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A Miniaturized Dual-Band Modified Rectangular-Shaped Antenna for Wireless Applications

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ABSTRACT- In this article, compact dual-band with rectangular-shaped monopole is presented for wireless applications. Presented antenna built of modified rectangular monopole and two C-shaped strips are attached on the radiating patch. An excellent matching to get the desired dual band operation is found from the back side of the substrate for possible feeding through microstrip. The suggested antenna has extremely small dimensions, measuring just 12 × 15 × 1.59 mm^3 while operating at the lower frequency of 2.4 GHz, and it has a bandwidth of 400 MHz (2.1-2.5 GHz) and 6.7 GHz (3.4-10.1 GHz) accordingly with an S_{11} value that is less than -10 dB. An investigation of the performance capabilities of this dual-band omnidirectional antenna with a variety of geometric parameters has been carried out. The final design is constructed and measured, and the findings from simulation and measurement show a good level of agreement with one another. Across the entirety of the operating band, observable characteristics include a stable radiation pattern, strong impedance matching, and a radiation efficiency of more than 91%.

Keywords: Monopole Antenna, Compact, Dual-Band, Wireless Communication.

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1. INTRODUCTION

As a result of the evolution of contemporary communication technology that is ultra-compact in size and has multi-profile uses, the communication sector has made a revolutionary mark in this 21stcentury [1, 2]. In recent years, wireless technology research has grown tremendously and as a direct result of the proliferation of newly developed technologies as well as the sharp rise in the number of subscribers requests: the antenna fulfils an extremely important function in this regard. As a direct consequence of this, the design of small size, low-profile, multipurpose antennas for upcoming multifunctional wireless systems have taken place. Simultaneously, multiband smart antennas have garnered considerable interest as a result of their capacity to incorporate a number of communication protocols inside a single space-saving design [3-5]. In [6-11] has recommended a variety of antenna designs for multi-band bands applications. An inverted L-shaped monopole design along with parasitic strip-based antenna is proposed in [6] and which is used for controlling operating frequency. Another folded slit with rectangular-shaped antenna is presented in [7] for multiband applications. The presented antenna is put into operation with both the inner and outer sections of the patch resonating at a quarter and a half wavelength, respectively. Another, an inverted L-shaped ground plane and a bended rectangular radiating patch are used to generate multiband applications in [8]. Two lateral strips with rectangular center strip structure antenna are proposed in [9] for dual band applications. In the paper [10], by filling a pair of narrow slots close to the radiating edges of a tiny microstrip antenna, a dual-frequency antenna was created from the base of the microstrip antenna. This enabled the antenna to operate at two different frequencies. Both frequencies have the same radiation properties and have polarization planes that are parallel to one another.

In recent years, a variety of antenna layouts for dual bands have been proposed, including a dual-band antenna [11], and dual wideband antenna [12]. An antenna with dual broadband bands is suggested for use in wireless applications. This design makes use of the electric fields (capacitive) and magnetic fields (inductive)and its coupling principles with two open-ended ring resonators in order to generate dual bands and increase the impedance bandwidth as a result of the effect of capacitive and inductive resonator loading [13, 14]. In [15], a reduced size continual multiple-band antenna is presented. Furthermore, a H-shaped multi-band antenna is presented in [16]. A dual-band patch antenna that employs metamaterial– EBG incorporated into its radiating edge is described in [17]. Miniaturization is a significant obstacle that has to be overcome before electronic devices may be successfully implanted. As a result, there have been attempts made to decline the size of the implanted antenna although simultaneously increasing its bandwidth.

In this article metamaterial-based antenna for multi-band applications is proposed and it contains of semi-circular shaped monopole radiator and the ground plane with metamaterial design. The two frequency bands in which the presented antenna works are from2.1 GHz to 2.5 GHz and 3.4 GHz to 10.1 GHz respectively to make it multi-band antenna. In the next section (*Section 2*), the design and analysis of the proposed

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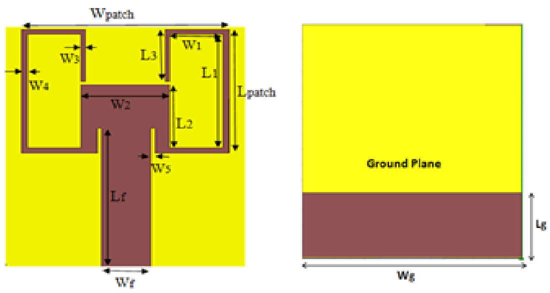
antenna are provided. *Section 3* outlines antenna designing stages. The parametric analysis of the proposed design has been done in *Section 4*. The measured and simulated results is discussed in *Section 5*. *Section 6* is a brief conclusion for this letter.

