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A Compact Metamaterial based Dual-Band Antenna with Improved Gain for WLAN Applications

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Abstract: In this paper, a compact metamaterial inspired dual band antenna is proposed for WLAN and WiMAX applications. The antenna consists of Square Split Ring Resonator structure with a defected ground plane and slots to enhance the bandwidth and gain parameters. Metamaterial based Microstrip patch antenna produces unique electromagnetic properties that allows us to control over the antenna parameters with a compact size. FR-4 epoxy is used as substrate its dielectric constant is 4.4 and loss tangent is 0.02. Dimensions of the antenna are 20 x 12 x 1.6mm^3 with very compact size and cost effective. The proposed metamaterial based antenna resonates at dual bands at 5.13GHz and 5.53 GHz with impedance bandwidth of ($|S_{11}|$<-10 dB) 4.96-5.26 GHz (300MHz) and 5.34-5.69 GHz (350MHz) respectively. The peak gains at resonant frequencies 5.13 GHz and 5.53 GHz are 1.61 dB and 1.62dB respectively. The proposed metamaterial based compact antenna can effectively work for WLAN and WiMAX application.

Keywords: WLAN, WiMAX, Metamaterial, SSRR and Dual-band.

I. INTRODUCTION

IN the advancement of wireless communication requires a compact size antenna with high performance. To obtain a compact sized antenna along with high performance, traditional approach of using a normal patch is not recommended. Instead, by integrating split ring resonators provides the high antenna parameters [3]. Compact sized antenna provides a homogeneous radiation pattern, wider bandwidth, and a low gain, to enhance that we use different techniques like metamaterials [5]. As there are many shapes of split ring resonators like circular, Rectangular, Square etc., each shape provides various advantages. Square and Rectangular shaped resonators provide a high gain and better return loss [1]. In this paper we designed a compact metamaterial based Microstrip patch antenna with FR-4 epoxy as the substrate. This antenna has a defective ground structure which helps to avoid mutual coupling between neighbor elements and helps to enhance bandwidth and gain. Square split ring resonator structure is integrated on the patch along with two slots. This structure provided the negative permittivity, which is verified through the MATLAB script [5]. This antenna provides a dual band with the peak gain of 1.61 dB and 1.62 dB at the resonant frequencies 5.1375 GHz and 5.5375 GHz respectively covering the WLAN and WiMAX applications [2]. All the relevant data for design analysis is used from papers [14-16].

In Section II presents the details of metamaterial inspired antenna geometry and design for proposed antenna. In section III, presents a detail analysis of proposed antenna with returns plot, Radiation characteristics and current distribution to explain performance of the antennas. Finally, conclusions are given in section IV followed by acknowledgement and references.

II. PROPOSED ANTENNA GEOMETRY

The proposed compact microstrip monopole metamaterial inspired antenna is shown in Fig.1. The antenna is imprinted on FR-4 epoxy substrate whose dielectric constant i.e; effective relative permittivity ε_{reff} = 4.4 and contains thickness of 1.6mm and is fed with microstrip line. The proposed antenna has a square split ring resonator shaped radiation strip along with partial ground structure along with some slots to improve the impedance matching and also to provide isolation between antennas when placed in the form arrays [4]. We have calculated the length of radiating element length by using below equation (1)

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \tag{1}$$

Here f_0 denotes lowest frequency at which VSWR =2 and c is the velocity of light.

