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Triple Band Slotted Microstrip Antenna with CPW-fed for WiMAX ,RADALT and WLAN Applications

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***Abstract*— The rapid development in wireless communication systems demands to use a single antenna to cover multiple frequency bands. For this reason, this paper aims to propose CPW-fed triple-band slotted antenna to operating at 2.5 GHz for WiMAX (2.5-2.69 GHz) band, 4.3 GHz for RADALT (4.2-4.4 GHz) band, and 5.8 GHz for WLAN (5.725 - 5.825 GHz) band. The triple-band antenna is simulated using ADS momentum software on FR4 substrate with 4.4 dielectric constant, 0.025 loss tangent, and 1.58 mm thickness.**

The simulation results for return loss, VSWR, and radiation pattern, are presented and discussed to evaluate the antenna performance at the desired wireless communication bands.

***Keywords*— Triple bands, slotted antenna, CPW-fed, WLAN, WiMAX, RADALT.**

I. INTRODUCTION

Antenna have fundamental important in the field of wireless communication. Nowadays, with the rapid development of the modern wireless communications technologies such as WiMAX, WLAN, and RFID, there has been an increasing demand for the development of the broadband antennas. The major disadvantage of these types of antennas is the lower and narrow bandwidth. The bandwidth of patch antenna can be enhanced by adding slots to the patch [1].

To achieve wideband operation and stable performance for planar antennas, different methods have been proposed. These methods included using resonant structures, parasite elements, filters, slots, different shaped radiators, modifying the shape of the radiator, adding slots on the ground plane, and modifying the shapes of the ground planes. Some researchers also combined several methods together to optimize the designs [2].

Printed slot antennas fed by a coplanar waveguide (CPW) have many advantages over microstrip antennas. Besides small size, light weight, low cost, good performance, ease of fabrication and installation, and low profile, they exhibit wider bandwidth low dispersion and lower radiation loss than microstrip antennas besides the ease of being shunted with active and passive elements required for matching and gain improvement [3]. Combination of the coplanar waveguide feed, antenna geometry, and variety of the slot shapes is a solution to improve and enlarge the antenna operating bandwidth [1].

A patch monopole antenna needs the improvement of impedance matching over the desired frequency. Various techniques to improve the matching over desired band have been proposed. These include the use of the feed gap optimization, bevels, ground plane shaping, multiple feeds, and offset feeding techniques.

Planar monopole antennas are able to radiate bi-directional radiation patterns with larger bandwidths. Patch can take various configuration such as rectangle, circular, and diamond [4].

Many techniques using planar technology have been proposed for the designs of dual-band or multi-band antennas, the dual-band monopole antenna was achieved by modifying the radiator to create multiple current paths, and designed using multi-branches. Parasitic elements were used in the monopole antennas to generate multiple resonances [5]. In [5] the radiator of the antenna consists of a short stem with two branches acting as monopole to generate two frequency bands

Recent researches on such type of antenna are on the go due to the continuous demand of various wireless communications such as WLAN IEEE802.11a bands are 2.4 GHz (2.400-2.484 GHz), 4.9 GHz (4.940-4.99GHz), 5.2 GHz (5.150 GHz- 5.350 GHz), 5.8 GHz (5.725 - 5.825 GHz) and 5.9GHz (5.85GHz-5.9GHz); WiMax IEEE802.16 has three licensed bands 2.5 GHz (2.5-2.69 GHZ), 3.5 GHz (3.4-3.69 GHz) and 5.5 GHz (5.25-5.85 GHZ).The IMT has (2.700 GHz-2.900 GHz), (3.400 GHZ-4.200 GHz) and (4.400 GHz-4.900GHz); and Radar Altimeter (RADALT) Application band 4.3 GHz (4.2-4.4 GHz) [6].

The main objective of this paper is proposing a new configuration of a compact triple-band slotted antenna with CPW-fed to cover WLAN in 5.8 GHz (5.725 - 5.825 GHz) band, WiMAX in the 2.5 GHz (2.5-2.69 GHz) band, and RADALT in 4.3 GHz (4.2-4.4 GHz) band. The Advanced Design System (ADS) software is used to simulate the proposed antenna and the simulation results is discussed to evaluate the performance of the antenna.

II. SIMULATION RESULTS

In this paper, the CPW-fed triple bands slotted antenna for operating over three bands, 2.5 GHz for WiMAX, 4.3 GHz for RADALT, and 5.8 GHz for WLAN applications, is presented,

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and it is simulated using Advanced Design System (ADS 2011.01) Momentum software. The substrate used in this work has a dielectric constant of 4.4, a loss tangent of 0.025 and a thickness of 1.58 mm. A configuration of the proposed slotted antenna is shown in Fig. 1.

