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Miniaturization of Microstrip Patch Antenna for Biomedical Applications

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ABSTRACT- In this study, a novel quad-band antenna for biomedical applications was designed, fabricated and analyzed. Biomedical application defines the use of antenna in detecting cancerous cells and its cure using hyperthermia. In this research paper, a rectangular micro strip patch antenna is modified with the circular and pentagonal shapes of negative media (Metamaterial). Antenna was reduced in size and ameliorated to operate on multiple frequency bands. Ameliorated antenna is operating at 1GHz also, which is the substantial operating frequency of cancer detecting tissues. Inclusion of metamaterial increased the bandwidth of and subsequently ameliorate the size of the proposed antenna.

Keywords: Multiband, Metamaterial, Rectangular microstrip patch antenna (RMPA), and Biomedical application.

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1. INTRODUCTION

The requirement for micro-strip patch antennas is increasing steadily. This increased demand attracted the attention of researchers hence the inclination of researchers is more towards this field. In recent years there has been a lot of study on this subject. This subject is a matter of attraction for new age analysts. Larger bandwidth, high gain, and small size antenna's that are capable of providing effective performance for a wider range of spectrum is the main requirement of modern mobile communication system. New techniques have been introduced in this field by many researchers. Some of the most beneficial of them are- Defected ground structure, The Defected Ground structure have been used to improve the performance of the antennas. The present study includes dumbbell shaped slots in the ground plane of the antennas [1]. Array of Antennas, the design of 4-Element micro-strip patch antenna array which uses the corporate feed technique for excitation [2], Different feeding techniques was also used, A good impedance matching condition between the line and patch without any additional matching elements depends heavily on feeding techniques was used [3], Neural Network, the neural network is trained by giving sufficient input data and the back-propagation method is employed to bring the output [4] and Metamaterial, a size reduction technique of the microstrip patch antenna using metamaterial proposed in [5].

By using Metamaterial many papers have been proposed. In this manuscript a novel metamaterial structure is proposed to improve Return loss, bandwidth, and frequency achieved all these parameters by maintaining small size.

Metamaterials are kind of materials which do not have physical significance or exist in earth's surface. They are smart materials which are engineered through different fashions and have properties that have not yet been found in nature. Basically, Metamaterials are artificial materials. Metamaterials are known for their unique shapes, geometry and orientations. These unique structures provide negative properties of permittivity and permeability which reluctantly are capable of manipulating the electromagnetic (EM) wave. These unique structures of metamaterial enhance, bend, absorb and block the EM wave to achieve the desired results according to required process for which they are manufactured or designed. Antennas are being designed for biomedical applications as well, frequency of operation for such applications is nearly 1 GHz [6]. Metamaterials are used as a cover on the patch antenna. Simulation was done this by using CST 2010 software later proposed antenna and metamaterial structure fabricated and analyzed. There are many other software for the simulation *viz.* IE3D, HFSS, *etc.* but author preferred CST over others because of its user- friendly software GUI. It stands for Computer Simulation Technology.

2. METHODOLOGY

Initially a rectangular patch antenna was designed at 2GHz. Microstrip patch antenna is designed by calculating its dimension from formulas available in literature. The parameters of antenna were calculated by using various formulas listed in [7]. Dimensions of the patch was calculated from the formulas and the same dimensions were used while designing the patch

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using the above stated simulation software. Calculated dimensions are listed in table below and also marked on the designed patch image in *figure 1*. All the parameters of antenna are given in the following table:

Table 1: Dimensions of Proposed RMPA

Parameters	Length (mm)	Width (mm)	Height (mm)
Ground	80	60	0.038
Substrate	80	60	1.6
Patch	35.8462	46.0721	0.038
Cut Depth	10	5	0.038
Feed Line	25.113	2.5	0.038

These above tabled dimensions are hereby marked on the designed patch below, for clear understanding of how these dimensions were used while designing the patch.