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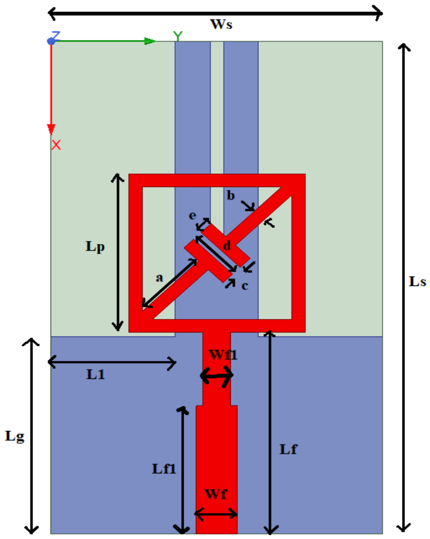

Fig.1a. Front view

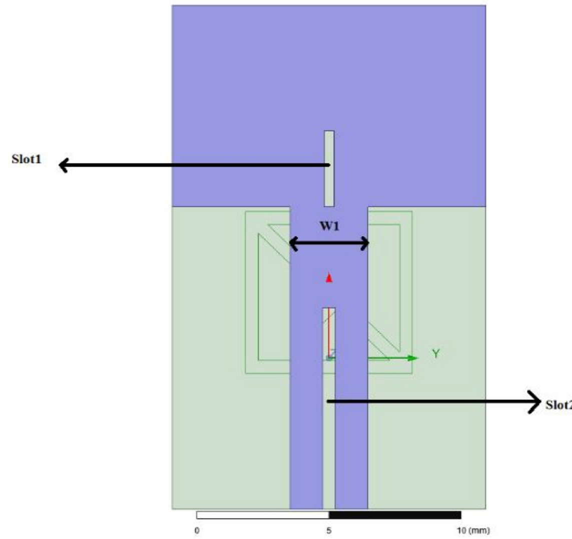

Fig.1b. Back view

Fig 1. Proposed antenna Design.

The Design which is shown above contains metamaterial inspired structure which exhibits different electromagnetic properties when the structure is designed in a specific manner. The above shown red color patch is metamaterial which shown negative permittivity is Square Split Ring Resonator. It is metamaterial inspired because of its property of negative permittivity is slightly off.

Our design dimensions are 20*12*1.6mm^3, we used FR4 epoxy as a substrate whose dielectric constant is 4.4 and loss tangent of 0.02. The ground contains the dimensions of Lg=8mm, Ls=20mm, Ws=12, W1=3mm along with two slots, it contains a defected ground structure where we have two slots on surface of ground of dimensions of slot1 (0.5*8) mm^2 and slot2 (0.4*3) mm^2. They will provide more impedance matching and gives us less return loss. The patch contains a square split ring resonator metamaterial inspired structure whose dimensions Lp=6.4mm, a=2.028, b=0.3535, c=0.3535, d=1.4142, e=0.2828 and the microstrip feed line dimensions are Lf=8.2mm, Wf=1.5mm, Lf1=5.2mm, Wf1=1mm. Here metamaterial properties are verified through another method and results are verified.

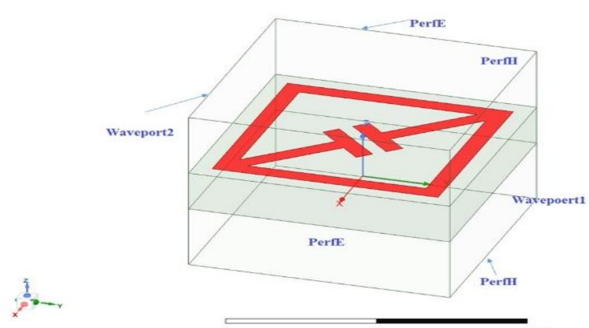

Fig 2. Unit cell Boundary conditions.

Ground slots are used for enhancement of Gain and bandwidth, generally in compact size antenna gives low gain due to their change in dimensions, but by the usage of metamaterial we can enhance and with the help of Cellular signal boosters, we can increase further gain [9]. Metamaterials are separately designed, and their assignment of boundaries are different compared to normal conventional antennas. It has master and slave boundary conditions after verifying the properties we can arrange the unit cell in arrays or else we can use unit cell as shown in Fig 2.

