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Research Paper

Engineering

Metamaterial Structure with Negative µ and ε for reduction of return loss of Microstrip Patch Antenna

KEYWORDS : Rectangular microstrip patch antenna (RMPA), Metamaterial (MTM) Impedance Bandwidth, Return loss.

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ABSTRACT

In the recent years the development in communication systems requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. The future development of the personal communication devices will aim to provide image, speech and data communications at any time, and anywhere around the world. This indicates that the future communication terminal antennas must meet the requirements of multi-band or wideband operations to sufficiently cover the possible operating bands.

Patch antenna loaded with metamaterial (MTM) is proposed for better reduction in the return loss at operating frequency 1.824 GHz. The proposed antenna is designed at a height 3.2 mm from the ground plane. At 1.824 GHz, the bandwidth is increased up to 22.7 MHz in comparison to RMPA alone of bandwidth 8.2 MHz. The Return loss of proposed antenna is reduced by -39.686 dB. Microstrip Patch antenna has advantages than other antenna as it is lightweight, inexpensive, easy to fabricate and achieve radiation characteristics with higher return loss. CST MICROWAVE STUDIO is used to design the metamaterial based rectangular microstrip patch antenna.

I. Introduction:

In telecommunication, there are several types of **microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or patch antenna. Microstrip antennas are attractive due to their light weight, conformability and low cost. In its most fundamental form, a microstrip patch antenna (MPA) consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.** The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. The "patch" is a low-profile, low –gain, narrow – bandwidth antenna. Aerodynamic considerations require low-profile antenna on aircraft and many kinds of vehicles. Radiation from the patch is like radiation from two slots, at the left and right edges of the patch. Advantages of patch antenna over several antenna are lightweight and inexpensive. The electric field is zero at the center of patch, maximum at one side, minimum on the opposite side. The important parameters of any type antenna are impedance bandwidth and return loss. The impedance bandwidth depends on parameters related to the patch antenna element itself and feed used. The bandwidth is typically limited to a few percent. CST MICROWAVE STUDIO is a software package for the electromagnetic analysis and design, use to design the metamaterial based rectangular microstrip patch antenna. The software contains four different simulation techniques like transient solver, frequency domain solver, integral equation solver, Eigen mode solver and most flexible is transient solver.

V.G. Veselago in 1968 provided a theoretical report on the concept of metamaterial (MTM) [3]. A Left- Handed metamaterial or Double-Negative Metamaterial exhibits negative permittivity and permeability [4].

II. Design specifications:

The RMPA parameters are calculated from the following formulas. Desired Parametric Analysis [6][7].

Calculation of Width (W):

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

where

C = free space velocity of light,

ε_r =Dielectric constant of substrate

The effective dielectric constant of the rectangular microstrip patch antenna:

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

Actual length of the patch (L):

Le= L + 2ΔL (3)

Calculation of length extension:

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

III. Analysis of Rectangular Microstrip Patch Antenna and Metamaterial Structure with Simulated Results:

The Rectangular Microstrip Patch Antenna is designed on FR-4 (Lossy) substrate at 50Ω matching impedance dielectric constant ε_r = 4.3 and height from the ground plane d=1.6mm. The parameter of rectangular microstrip patch antenna are L= 35.8462 mm, W= 46.0721 mm, Cut Width= 5mm, Cut Depth= 10mm, length of transmission line feed= 29.58mm, with width of the feed= 5mm shown in figure1.

The simple RMPA is inspired by metamaterial structure at 1.824 GHz.

Table1.Rectangular Microstrip Patch Antenna Specifications

Parameters	Dimension	Unit
Dielectric constant	4.3	-
Loss tangent (tan)	.02	-
Thickness (h)	1.6	Mm
Operating frequency	1.794	GHz
Length L	35.85	Mm
Width W	46.07	Mm
Cut width	6	Mm

Cut depth	10	Mm
Path length	29.58	Mm

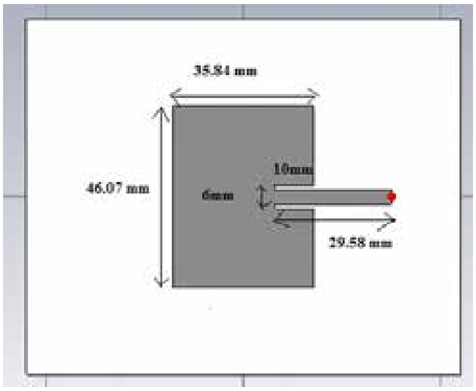

Figure 1. Rectangular microstrip patch antenna at 1.824 GHz.

