A Microstrip Triple-band Antenna with T-strip and Dumbbell Defected Ground Structure for Wireless Applications

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ABSTRACT
A microstrip triple-band antenna with "T"-shaped strip and dumbbell DGS has been proposed for wireless communication. The antenna was designed and simulated using Simulation Technology (CST) Studio Suite 2014. Characteristics of the proposed antenna were improved by parameters design modification. The antenna was able to resonate in three frequencies, i.e., 2.35 GHz, 3.20 GHz, and 5.88 GHz, which covered the frequency band standard of WLAN and WiMAX applications. The antenna has a bidirectional radiation pattern at a frequency of 2.35 and 3.20 GHz, while at a frequency of 5.88 GHz, the antenna is omnidirectional. The advantages of the proposed antenna are having a compact size, a simpler design, three resonant frequencies, and reasonable gain. Therefore, the proposed antenna can be a suitable device for the development of WLAN and WiMAX applications.

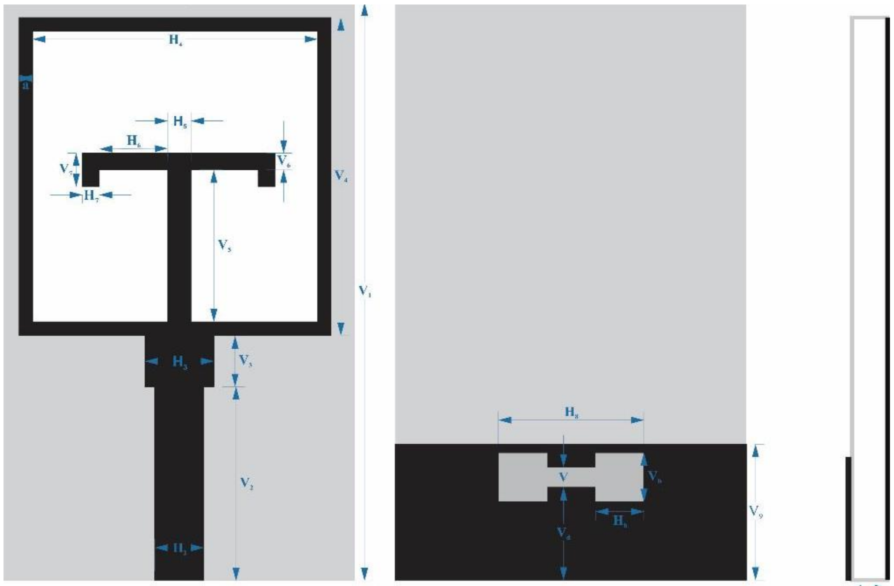
Keywords: *Triple-band antenna, "T" shaped strip, Defected ground structure, WLAN/WiMAX application.*

1. INTRODUCTION

Wireless telecommunication technologies have been developing rapidly. Almost the majority population in the world use wireless technology in their daily activities. Technology devices that implement varied of wireless application use antenna for their operations. Therefore, many kinds of antennae such as microstrip antenna and multiband antenna have become the attention of many researchers. The multiband antenna has been designed based on working frequency range in many applications such as WLAN (2.4-2.484 GHz, 5.15-5.35 GHz and 5.725-5.825 GHz), WiMAX (2.5-2.69 GHz, 3.4-3.69 GHz, and 5.25-5.825 GHz) and point to point (5.925-8.5 GHz) [1].

Many previous studies have been carried out to produce multiband antennas, such as the coplanar waveguides [1], the use of stepped impedance resonators [2-3], enhanced microstrip antenna by shaped slit [4], defective ground plane [5], and microstrip antenna designs with variations in substrate thickness [6]. The technique focused on the size reduction and broader bandwidth to increase data rate and get higher profit. However, this design still has a relatively large size with a very complex design.

