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Reduced Size & Wide Band Rectangular Microstrip Patch Antenna loaded with "STRR" at 1.52GHz

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Abstract

Wireless communication needs small size, wide band and highly directive planar antennas. For such requirement this work analyzes the simulation and experimental verification of a rectangular microstrip patch antenna (RMPA) with "Split Triangular Rings Resonators (STRR)" metamaterial structure at a height of 3.2mm from the ground plane. This work also investigates the potential properties i.e. negative permittivity & permeability of the proposed metamaterial structure by Nicolson-Ross-Weir (NRW) approach. The proposed Antenna is designed at a operating frequency of 1.522GHz to meet L-Band (1-2GHz) applications. By loading "STRR" metamaterial structure with the rectangular patch antenna at a height of 3.2mm, the patch antenna size is found to be reduced by 28% (area wise) to the conventional RMPA & the antenna's bandwidth is found to be increased up to 94MHz and return loss is reduced to -30dB.

Keywords: *Rectangular Microstrip Patch Antenna(RMPA), Double-Negative Metamaterial, Wide Band, Split triangular Rings Resonator(STRR), NRW.*

1 Introduction

Conventional RMPA generally have a conductive patch fabricated on a microwave substrate with a high dielectric constant . However, RMPA in L-Band have a large size, narrow bandwidth. Presently applications in wireless needed a miniaturized requirement of patch antenna, thus size reduction is becoming major design considerations for practicable applications of RMPA.

Victor Georgievich Veselago [1][4][6], a Russian physicist was the first to discover materials, which exhibit negative permittivity ε, and permeability μ [5] called metamaterial [8][17]in 1967. Electromagnetic metamaterial can be defined as artificial effective homogeneous electromagnetic materials with unusual properties not readily found in nature. A Left-Handed metamaterial [11-12] or Double-Negative Metamaterial exhibits negative permittivity and permeability. This phenomena can be characterized by the negative refraction index and the anti-parallel phase velocity which is also known as backward wave.
Experimental verification is done by spectrum analyzer and simulation work is done using CST-MWS (Computer Simulation Technology Software) and MathCAD software is used for finding the Values of μ and ε by NRW method.

2 Designing, Testing & Simulation of RMPA & RMPA loaded with Proposed Metamaterial Structure

The conventional RMPA is etched on FR4 (Lossy) substrate of thickness h = 1.6mm from the ground plane with 50Ω matching impedance., and dielectric constant εr =4.4 by using copper material as the conducting plane. The designing conventional RMPA limitations are calculated from the designing formulas [2][3].

The figure 1 below shows the dimensional view of the conventional RMPA operating at 1.522GHz

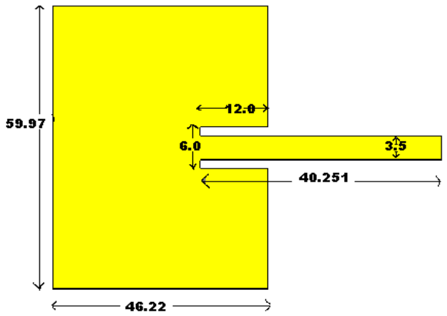


Figure 1: conventional RMPA designed at 1.522GHz (all dimensions in mm).

After designing the RMPA, simulate the design on CST-MWS and results are shown in figure 2 and figure 3.

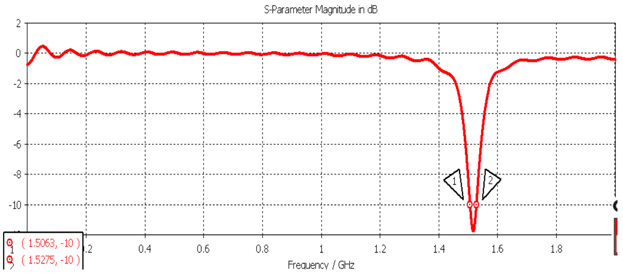
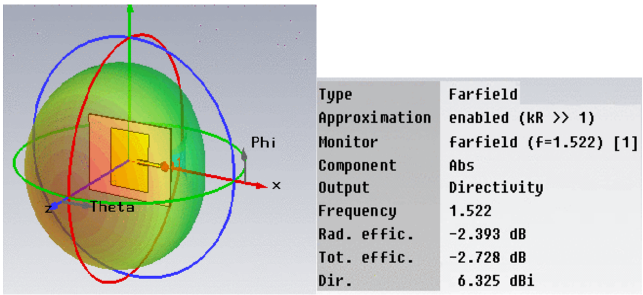


Figure 2: Simulated result of RMPA showing bandwidth of 21.2MHz and return loss of -12dB.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=1.522) [1]
Component	Abs
Output	Directivity
Frequency	1.522
Rad. effic.	-2.393 dB
Tot. effic.	-2.728 dB
Dir.	6.325 dBi

Figure **3**: Radiation Pattern of RMPA showing directivity of 6.3dBi and total efficiency is 53.6% .

