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A S-Band "Square Shape" Metamaterial Structure to Enhance the Performance of Rectangular Micro-strip Patch Antenna

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Abstract

A communication system always involves a spectrum or band of frequencies and as such the question of bandwidth is an important parameter in RMPA. But miserable efficiency, narrow bandwidth and high return loss are the major drawbacks of Micro-strip patch antenna. Even though, to enhance the characteristic parameter of RMPA, metamaterial is founded as a better candidate. The main motive of this design is to improve the distinctive parameter of RMPA like bandwidth and return loss. So it will be possible with the help of S-band (2 GHz-4 GHz) square shape metamaterial structure over the RMPA, associated at the vertical distance of 3.276 mm from the ground plane. The frequency 2.691 GHz is the frequency at which are RMPA without proposed metamaterial is operating at 55.6 MHZ bandwidth. The parameters of RMPA like bandwidth and return loss are improved up to 27.15% and 268.76% respectively with the help of CST-MWS, the proposed meta-material structure and simple RMPA are designed and simulated. But for proving metamaterial property MS-EXCEL is used.

***Keywords**: Left Handed Metamaterial (LHM), Rectangular Micro-strip Transceiver(RMT), Double Negative Metamaterial(DNG), Impedance Bandwidth, Return Loss, Nicolson-Ross-Weir(NRW).*

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INTRODUCTION

In innovative communication system, to improve the quality of Micro-strip patch antenna, metamaterial surface antenna technology offers an affordable and efficient way, that in which a metamaterial antenna is created by reactively loading the metamaterial structure over the substrate. But, due to small size, low cost and ease of production the demand of RMPA is very large[1-4]. Initially, the concept of metamaterial based structure discovered by Pendry and where the theoretical concept on metamaterial is given by Victor Veselgo (1968), Engheta[1,4,5] and Ziolkowski (2006). According to this theory Metamaterials are man-made materials that properties are not found in nature. A significant enhancement in the performance of antenna recital[6-10] is prophesied for a class of metamaterials exhibiting the value of permittivity and permeability should be negative. Several metamaterial antenna methods can be engaged to backing surveillance sensors, communication links, navigation systems, and command and control systems.

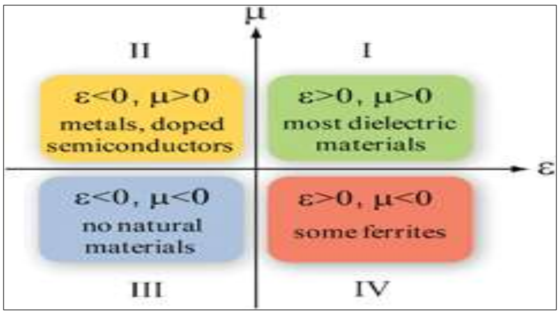

***Fig. 1:** Classification of metamaterial.*

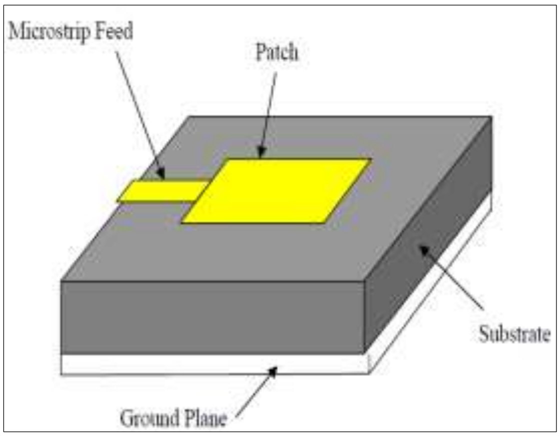

Fig. 2: *General Block Diagram of RMPA.*

SIMULATED RESULTS

Following formulae is used to calculate the dimension of RMPA[2].

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2\,f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

$$L = \ L_{eff} - 2\Delta L$$

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

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

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

Where

ε_{eff} = Effective dielectric constant.
ε_r = Dielectric constant of substrate.
h = Height of the dielectric substrate.
W = Width of patch.
L = Length of the patch.
ΔL =Effective length.
f_r = Resonating frequency.

Table 1*: Dimension Of The Rectangular Patch.*

Parameters	Dimensions	Unit
Dielecric constant of FR-4 (lossy)(ε_r)	4.3	-
Loss tangent(tan ∂)	0.025	-
Thickness of FR-4 (lossy) (h)	1.6	mm
Operating frequency	2.691	GHZ
Length(L)	26	mm
Width(W)	34	mm
Cut width	6	mm
Cut depth	8	mm
Path length	20	mm
Width of feed	4	mm

In Figure 3, after the dimension calculation of RMPA, it will be simulated by using computer simulation technology software (CST-MWS).