Among many microstrip antenna designs, the strip antenna has many advantages such as cheaper cost, lighter weight, lower profile, less fragile, and easier to fabricate. Thus, a monopole microstrip-fed modified rectangular ring antenna is proposed in this paper. The proposed antenna should operate for WLAN and WiMAX applications, and it has a compact size and a more straightforward design. In previous research, there were many techniques to enhance antenna performance, such as set reflector to the antenna [7], modified the antenna substrate [8], modified design of antenna builder [9-10], etc. However, in this study, the antenna performance was enhanced only by modifying the antenna design. The modification was by introducing a rectangular ring, adding "T"-shaped strip to generate triple band frequencies, and embedding dumbbell-shaped Defected Ground Structure (DGS) to obtain a significant triple-band for WLAN and WiMAX applications. The antenna characterization discussed in this paper is return loss, resonant frequency and pattern radiation with varying enhanced techniques and antenna parameters.



Front View Back View Side View

Figure 1 The geometry of microstrip fed "T"-shaped strip antenna with Dumbbell DGS.

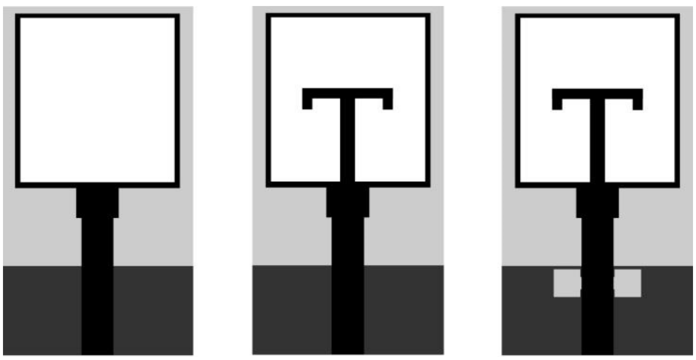
Table 1. Parameter of proposed antenna design

Antenna Parameter	Length (mm)	Antenna Parameter	Length (mm)
V_1	34.0	H_1	18.0
V_2	13.4	H_2	3.0
V_3	3.0	H_3	4.0
V_4	17.0	H_4	15.5
V_5	9.0	H_5	1.4
V_6	1.0	H_6	2.8
V_7	2.0	H_7	1.0
V_8	1.2	H_8	8.2
V_9	8.7	H_b	2.5
V_d	6.3	h	1.6
V_b	3.2	a	1.0

2. METHODS

In this study, the design of the proposed antenna was built on an FR4 substrate with constant dielectric relative permittivity (ε_r) of 4,3 and thickness of 1,6 cm. Figure 1 represents detailed of the proposed antenna design. The antenna was enhanced by employing a defective ground structure that shaped square. According to previous research on the dissertation by Zulkifli, 2008 [5]. implementing dumbbell shaped DGS could press mutual coupling effect until 19.13 dB.

The proposed antenna was designed and simulated using Simulation Technology (CST) Studio Suite 2014. The parameters of the designed antenna, mentioned in Table 1, use the reference in the previous paper [4] to get the desired frequency band and impedance matching. The proposed antenna was design step by step to understand the mechanism of generating the three resonant frequencies in the antenna. Figure 2 illustrates the process of antenna design.



Antenna I Antenna II Antenna III

Figure 2 The design process of the proposed triple-band antenna.

The antenna I is obtained by modifying the ordinary rectangular patch of microstrip antenna with a square slot to obtain a rectangular ring as in Figure 2. The introduction of strip-shaped "T" was modifying antenna I to be antenna II. Afterwards, on antenna III, the performance of the antenna was improved by adding the DGS-shaped.