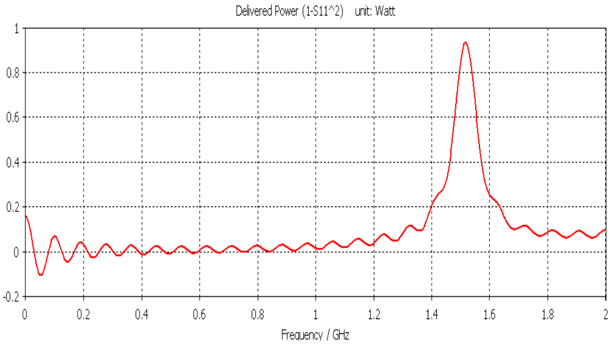


Figure 4: Deliverd power to RMPA

“STRR” shaped metamaterial structure is proposed at height 3.2mm from the ground plane and its obtained from NRW method at designing frequency 1.522GHz and gives comparatively good results to patch antenna alone and dimensions of a single STRR with center (0,0) are shown in figure 5 and the other STRRs are in all the quadrants with center (20,15).

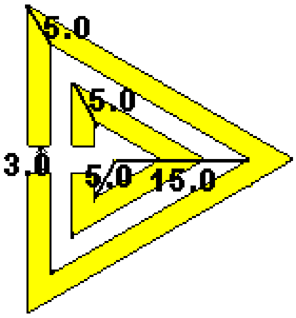


Figure 5: Dimensional view of a single STRR (all dimensions in mm).

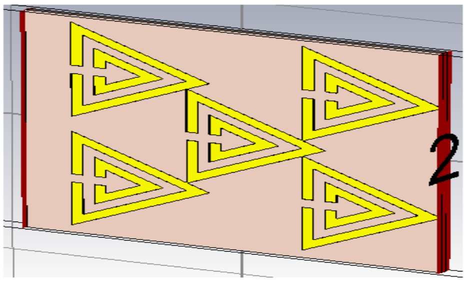


Figure 6: Proposed metamaterial structure placed between the two Waveguide Ports at the left & right of the X-axis.

Two waveguide ports [16] were defined at the left and right of the X-Axis in order to calculate the S11 & S21 parameters as shown in figure 6. The obtained S-parameters are exported to MathCAD for calculating the value of the permittivity and permeability of the proposed metamaterial structure, by using the Nicolson-Ross-Weir (NRW) approach.

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

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

$$\varepsilon_r = \mu_r + \frac{2.S11.c.i}{\omega.d} \tag{2}$$

Where,
$v2$ = S21 - S11
ω = Frequency in Radian,
d = Thickness of the Substrate,
c = Speed of Light, and
$v2$ = Voltage Minima

Graph in figures 7 & 8 are obtained from the equation 1 and 2, shows that the proposed metamaterial structure possesses negative values of permittivity (ε) and permeability (μ) at the operating frequency, that proves the proposed structure is metamaterial.

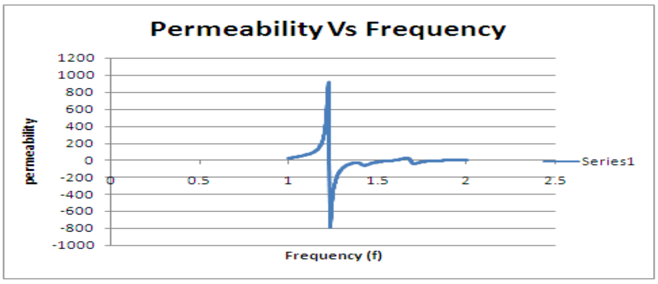


Figure 7: Permeability versus Frequency Graph of the proposed "STRR"

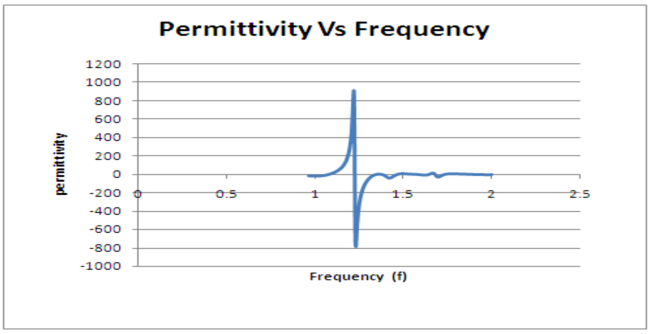


Figure 8: Permittivity versus Frequency Graph of the proposed "STRR"

The figure 9 below shows the reduced size RMPA loaded with the "STRR" metamaterial structure at a height of the 3.2mm from the ground plane & figure 11(a) and 11(b) shows the fabricated structure & experimental verification respectively.