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III. RESULTS AND DISCUSSION

The proposed antenna is simulated in HFSS, and results are drawn in which the return loss is plotted which us shown in Fig. 4. Antenna radiates with nearly 84% efficiency. To prove a structure to be metamaterial then its permittivity or refractive index should be negative that property is extracted using MATLAB [9]. The permittivity value is nearly -4 at 5.2 GHz Resonant Frequency as shown in fig. 3. To prove that the design is metamaterial then at least one resonant frequency's permittivity should be negative.

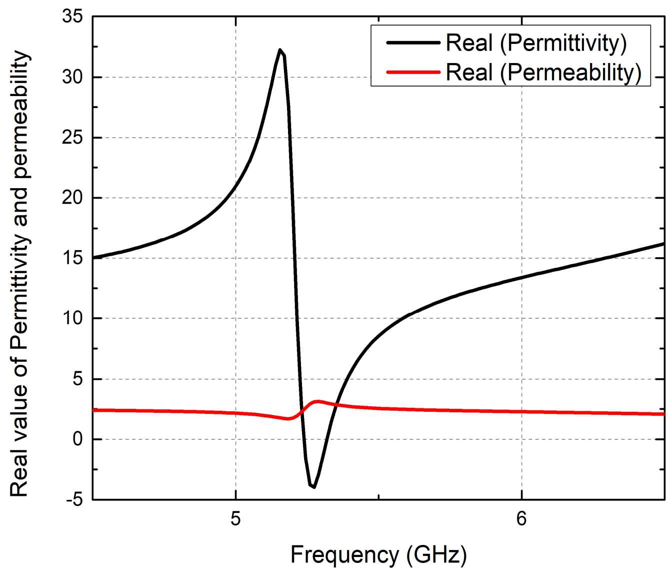

Fig 3. Return loss of Antenna.

Power transfer from port 1 to 2 and port 1 to 1 i.e.; return loss also known as reflections, of unit cell is also calculated in order to prove the metamaterial property along with the negative permittivity. The S_{11} and S_{21} plot of metamaterial is shown in Fig.4.

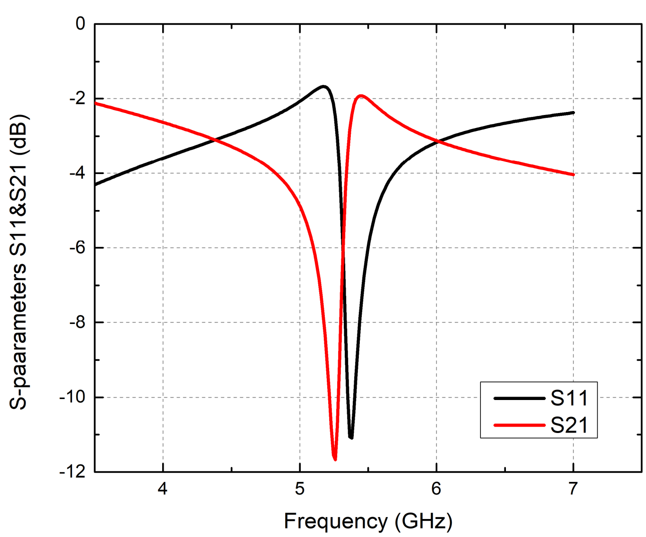

Fig 4. S11&S21 parameter of unit cell

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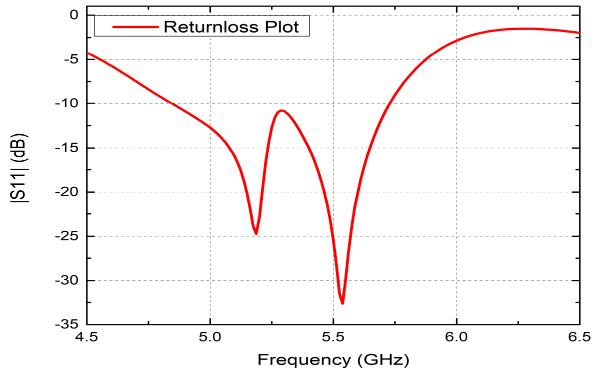
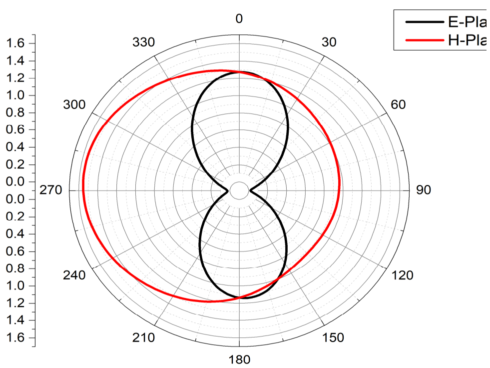