3. RESULTS AND DISCUSSION

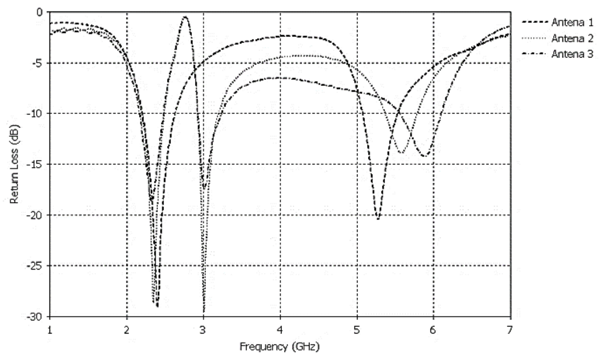


Figure 3 The result of simulation S_{11} for antenna I, I I, and III.

Figure 3. shows that resonant frequency of antenna 1 is obtained at 2.40 GHz and 5.28 GHz, antenna II is obtained at 2.35 GHz, 3.00 GHz, and 5.58 GHz, while antenna III is obtained at 2.35 GHz, 3.01 GHz, and 5.88 GHz. By introducing the "T"-strip, a slight shift of the resonant frequencies of the antenna occurred from 2.40 GHz to 2.35 GHz, and a significant shift occurred from 5.28 GHz to 5.58 GHz. Antenna II obtains an additional resonant frequency at 3 GHz, and it is due to the increase of inductance value by implementing strip.

By comparing the result of antenna II and III in Figure 3, it is observed that the addition of DGS can enhance bandwidth. However, the gain of antenna III is decreased because of the disturbance in the current distribution. The DGS also can influence the input impedance and the current flow of the antenna. Therefore, antenna III has the best performance among others.

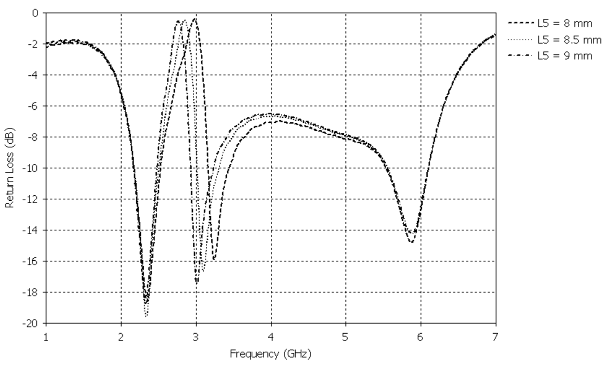


Figure 4 Simulated S_{11} by varying the height of strip antenna (L_5).

By varying the height of strip "T" (L_5) and the length of dumbbell shaped DGS (W_8), the parameter was analyzed. The simulation analyses results in Figure 4. describes that resonant frequency can shift by reducing the strip height, and the higher strip can produce a lower resonant frequency. It happens due to the inductance value of antenna increased by reducing the height of strip, and thus resonant frequency increases too. According to the analyses, the eight mm-strip height produced the best frequency band acceptable for WiMAX application.

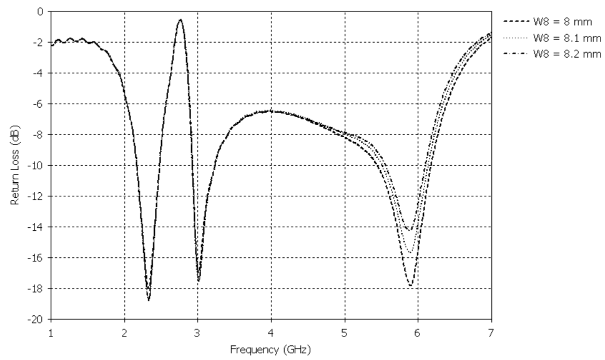


Figure 5 Simulated S_{11} by varying the length of Dumbbell shaped DGS (W_8).

Figure 5 shows that reducing the length of the DGS shaped dumbbell (W_8) will reduce the return loss value. It also describes that antenna gain increases because better impedance matching with feed point impedance can be obtained by reducing the length of DGS. According to the analyses, the DGS length in 8 mm was the best parameter that produced the lowest return loss or the best gain. Thus, the fixed proposed antenna uses the best parameter of the analyzed results and is simulated, shown in Figure 6.