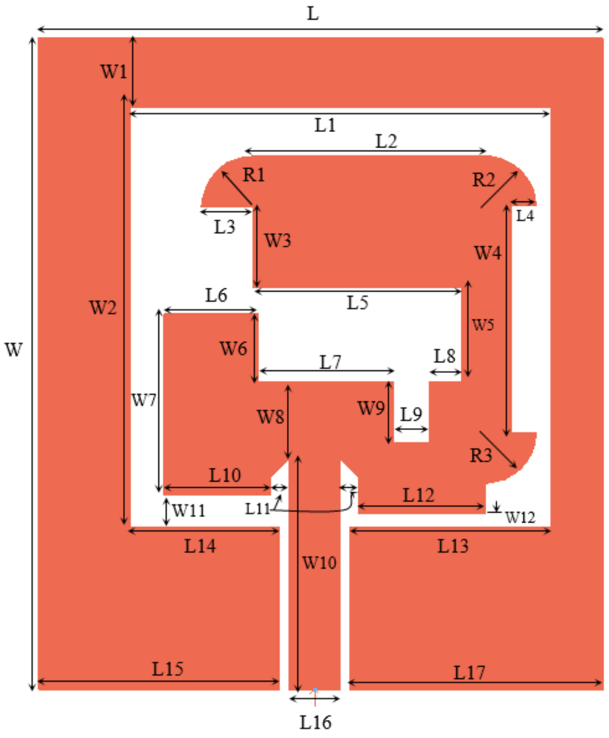


Fig 1. Configuration of a Triple band CPW-fed slotted Antenna.

The dimensions of the antenna structure are tabulated in Table I.

TABLE I
DIMENSIONS OF THE PROPOSED ANTENNA

Letter	Value (mm)	Letter	Value (mm)	Letter	Value (mm)	Letter	Value (mm)
W9	3.63	W	38.52	L9	2.02	L	32.47
W10	13.59	W1	4.08	L10	6.17	L1	24.23
W11	1.86	W2	24.81	L11	1.00	L2	13.32
W12	0.78	W3	4.80	L12	7.33	L3	2.98
R1	2.98	W4	13.38	L13	11.60	L4	1.46
R2	2.98	W5	5.58	L14	8.64	L5	11.98
R3	2.98	W6	4.01	L15	13.89	L6	5.44
		W7	10.69	L16	3.00	L7	7.78
		W8	4.58	L17	14.59	L8	1.87

The simulated results of the variation of return loss versus the frequency is illustrated in Fig. 2. From the Fig., it can be observed that the three resonant frequencies are located at the desired values of 2.5 GHz with return loss of -18.089 dB for WiMAX band, 4.3 GHz with return loss of -43.150 dB for RADALT band, and 5.8 GHz with return loss -20.238 dB for WLAN band.

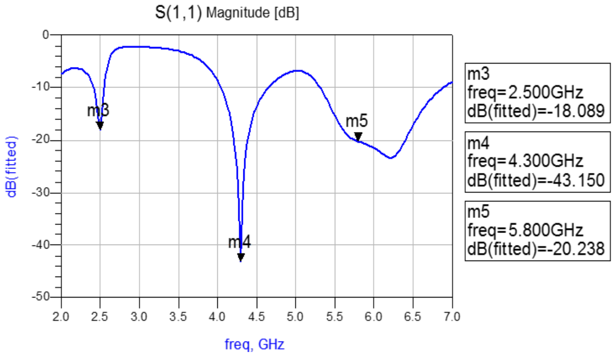


Fig. 2. Variation of return loss vs. frequency for the antenna

Table II presents the frequency bandwidth and the impedance bandwidth of the proposed antenna.

TABLE II
BANDWIDTH OF THE PROPOSED ANTENNA

Application	Impedance BW (%)	Frequency B.W (GHz)
WiMAX	5.466	2.420-2.556 (136 MHz)
RADALT	13.25	4.050 – 4.650 (600 MHz)
WiFi	25.759	5.310 – 6.880 (1570 MHz)

Fig. 3 shows the variation of VSWR versus the frequency for the slotted antenna; and the variation of the input impedance of the antenna with frequency is plotted on the Smith chart as shown in Fig. 4.

