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Design a Microstrip Patch Antenna inspired by Metamaterial Structures for Wireless Applications

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Abstract— In this paper, the proposed antenna design is inspired by metamaterial structure with rectangular patch antenna represented. It shows the metamaterial property at 1.57mm and shows three bands with resonant at 5.6 GHz; 7.4 GHz and 9.4 GHz and corresponding bandwidths obtained 300MHz, 900GHz and 105 MHz respectively. It achieved the gain of 3.58 dB. Proposed antenna is fabricated using Bakelite substrate with 1.57 mm thickness. The proposed antenna has application in amateur satellite (downlink), IEEE 802.11a WLAN and some weather Radar system.

Key words: Left-Handed Material (LH.M), Microstrip Patch Antenna (MPA), Metamaterial (MTM), Return Loss, Gain, Complimentary Split Ring Resonator (CSRR), Defected Ground Plane

I. INTRODUCTION

The modern requirements of antenna properties are low fabrication cost, minimal weight, high gain and larger bandwidth. The future aspect of antennas is to provide reduction in size and high speed data rate. The microstrip patch antennas are commonly used in the wireless devices [1]. Reduction in size of antenna helps in miniaturizing the volume of entire communication device. The patch is a low profile, low gain antenna. The thickness (t) of a patch antenna is typically about λ_0/100. The patch antenna is cheaper as compared to others. The return loss and bandwidth of patch antenna is small that is disadvantage of patch antenna. Metamaterial based rectangular patch antenna improves the return loss as well as gain bandwidth of patch antenna. HFSS version13 is a software package for electromagnetic analysis and design. The software provides full flexibility for the analysis of the design and results.

A. Metamaterial

A third quadrant (ε<0, μ<0) represents Metamaterial, having both permittivity and permeability negative also called left handed material (LHM) because it follows left hand system. Metamaterials do not exist in nature but its properties can derive by special periodic arrangement of metallic wire. Particular, in which the vectors E, H and k form a left-handed system. It follows the left handed rule because propagation of wave takes place in backward direction in this medium [2]. This word Metamaterial is a combination of "meta" and "material", Meta [4] is a Greek word which means something beyond, altered, changed or something advance. Metamaterial are usually implemented in a periodic arrangement of unit cells. A unit cell is a combination of SRR and wire structure [4].

II. DESIGN SPECIFICATION

To design the patch antenna some parameters are necessary such as resonant frequency, dielectric constant, and substrate [8].

A. Calculation of parameters

Return loss: 20 log |Γ|
Γ -Reflection Co-efficient

B. Calculation of VSWR:

$$S = \frac{1+|\Gamma|}{1-|\Gamma|}$$

C. Calculation of Width (W):

$$W = \frac{c}{2f0\sqrt{\frac{\epsilon_r+1}{2}}}$$

C = Free space velocity of light

ε_r= Dielectric const. of substrate

Effective dielectric constant of MPA:

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-1/2}$$

Actual length of the patch (L):

$$L = L_{eff} - 2\Delta L$$

D. Calculation of Length Extension:

$$\Delta L = 0.412h\,\frac{(\epsilon_{eff}+.3)(.264+\frac{W}{h})}{(\epsilon_{eff}-.258)(.8+\frac{W}{h})}$$

III. ANALYSIS OF DESIGNED ANTENNA

The Rectangular Microstrip Patch Antenna is designed on Bakelite substrate at 50Ω matching impedance [10], dielectric constant ε_r = 4.8 and height from the ground plane d=1.57mm.The parameter of rectangular microstrip patch antenna are L= 50 mm, W= 50 mm, radius of coax feed is 2.15 mm at center position of (28, 20, 0) with a probe of radius .35 mm at h=1.57mm.PEC material is used in probe and coax pin.

The structure inspired by metamaterial structure to get the better result in both return loss as well as bandwidth.

Parameters	Dimension	unit
Die-electric constant	4.8	-
Loss tangent (tan)	.01	-
Thickness (h)	1.57	mm
Operating frequency	2.4	GHz
Length L	50	mm
Width W	50	mm
Radius of probe	.35	mm
Radius of coax feed	2.15	mm
Type of feed	Co axial line	-

Table 1: Rectangular Microstrip Patch Antenna Specifications

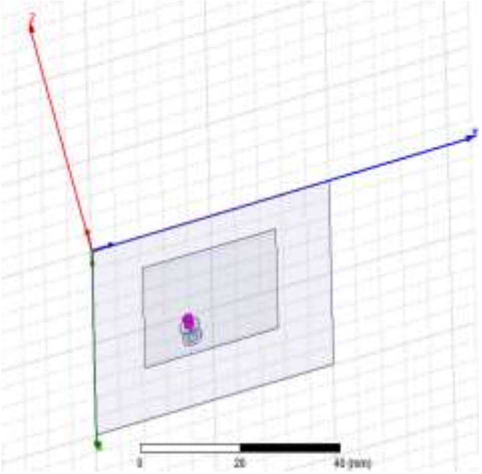

Fig. 1: Rectangular microstrip patch antenna

HFSS 13 software is used to design the Rectangular microstrip patch antenna (MPA) at operating frequency at 2.4 GHz. Simulated result of Return loss and bandwidth of Rectangular Microstrip Patch antenna (MPA) which will provide the base for comparison of parameter is shown in fig 2.