In which the position of the port of RMPA is (X = 25 mm, Y = 0, Z = 0 to 1.676 mm).

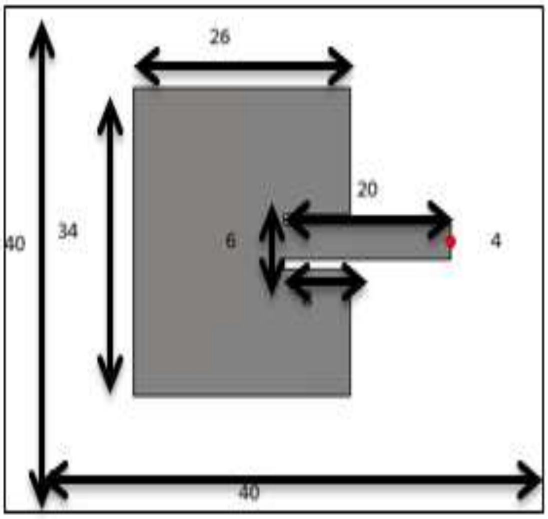

Fig. 3: *Simulated Structure of RMPA at The Height of 3.276 mm From The Ground Plane(All Parameters in mm).*

In Figure 4, return loss graph of RMPA is shown. In which return loss and bandwidth of RMPA is –12.73 db and 55.6 MHZ respectively at the 2.691 GHZ frequency.

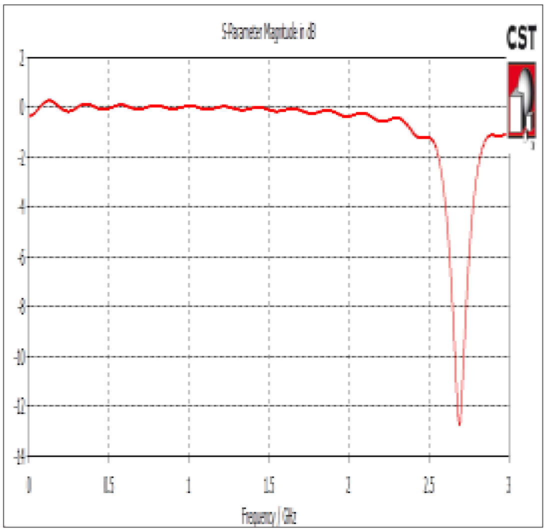

Fig. 4: *Return Loss Graph (S_{11} – Graph) Of RMPA.*

In Figure 5, 3D radiation pattern result of RMPA is shown. It is showing the directivity and efficiency of RMPA.

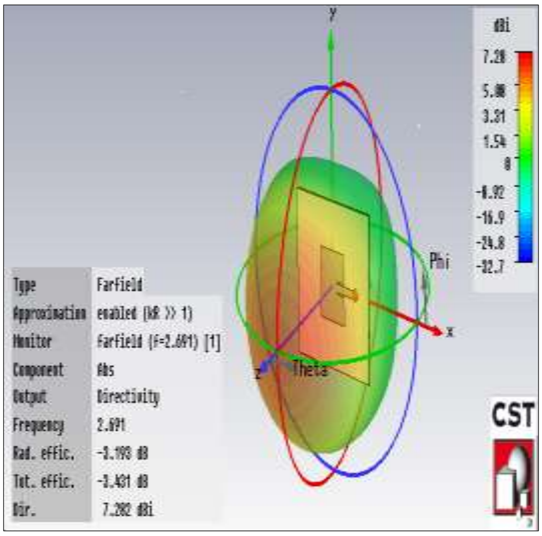

Fig. 5: *3D Radiation pattern result of RMPA at 2.691GHZ frequency. In which T.E.(-3.431 db) and Directivity(7.282 dbi).*

To achieve better characteristic parameter of RMPA, square shape metamaterial structure is loaded on the RMPA at the vertical distance of 3.276 mm from the ground plane. It will be achieved by CST-MWS, which will depict in below Figure 6.

