International Journal of Electrical & Electronics Research (IJEER)
Volume 3 issue 2, Pages 27-30, June 2015, ISSN: 2347-470X

Analysis and Design of Rectangular Resonant Microstrip Patch Antenna Loaded with "SLOTTED RHOMBUS" Shaped Left-Handed Inspired Metamaterial Structure

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ABSTRACT- Authors analyzed and explored a significant concept of micro-strip patch antenna configured by double negative left handed metamaterial structure. Basic aim of this paper is to explain the general properties of rectangular micro-strip patch antenna with metamaterial structure like return loss, bandwidth, directivity and Smith chart. In this paper authors have compared the return loss of the micro-strip patch antenna at a frequency of 2.26 GHz and height of 3.2 mm from the ground plane with "SLOTTED RHOMBUS" Shaped left-handed structure. It has been observed that the return loss has reduced by 25 dB approximately.

Keywords- Rectangular Microstrip Patch antennas, Double Negative Left-Handed Metamaterial.

I. INTRODUCTION

The unusual properties of the metamaterials are utilized here in a microstrip patch antenna at a frequency of 2.26 GHz in order to achieve a more efficient antenna. Metamaterials were first introduced by Veselago [1] in 1967. Metamaterials are manmade artificial materials which exhibit negative permittivity, negative permeability and negative refractive index, which are not found in the available materials. For the proposed antenna only the negative permittivity and negative permeability [4-6] are of importance. Veselago first analyzed theoretically the wave propagation in a material with a negative electric permittivity and a negative magnetic permeability. In such a left-handed (LH) material the electric field, the magnetic field, and the wave vector of an electromagnetic wave propagating obey the left-hand rule (instead of the right-hand rule for usual materials). Metamaterials permit patch antenna elements to cover a wider frequency range. Some applications for metamaterial antennas are wireless communication, space communications, global positioning system (GPS), satellites, space vehicle navigation, and airplanes.

The rectangular patch microstrip antenna [11] consists of a conductive patch on substrate materials above a conductive ground plane. The excitation of the patch is accomplished via microstrip feedline. This feed technique supply the electrical signal to the patch which will be converted to an electromagnetic wave. This paper is organized as follows. The section 2 is concerned with the design and simulation of rectangular microstrip patch antenna along and "SLOTTED RHOMBUS" Shaped metamaterial structure. The section 3 discusses the results of the paper and finally, section 4 concludes the work.

II. DESIGN AND SIMULATION OF RECTANGULAR MICROSTRIP PA-TCH ANTENNA AND "SLOTTED RHOMBUS" SHAPED META-MATERIAL

The parameters of rectangular microstrip patch antenna [7-8] are W= 31.65 mm, L=40.77 mm, Cut Width= 5mm, Cut Depth= 10mm, with width of the feed= 3.009 mm as shown in Figure 1. The rectangular microstrip patch antenna designed on one side substrate with εr = 4.3 and height from the ground plane d= 1.6mm. The proposed design is based on "SLOTTED RHOMBUS" Shaped metamaterial structure.

TABLE 1: RECTANGULAR MICROSTRIP PATCH ANTENNA SPECIFICATIONS

	Dimensions	Unit
Dielectric Constant (εr)	4.3	-
Loss Tangent (tan ∂)	0.02	-
Thickness (h)	1.6	mm
Operating Frequency	2	GHz
Length (L)	31.65	mm

Width (W)	40.77	mm
Cut Width	5	mm
Cut Depth	10	mm
Width Of Feed	3.009	mm

The "SLOTTED RHOMBUS" Shaped Metamaterial Stucture is placed above the patch antenna at a height of 3.2 mm from ground plane in order to study its influence, and the results are compared with those of the Patch antenna alone. The required specifications of this design are shown in the Figure 4.

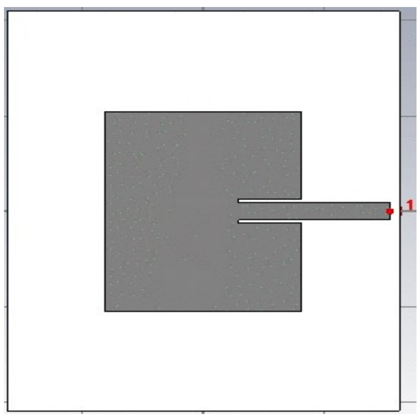

Figure 1: Rectangular patch antenna at 2.26 GHz, (all dimensions in mm)

