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Design of triband antenna for telecommunications and network applications

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ABSTRACT

In today's world, the need for multifunctioning with the minimum possible physical size of the appliances has gone very vast. This paper presents a novel triband microstrip antenna with two slit cuts that is designed and simulated by exploiting CST microwave studio suite 2016. Proposed antenna is composed of one square patch on the top layer and an incised ground bottom layer. Designed antenna operates on three wireless bands and can be utilized for various wireless and networking applications. Bands of interest are 3.3 GHz (lower WIMAX & possibly sub-6 GHz 5G applications), 4.5 GHz (data link system for UAV drones) & 5.8 GHz (WLAN). This work also focuses on the physical layer of the TCP/IP networking Paradigm model, the optimized design and fabrication in the physical layer is vital because any design issue will create a bottlenecking effect even if the upper networking layer were optimized. Designing an efficient wireless antenna will benefit service providers as they will depend on such robust physical layer to push more traffic reliably and efficiently. Antenna is low profile, with low fabrication cost. Antenna size is 29.6×30.5×1.5 mm^3. Parameters such as input reflection coefficient and far-field radiation pattern have been simulated and analyzed.

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1. INTRODUCTION

Antennas in general can be exploited for multiple uses in the modern communication world. Ranging from the ground penetrating radar (GPR) sensors to the unmanned aerial vehicles (UAV) going through the monopole, circular, triangular and various antenna designs that are invested in various beneficial applications [1]-[4]. The unlimited design tactics of antenna and the mechanism of its work grants the researchers and manufacturers a wide range of varieties both in shape and application. From the simple monopole antenna to the rather larger horn antenna, the researchers exploited the antenna mechanism in different applications [5], [6]. Microstrip patch antennas (MPAs) are used for applications in the range of microwave frequency range 300 MHz - 30 GHz. MPA has low profile and easy fabrication at low cost of raw materials [7], [8]. The size of the microstrip patch antenna is considered to be compatible for applications within the range of microwave frequencies such as sub-6 GHz & WLAN applications [9]. A microstrip patch antenna is very appropriate for use in wireless communication applications [10] due to its light weight and low planer configuration. Karthick [11] offered a simple design of microstrip antenna to serve for WLAN applications.

As our world is in continuous evolution, humans are always in change and update about almost every life detail. Technology is a very vital matter in today's life, so any idea that might bring technology closer to humans' comfort is sure needed. The main reason behind starting this research is the fact that the concept of exploiting one physical antenna to operate on multiple frequencies and consequently on multiple applications can somehow enhance humans' life in terms of time, cost, and sure communication approaches. It's much better to have one tiny equipment that can run more than one appliance simultaneously. The concept of optimization indeed eases life and that's a big drive for us as researchers to work our best to get good results and distribute usefulness. The contribution of this work is all about sophisticated design optimization. Designing one antenna to operate on three different modes saves lots of effort, cost and space. It's practically much better to invest in one appliance that is capable of running multiple applications rather than buying an apparatus for each application. This is also more intriguing for a better environment. The rest of this paper is organized as: section 2 will negotiate the similar works, section 3 will introduce the reader to the design and analysis of the proposed antenna, next section 4 will demonstrate the obtained results with some discussion. Last there will be the conclusion from this research in section 5.

2. METHODLOGY

There is a plethora of researches about exploiting the antenna generally in various technology demands with a wide range of techniques. As for nowadays technology and demands, various technologies use various radio frequencies, so it will be much more efficient to exploit the concept of multiband antenna. One physical antenna can be designed to operate on multiple frequency bands and thus serves for multiple communication and networking applications, all together. Researchers offer a great deal of interest for the topic of multiband antenna. Ali *et al*. [12], authors represent a reconfigurable antenna with slots to serve more than one band. Kaur and Sivia [13], authors offer a multiband antenna with compact size for wireless applications.