Fig 5. Return loss of antenna.

Resonant frequencies are at 5.18 GHz, 5.53 GHz whose return loss is highly acceptable. The above graph shows the results of the return loss i.e.; S11 parameter. The return loss plot of proposed metamaterial dual-band antenna is shown in Fig.4.



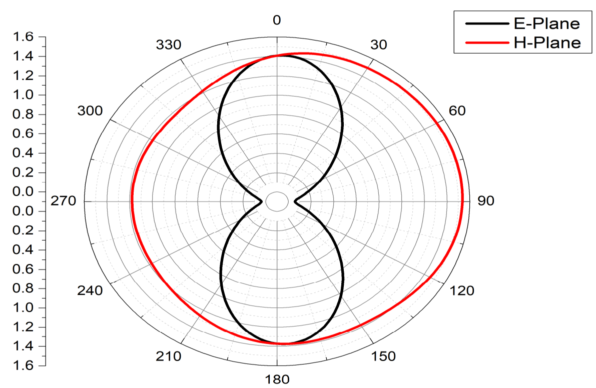
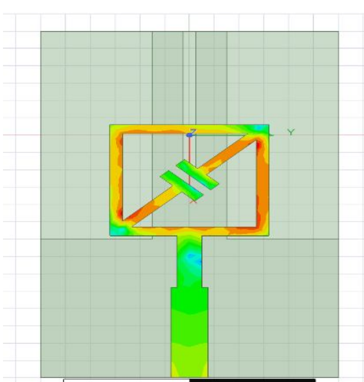


Fig 6a. Radiation pattern at 5.18 GHz

Fig 6b. Radiation pattern at 5.53 GHz

Fig 6. Radiation Patterns in XY plane and YZ plane

The radiation pattern depends on the structure of the antenna which changes when the current distribution changes on the radiating element of the antenna.



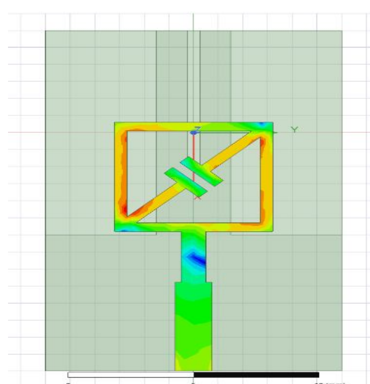


Fig 7a. Current Distribution at 5.18 GHz

Fig 7b. Current Distribution at 5.53 GHz

Fig 7. Current distribution at Resonant frequencies.

IV. CONCLUSIONS AND FUTURE SCOPE

A compact metamaterial inspired dual band monopole antenna is designed and validated on a 20 x 12 x 1.6mm^3 FR-4 epoxy substrate. Proposed design contains square split ring resonator which is a metamaterial inspired and whose permittivity value is negative and verified with the help of MATLAB. HFSS simulation tool is used to design. The proposed antenna can radiate at dual band frequencies at 5.18 GHz and 5.53 GHz with return loss of -25dB and -32.5dB respectively. This compact antenna has gain of 1.6 dB and 1.62 dB at respective resonant frequencies. Due to its compact size, the achieved gain is moderate, an external devices like Cellular signal boosters to maintain constant gain throughout the transmission. We can achieve the better results when the antenna is arranged in the shape of arrays and arrays will increase the gain and directionality of the antenna. The proposed design can be effectively used for WLAN and WiMAX applications.