2. ANTENNA STRUCTURE AND DESIGN PARAMETERS

Figure 1 shows the geometry and configuration of the proposed antenna. It illustrates the layout that has been used for conniving a miniaturized dual-band applications-based patch design, in which the radiating patch is a basic semi-rectangular shaped monopole and two rectangular-shaped folded strip is attached. A microstrip feed line is used for exaction. A partial ground plane is used for enhancing overall bandwidth. The proposed design is intended on FR4 material with dielectric constant 4.3 and thickness of the substrate is 1.59 mm. Size of substrate is 15mm×12mm. About a quarter-wavelength has been considered as the length of this small antenna. A microstrip line with a width of 2 millimeters is linked to a rectangular patch. Size of patch is 7.4mm × 9.2mm. The top and bottom layer design of patch antenna is shown in *figure 1(a) and (b)*, and dimension of each part of antenna is as follows and all dimensions are in mm.

$\text{Lpatch} = 7.6, \text{Wpatch} = 10.1, \text{L1} = 7, \text{L2} = 3.94, \text{L3} = 3.2, \text{Lf} = 8.7, \text{Wf} = 2.4, \text{Lg} = 4.2, \text{W1} = 2.6, \text{W2} = 4.3, \text{W3} = \text{W5} = 0.2, \text{W4} = 0.3 \text{ and } \text{Wg} = 12$

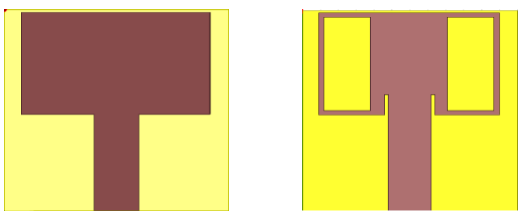


(a) (b)

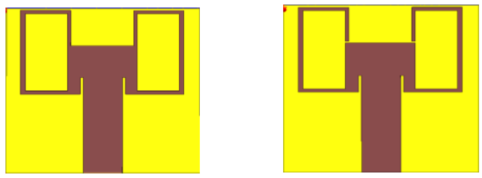
Figure 1: Antenna layout and dimensions (a) Front portion (b) Back portion

3. ANTENNA DESIGN STEPS

This part of the article will describe the planning and analysis that went into creating a tiny folded rectangular strip antenna. The antenna is in miniature form. In all cases ground plan is fixed, only variation is done in the upper part. *Ansoft* HFSS is used to simulate the proposed design. *Figure 2* depicts the design process.



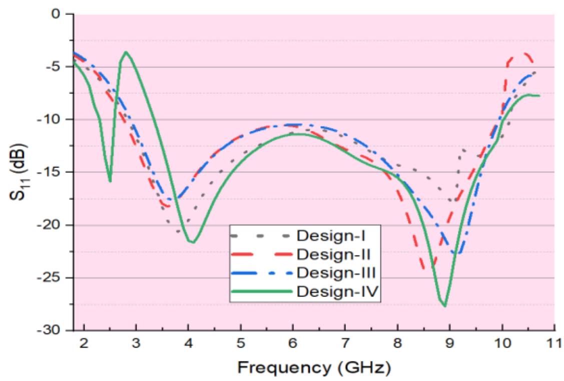
(a) Design-I (b) Design-II



(c) Design-III (d) Design-IV

Figure 2: Evolution steps of proposed design

A rectangular monopole antenna that is fed by microstrip is depicted in *figure 2. (a)* and the *figure* depicts the design of a microstrip line with a width denoted by W_f and a length denoted by L_f. The resonance frequency for Design-I is 3.9 GHz as shown in *figure 3(a)*. The S_{11} characteristics indicate that there is a resonance at 2.8 GHz that is not well matched. Radiating patch and ground plane may be to responsibility for this effect. The $\lambda/4$ monopole strip is clearly responsible for the first resonance. This section is all about finding the second resonance's resonant length. Because the second resonance is so weak, it cannot be matched. It is possible to achieve better matching by increasing this real component of the impedance. Only by thoroughly studying the antenna's resonance behaviour would this be possible. It is necessary to examine the current distribution in the antenna at both of its resonant frequencies in order to have an understanding of the resonance behaviour of the antenna. The surface current distributions that were simulated for the resonant frequencies are displayed in *figures 4*, and it is evident that there is a variation in the current throughout the longitudinal dimension of the monopole strip that corresponds to the opening resonance. This variation is in the form of a quarter wave. There is not a great lot of variation along the ground plane, which was something that was to be anticipated. It was to be anticipated that the distribution of current would be somewhat comparable to that of a quarter-wave ground plane antenna as this was the case. Along the boundaries of the ground plane on either side of the monopole strip, current flows in the opposite direction from one side to the other. *Figure 4* shows that at the additional resonance, both the strip and the perimeter of the ground plane get an identical amount of current (b). The rectangular-shaped path, which may have an asymmetrical behaviour, can be extrapolated from the current distribution. Because the feeding is administered in a symmetrical fashion in relation to the ground plane, the radiating patch has two folded strips in the shape of a rectangular rectangle added to it.