Different techniques are used for designing and optimizing microstrip patch antenna. One of these techniques is the defected ground structure (DGS) that is used in [14], [15]. The researcher in [2] also deployed the DGS technique and fractal patch to design a multiband antenna to serve for multiple wireless and mobile applications. And so did the authors of [16] where they also exploit the DGS technique along with proximity coupled feed to realize a multiple-band antenna that serves for various wireless applications. Kumar and Singh [17] authors invested in Koch and meander geometry to design a multiband hybrid fractal antenna to serve for diverse wireless applications. Yon *et al*. [18], authors developed a 5G high gain antenna that looks like a microphone. Nafea [19], author used multi-layer substrate to imrove antenna performance in terms of gain and input reflection coefficient.

One of the main research topics today in communication and networking track is the 5th generation applications in terms of frequencies used, throughput and more specifications. Amjad *et al*. [20] exploited the slot-based patch antenna to produce a multiband antenna for sub-6 GHz 5G applications. Li *et al*. [21] introduced an antenna array to serve for multiband sub-6 GHz 5G applications. As we mentioned earlier, 5G and optimized antenna technology will have a huge impact on service delivery and data rates, this comes in terms of better internet service, faster downloads and better connectivity, especially in the world of "internet of things" (IoT). Old fashioned OSI protocol will no longer better serve the demanding speed of such improved physical medium, therefore there is a demand for a modern protocol structure that uses network slicing and software defined network (SDN) in its operation [22]. In this paper, a novel Triband antenna is designed and simulated to serve for various networking and communication applications. The antenna shows resonance at 3.3, 4.5 & 5.8 GHz and can be exploited for any application that operates on any of these bands. The antenna is small in size and easy to fabricate.

3. DESIGN AND ANALYSIS

In this section the details of the proposed design will be illustrated. The Triband microstrip antenna design and simulation is done by using CST microwave studio suite 2016. This software is very adequate in terms of design details and accuracy. The bottom layer is the ground metallic layer, it's made of annealed copper. The ground layer height is t=0.035 mm. This layer has two linear engravings with the shape of a square with a cut. This defected ground structure (DGS) improves the antenna in many aspects. It helps improve the antenna gain and bandwidth by adding changes to the capacitance and inductance of the microstrip antenna [23].

Next there will be the second layer which is the insulator substrate layer which is made of FR4 material. The FR4 lossy (thermal anisotropic) substrate is the material of choice for lots of printed circuit board (PCB) antennas due to its very low cost, availability in the local market and very good mechanical properties. This makes the FR4 material as a preferred option for a wide range of electronic component applications. As more and more microwave applications are developed, there is a great deal of interest in minimizing the cost of these systems. Major savings of cost could be achieved by using FR4 in place of other costly types of substrates for microwave circuits and antennas [24]. The height of the substrate layer is found to be best at h=1.5 mm.

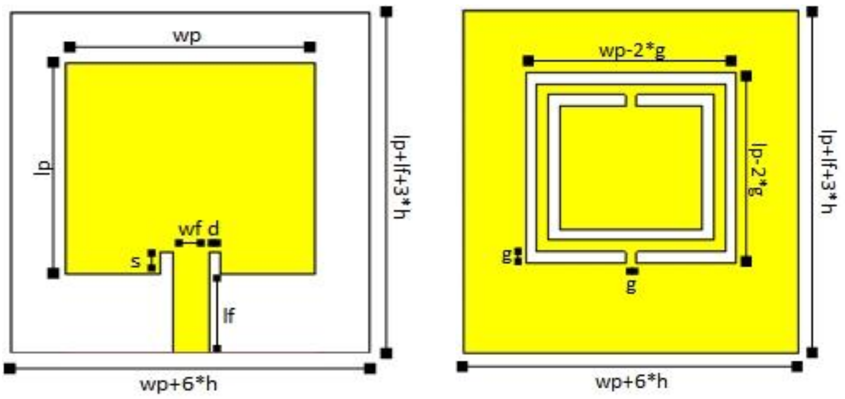
The 3rd and last layer of the proposed design is the microstrip patch which is also made of annealed copper. The patch is to be connected to the excitation source via a microstrip feed line that is located between two rectangular slits on the patch. It can be observed that the slits increase the electrical length of the antenna and this increases its electrical size and thus helps in obtaining better results for the multiband antenna [25]. The patch is of the same height as the ground layer. Figure 1 shows the proposed antenna in both front and back views while Table 1 shows the dimension details.

