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Development of Triangular Shaped Dual Band 802.11A WLAN Applications

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Abstract: In this study, a printed dual band antenna for WLAN applications is presented. The proposed and developed antenna consists of microstrip line fed triangular patch with partial Koch fractals. Introduction of partial Koch fractals in designed triangular patch results in the antenna with improved return loss (34.43 dB at 5.18 GHz and 38.90 dB at 5.78 GHz) and high gain (5.12 dB at 5.18 GHz and 5.85 dB at 5.78 GHz). The dual band frequency operation is achieved by loading one pairs of narrow slots on one side of an equilateral triangle. The overall dimension of the antenna is $25.6\times18.1\times1.6$ mm^3. The measured result shows that the proposed antenna would cover two different-10-dB impedance bandwidths of 160 MHz (5.08-5.24 GHz) and 220 MHz (5.68-5.9 GHz), necessary for dual band IEEE 802.11a WLAN applications.

Key words: Dual-band, microstrip antenna, Wireless Local Area Network (WLAN), Triangular Microstrip Antenna (TMSA), impedance bandwidths, proposed antenna, dual

INTRODUCTION

Microstrip antennas have proved to be promising for WLAN applications with the frequency range of 5.154-5.35 and 5.725-5.825 GHz. To design a dual band WLAN antenna, different designs were reported by Ali *et al.* (2004), Sun *et al.* (2012), Khaleghi (2007), Huang and Yu (2011). However, these antennas were not designed for IEEE 802.11a WLAN applications. Chakraborty *et al.* (2014) proposed a dual band microstrip antenna using a rectangular patch with the slotted ground plane for IEEE 802.11a WLAN applications. The antenna was designed by using a rectangular patch and the antenna had gains in two bands of 1.71 and 2.12 dB. Most of the research cited in the available literature has been carried out for improving return loss and gain in a microstrip antenna targeted on a rectangular and square patch antenna. In this study, triangular patch is chosen for discussion and the fractal geometry structure is added to the patch to improve the antenna performance. The application of fractal geometries was shown to enhance gain, return loss and directivity (Cohen, 1996). Fractal slot antennas were used to improve the gain and directivity (Borja and Romeu, 2003). However, these techniques increased the antenna size. Partial Koch boundaries with two iteration and air gap were introduced in a triangular patch antenna to improve the return loss and gain (Fazal *et al.*, 2012). In this research, a dual band triangular microstrip patch antenna was designed for WLAN applications and the performance of the antenna was improved by the introduction of Koch boundary with single iteration. The results and comparison between the 2 microstrip antennas (triangular patch antenna with and without Koch boundary) are presented.

MATERIALS AND METHODS

An equilateral triangle microstrip antenna: The proposed design consists of a microstrip line fed triangular patch antenna which occupies smaller metalized area on the FR4 substrate compared to other shapes such as circular and rectangular. FR4 substrate with dielectric constant value of $\varepsilon_r = 4.4$ with the thickness of h = 1.6 mm is chosen to fabricate the antenna. The Flame Retardant (FR4) is a popular substrate with good strength to weight ratios and possess considerable mechanical strength with zero water absorption. The equilateral triangular patch antenna shown in Fig.1 was designed with a side length of a = 15.4 mm. For an equilateral triangular microstrip antenna (Dahele and Lee, 1987) the side length 'a' is calculated by using the Eq. 1:

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}} \tag{1}$$

Where:

c = The speed of light (3×10^8 m/sec)
a = Side length of the equilateral triangle in mm
ε_r = The relative permittivity of the substrate (FR4)
f_r = The resonant frequency in GHz

The line feeding technique is an important design parameter since it influences the input impedance and characteristics of the antenna. The 50 Ω microstrip line

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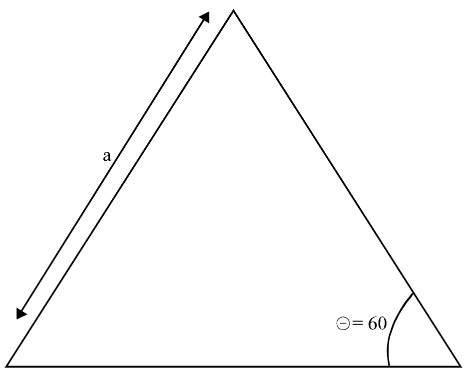