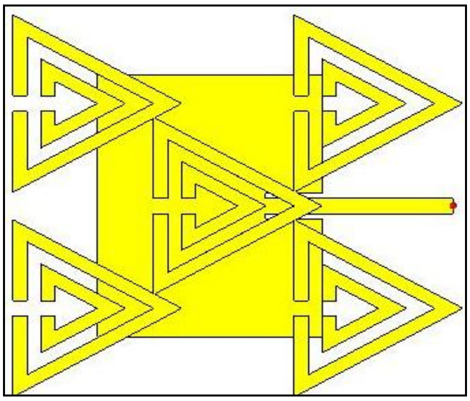


Figure 9: Reduced size RMPA loaded with "STRR" metamaterial structure at a height of 3.2mm from the ground plane.

Figure 10 & 12 shows the simulated and experimently tested results of the reduced size RMPA along with proposed metamaterial structure respectively , it is clear from figure that the bandwidth of the proposed antenna is remarkably improved[14-17] in operating frequency range and return loss is significantly reduced in comparison to the conventinal RMPA.

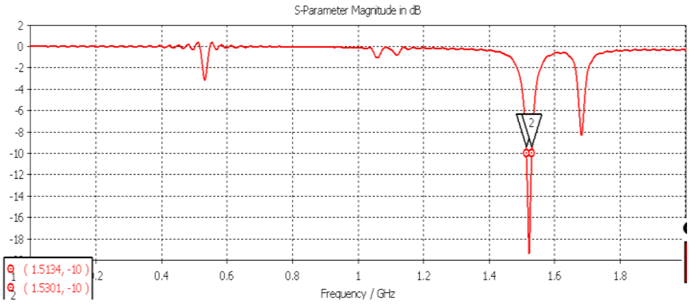


Figure 10: Simulated result of the reduced size RMPA along with “STRR” metamaterial structure .

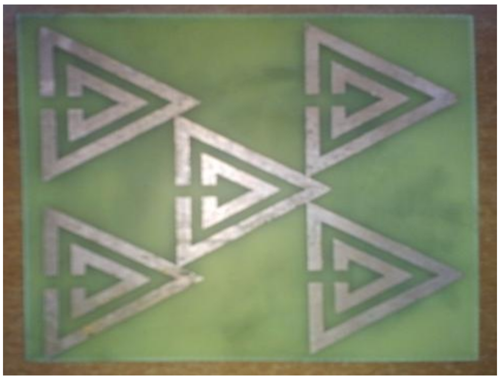


Figure 11(a) Fabricated reduced size RMPA loaded with “STRR” metamaterial structure at a height of 3.2mm from the ground plane

Figure 11(b): Experimental Testing of reduced size RMPA loaded with “STRR” metamaterial structure on Spectrum Analyzer.

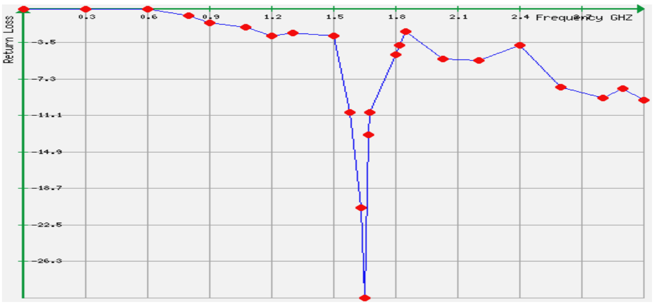
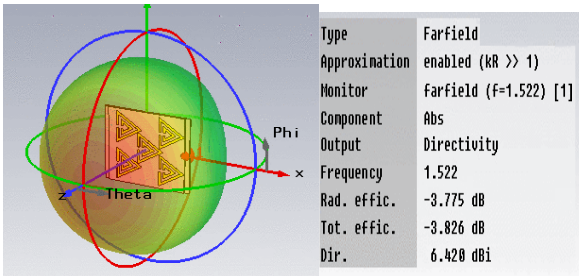


Figure 12: Experimentally measured result of the reduced size RMPA along with “STRR” metamaterial structure showing Bandwidth of 94MHz & Return Loss of -30dB

It is clear from figure 13 that directivity of antenna increased with reference to conventional RMPA alone.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=1.522) [1]
Component	Abs
Output	Directivity
Frequency	1.522
Rad. effic.	-3.775 dB
Tot. effic.	-3.826 dB
Dir.	6.420 dBi

Figure 13: Radiation Pattern of the reduced size RMPA loaded with “STRR” metamaterial structure showing directivity of 6.4dBi