Table 1. Proposed antenna dimensions

Parameter	Dimension (mm)
wp	20.6
lp	19
lf	7
h	1.5
s	2
g	1
t	0.035
wf	3
d	1

The dimensions are chosen carefully after lots of trials in order to get the best results for the three operating bands as shown in Figure 1(a). The design is clear to be miniaturized in size, and thus serves to be used in several networking and communication applications. The biggest of the antenna dimensions is no more than 30.5 mm which is very suitable for networking and communication uses, especially now the emergence of 5G technologies pushed the manufacturers into minimizing the equipment to the minimum possible size. It's obvious from Figure 1(b) that the thickness of each of the two engravings and the space between both chiseled squares is g=1 mm. This is chosen after several trials to get the best results in terms of minimizing the design size and maintaining a good performance at the three operating bands 3.3, 4.5 & 5.8 GHz. The engravings in the ground plane increase the capacitance of the antenna and this drops the resonance frequency significantly to a lower value. This comes in analogy with what in (1) states, as the equation shows a reversed relationship between capacitance *Cc*, inductance *Lc* and the resonance frequency f_0 [7].

$$f_0 = 1/2\pi\sqrt{L_c C_c} \tag{1}$$



(a) (b)

Figure 1. Proposed antenna design (a) front view and (b) back view

This novel compact antenna design enabled higher transmission rates to be achieved and this will in its turns enable higher resolution streaming (4K) and even next generation gaming on a cloud platform to be a reality. Many companies now push their services to be cloud based because of these higher transmission rates and this will enable networking vendors to push forward higher end network devices. Many new trends that used to be only research subjects are now reality such as software defined networking and software defined radio are implemented by major networking vendors such as Cisco and Huawei [26]-[28].

4. RESULTS

The proposed antenna design and simulation are done by using the CST-MWS Suite 2016. As known by the engineers, a resonant antenna at a certain frequency means that the antenna has an impedance matching of less than -10 dB at that same frequency. The results demonstrated in Figure 2 show antenna resonance at 3.3 GHz, 4.5 GHz & 5.8 GHz. The impedance matching ($S_{1,1}$ parameter) for all the three bands lie below the standard -10 dB and thus assures that the antenna can operate at all the three bands and serve for any communication and networking application that uses these bands.

