

MICROSTRIP ANTENNA BY INTEGRATED METAMATERIAL STRUCTURE

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Abstract: Author proposed a new plan of metamaterial to offer improvement into the components of rectangular microstrip fix radio wire at the resonating recurrence of 2.025 GHz. In the proposed work enhancement of the radio wire factors are given by utilizing a metamaterial structure coordinated on the RMPA. The radio wire parameter like Bandwidth, productivity and return misfortune get improved after the consolidation of the proposed plan structure. CST programming is utilized the entire reenactment procedure of fix radio wire and metamaterial structure. When using the new configuration the antenna frequency is improved from 27.5 MHz to 31.4 MHz, the return loss is decreased from -12.8 dB to -35.14 and the output is improved when 19.8% (33.56 to 53.4%).

Keywords: RMPA, Norms (Antenna's Parameters), CST (Computer Simulation Technique), Bandwidth, Return loss, Efficiency

1. Introduction

A patch antenna is a kind of high efficient and low profile microstrip antenna that can be installed conveniently on a plane surface. It has two sheets of metal with a minimal thickness of 0.038 mm divided by 1.6 mm thick substratum and 4.3 dielectric constant shown in table1. Patch antenna comprises a thin rectangular sheet of metal "patch," mounted on a larger sheet of metal called a ground plane. Therefore this antenna type is called patch antenna. Patch antennas with very small dimensions are quick to build and easy to change and customize. By adding metamaterial structure into it, the antenna performance can be enhanced.

The material which has negative permittivity and negative permeability simultaneously is called as Metamaterial. It is not a substance that has been technically accomplished but metamaterial can be accomplished in reality by using other different structures. Metamaterial concept testing can be performed by the NRW double negation properties process. The NRW solution consists of a series of

mathematical equations which use the design perimeters to provide the permittivity and permeability values.

Victor Georgievich Veselago [1][4][6], the first Russian physicist who in 1967 scientifically introduced the concept of the metamaterial. J. B. Pendry had also studied the area of metamaterials. Smith made the first LHM conceptual structures after that in 2001[2]. The LHM blends Single Ring Resonator with thin wire. Metamaterial is used as the process for enhancing antenna parameters is easy to produce, replicate and convenient. All simulation work have been performed by CST-MWS.

2. Desired Formulae for Calculation

Width of the Panel

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} = \frac{C}{2 f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Effective dielectric constant:

$$\epsilon_{\text{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{1 + \frac{12h}{w}} \right) \quad (2)$$

The Actual length of the panel

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

Where

$$L_{\text{eff}} = \frac{C}{2 f_r \sqrt{\epsilon_{\text{eff}}}} \quad (4)$$

Calculation of Length extension:

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

Where,

ϵ_r = Dielectric constant of substrate,

ϵ_{reff} = Effective dielectric constant,

L = Length of patch,

C = Speed of Light,

f_r = Resonating frequency,

ΔL = Effective Length

h = Height of dielectric substrate,

W = Width of patch

After calculation, the value of RMPA specifications is shown in the table 1 given below:

Table1: RMPA Parameters

Parameters	Dimensions
ϵ_r	4.3
Feed Length	27.48 mm
Width Of Feed	3 mm
Cut Depth	10.0 mm
Cut Width	4.8 mm
Width	44.946 mm
Length	34.96 mm
Thickness	1.6 mm
Operating frequency	1.989 GHz

3. Designing and Simulation:

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

3.1 Designing of patch antenna

After the figuring of width and length, RMPA is structured in CST and right now, zone of ground and FR-4 lossy substrate is $80 \times 80 \text{ mm}^2$. All parameters of alone RMPA for reverberating recurrence 2.025 GHz are appeared in fig. 1.

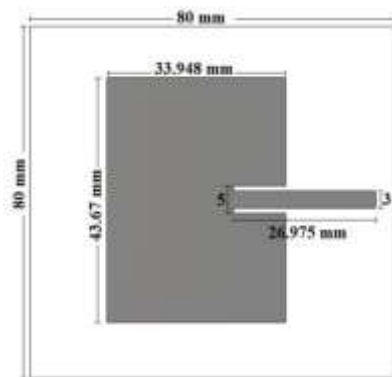


Fig. 1: Dimensional View of RMPA at 2.025 GHz

3.1.1 Simulated results after designing RMPA

The most important parameter of the antenna is return loss for system analysis which is indicates by S_{11} in S-parameter. Initially for RMPA, the BW [17] is 27.5 MHz and the Return Loss is -12.6 dB, as shown in fig. 2.