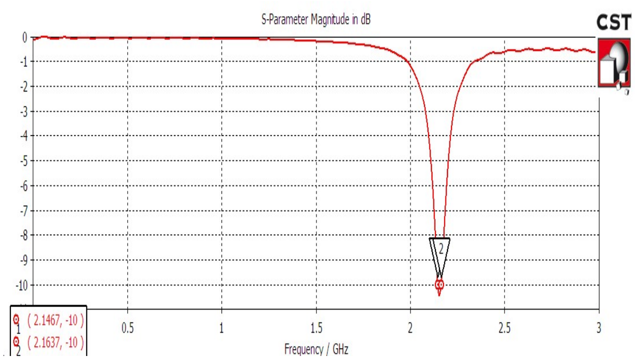

Figure 2: Return loss S11 of Rectangular Microstrip patch antenna

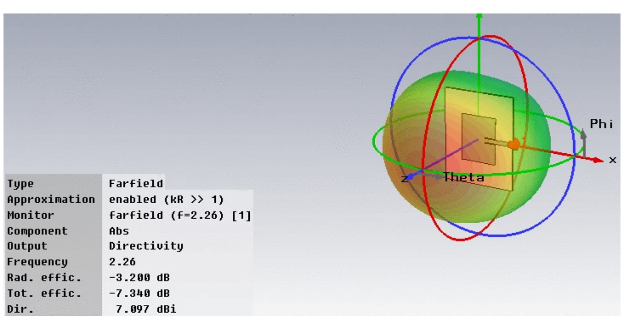

Figure 3: Radiation Pattern of Rectangular Microstrip patch antenna

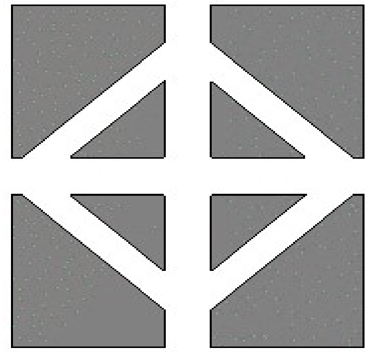

Figure 4: Rectangular Microstrip patch antenna with "SLOTTED RHOMBUS" Shaped Metamaterial Structure (dimensions in mm)

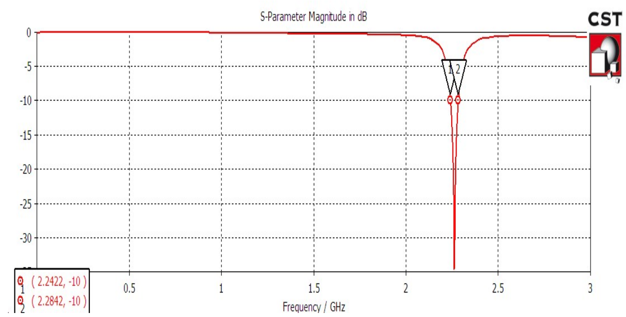

Figure 5: Simulation of Return Loss of Rectangular Microstrip Patch Antenna with "SLOTTED RHOMBUS" Shaped Metamaterial Structure

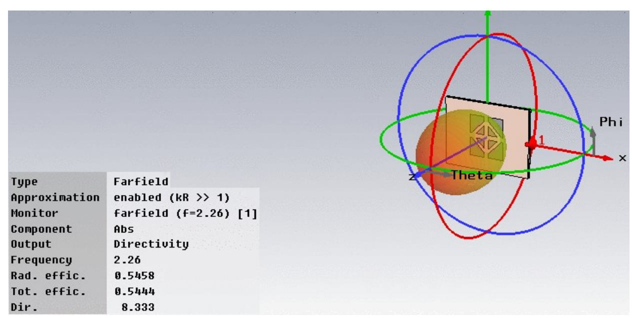

Figure 6: Radiation Pattern of Rectangular Microstrip patch antenna with "SLOTTED RHOMBUS" shaped metamaterial structure

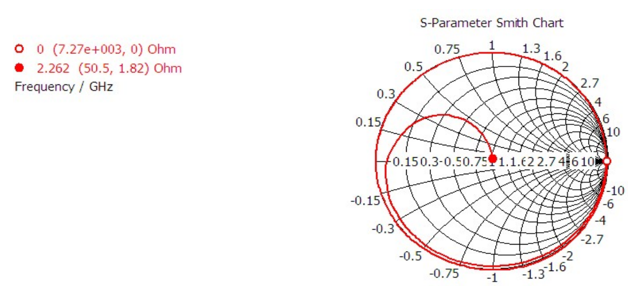

Figure 7: Smith chart of Rectangular Microstrip patch antenna with "SLOTTED RHOMBUS" Shaped Metamaterial structure

DESIRED PARAMETRIC ANALYSIS [2-3]

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 Microstrip antenna to account for fringing field.

Effective dielectric constant is calculated from**:**

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

The actual length of the Patch (L)

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

Where

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4)$$

Calculation of Length Extension

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

III. RESULT AND DISCUSSIONS

The simulated results of rectangular microstrip patch antenna with “SLOTTED RHOMBUS” shaped structure are shown in the figures above. Cst-10 (Computer Simulation Technology software) was chosen to simulate the antenna. At 2.26 GHz frequency the simulated rectangular microstrip patch antenna shows (figure 2) return loss of -10.65 while the same when designed with “SLOTTED RHOMBUS” shaped metamaterial structure at 3.2mm from the ground plane it shows (figure 5) return loss of -34.16 dB, which shows significant reduction in return loss [9-10]. Radiation Pattern in Fig. 3 & Fig. 6 shows that the directivity is also improved by 1.2 dBi approximately at 2.26 GHz frequency. In figure 7 smith chart [12] of both the antennas shows the normalized impedance at different frequency range from 1GHz to 3 GHz.

IV. CONCLUSION

The “SLOTTED RHOMBUS” shaped metamaterial structure with Rectangular microstrip patch antenna has been proposed in this paper. The simulated results provided the improvement in gain i.e. reduction in magnitude of return loss by 25dB approximately. On making different structures by double negative left handed metamaterials antenna parameters like gain, directivity, and bandwidth can be improved up to a desired limit but practical limitations should be taken care of while fabricating the structure with CST-10 simulation software.

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