS (computer simulation Technology) was chosen to simulate the structures shown in the figures below.

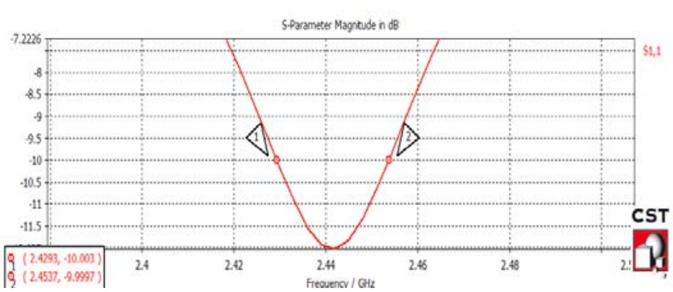

Figure 2: Simulated Result of Rectangular microstrip patch antenna showing return loss of -12 dB and 14.9 MHz Bandwidth.

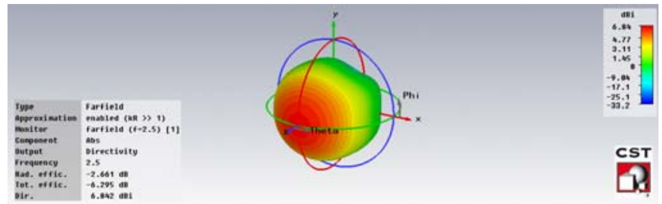

Figure 3: Radiation Pattern of Rectangular microstrip patch antenna.

Nicolson-Ross-Weir Method (NRW):

One methodology that makes use of the scattering parameters S11 and S21 to calculate the mentioned complex parameters of samples is named Nicolson-Ross-Weir (NRW) (Nicolson and Ross, 1970; Weir, 1974). The NRW modeling is the most common used method to perform the calculation of complex permittivity and permeability of materials. The obtained S-parameters are then exported to Microsoft Excel Software for calculating the value of the permittivity and permeability of the proposed design, using the Nicolson-Ross-Weir (NRW) approach.

The proposed structure is placed between the two waveguide ports [11][13-14] at the left & right of the X-Axis (shown in figure 4) in order to calculate the S11 and S21 parameters so as to prove that the proposed structure possesses Double Negative metamaterial properties. In figure 4, Y-Plane was defined as Perfect Electric Boundary (PEB) and Z-Plane was defined as the Perfect Magnetic Boundary (PMB). Subsequently, the wave was excited from the negative X-axis (Port 1) towards the positive X-axis (Port 2).

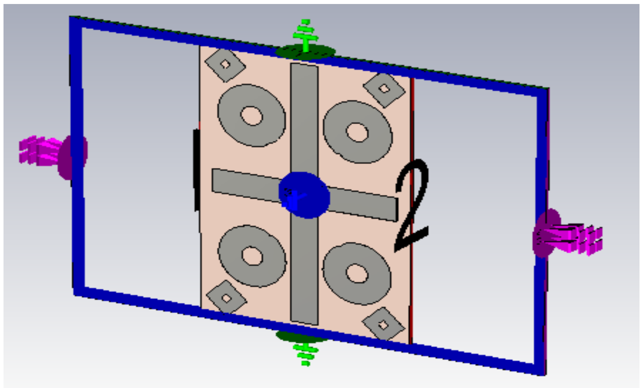

Figure 4: Proposed metamaterial Structure placed between the two Waveguide Ports at the left & right of the X-Axis.

NRW Method:

Equations used for calculating permittivity & permeability using NRW approach[9][10][13]:-

$$\mu_r = \frac{2.c(1-v2)}{\omega.d.i(1+v2)} \qquad (5)$$

$$\varepsilon_r = \mu_r + \frac{2.S11.c.i}{\omega.d} \qquad (6)$$

Where,

$v2$ = S21 - S11 (7)

ω = Frequency in Radian,
d = Thickness of the Substrate,
c = Speed of Light,
$v2$ = Voltage Minima

Figure 5 & 6 shows the negative value of permittivity and permeability [4-5] [15-16] obtained from the equation 5 & 6 at the designed frequency.

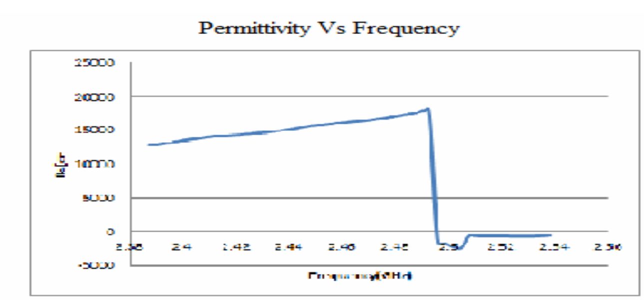

Figure 5: Permittivity versus Frequency Graph obtained from Microsoft Excel Software.

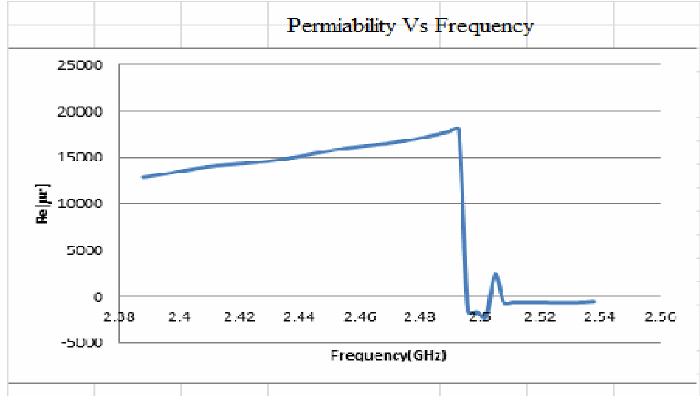

Figure 6: Permeability versus Frequency Graph obtained from Microsoft Excel Software.