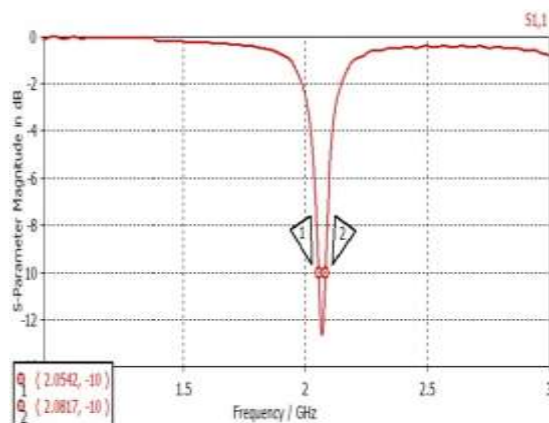


Fig.2: Bandwidth 27.5 MHz and Return Loss of -12.6 dB of RMPA.

Radiation design characterized the force emanated or got by the reception apparatus as a component of the rakish position and outspread good ways from the receiving wire and Efficiency is utilized to communicate the proportion of the all out force transmitted by radio wire to the net force acknowledged by receiving wire from the associated transmitter. The Radiation Pattern of the RMPA at working recurrence 2.025 GHz is appeared in fig. 3.

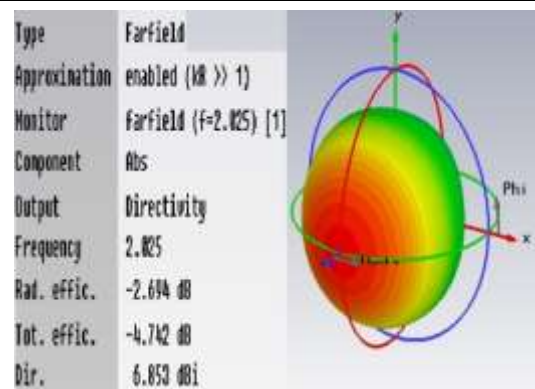


Fig. 3: Radiation Pattern of RMPA shows 33.56% total efficiency & 6.853 dBi directivity.

3.2 Designing of metamaterial Cover on RMPA

After completing the designing and simulating the lone RMPA, the suggested material cover is sited 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 the circles and octagon are shown in figure. Suggested cover is shown in fig. 4.

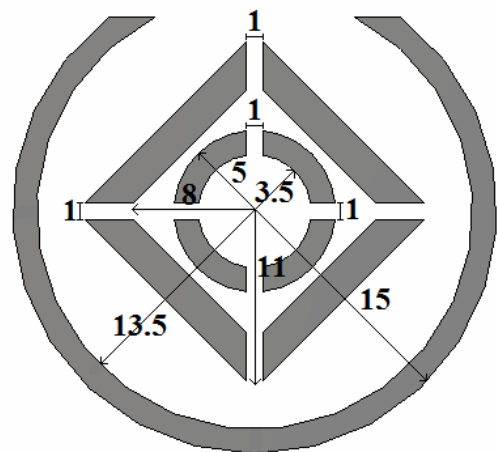


Fig. 4: Dimensional of the proposed metamaterial cover (in mm).

3.2.1 Simulated result after placing proposed design structure

This structure shows the improved bandwidth of 31.4 MHz and reduced return loss of -35.13 dB as shows in Figure 5.

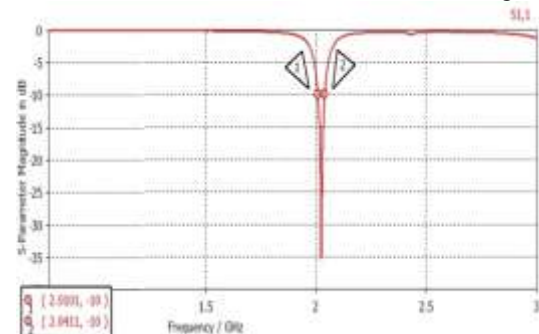


Fig. 5: Output of the RMPA along with proposed metamaterial cover showing Return Loss of -35.13 dB and Bandwidth of 31.4 MHz'

Fig. 6 showing the RMPA radiation pattern along with metamaterial cover at resonating frequency 2.025 and figure shows the directivity of 6.760 dBi and total efficiency of 53.4%.

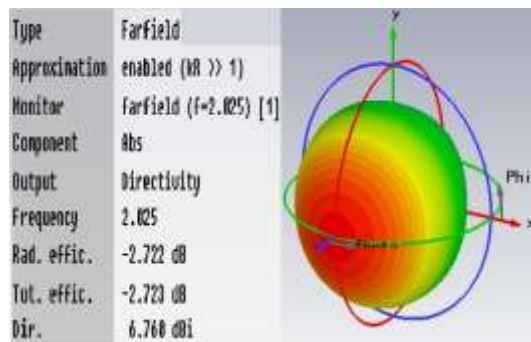


Fig. 6: RMPA Radiation Pattern along with the suggested metamaterial cover showing total efficiency of 53.4% and the directivity 6.76dBi.

3.3 Nicolson-Ross-Weir (NRW) Approach

NRW approach is utilized for demonstrating that the recommended material shows twofold negative property. By this methodology, decide estimation of permittivity and penetrability and check these are negative in a specific scope of recurrence.