Fig. 1: Prototype of an equilateral triangular microstrip patch antenna

feed with a length of 5.7 mm and width of 1.6 mm was used in this work for better matching. The geometry of the proposed triangular patch antenna was formed by four stages of modifications. From Antenna 1-5, a triangular patch antenna was assumed to be equilateral with side length of a = 15.4 mm. In the 1st stage, a Triangular Micro Strip Antenna (TMSA) was designed to work as reference antenna (Antenna 1) as shown in Fig. 2a. The simulated result showed that the Antenna 1 had -10 dB impedance of bandwidth 208 MHz (5.981-6.159 GHz). To operate the antenna in a dual band, a pair of narrow slots were introduced on one side of the triangle patch of the Antenna 1. In the 2nd stage, a rectangular slot was added on one side of the triangular patch antenna (Antenna 2) as shown in Fig. 2b and in the 3rd stage another rectangular slot closer to the 1st one was introduced (Antenna 3) as shown in Fig. 2c. The simulated result showed that the Antenna 2 had 10 dB impedance bandwidth of 401 MHz (5.505-5.906 GHz) and Antenna 3 resonated at two frequencies with 10 dB impedance bandwidths of 130 MHz (5.466-5.596 GHz) and 250 MHz (5.76-6.01 GHz). The dimensions of the designed Antenna 1-3 after optimization without slots are shown in Table 1. The simulated reflection coefficient (S_{11}) versus frequency of Antennas 1-3 is shown in Fig. 3. The simulated resonant frequency and -10 dB bandwidth of the Antenna 1-3 are shown in Table 2. It was observed that after the insertion of slots, the antenna resonated for a dual frequency.

Dual band triangular microstrip antenna: In the 4th stage, a pair of slots was added to one side of the triangular microstrip antenna (Antenna 4) as shown in Fig. 4 for the dual band operation and the resonant frequency of the antenna was shifted for WLAN applications. It was observed that after the insertion of two slots, the resonant frequency got shifted to lower

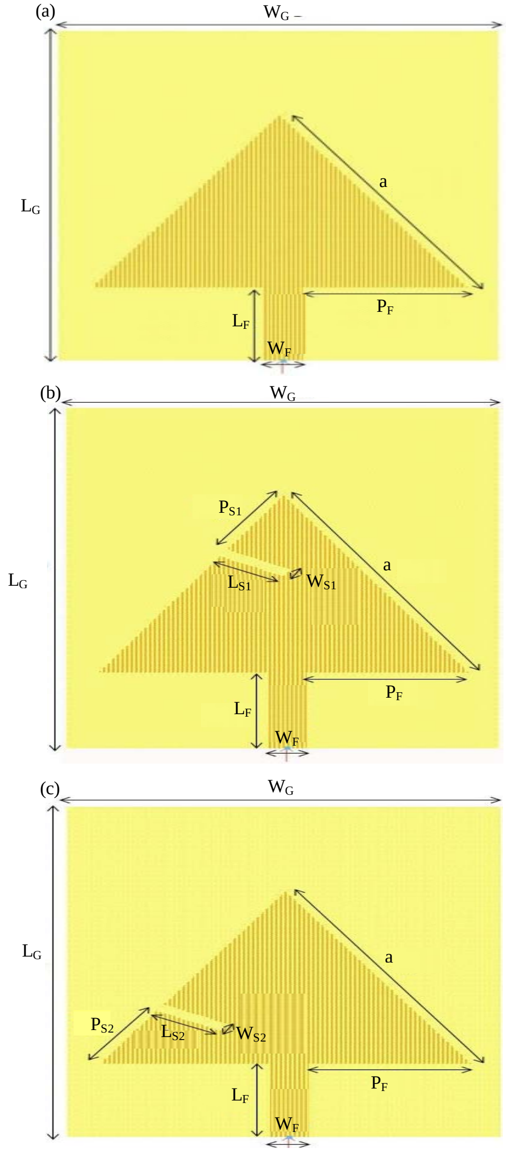

Fig. 2: Reference TMSA: a) Antenna 1 or reference TMSA; b) Antenna 2 or L_{s1} slotted TMSA and c) Antenna 3 or L_{s3} slotted TMSA

Table 1: Parameters of Antenna 1-5

Antenna parameters	Values (mm)
a	15.40
P_{S1}	4.71
L_{S1}	3.05
W_{S1}	0.59
P_F	6.75
L_F	5.70
W_F	1.60
L_G	25.60
W_G	18.10
P_{S2}	4.71
L_{S2}	3.05
W_{S2}	0.59
K_B	3.33