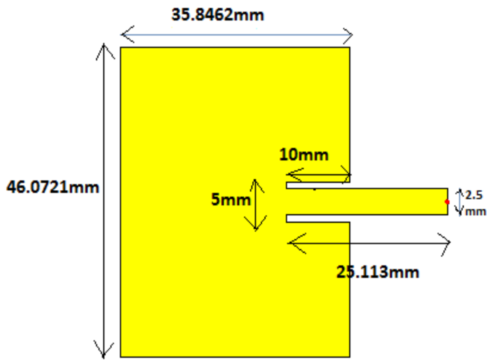

Fig. 1: Rectangular Micro-strip Patch Antenna

Antenna in *figure 1*, was simulated and its parameters were analyzed, following are the results of simulated antenna shown in *figure 2 and 3*. Main antenna parameters which will be used in the application are return loss and directivity of the designed antenna. Radiation pattern of the antenna is defined as the reflection loss with respect to the idle antenna, it depends of the ratio of strength of the radio wave which is coming and going out of the proposed antenna. As far as directivity is concerned, it is basically a figure of merit specifically for the antenna. It is defined as the maximum gain. It is calculated based on the power density which is radiated by the antenna in a particular direction with respect to the power density radiated by isotropic antenna.

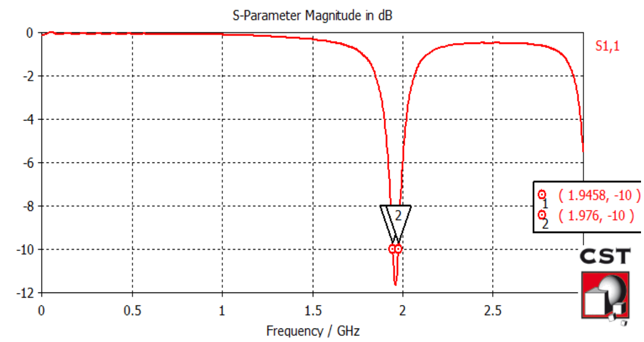

Fig. 2: Variation between Return Loss and Frequency

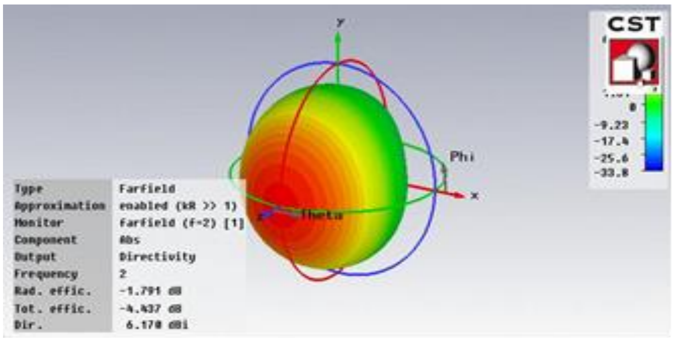

Fig. 3: Radiation Pattern with Directivity and Efficiency

Simulated result shows return loss -11.62dB and directivity 6.178dBi. This designed antenna is having very weak parameters that needs alteration to make it for the significant in applications like treating diseases in biomedical fields. So Metamaterial Cover was implemented for amelioration of the parameters. Authors had incorporated cover shown in figure below in *figure 4* on the surface of antenna known as Metamaterial at a height of 3.276 mm from ground plane.

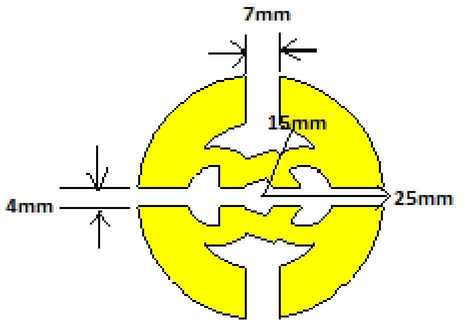

Fig. 4: Proposed negative medial Structure

Fig. 4 shows the metamaterial structure which the author had made with the help of circular and pentagonal structure. The combination of these structure helps to enhance the parameters of the antenna. Following *figure*s shows the simulation results post implementing negative media cover.