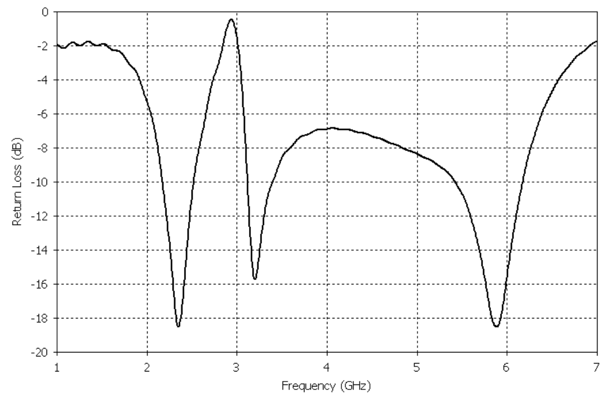


Figure 6 Simulated S_{11} using the fixed parameter of antenna.

The proposed antenna using a fixed parameter achieved three resonant frequency bands that were 2.17–2.51 GHz, 2.93–3.40 GHz, and 5.42–6.17 GHz. The frequency band embraced almost all WLAN and WiMAX band applications and resonated on 2.35 GHz, 3.20 GHz, and 5.88 GHz.

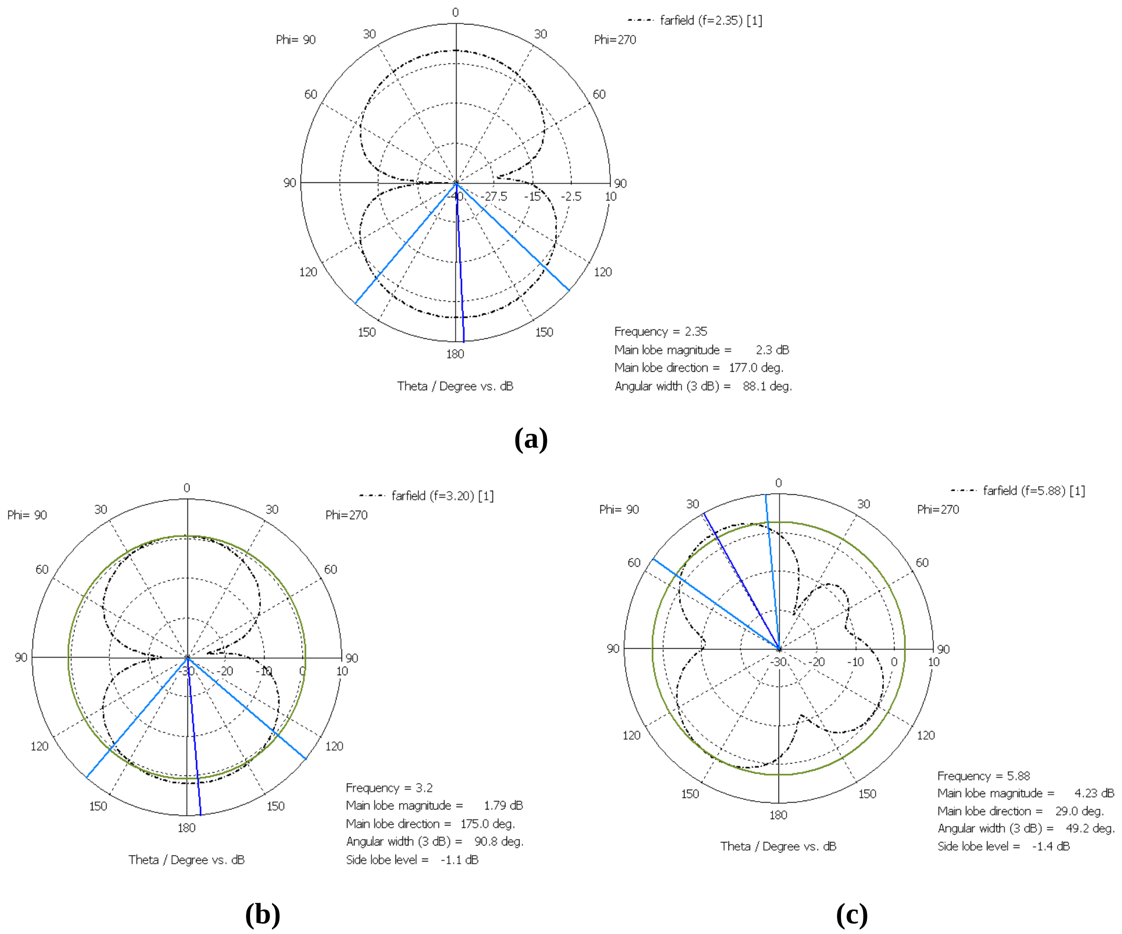


Figure 7 Radiation pattern of the proposed antenna with resonant frequency at (a) 2,35 GHz; (b) 3,20 GHz; (c) 5,88 GHz.

Figure 7 shows the radiation pattern in the azimuth plane (Gain phi) on the three resonant frequencies. On resonant frequency 2.35 GHz, the proposed antenna had a bidirectional radiation pattern with maximum radiation in θ = 0° and θ = 177° direction, which reached a gain about 2.30 dB. Bidirectional radiation also was obtained when using a resonant frequency of 3.20 GHz. On that frequency, maximum radiation happened in θ = 0° and θ = 175° direction with maximum gain reached 1.79 dB. Meanwhile, on the highest resonant frequency of 5.88 GHz, the characteristics of the radiation pattern were almost omnidirectional. On that resonant frequency, the proposed antenna radiated maximum in the direction of θ = 30° with a gain of 4.22 dB.

Table 2. Comparison with previous studies

No	Reference	Antenna type	Frequency (GHz)	VSWR	Return Loss (dB)	Gain (dB)
1	[8]	Compact	2.4	1.15	-23	4
2	[9]	Compact	2.4	1.3	-18	5
3	[10]	Compact	3.7	-	-27	-
4	Antenna proposed	Compact	2.35 3.5 5.88	-	-19 -15.8 -19	2.3 1.79 4.22

