Quintuple Slotted Squares with Circular Disks Structure Amalgamated over RMPA for Enhancement of Variant Parameters for WLAN

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Abstract: A Rectangular Microstrip Patch Antenna with “Quintuple slotted squares with circular disks” shaped metamaterial cover is designed and replicate at a height of 3.2mm from the ground plane. The antenna along with the proposed metamaterial cover is designed to resonate at 1.9 GHz frequency (in S-Band). But the proposed metamaterial cover significantly reduces the return loss and increases the bandwidth, efficiency and gain of the antenna in comparison to rectangular microstrip patch antenna alone. The proposed antenna is suitable for application of WLAN requiring 33 MHz bandwidth space and reduced return loss, of about -29.98dB and its efficiency increases by 56% (approx 36%). Hence there is increase in gain of the metamaterial about 4.468dB of about 297% of the antenna. The scope of this paper is to design and simulate the proposed artificial structure with simultaneous negative permittivity and permeability or the so-called Left Handed Metamaterial. Nicolson-Ross-Weir approach has been used for verifying the double-negative properties of the proposed metamaterial.

Keywords- Rectangular Microstrip Patch Antenna (RMPA), Double Negative Left-Handed Metamaterial, Return loss (LH-MTM), Nicolson-Ross-Weir (NRW).

I. Introduction

The Microstrip Patch antenna are an enhance antenna based on their applications, which has some vitues like low assembly weight and cost, and operating at high frequency range.History of LHM was started from Veselago [1] when he made a theoretical assumption of this artificial material that revaluate negative permittivity and negative permeability.

Smith made the first exemplar structures of LHM [2]. The Metamaterial, are left-handed metamaterial (LHM) where the permeability and permittivity are concurrently negative.With these properties, the LHM will be mainly used to focus on the radiation of an antenna.

LHM certainly deserves more than an increased gain in the microstrip technology, miniaturizes patch antenna size, adjusts the bandwidth and also find its application in filtering the unwanted signals.

Computer Simulation Technology (CST-MWS) Software has been used for all the simulation. We use the MathCAD Software for verifying the Double Negative properties for the proposed design [4].

2. Design Methodology and Simulated Results

The Rectangular microstrip patch antenna parameters are calculated from the formulas given below.

Desired Parametric Analysis [2][3]:

Calculation of Width (W)

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

Where,

c = free space velocity of light,

ε_r = Dielectric constant of substrate,

Effective dielectric constant is calculated from**:**

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r}{:} \quad (2)$$

The actual length of the Patch (L)

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

Where,

Leff (4)

Calculation of Length Extension

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+}{(\varepsilon_{eff}-} \quad (5)$$

The RMPA (in figure 1) is designed using the calculated parameters shown below in Table 1.

Table 1: RMPA Specifications:

	Dimensions	Unit
Dielectric Constant (εr)	4.3	-
Loss Tangent (tan ∂)	0.02	-
Thickness (h)	1.6	mm
Operating Frequency	1.9	GHz
Length (L)	35.44	Mm
Width (W)	45.64	Mm
Cut Width	5	Mm
Cut Depth	10	Mm
Path Length	32.82	Mm
Width Of Feed	3	Mm

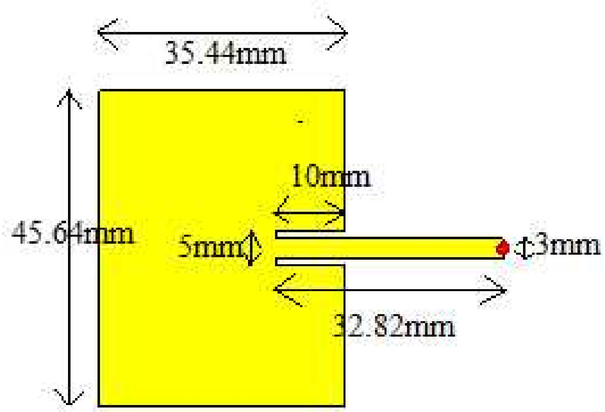

Figure 1: Rectangular microstrip patch antenna at 1.9 GHz (all dimensions in mm). (Source: Ms paint)

Designed RMPA is simulated in CST-MWS software [5] in Transient Mode at the operating frequency, the simulated results are shown in figure 2 and figure 3 below.