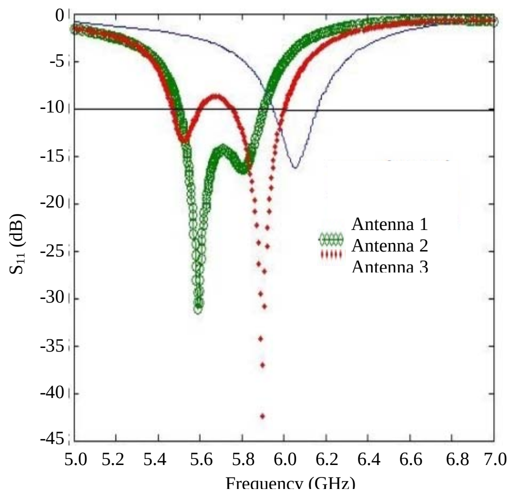

Fig. 3: Simulated reflection coefficient (S_{11}) vs. frequency plots of Antennas 1-3

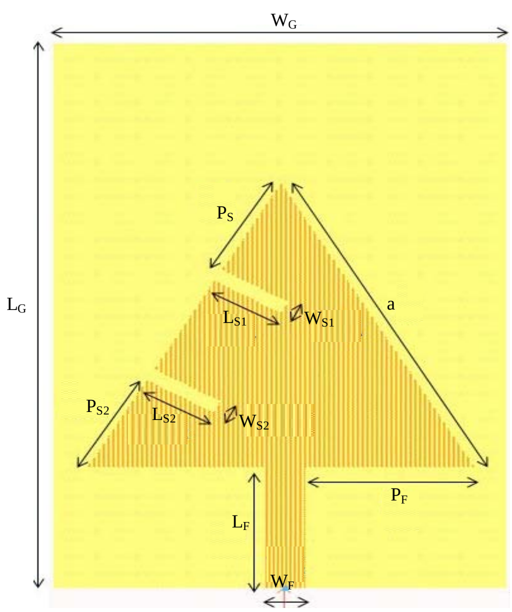

Fig. 4: Configuration of the Antenna 4

Table 2: Responant frequencey and -10 dB impedance bandwidth of Atennas 1-3

TMSA	Responant frequencey (GHZ)	-10 dB impedance bandwidth
Antenna 1	6.056	208 MHz (5.95-6.15 GHz)
Antenna 2	5.59	401 MHz (5.50-5.90 GHz)
Antenna 3	5.52 and 5.9	130MHz (5.59-5.46 GHz) And 250 MHz (5.76-6.01 GHz)

values. The simulated results showed that the Antenna 4 could effectively cover 2 separated impedance bandwidths of 66 MHz (5.176-5.242 GHz) and 107 MHz (5.79-5.906 GHz) which could have coverage on both 5.2/5.8 GHz WLAN bands as shown in Fig. 5. The gain of

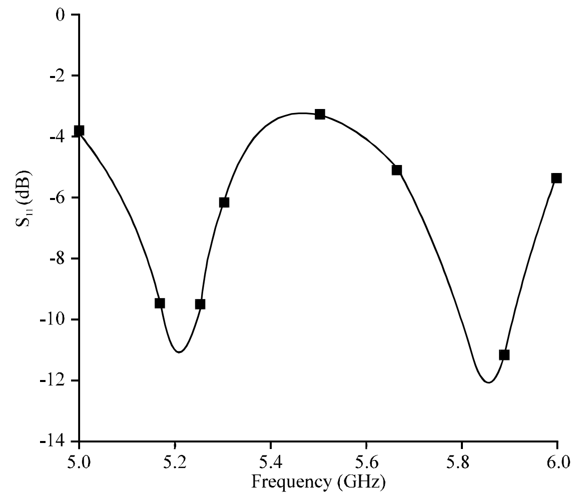

Fig. 5: Simulated reflection coefficient vs. frequency plot of Antenna 4

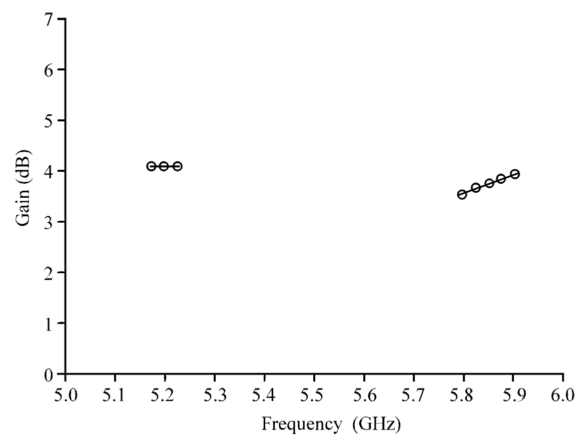

Fig. 6: Simulated gain of the Antenna 4 for -10 dB bandwidth

the antenna at 5.2 GHz was found to be 4.08 dB and at 5.8 GHz it was 3.53 dB. The simulated gain for -10 dB impedance bandwidth (Antenna 4) is shown in Fig. 6.