CST-software is used to design the Rectangular microstrip patch antenna (RMPA) at oprating frequency 1.824 GHz.

However, their employment raises some problems, such as, difficulty impedance matching or increasing of surface waves in the substrate that could decline the radiation efficiency and the radiation pattern. Bandwidth of the antenna may be considerably becomes worse [8].

Simulated result of Return loss and bandwidth of Rectangular Microstrip Patch antenna(RMPA) is shown in fig 2.

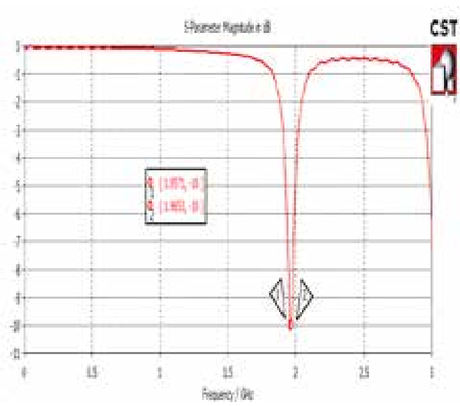

Figure 2. Simulation of return loss and bandwidth of RMPA.

The bandwidth of simple RMPA is 8.2 MHz and Return loss is -10.3 dB.

The Rectangular microstrip patch antenna has 3D Radiation pattern at 1.824 GHz as shown in figure 3. The radiation pattern shows the directivity of simple RMPA is 6.868 dB shown in fig 4.

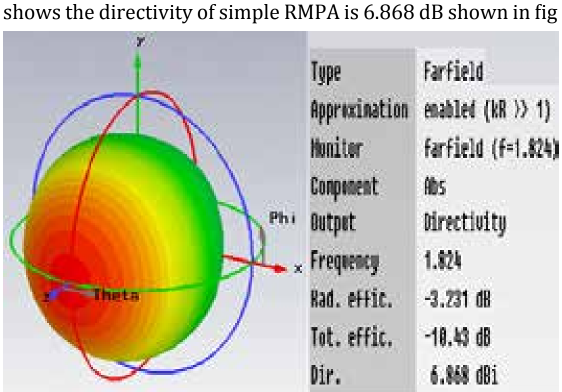

Figure 3. Radiation pattern of RMPA at 1.824 GHz.

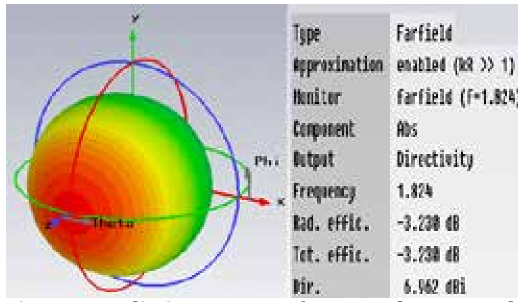

Figure 4. Radiation pattern of proposed antenna showing Directivity of 6.962 dBi.

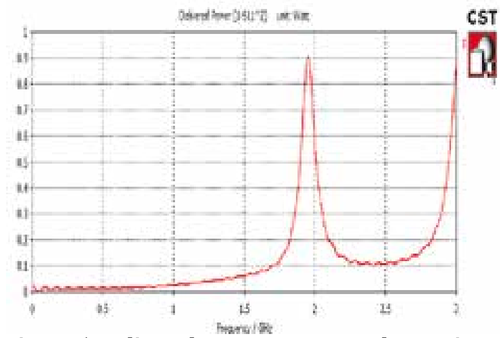

Figure 5. Delivered power to RMPA. The maximum power deliver to patch antenna is above 0.90 watt.