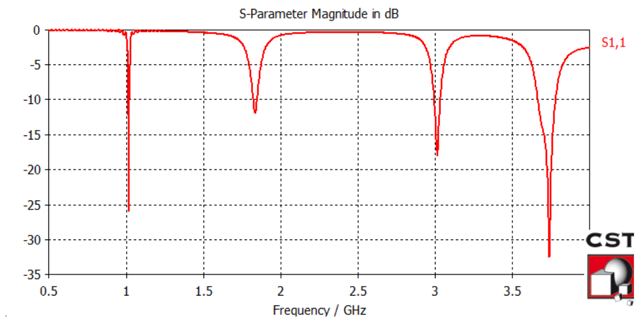

Fig 5. Return losses of multiband

Fig. 5 shows the graph of the various bands which has been obtained after the metamaterial structure incorporation. In this graph, there are four bands and the return losses are -25.92dB, -12dB, -18.05dB, - 32.44498dB at frequencies 1.018 GHz, 1.837 GHz, 3.0165 GHz and 3.7445 GHz simultaneously.

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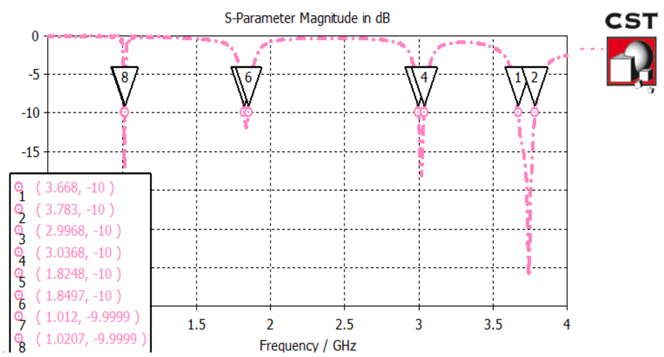

Fig. 6: Variation between Return losses and frequencies

Fig 6. Shows bandwidths for all four radiating frequencies simultaneously for 1.018 GHz, 1.837 GHz, 3.0165 GHz and 3.7445 GHz, which are 8.7MHz, 24.9MHz, 40MHz, and 115 MHz so after using metamaterial structure the author's antenna can work on four bands and therefore can work on four frequencies.

Following *Fig. 7* represents the theta/phi graph of the proposed antenna. In the radiation pattern single peak of directional antenna is presented, this is the direction where bulk of the energy is being transmitted by the antenna. This radiation plot is visual demonstration of the antenna radiated energy.