V. ACKNOWLEDGMENT

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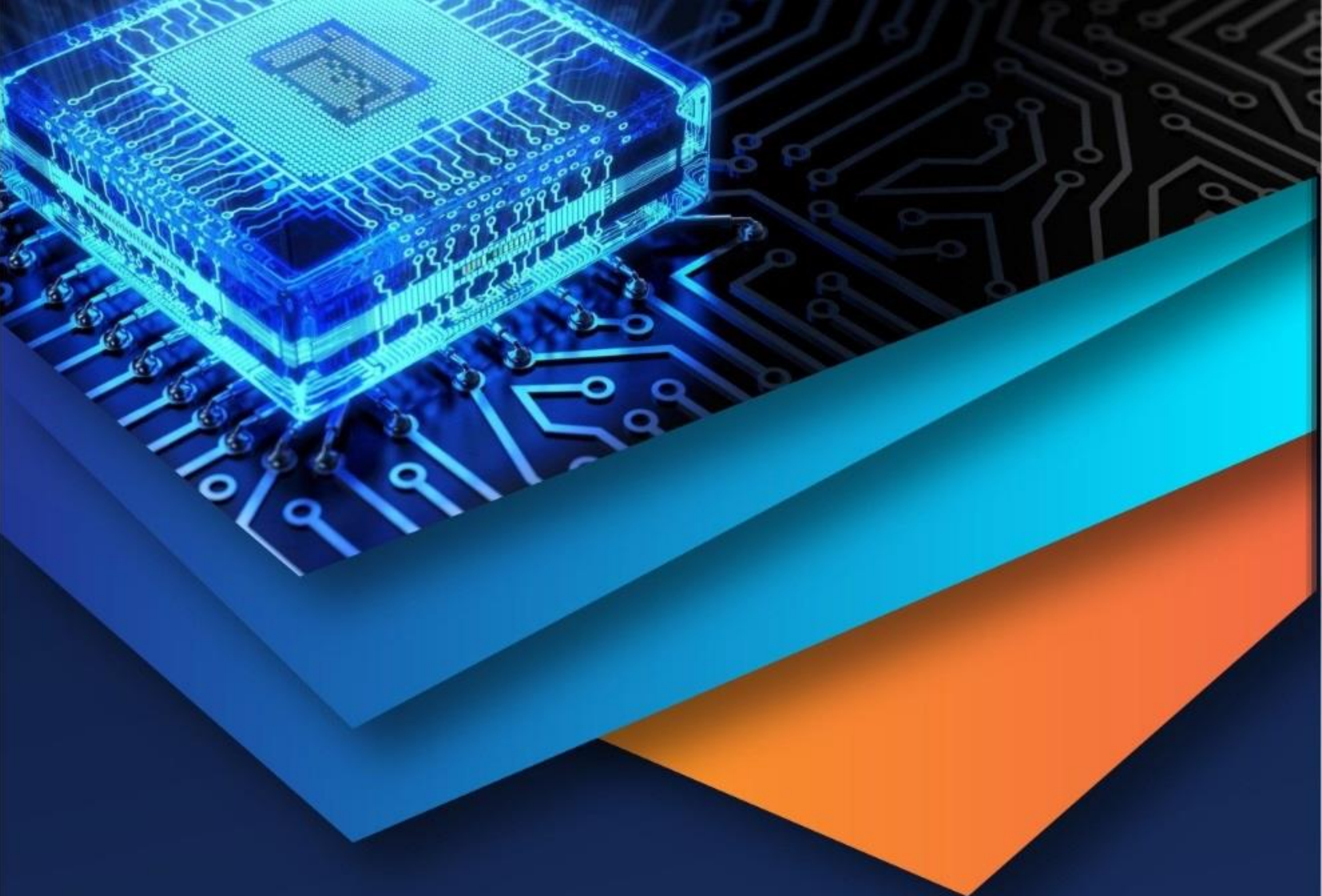

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