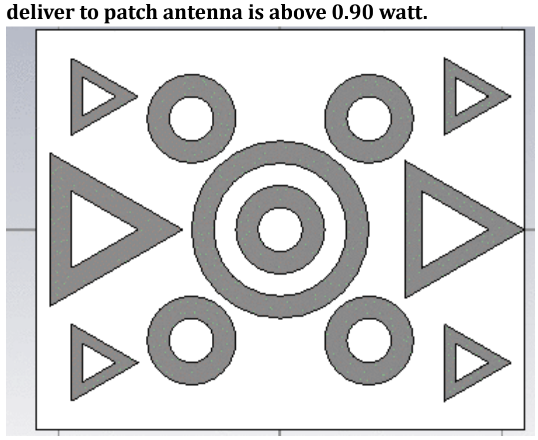

Figure 6. Design of proposed metamaterial structure at the height of 3.2 mm from ground plane.

In this metamaterial design (fig 6), concentric cirles in between symmetrical triangles are loaded on the patch antenna. This design gives the better improvement in impedance bandwidth and reduction in return loss.

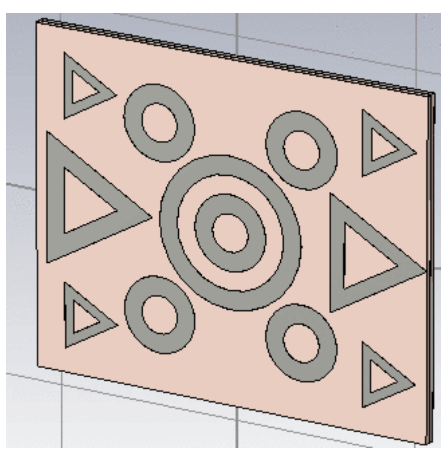

Figure 7. Rectangular microstrip patch antenna with proposed metamaterial structure.

Simulation result of Return loss and bandwidth of Rectangular microstrip patch antenna loaded with metamaterial structure is shown in Fig 8.

The proposed metamaterial structure reduces the return loss by -39.686 dB and increases the bandwidth up to 22.7 MHz.

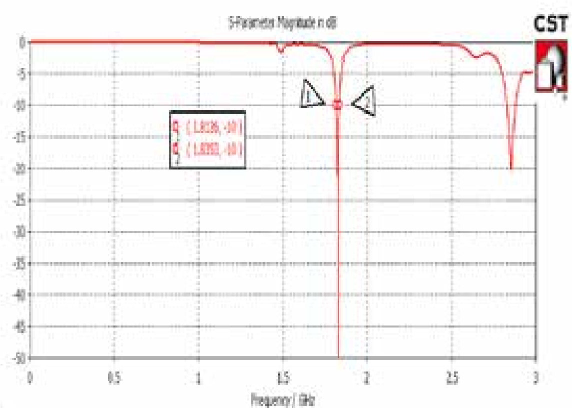

Figure 8. Simulation of Return loss and impedance bandwidth of proposed metematerial at operating frequency 1.824 GHz.

The Simulated result of RMPA loaded with proposed shaped metamaterial is showing return loss of -49.986dB and bandwidth of 22.7 MHz.

It is clear that the directivity of proposed antenna is almost unaffected in comparison to simple RMPA alone.

Nicolson-Ross-Weir (NRW) Approach:
In this work Nicolson-Ross-Weir (NRW) technique [9]-[10] has been used to obtain the values of permittivity and permeability as this is a very popular technique to convert S parameters due to the fact that this technique provides easy as well as effective formulation and calculation. Here in this work for extracting the S-Parameters, proposed metamaterial structure is placed between the two waveguide ports [11] [12] at the left and right hand side of the X axis as shown in

Fig.4. In Fig. 4, Y-Plane is defined as Perfect Electric Boundary (PEB) and Z-Plane is defined as the Perfect Magnetic Boundary (PMB), which creates internal environment of waveguide. The simulated S-Parameters are then exported to Microsoft Excel Program for verifying the Double-Negative properties of the proposed metamaterial structure [13].