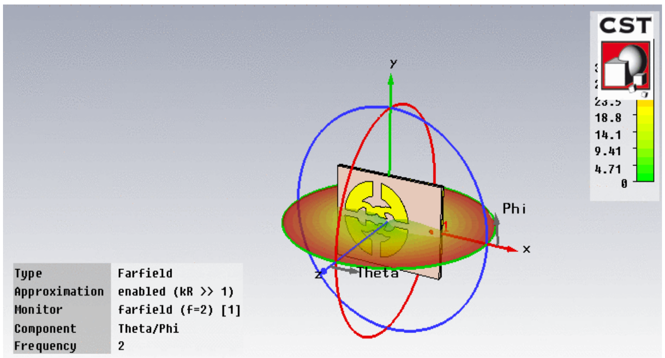

Fig. 7: At 1.018 GHz, Return loss=-25.92dB, Bandwidth= 8.7 MHz

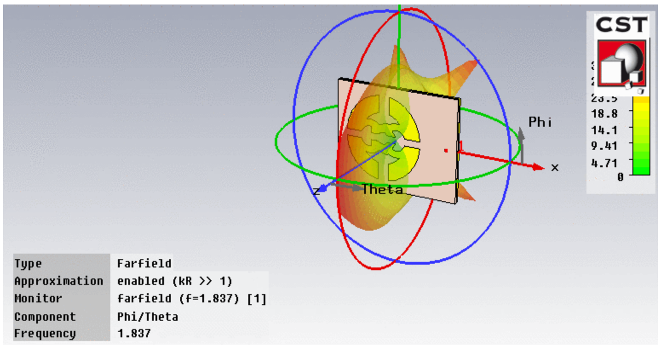

Fig. 8: At 1.837 GHz, Return loss= -12 dB, Bandwidth= 24.9 MHz

Fig. 8 shows the phi/theta graph of antenna at 1.837 GHz frequency in which the return loss was -12 dB and bandwidth was -24.9MHz. Theta waves generate the theta rhythm a neural oscillatory pattern in electroencephalography (EEG) signals, recorded either from inside the brain or from electrodes glued to the scalp.

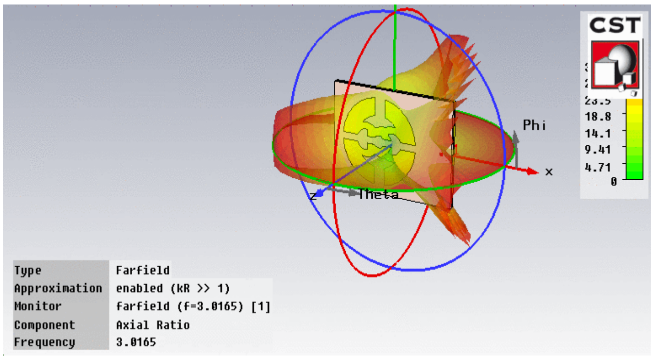

Fig. 9: At 3.0165 GHz, Return loss= -18.05 dB, Bandwidth= 40 MHz

Fig 9. Shows the axial ratio graph of antenna at 3.0165 GHz frequency in which the return loss was - 18.05 dB and the bandwidth was 40 MHz

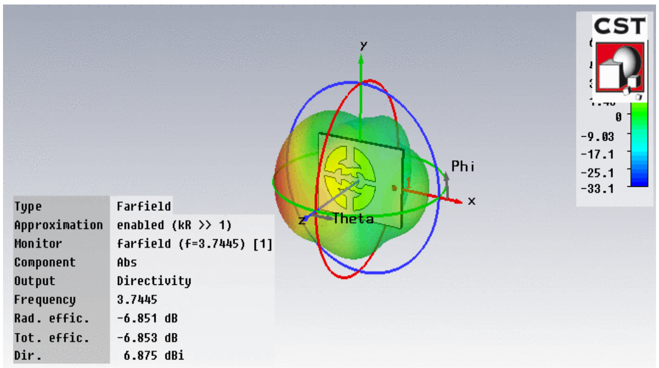

Fig. 10: At 3.7445 GHz, Return loss= 32.44498 dB, bandwidth = 115 MHz

Fig 10. Shows the Abs component graph of antenna at 3.7445 GHz frequency in which the return loss was 32.44498 dB and the bandwidth was 115 MHz this was the highest bandwidth attained by the authors.

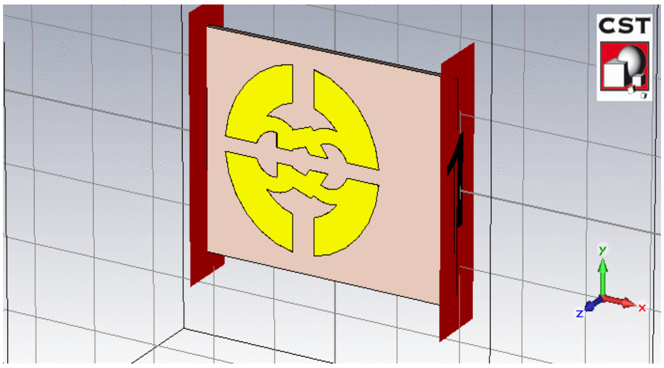

Fig. 11: Metamaterial structure with Ports

Fig. 11 shows the two ports which are attached to the side of metamaterial structure. After we had introduced the metamaterial structure its necessary to prove that the structure which has been proposed to enhance the parameter of antenna

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is Meta. For this purpose, we need to use the NRW (Nicolson Ross Weir) approach [8, 9]. In NRW approach two ports are implemented on the Y axis. And boundary conditions were defined, Y is considered as perfect electric boundary (PEB), and Z as perfect magnetic boundary (PMB). After simulation, we need to calculate the permittivity and permeability, for that the authors had exported the S11 and S21 parameter to Microsoft Excel.