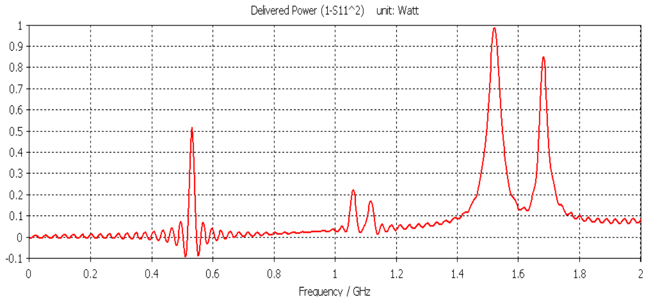


Figure 14: Delivered power to reduced size RMPA loaded with “STRR” metamaterial structure

In figure 15(a) and 15(b) shows E field and H field broadband radiation pattern of the proposed antenna respectively.

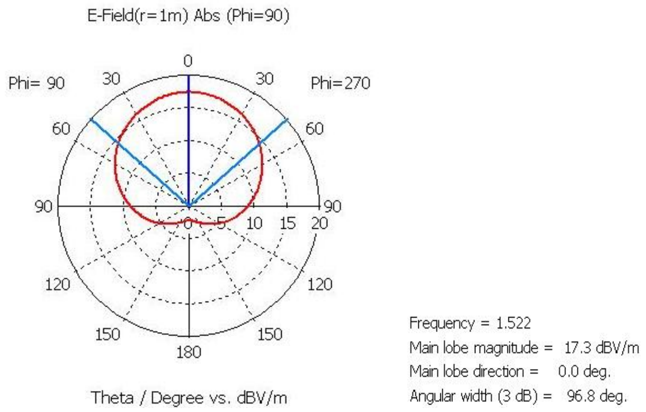


Figure 15 (a): E Feild of the reduced size RMPA loaded with “STRR” metamaterial structure at 1.522GHz.

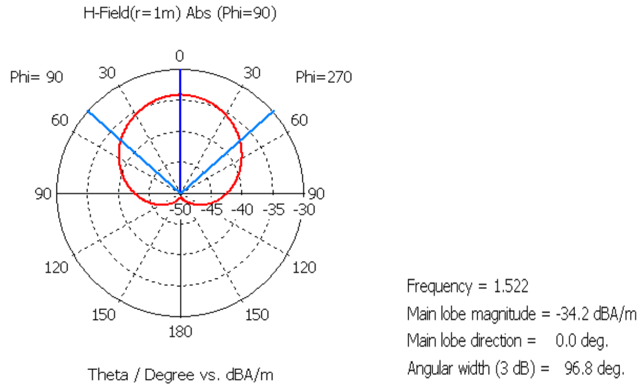


Figure 15 (b): H Feild of the reduced size RMPA loaded with “STRR” metamaterial structure at 1.522GHz.

Figure 16 shows the smith chart [7] of the reduced size RMPA along with “STRR” metamaterial structure, it has been found that impedance curve passes through the center (normalized match impedance) of the smith chart i.e. impedance of the antenna is matched with the co-axial cable.

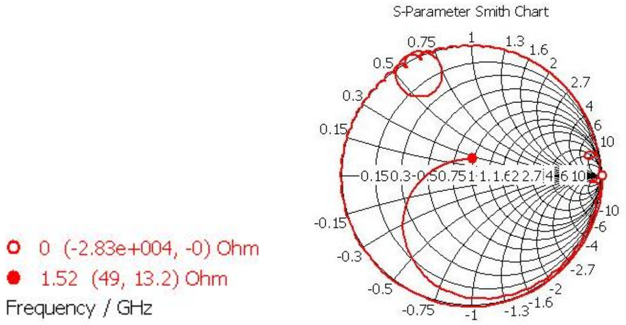


Figure 16: Smith chart of the reduced size RMPA loaded with “STRR” metamaterial structure at 1.522GHz.

Table 1: Dimensions Comparision of Rmpa Alone and Proposed Reduced Size Antenna

	Dimensions of RMPA	Dimensions of proposed Reduced Size Antenna	Unit
Length (L)	46.722	39.435	Mm
Width (W)	59.97	50.71	Mm
Cut Width	6.0	5.0	Mm
Cut Depth	12.0	10.0	Mm
Path Length	40.251	34.55	Mm
Width Of Feed	3.5	3.0	Mm

Table 1 compare the conventional RMPA with small size RMPA that shows the significance reduction in the size of the conventional RMPA.

3 Conclusion

In this work it is found that the incorporation of “STRR” metamaterial structure on a reduced size RMPA at a height of 3.2mm from the ground plane remarkably improves the desired antenna parameters like bandwidth, gain, directivity and efficiency. The purpose of the work is to design a small size, less power consumed and low cost antenna that can be used for wideband communication applications. It is clear from the investigation that measured and simulated results are likely same, but some fabrication losses and environmental condition little alter the results.

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