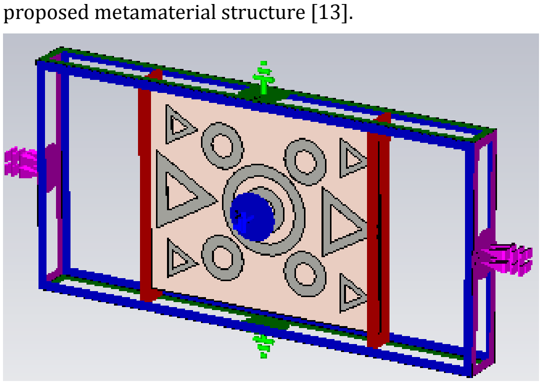

Figure 9: Proposed metamaterial structure between the two waveguide ports.

B. Equations used for calculating permittivity and permeability using NRW approach [14]-[15].

$$\mu_r = \frac{2c(1-v_1)}{\omega di(i+v_2)} \qquad (1)$$

$$\varepsilon_r = \mu_r + \frac{2.S_{11}.c.i}{\omega d} \qquad (2)$$

Where,

V2 = S21 - S1
Ω = FREQUENCY IN RADIAN
D = THICKNESS OF THE SUBSTRATE
I = IMAGINARY COEFFICIENT
C = SPEED OF LIGHT
V2 = VOLTAGE MINIMA

For satisfying Double Negative property, the values of permeability and permittivity should be negative within the operating frequency range. The values of these two

quantities are obtained from the MS-Excel Program, whereas Fig. 10 & Fig. 11 shows the graph between permeability & frequency and permittivity & frequency respectively.

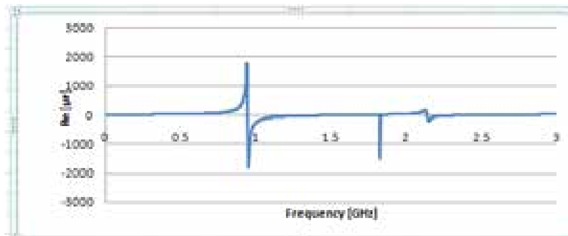

Figure 10: Permeability versus Frequency Graph.

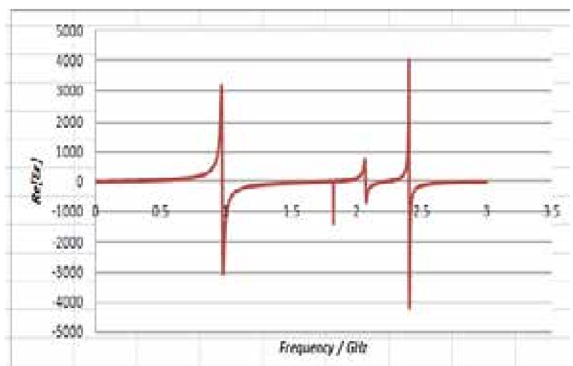

Figure 11: Permittivity versus Frequency Graph.

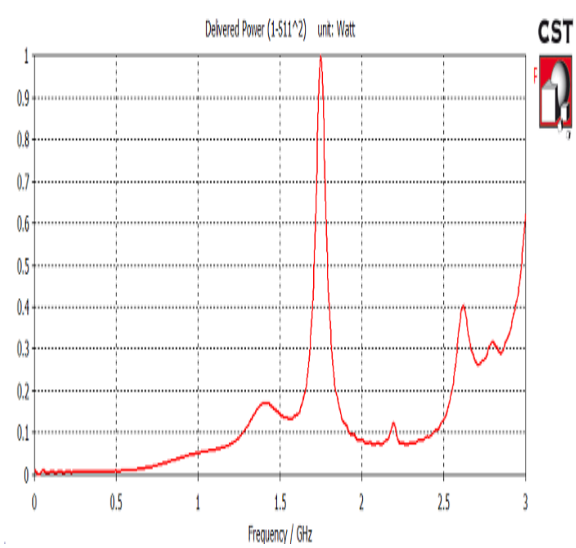

Figure 12. Delivered power to reduced size RMPA loaded with metamaterial structure.

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The maximum power delivered to proposed rectangular microstrip patch antenna is 1 watt in figure 12.