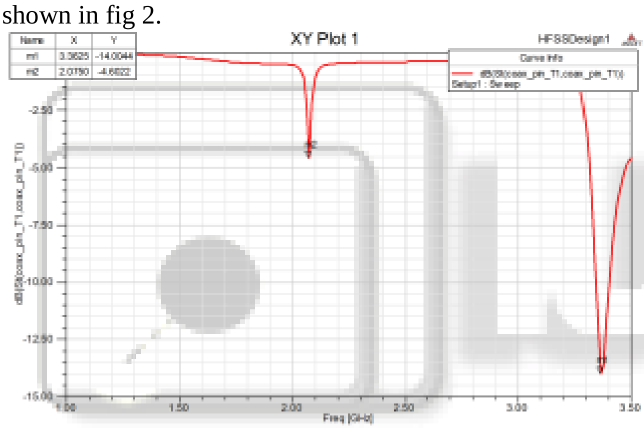

Fig. 2: Simulation of return loss and bandwidth of MPA

The bandwidth of simple MPA is at 72 MHz and Return loss is -14 dB at 3.62 GHz and it return loss is at 2.36 GHz is -5 dB The microstrip patch antenna has 3D Radiation pattern in HFSS. Return loss or reflection loss is the reflection of signal power from the insertion of a device in a transmission line or optical fiber. It is expressed as ratio in dB relative to the transmitted signal power.

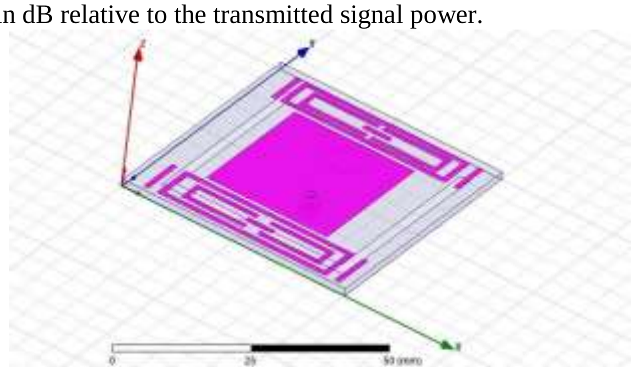

Fig. 3: Design of proposed metamaterial structure at the height of 1.57 mm from ground plane.

Multiband antenna parameters are calculated with TLM equation. It is having 50mm ×50mm×1.57 mm overall volume and it contains patch thickness of 0.035 mm of copper foil. It is having combination of wires and SRR to produce negative value of ε and μ.

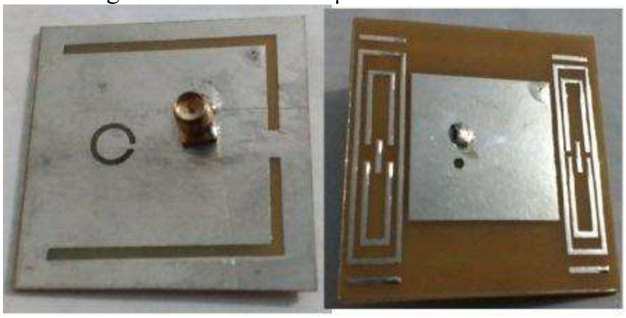

Fig 4: Bottom and Top view of the fabricated antenna

This design provides a better bandwidth and return loss [11]. Simulation result of bandwidth and return loss of MPA loaded with metamaterial structure is shown in fig.5. It will touch the return loss of -22 dB at 7.4 GHz. This result is far better than MPA in terms of both parameters. We can see that graph of fig 5 becomes broader at -10 db. So bandwidth will be greater than former simulated graph of fig. 2. So we got the desirable result

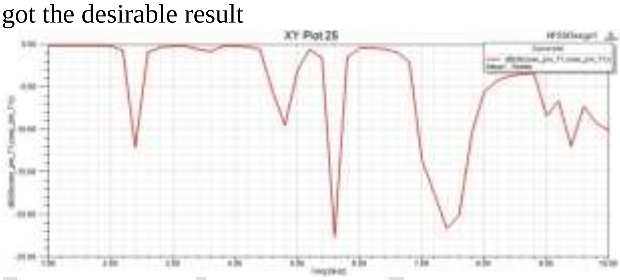

Fig.5: Simulation of Return loss and bandwidth of MPA with proposed metamaterial structure