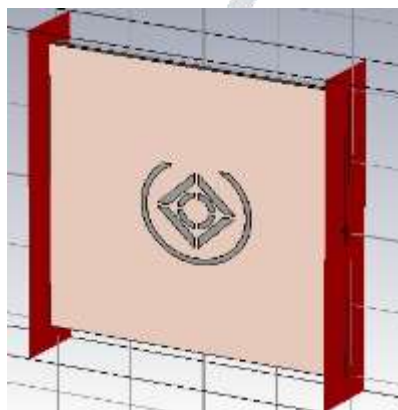


Fig. 7: Suggested material cover placed between the two Waveguide Ports.

Following formulae are used to find the estimation of ϵ_r and μ_r using NRW approach [9][10][12]:

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

$$\epsilon_r = \mu_r + \frac{2S_{11}Ci}{\omega d} \quad (7)$$

Where,

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

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

$$\omega = \text{Frequency in Radian,}$$

$$d = \text{Thickness of the Substrate,}$$

$$C = \text{Speed of Light,}$$

$$V_1 = \text{Voltage Maxima, and}$$

$$V_2 = \text{Voltage Minima.}$$

The values of ϵ_r and μ_r are measured by using eq. 6 and 7 in the simulated frequency range. Graph in fig. 8 and fig. 9 shows that the proposed material cover possesses negative values of ϵ_r and μ_r respectively in the certain range of frequency.

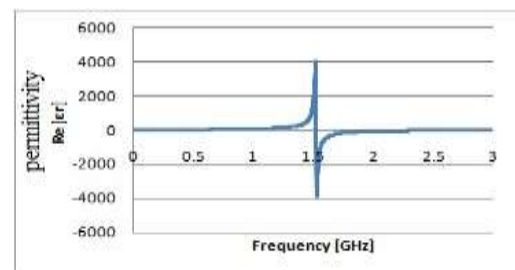


Fig. 8: Plot between Permittivity and Frequency.

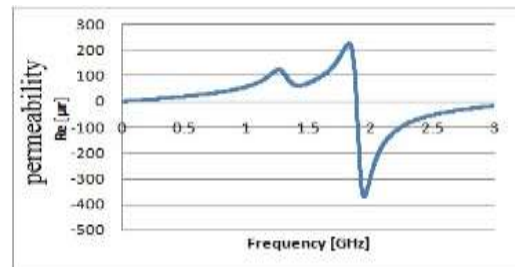


Fig. 9: Plot between Permeability and Frequency.

Table 1 and 2 shows the negative values of ϵ_r and μ_r only in frequency range 2.016–2.03099 GHz.

Table 1: Permittivity values at frequency range 2.016–2.03099 GHz.

Sample Point	Frequency (GHz)	Real value of Permittivity $Re(\epsilon_r)$
676	2.016	-72.924
677	2.0190001	-72.398
678	2.0219998	-71.882
679	2.0249999	-71.371
680	2.0279999	-70.867
681	2.0309999	-70.368

Table 2: Permeability values at frequency range 2.016–2.03099 GHz.

Sample Point	Frequency (GHz)	Real value of Permeability $Re(\mu_r)$
676	2.016	-258.46
677	2.0190001	-253.71
678	2.0219998	-249.08
679	2.0249999	-244.58
680	2.0279999	-240.21
681	2.0309999	-235.95

From the figure 10 smith chart it is clear that the impedance of the proposed RMPA metamaterial antenna is matched with the coaxial cable which is 50Ω .

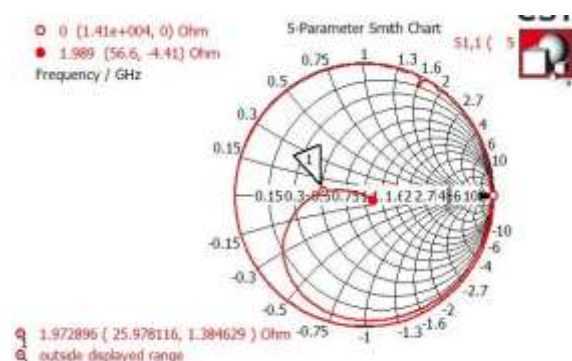


Fig. 10: Smith chart of the RMPA along with proposed metamaterial cover at 2.025GHz.

4. Conclusion and Result

It is simple to produce a microstrip antenna, installation is also easy and highly efficient. Usage of this kind of antenna in satellite communication and wireless communication is strongly favored. The size of the antenna is decreased proportionally at the high frequencies. And the antennas of large scale are replaced with this one. Due to the big reduction in return-loss this antenna provides high gain. The use of metamaterial brings important advancement to RMPA parameters. Through using CST simulation tools, we can quickly evaluate the RMPA parameters such as bandwidth (4 MHz), performance (19.8%) and return loss (-12.6 to -35.13 dB) are modified.

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