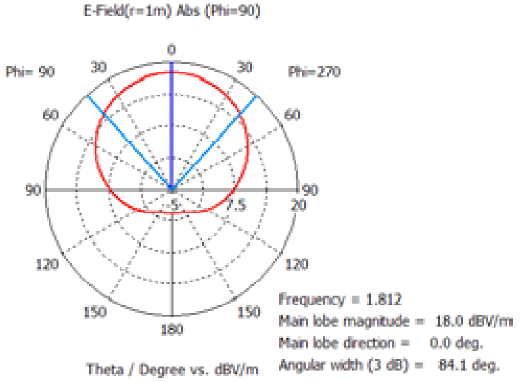

Figure 13. E Field of the reduced size RMPA loaded with Metamaterial

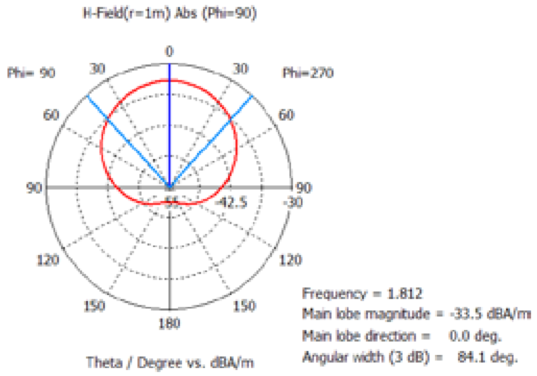

Figure 14. H Field of the reduced size RMPA loaded with Metamaterial.

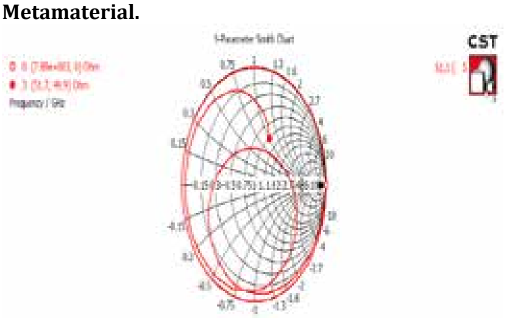

Figure 15. Smith chart of simple Rectangular microstrip patch antenna.

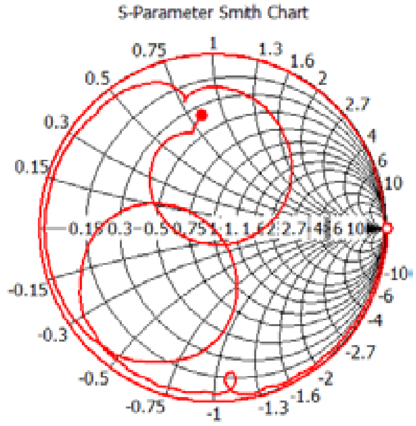

Figure 16. Smith chart of RMPA loaded with metamaterial.

The smith chart is very useful when solving transmission problems. The real utility of the Smith chart, it can be used to convert from reflection coefficients to normalized impedances (or admittances), and vice versa.

Above Fig. shows the impedance variation in the simulated frequency range and received impedance matching for proposed antenna at characteristic impedance.

IV. Simulation Results

In this paper, rectangular microstrip patch antenna loaded with concentric cirles in between symmetrical triangles metamaterial structure is simulated using CST-MWS software. The proposed design in comparison to RMPA alone, found that the potential parameters of the proposed antenna is increased. This is clear from Fig.2 & Fig.8 that the return loss is reduced by -39.686 dB and bandwidth is increased by 14.5 MHz. From the Fig.4, it is clear that the directivity of proposed antenna design is almost unaffected. The maximum power deliver to proposed rectangular microstrip patch antenna is 1 watt.

V. Conclusion

The main drawback of patch antenna was impedance bandwidth. For this purpose, Rectangular microstrip patch antenna loaded with concentric cirles in between symmetrical triangles metamaterial structure has been proposed and analyzed in this paper. The simulated results provide that, improvement in the bandwidth is 14.5 MHz and the Return loss of proposed antenna is reduced by -39.686 dB. It is clear that we can easily overcome the drawbacks of RMPA by using the properties of Metamaterial (MTM). By using Metamaterial, the maximum power delivered to proposed antenna is 1 watt as compared to the RMPA delivered power of 0.9 watt.

VI. Acknowledgement:

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