3. RESULT & DISCUSSION

Table 2: Comparison Showing the Simulation Results with and without Metamaterial

S. No.	Simulated Parameter	RMPA alone at 2 GHz	After Negative Media Incorporation			
			At 1.018 GHz	At 1.837 GHz	At 3.0165 GHz	At 3.7445 GHz
1.	Return Loss	-11.62 dB	-25.92 dB	-12 dB	-18.05 dB	- 32.44498 dB
2.	Bandwidth	42.9 MHz	8.7 MHz	24.9 MHz	40 MHz	115 MHZ
3.	Directivity	6.170 dBi	4.429 dBi	6.058 dBi	3.531 dBi	6.875 dBi
4.	Efficiency	66.20 %	10.61 %	56.79 %	35.63 %	20.64 %

Table II contains the comparison of simulated results. It clearly indicates the behavior of antenna characteristics before and after incorporation of metamaterial over the patch. Before metamaterial introduction, antenna was operating on single frequency, but metamaterial introduction converted this antenna into multiband antenna.

After simulation, the authors had done its hardware implementation. The results obtained during hardware testing were different as that obtained during simulation. *Fig. 14* shows the fabricated patch and metamaterial cover, indicating their dimensions. And in *fig. 15* the spectrum analyzer showing its testing results. Maximum return loss was -23.3 dB, and antenna was radiating on two bands.

Fig. 14: Fabricated patch antenna and metamaterial structure

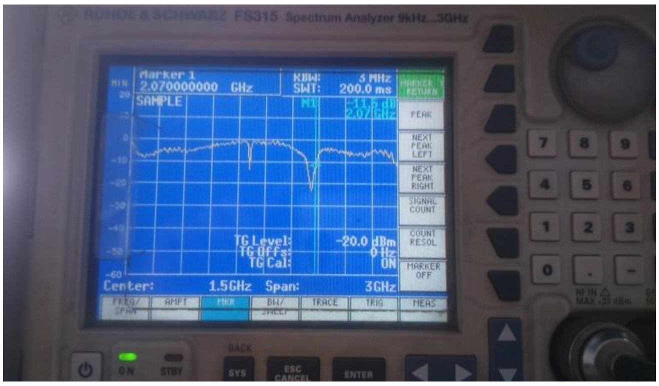

Fig. 15. Measurement result

4. CONCLUSION

It is clearly evident from the results that incorporation of metamaterial enhanced the antenna characteristics. It was validated by the fabrication results as well. Maximum return loss and Bandwidth are as good as -32.445 dB and 115 MHz respectively. This antenna radiates on four bands and its size is also reduced, even at 1 GHz frequency the antenna size is small as compared to other antennas. The main attainments are return loss and bandwidth which is depicted in *figure 5* and *6*. The negative values of permittivity and permeability which proves that it is a metamaterial is depicted in *figure 12* and *13*.

This antenna is having many applications like it can be used in mobile, satellites, etc. As this antenna is radiating in L and S bands, so it will be applicable on L and S band applications. This antenna will be beneficial to use in bio-medical field because as a single antenna works on many frequencies. So, it will be helpful in treating dieses like tumors and hyperthermia where different microwave frequencies are used to burn the virus tissues by increasing the body temperature. So, this antenna will be helpful in this case as a single antenna can be used for different frequencies.

CONFLICT OF INTEREST: The Author(s) declares no conflict of interests.

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