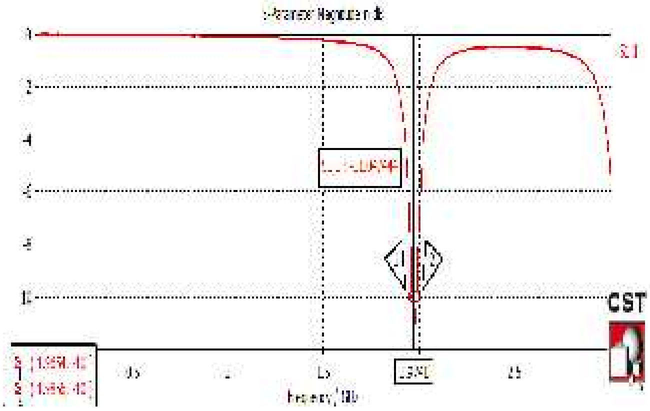

Figure 2: Simulated Result of Rectangular microstrip Patch antenna showing Return Loss of -11.04 dB. (Source: CST)

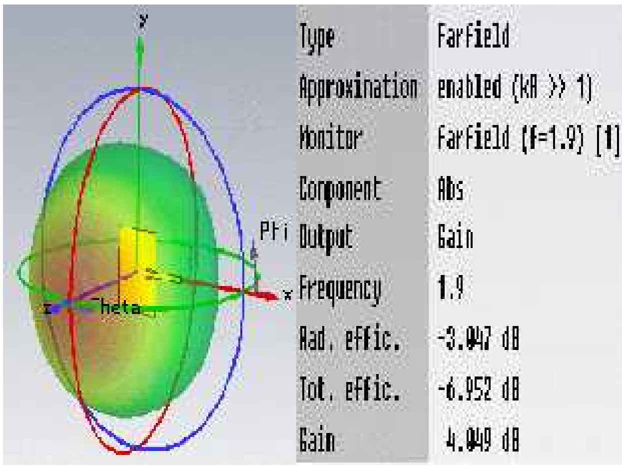

Figure 3: Radiation Pattern of Rectangular microstrip patch antenna showing gain of 4.049dBi about 254% & total efficiency of 20.17 %.(Source: CST)

After designing & simulating the RMPA, the proposed "Quintuple slotted squares with circular disks" shaped metamaterial cover is taken into analysis as shown.

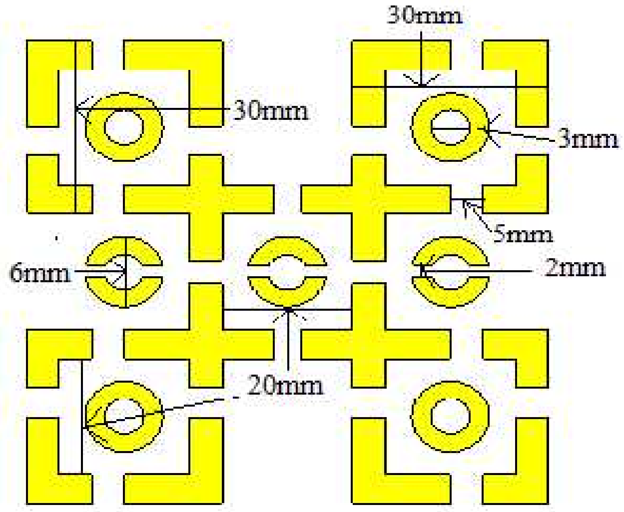

Figure 4: Dimension view of the proposed design (all dimensions in mm). (Source: Ms paint)

The proposed metamaterial cover design is placed between the two waveguide ports [17] at the left & right of the X-Axis as shown in figure 5, in order to calculate the S11 and S21 parameters[11][16]. The excitation of the signal was done from the left side to the right side of the structure assuming the surrounding was air. The Y-Plane was defined as Perfect Electric Boundary (PEB) and Z-Plane was defined as the Perfect Magnetic Boundary (PMB). Subsequently, the wave was excited from the negative X-axis (Port 1) towards the positive X-axis (Port 2).