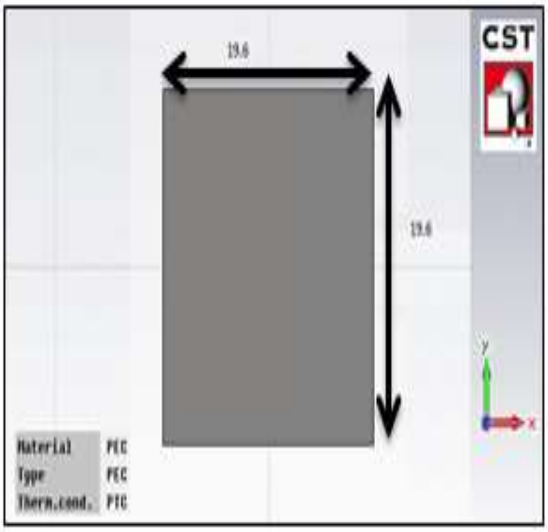

Fig. 6: *A square shape metamaterial structure loaded on RMPA at the height of 3.276 mm from the ground plane (All Parameters in mm).*

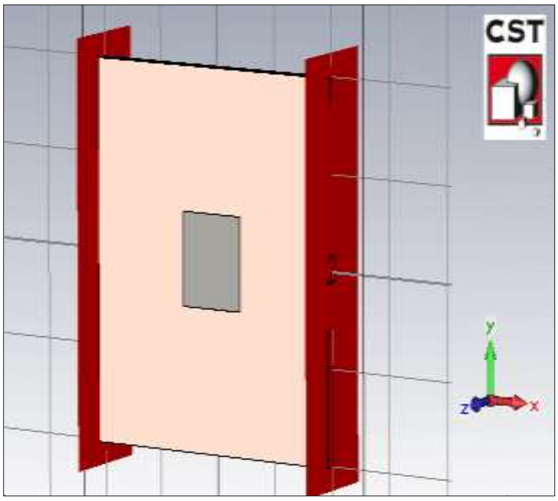

Fig. 7: *Proposed Metamaterial Structure between the Two Port Waveguide.*

To prove the property of negativity ($\mu r < 0, \varepsilon r < 0$)[1], that means the value of permittivity and permeability should be negative Nicolson Ross Weir (NRW) approach is used. In which the proposed metamaterial structure is placed between the X-axis of two port waveguide in Figure 7 and after that S11 and S21 parameters are calculated to prove the double negative property. After this process S-parameters value are exported to MS-EXCEL software for verifying the double negative property of metamaterial structure. To find the value of permittivity and permeability effective formulation is used in NRW approach[6.8,9].

$$\mu_r = \frac{2\,c\,(1 - v_2)}{\omega di\,(1 + v_2)}$$

$$r = \frac{2\,c(1 - v_2)}{\omega di\,(1 + v_1)}$$

$$V_2 = S_{21} - S_{11}$$

$$V_1 = S_{11} - S_{21}$$

Where

ε_r= Permittivity, μ_r= Permeability

c= Speed of Light, ω= Frequency in Radian

d= Thickness of the Substrate.

i= Imaginary coefficient.

V_1=voltage maxima.

V_2= voltage minima.