Dual band triangular microstrip antenna with koch boundary: To improve the performance of the dual band microstrip antenna (Antenna 4) further, a partial Koch boundary was introduced across the sides of the triangular patch. By introducing Koch boundary the parameters such as return loss, gain and -10 dB bandwidth could be improved. There are various types of fractal structures and geometrical shapes like Koch Curve, Serpinski triangle, T-Square, etc. The Koch curve is a mathematical curve which is constructed simply by using an iterative procedure, starting with the initiator of the set with the unit line segment k = 0 as shown in Fig. 7. The

Fig. 7: Koch curve with zero iteration k = 0

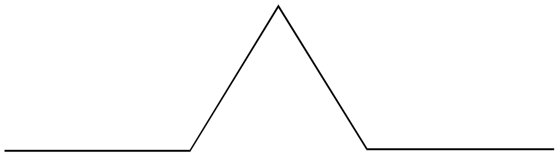

Fig. 8: Koch curve with one iteration k = 1

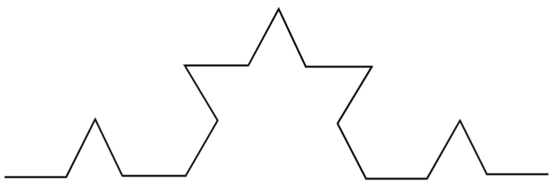

Fig. 9: Koch curve with two iterations k = 2

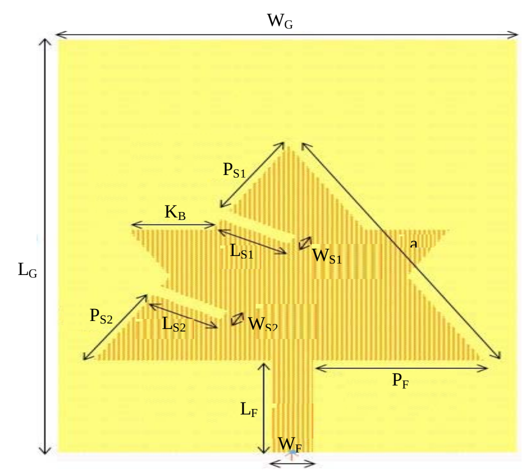

Fig. 10: Configuration of the Antenna 5

unit line segment is divided into three parts and the middle part is removed and replaced with two equal segments, both one-third in length which forms an equilateral triangle k = 1. This step is the generator of the curve as shown in Fig. 8. At the next step k = 2, the middle third is removed from each of the 4 segments and each is replaced with two equal segments as shown in Fig. 9. This step is repeated infinitely to produce a Koch curve.

In the dual band triangular microstrip antenna (Antenna 4), the Koch curve k = 1 is introduced on 2 sides of the equilateral triangle as shown in Fig. 10. It is observed that the 1/4.5 Koch patch on dual band microstrip antenna has much improved return loss, gain and bandwidth (Fazal *et al*., 2012). The simulated results showed that the Antenna 5 could effectively cover two separated impedance bandwidths of 134 (5.134-5.268) and