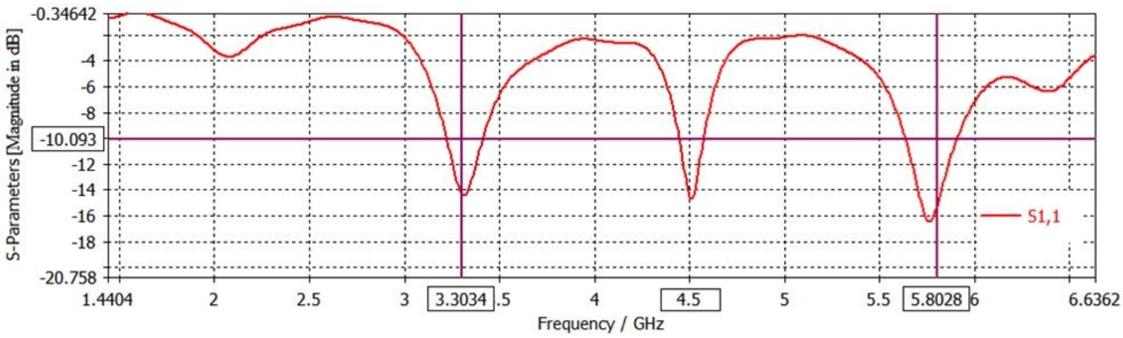


Figure 2. $S_{1,1}$ Response for the proposed design

The 3.3 GHz is used for the lower WIMAX & possibly sub-6 GHz 5G applications. The 4.5 GHz is used for networking applications like the data link system for UAV drones. The 5.8 GHz has many uses and the most of all is the for the WLAN. Figure 2 shows the graph of impedance matching response for the proposed design which clarifies that the antenna is resonant at the three bands of interest and thus achieves the goal of the proposed design.

5. DISCUSSION

The far-field radiation patterns for all the operation bands are shown in Figure 3 in both 3D & polar forms. The 3D radiation patterns show a directivity of more than 4.3 dBi for each of the resonant bands which assures the ability of this design to be used for various applications with special requirements in terms of gain and directivity. The 3D figures also clarify that the antenna radiates on almost all of its sides as shown in Figure 3(a) for 3.3 GHz, and thus magnifies its being practical and handy. The polar radiation pattern for the 3.3 GHz shown in Figure 3(b) band shows an eight-like shape main lobe for phi=90^o. The 3D radiation pattern for 4.5 GHz shown in Figure 3(c) shows a directivity of 4.85 dBi and a pear-like radiation pattern. The polar radiation pattern for 4.5 GHz band illustrated in Figure 3(d) shows a more directive shape at phi=90^o. The 3D radiation patttern for 5.8 GHz shown in Figure 3(e) illsutrates a directivity of 4.45 dBi with radiation pattern that looks like a peach. The polar radiation pattern in Figure 3(f) for 5.8 GHz band shows a heart-like shape at phi=90^o.

The application of the proposed antenna can be useful for various communication approaches. It can be exploited for 5G communication systems, as the 3.3 GHz band serves as one of the 5G bands which is the sub-6 GHz. As stated by [29], this band marks the basis for building the initial 5G implementations around the globe as it provides harmony globally and a balance between capacity and coverage. So an antenna that operates with a good performance at 3.3 GHz frequency would be highly requested by communication companies that are willing to expand their services to the 5th generation communication.

As for the 4.5 GHz frequency, it can be utilized for multiple purposes. It's considered as a main frequency for ground penetrating radar (GPR) sensors as stated by [1]. It's also used for snow depth measurement as in [6] and for many UAV communication applications as in [3]. As for the resonating frequency 5.8 GHz, it has a wide range of applications. it could be exploited for wireless applications as in [14]. RFID reader is also an application for the 5.8 GHz resonating frequency as in [30]. All the mentioned applications for the three resonating bands of this proposed antenna are just examples of this proposal's application capability. In fact, there are way more uses for these bands as they all could be found in different communication aspects.