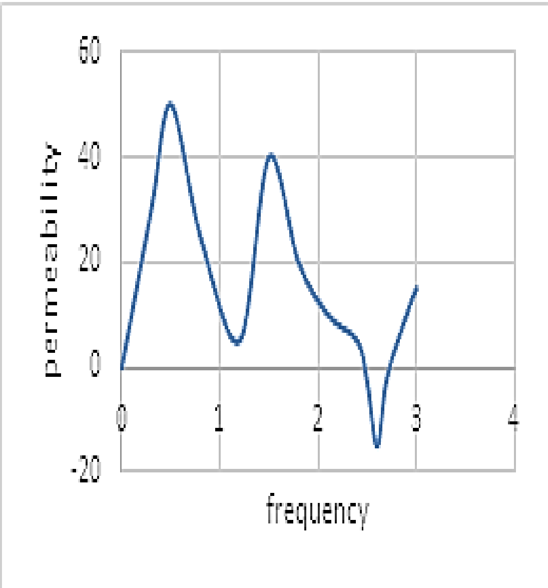

***Fig. 8**: Permeability versus Frequency Graph Obtained By MS-EXCEL.*

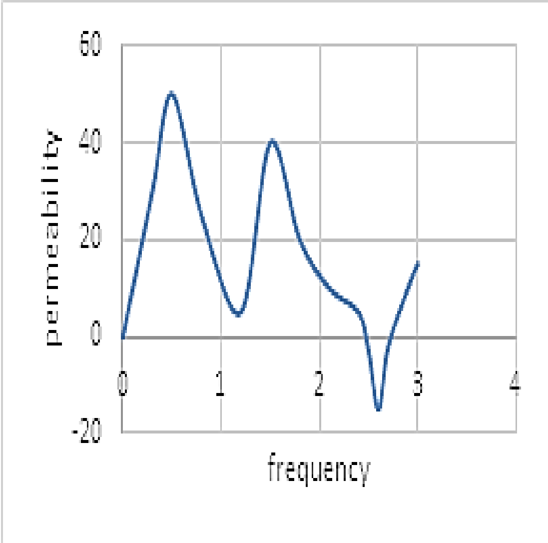

***Fig. 9:** Permittivity versus Frequency Graph Obtained by MS-EXCEL.*

In Figure 8 and 9, the negative value of permeability and permittivity by using MS-EXCEL software in the frequency range 2.5 GHZ to 2.7 GHZ.

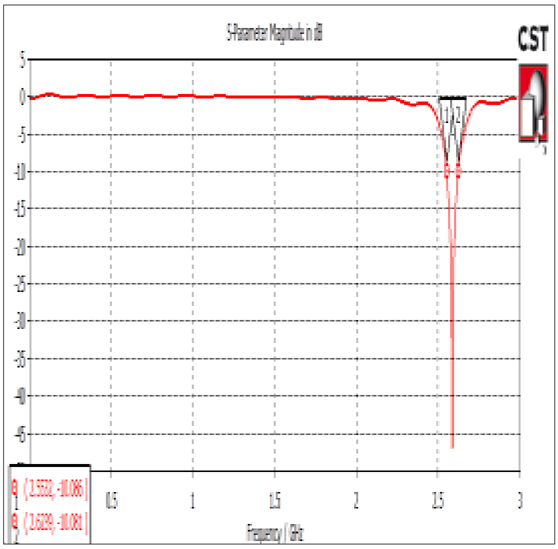

***Fig. 10:** Return Loss Graph (S_{11} Graph) Of RMPA with Proposed Metamaterial Structure.*

In Figure 10, after this simulation return loss graph of RMPA with proposed metamaterial structure achieve. In which the lowest dip is shifting to a frequency other than the operative frequency i.e.at 2.589 GHZ, with minimized return loss and increased bandwidth.

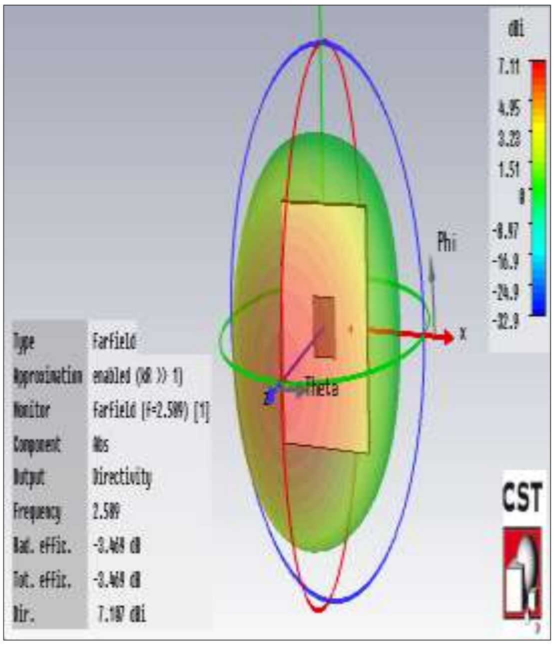

Fig. 11: *3D Radiation Pattern of RMPA with Proposed Metamaterial Structure.*

In Figure 11, 3D radiation pattern shown, which will show the directivity and efficiency of RMPA with proposed metamaterial structure[11, 12].

RESULT

With the help of "square shape" metamaterial structure characteristic parameter of RMPA are improved. In which three improvements were achieved by using single metamaterial structure that are return loss, bandwidth and size, where Return loss and bandwidth are improved up to 268.76% and 27.15% respectively, but the size is reduced up to 9.875%.

CONCLUSION

To improve the performance of RMPA, authors allocate a latest designing methodology. In which single layer is simulated over the RMPA at the height of 3.276 mm from the ground plane and where this simulated structure is metamaterial structure. But due to its small size, low cost and low profile characteristic, antenna has many applications in communication system.

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