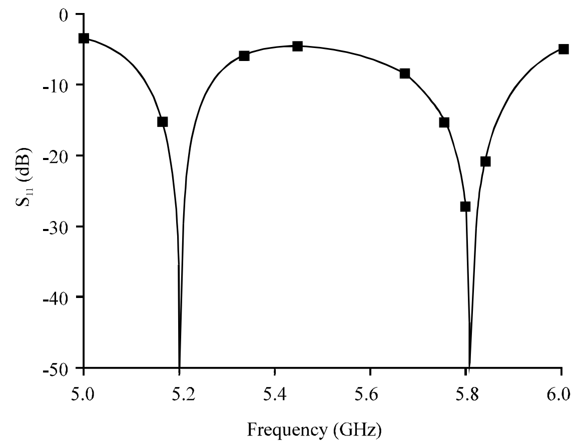

Fig. 11: Simulated reflection coefficient versus frequency plot of Antenna 5

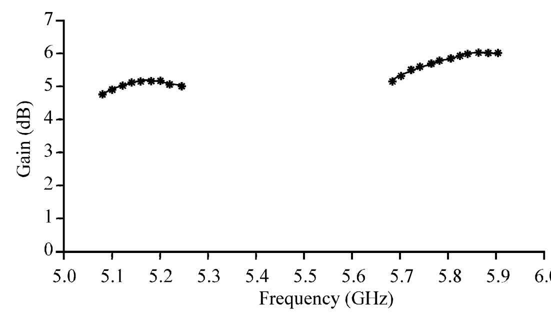

Fig. 12: Simulated gain of Antenna 5

211 MHz (5.693-5.904 GHz) which could have coverage on both 5.2 /5.8 GHz WLAN bands as shown in Fig. 11. The gain of the Antenna 5 for -10-dB impedance bandwidth is shown in Fig. 12. The return loss, gain and bandwidth could be improved by the introduction of partial Koch boundary. The gain of the antenna could be improved as shown in Fig. 12 by the addition of Koch boundary.

RESULTS AND DISCUSSION

The Antenna 1-5 were designed and optimized with the aid of Advanced Design System (ADS). Antenna 4 and Antenna 5 prototypes were built as shown in Fig. 13 and 14. They were tested for return loss and VSWR using Vector Network Analyzer (VNA Agilent N9923A). The measured reflection coefficients (S_{11}) of Antenna 4 and 5 are shown in Fig. 15 and 16, respectively. The measured impedance bandwidth for Antenna 4 with $S_{11} \leq$-10 dB was 60 MHz for both the bands (5.12-5.18 to 5.78-5.84 GHz) as shown in Fig. 14 and for Antenna 5, $S_{11} \leq$-10 dB it was 160 MHz (5.08-5.24 GHz) and 220 MHz (5.68-5.9 GHz) as shown in Fig. 16. The resonant frequencies of Antenna 4 (fabricated) were 5.15 and 5.81 GHz and the maximum values of return loss were 10.82 and 11.35 dB, respectively. The resonant frequencies of Antenna 5 (fabricated) were 5.18 and 5.78 GHz and the maximum values of return loss were 34.43 and 38.90 dB, respectively. The measured results established that after the introduction of Koch boundary to Antenna 4, the performance of the antenna improved. It could be clearly seen that there was a good agreement between the simulated and the measured results for Antenna 4 and 5.