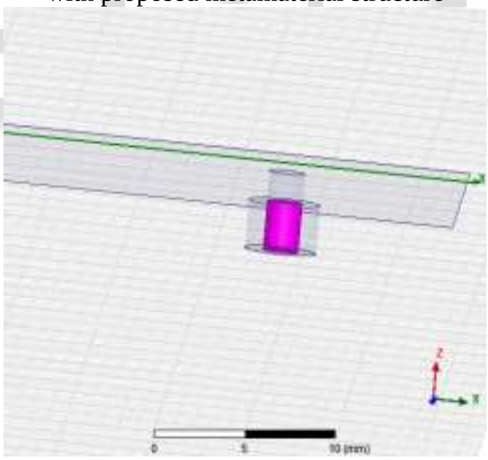

Fig. 5: Coaxial feed inserted in the patch

Coaxial feed is used in the analysis with inner radius .35 mm and outer radius 2.15 mm. Fig 5 shows the side view of insertion. We cut out the substrate part for insertion of coax cable. While using feeding, leakage and insertion loss of the structure should be in mind.

A. *Defected Ground Plane (DGP)*

The Ground of proposed antenna has defected or irregular at surface. Dual L slots are given (as shown in figure 6) for defecting the ground plane. Due to slots the electrical length or path for conduction of current increases which shift the frequency band to lower range.

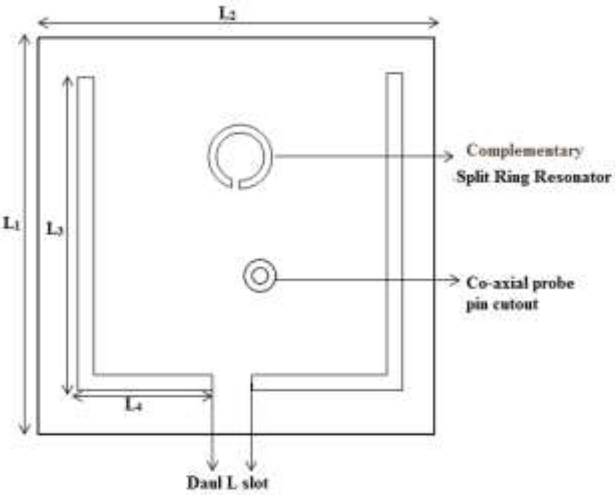

Fig. 6: Defected Ground Plane loaded with CSRR

Besides the slots a CSRR is also load in ground plane which further increases the electrical length as well as its act as resonator and improves the gain-bandwidth product. Dimensions of defected ground plane are in the table below:

Variable	Value(in mm)
L1	50
L2	50
L3	39.5
L4	15
Ring slot width	1
L slot width	2

Table 2: Dimensions of DGS

IV. SIMULATION RESULT AND DISCUSSION

In this paper, Rectangular microstrip patch antenna loaded with metamaterial structure is simulated using HFSS13 software. The proposed design in comparison of MPA alone is far better. This design is operated at 2.4 GHz and it provided bandwidth enhancement. The simulated return loss of the proposed antenna is shown in Fig. 5. The Fig. 5 shows that there are three peaks below a -10 dB at 5.6 GHz, 7.4 GHz and 9.4 GHz with bandwidth of 300 MHz, 800 MHz and 105 MHz. This results a multiband performance of proposed antenna. Simulated antenna has been fabricated and parameters are measured on PNA. Measured return loss is shown in Fig. 7.

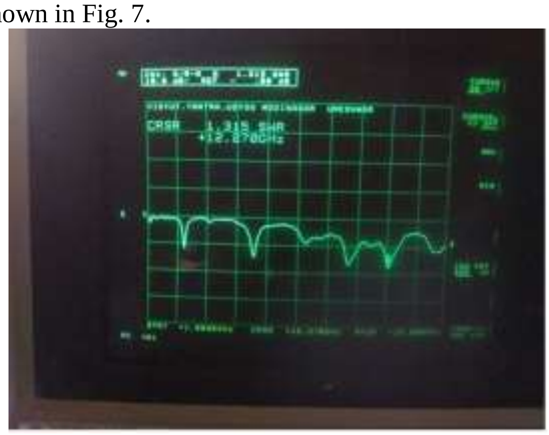

Fig. 7: Return Loss of Fabricated Proposed Antenna

V. CONCLUSION

Microstrip patch antenna is a part of widely growing communication field. Patch antenna normally works at low frequency. There are different methods for enhancement of Patch antenna parameters. In proposed paper parameters are enhanced using metamaterial. Proposed antenna is patch antenna that is loaded with a metamaterial-inspired structure and it is fed using a coaxial feed line that has been designed to have a characteristic impedance of 50 Ω. the compact antenna is a high gain antenna with a multiple peaks. In future, the performance can be improved by using the other suitable substrate and appropriate feeding arrangements.

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