(a)

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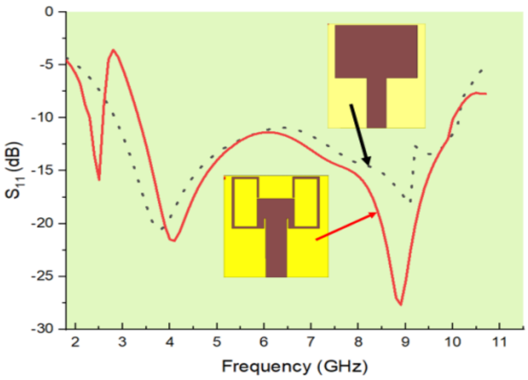
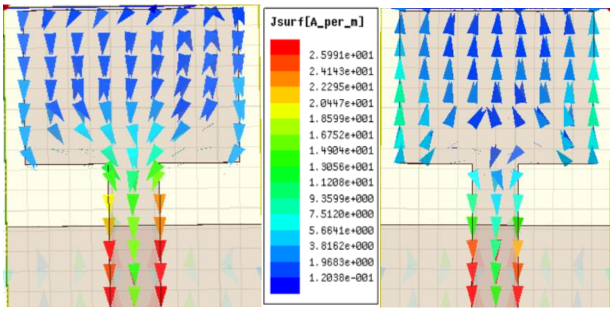


(b)

Figure 3(*a*)**:** Simulated S_{11} for various design steps and *(b)* S_{11} for with and without folded strips

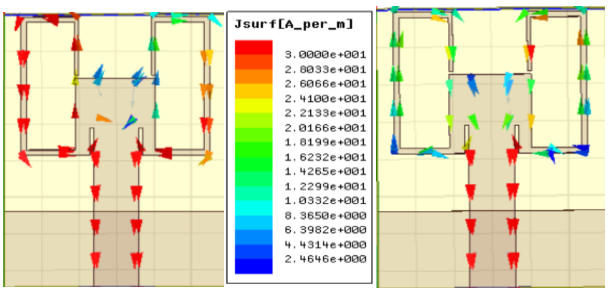


(a) 2.8 GHz (b) 3.5 GHz

Figure 4: Surface current distribution

For the two resonances, the simulated surface current distribution is given in *figure 5*. At the lower resonance frequency of 2.4 GHz, the surface current density is higher on the folded strip than it is on the other half of the device. This unequivocally demonstrates that, with the exception of the folded strip, the other components of the circuit have a negligible effect on the subsequent reverberation, which is predominantly caused by the monopole ground plane strip that is positioned above the substrate.

In a similar fashion, at the higher resonance (5.5 GHz), the surface current density is lower when compared to the lower resonance frequency, and it is abundantly obvious that the current direction is counter clockwise in the natural world.



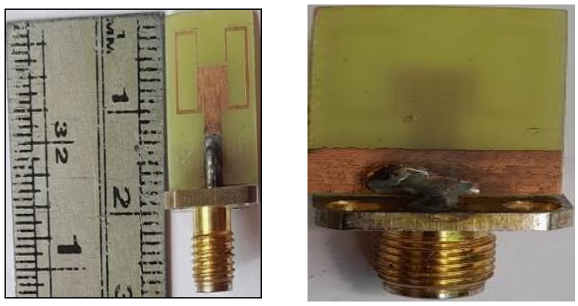
(a) 2.4 (b) 5.5 GHz

Figure 5: Surface current distribution

4. RESULTS AND DISCUSSION

The antenna prototype illustrated in *figure 6* was built to verify the proposed designs optimal dimensions. The impedance bandwidth of proposed antenna exhibits the multiband characteristic and simulated bandwidth is 2.3-2.6 GHz and 3.3-10.3 GHz and measured bandwidth is 2.1-2.5 GHz and 3.4-10.1 GHz respectively as shown in *figure 7*. The deeper resonance frequency can be observed in the proposed antenna at frequencies of 2.4 GHz, 5.1 GHz, and 8.9 GHz respectively.