Fig. 13: Photograph of Antenna 4

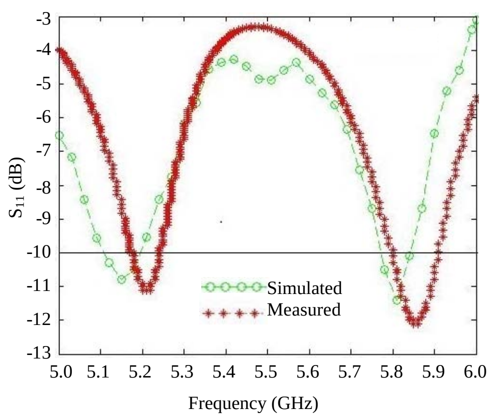

Fig. 14: Photograph of Antenna 5

Fig.15: Simulated and measured reflection coefficient of the Antenna 4

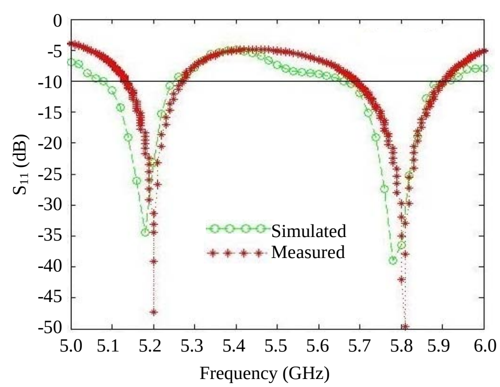

Fig. 16: Simulated and measured return losses in Antenna 5

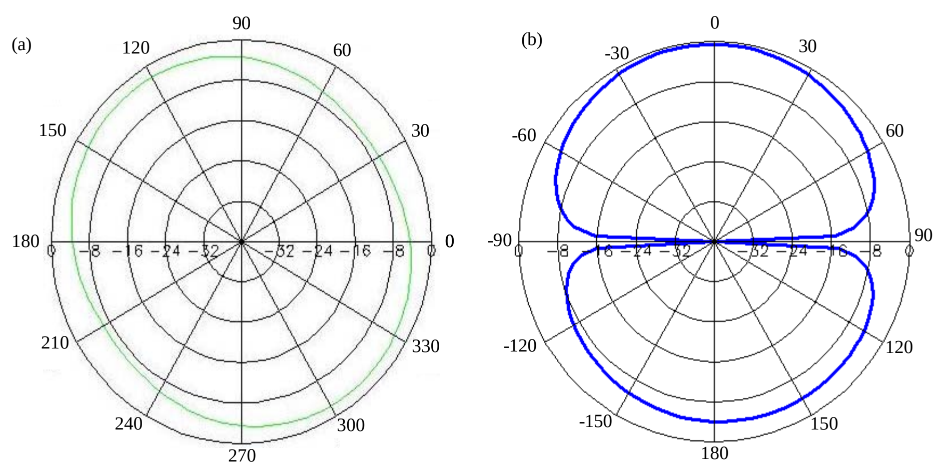

Fig. 17: Continue

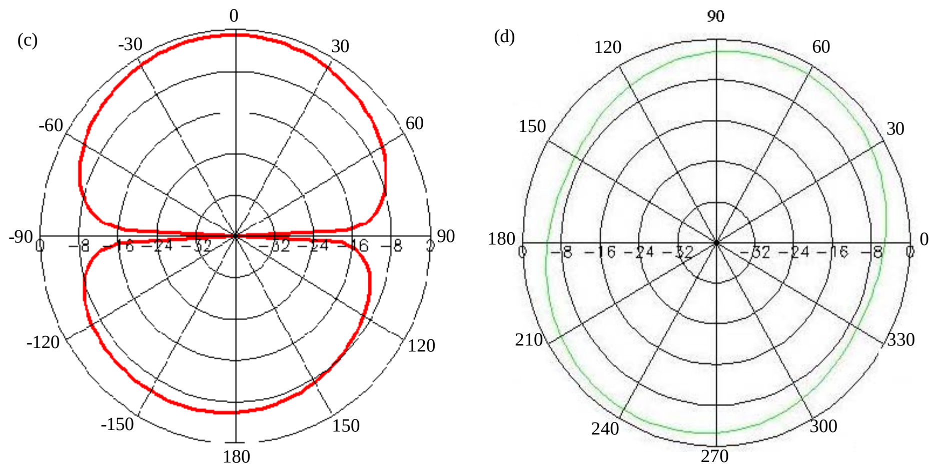

Fig. 17: Simulated radiation pattern at: a) 5.2 GHz of the Antenna 5 (E-plane); b) 5.8 GHz of the Antenna 5 (H-plane); c) 5.2 GHz of the Antenna 5 (H-plane) and d) 5.8 GHz of the Antenna 5 (E-plane)

Table 3: Measured and simulated results of Antenna 4 and 5

TMSA	-10 dB impedance bandwidth (Simulated-GHz)	-10 dB impedance bandwidth (Measured-GHz)	Resonant frequency (GHz)	Simulated gain (dB)
Antenna 4	5.17-5.24 and 5.79-5.90	5.12-5.18 and 5.78-5.84	5.15 and 5.81	4.12 and 3.53
Antenna 5	5.13-5.26 and 5.69-5.90	5.08-5.24 and 5.68-5.90	5.18 and 5.78	5.16 and 5.77

The shift in frequency and variation in return loss could be due to the imperfect fabrication as well as the introduction of SMA connector. The simulated radiation patterns at 5.2 and 5.8 GHz in the E and H-plane for Antenna 5 are shown in Fig. 17. Antenna 5 could provide omni directional pattern in H-plane and bidirectional pattern in E-plane for two bands of frequencies. The antenna performance could be improved by the introduction of Koch boundary as given in Table 3.

CONCLUSION

A dual band microstrip line fed triangular patch antenna was presented in this study. The measurement results showed that the designed dual-band triangular microstrip patch antenna could provide 2 frequency bands to support the IEEE 802.11a WLAN band (5.08-5.24 and 5.68-5.90 GHz).The measured results correlated well with the simulated ones. The proposed antenna thus becomes an excellent choice for IEEE 802.11a WLAN applications after the introduction of Koch boundary.

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