Then, the "Symmetric Cylinder Shapes of Zero &Four segment" metamaterial structure is placed above the patch antenna at a height of 3.2 mm from ground plane in order to study its influence, and the results are compared with those of the Patch antenna alone. The required specifications of this design are shown in the figure7.

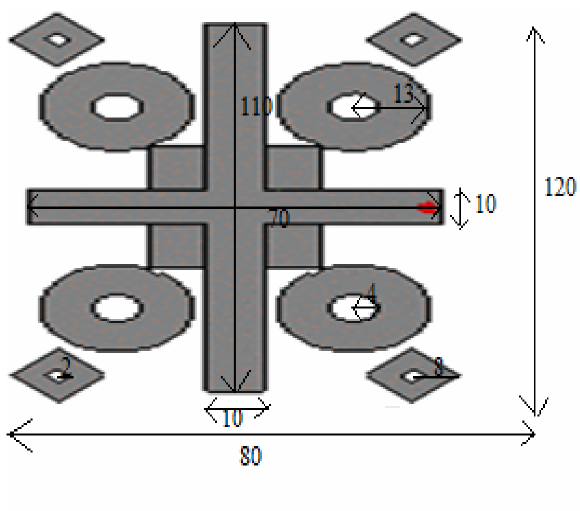

Figure 7:Rectangular microstrip patch antenna loaded with "Symmetric Cylinder Shapes of Zero & Four Segment" metamaterial Structure (All dimensions in mm).

RESULT:

A Research on [7-8]metamaterial was carried out to understand the fundamentals of the newly discovered substance. The simulated result of rectangular microstrip patch antenna with "Symmetric Cylinder Shapes of Zero and Four Segments"The results of structure is shown in figure 2& 8. At 2.5GHz frequency the simulated rectangular microstrip patch antenna results in Return Loss of -12dB&

14.9MHz Bandwidth while when it is designed with "Symmetric Cylinder shapes of Zero & Four Segment" metamaterial structure at 3.2mm from the ground plane, it shows Return Loss of -40dB& 33.7MHz Bandwidth which shows improvement of bandwidth [17] and significant reduction in return loss.The Return Loss of the proposed metamaterial structure is reduced by 28dB and bandwidth improved by 18.8 MHz [9-10] [12] in comparison to the RMPA alone.

The response of the proposed metamaterial when tested with the help of spectrum analyzer shows the return loss of -38db & 31.5 MHz band width which is slightly less than the simulated response due to the practical conditions & limitations.

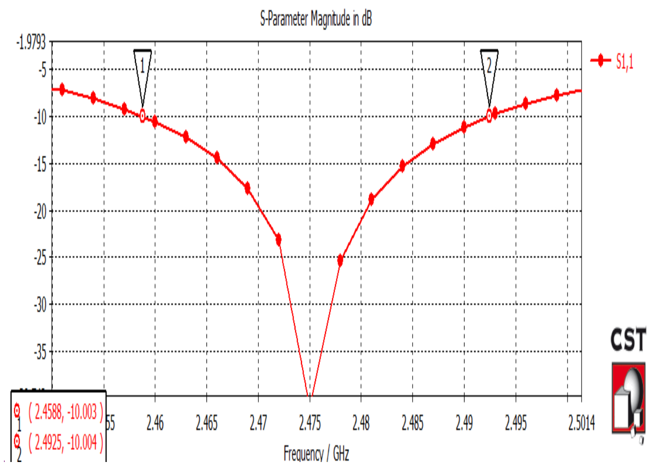

Figure 8: Simulated Return Loss of Rectangular microstrip patch antenna loaded With "Symmetric Cylinder Shapes of Zero &Four segment" metamaterial Structure.

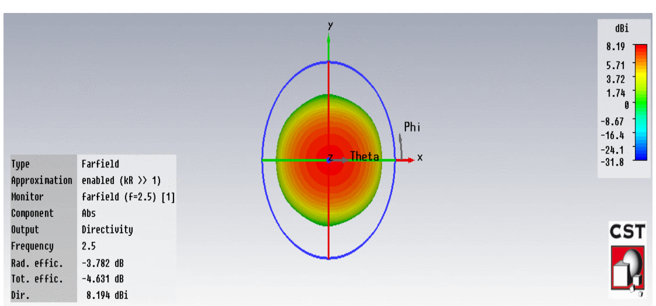

Figure 9: Radiation Pattern of Rectangular microstrip patch Antenna along With "Symmetric Cylinder Shapes of Zero &Four segment" metamaterial Structure.

Smith Charts[6] showen in figure 10 represents the impedance matching of antenna with coaxial cable of 50 ohm.

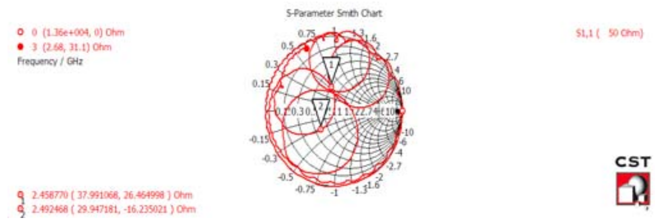

Figure 10: Smith Chart of Rectangular microstrip patch antenna loaded with "Symmetric Cylinder Shapes of Zero and Four Segments" metamaterial Structure.

III. CONCLUSION

The "Symmetric Cylinder Shapes of Zero &Four segment" metamaterial structure with Rectangular microstrip patch antenna has been proposed in this paper. The simulated results provide gain, bandwidth and directivity improvement, which encourages fabricating the structure. On making some variations in antenna parameter gain can be improved up to desired limit but some practical limitation should be taken care while fabricating the structure on CST-MWS software.

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