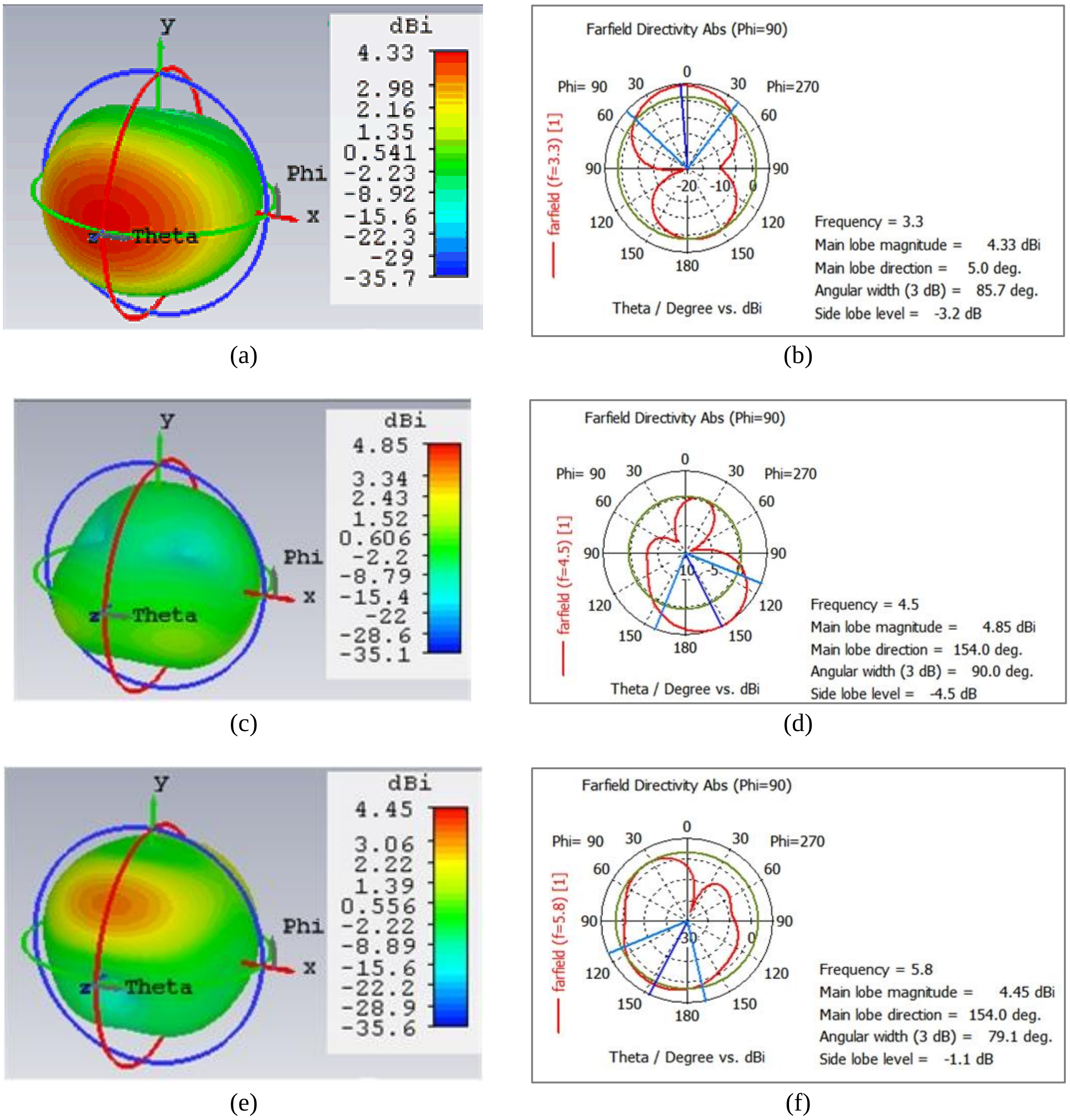


Figure 3. Radiation patterns for the operating bands in both 3D & polar forms (a) 3D radiation patttern for 3.3 GHz, (b) polar radiation pattern for 3.3 GHz, (c) 3D radiation patttern for 4.5 GHz, (d) polar radiation patttern for 4.5 GHz, (e) 3D radiation patttern for 5.8 GHz and (f) polar radiation patttern for 5.8 GHz

6. CONCLUSION

This paper presents a novel Triband microstrip antenna design that resonates at three different bands in order to serve for various networking and communication solutions. The antenna design and simulation are done by using CST-MWS Suite 2016 software. The design is minimum in size and is optimized by chiseling the ground layer with two square engravings. The results show an acceptable input impedance matching at 3.3, 4.5 & 5.8 GHz and the radiation pattern at each of these bands assures that the antenna radiates in almost all of its sides with a directivity of more than 4.3 dBi for each band. The proposed antenna may be exploited in the modern networking systems, data link system for UAV drones and 5G communication applications.

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