The gain of antenna is good, maximum gain is 1.61 dBi as shown in *figure 8* and radiation efficiency of antenna is approximately more than 91% within the band as shown in *figure 8*. The radiation pattern of the antenna in H-field is omnidirectional and E-field is directional at frequency 2 GHz as well as 3-D radiation pattern is shown in the *figure 9*. 3-D pattern shows that radiation intensity of the presented in the plane. A multiband wireless communication system can benefit from this antenna design.



(a) Front (b) Back side

Figure 6: Photograph of the proposed prototype antenna

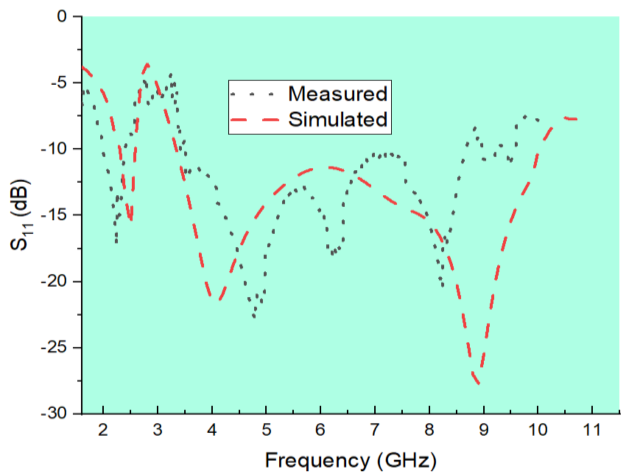


Figure 7: impedance bandwidth

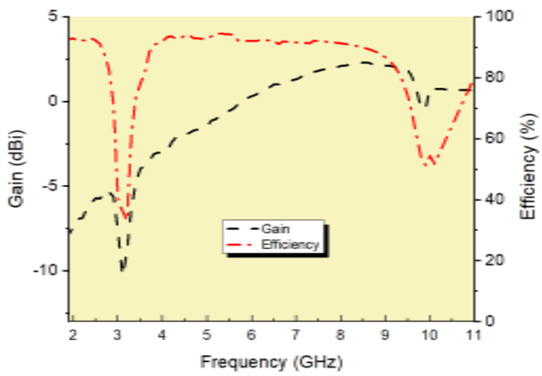


Figure 8: Gain and efficiency

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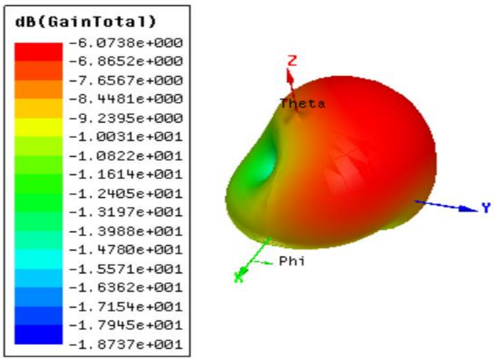

Figure 9: 3-D radiation pattern of the proposed antenna

Table 1 shows the ccomparative analysis of various dual based antenna and proposed structure better than other reported antenna in term of overall size, resonating frequency, BW and simple geometry.

Table 1: Comparison of various metamaterial-based antenna

Ref.	Size (mm^2)	Working Freq. Band (GHz)
[11]	63.8 × 52.9	2.4-2.52, 5.1-5.85
[12]	28 × 33	2.24-2.81, 3.35-6.51
[14]	60 × 90	2.18-2.76, 4.8-6.1
[15]	58 × 62	1.9-2.45, 4.9-5.9
[16]	60 × 60	2.39-2.69, 4.97-5.93
Proposed	12 × 15	2.1-2.5, 3.4-10.1

5. CONCLUSION

Analysis is carried out to proposal Miniaturized Dual-Band Modified Rectangular-Shaped Antenna for dual band applications. The performance of the antenna is strongly impacted by the width and length of the folded strip, in addition to the ground plane width exists opposite side of the radiating patch. The antenna has an operating impedance bandwidth (S_{11}< - 10 dB) from 2.1 GHz to 2.5 GHz and from 3.4 GHz to 10.1 respectively over the entire operating frequency band. The gain and radiation pattern this antenna is stable. Therefore, the planned antenna model is more appropriate for current wireless communications system. In the proposed design is based on single layer F R-4 dielectric material. So, gain of the proposed antenna is very low due to compact in size and lossy nature of dielectric material. In the future, composite metamaterial can be used to design antennas with enhanced performance parameters.

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