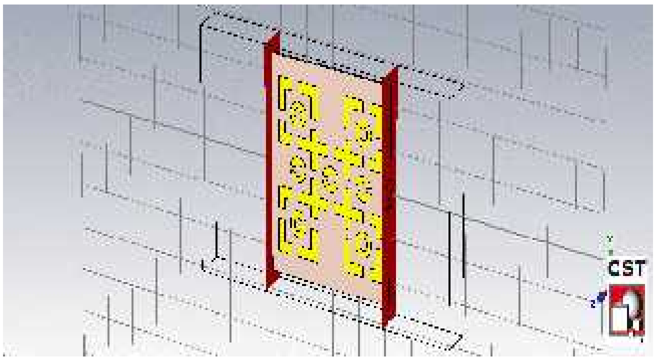

Figure 5: Proposed metamaterial cover placed between the two Waveguide Ports at the left & right of the X-axis. (Source: CST)

Through this arrangement, the S11 and S21 parameters were obtained in complex form, which are then exported to MathCAD program for verifying the double-negative metamaterial properties of the proposed metamaterial structure by using the NRW approach.

Formulas for calculating the value of permittivity & permeability using NRW approach [9][10][13]:-

$$\mu_r = \frac{2.c(1-v2)}{\omega.d.i(1+v2)} \quad (6)$$

$$\varepsilon_r = \mu_r + \frac{2.S11.c.i}{\omega.d} \quad (7)$$

Where,

$v1$ = S11 + S21

$v2$ = S21 - S11

ω = Frequency in Radian,

d = Thickness of the Substrate,

c = Speed of Light,

$v1$ = Voltage Maxima, and

$v2$ = Voltage Minima.

The values of permittivity (ε) and permeability (μ) are calculated by using equation 6 & 7 in the simulated frequency range. Graph in figures 6 & 7 shows that the proposed metamaterial cover possesses negative values of permittivity & permeability [8] at the resonating frequency.

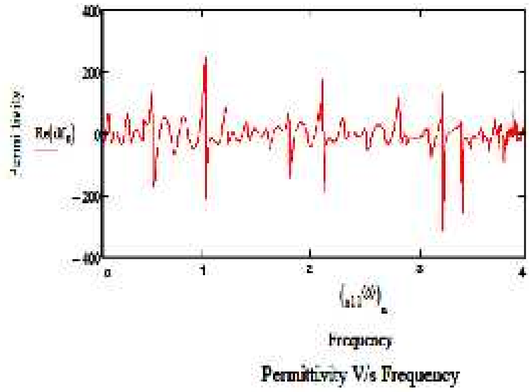

Figure 6: Permittivity versus Frequency Graph obtained from MathCAD Software. (Source: Math Cad)

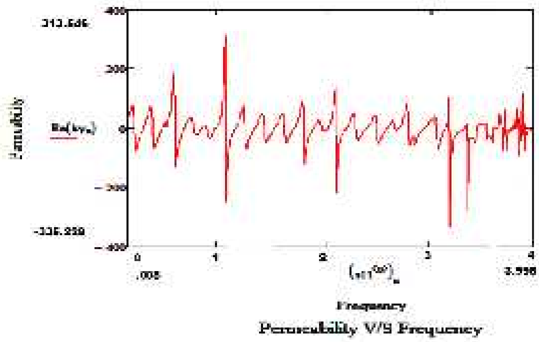

Figure 7: Permeability versus Frequency Graph obtained from MathCAD Software. (Source: Math Cad)

RMPA integrated with proposed metamaterial cover at a height 3.276mm from the ground plane as shown in figure 8.

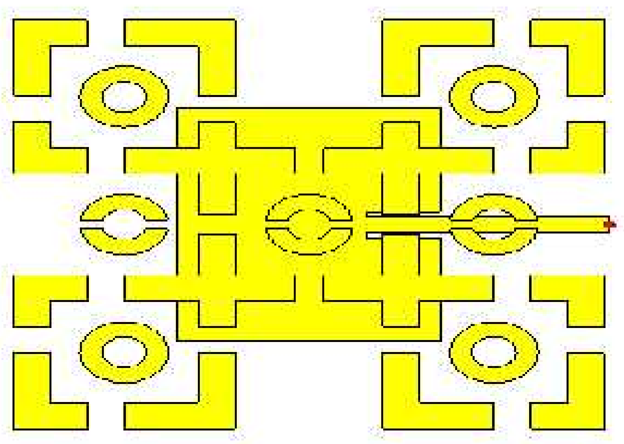

Figure 8: Rectangular microstrip patch antenna along with "Quintuple slotted squares with circular disks" shaped metamaterial cover at a height of 3.2mm from the ground plane. (Source: CST)

The simulated results of the RMPA along with proposed metamaterial cover are shown in figure 9 & 10, it has been found that the potential parameters like [14][15] (gain, total efficiency, & directivity) of the proposed antenna increases significantly in comparison to RMPA alone. The return loss of the RMPA along with proposed metamaterial cover is reduced by 29.98dB.