By comparing to the previous studies in table 2, the proposed antenna design has many advantages. The first advantage is that the proposed antenna has three resonant frequencies at 2.35 GHz, 3.5 GHz and 5.88 GHz. Thus, WLAN and WiMAX applications can be simultaneously applied using the proposed antenna. The second advantage, the proposed antenna also has a relatively high gain of 4.22 dB at 5.88 GHz of the resonant frequency. Furthermore, the proposed antenna also has advantage in the return loss value. The return loss value for each antenna frequency is quite good at around -19 dB, 15.8 dB, and 19 dB.

4. CONCLUSION

A microstrip triple-band antenna with a "T"-shaped strip and dumbbell-shaped Defected Ground Structure (DGS) had been designed and simulated for wireless applications in the WLAN and WiMAX frequency bands. Analysed results represented that the proposed antenna could operate on WLAN and WiMAX application frequency band with the resonant frequency of 2.35 GHz, 3.20 GHz, and 5.88 GHz. The proposed antenna had a bidirectional radiation pattern at 2,35 and 3.20 GHz, while at 5.88 GHz, the radiation pattern was omnidirectional. Analysed results also signified that the proposed antenna had many advantages. These included having a three-band frequency with large bandwidth and good gain, representing a compact size and more straightforward design that was easy to fabricate. Therefore, the proposed antenna could be suitable for WLAN/WiMAX applications.

AUTHORS' CONTRIBUTIONS

Muhimmatul Khoiro: conceptualization, method and drafting manuscript. Rohim Amirullah Firdaus: review and editing of manuscript

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