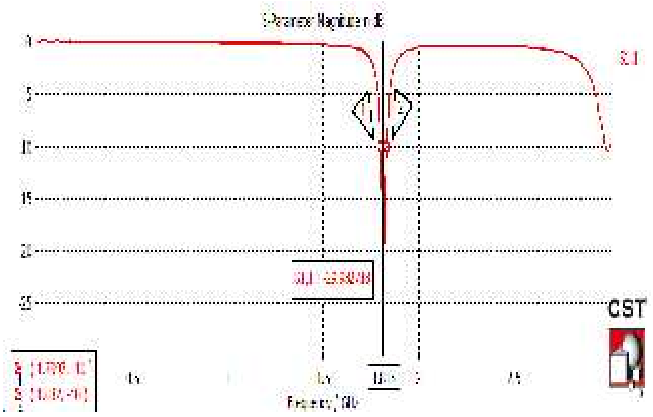

Figure 9: Simulated result of the RMPA along with proposed metamaterial cover showing Return Loss of -29.98dB. (Source: CST)

Radiation pattern is defined as the power radiated (transmitted) or received by an antenna in a function of the angular position and radial distance from the antenna. It describes how an antenna directs the energy it radiates and it is determined in the far field region.

The figure 10 below shows the radiation pattern of the RMPA along with proposed metamaterial cover. It has been observed that the gain is improved by .419dBi and the total efficiency [12] is increased from 20.17% to 56.0% in comparison with the RMPA alone.

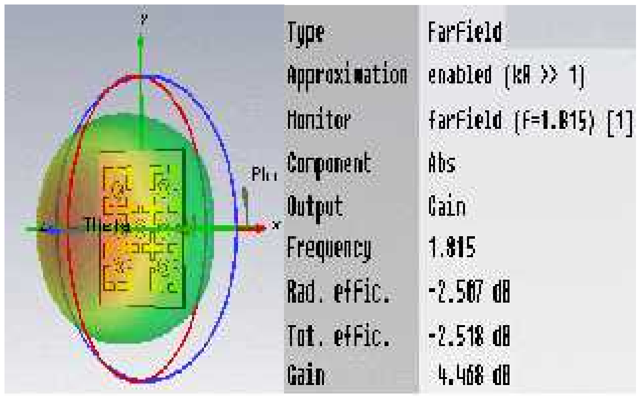

Figure 10: Radiation Pattern of the RMPA along with proposed metamaterial cover showing gain of 4.468dBi about 297 % & total efficiency of 56.0 %.(Source: CST)

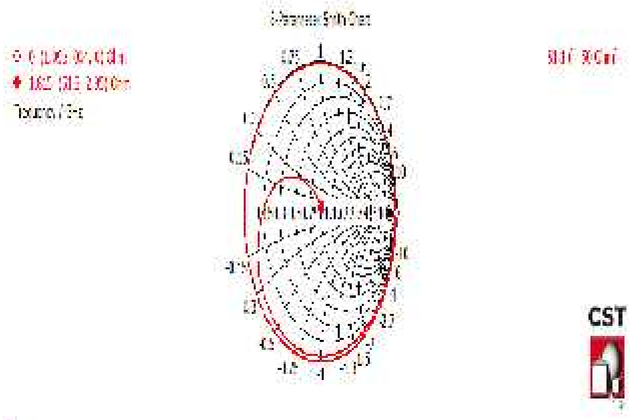

Figure 11: Smith chart of the RMPA along with proposed metamaterial cover at 1.815GHz. (Source: CST)

Figure 11 shows the smith chart [6][7] of the RMPA along with proposed metamaterial cover, it is clear from the figure that the impedance of the antenna is matched with the co-axial cable i.e., 50Ω

Conclusion

We can see that RMPA structure having certain specification can be enhanced by using LH-MTM. So that its bandwidth, efficiency, return loss and gain could be ameliorated. Hence this work could be further amended by using variant patterns of metamaterial structures. Further in future this work could be shifted in higher frequencies so that micro antennas could be used for the WLAN technologies.

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