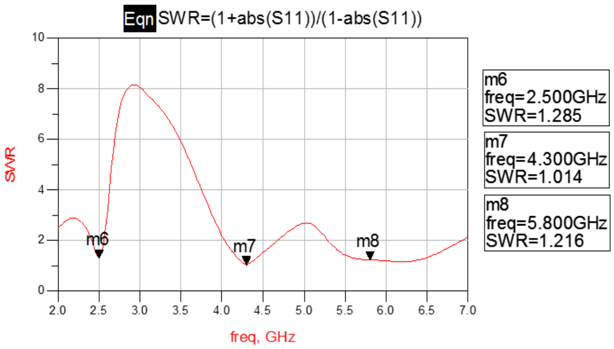


Fig. 3. Variation of return loss vs. frequency for the antenna

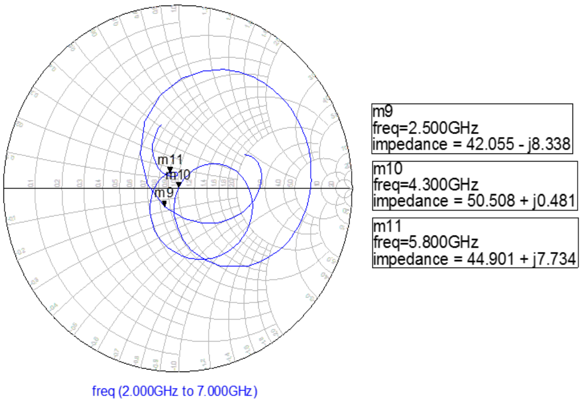


Fig. 4. Variation of the antenna input impedance vs. frequency

The simulation results of SWR, reflected power, and antenna input impedance at the desired frequencies are presented in Table III.

TABLE III
SWR, REFLECTED POWER, AND INPUT IMPEDANCE OF THE ANTENNA

Resonant frequency (GHz)	SWR	Reflected power (%)	Input impedance (Ω)
2.5	1.285	1.5557	42.055 + j 8.338
4.3	1.014	0.0048	50.508 + j 0.481
5.8	1.216	0.9501	44.901 + j 7.734

From Table 3, at the resonant frequencies, it can be noted that the VSWR are less than 2, and the reflected power less than 2% due to the acceptable impedance matching obtained between the antenna input impedance and the impedance of feeding transmission line.

A. *Antenna characteristics at 2.5 GHz*

The 3D illustration of the radiation pattern of the antenna at 2.5 GHz is shown in Fig. 5.

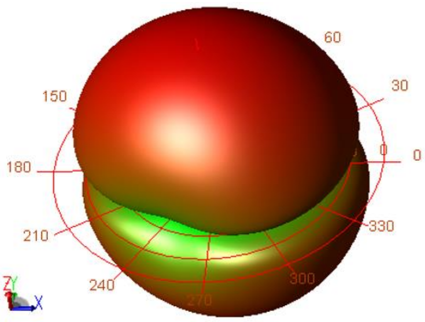


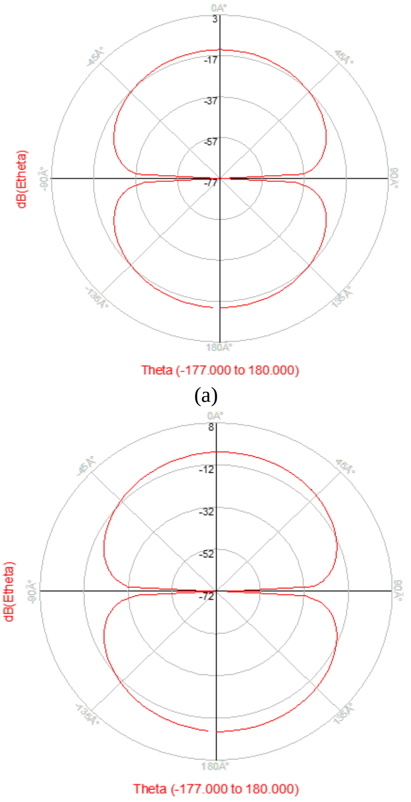
Fig. 5. 3D radiation pattern of the antenna at 2.5 GHz

The values of antenna parameters at 2.5 GHz, radiated power, directivity, gain, and efficiency are listed in Table IV.

TABLE IV
PARAMETERS OF THE SIMULATED ANTENNA AT 2.5 GHZ

Parameter	Value
Radiated power (mW)	2.280
Directivity (dBi)	3.598
Gain (dBi)	3.259
Efficiency (%)	92.497

At 2.5 GHz, the two field patterns with $\emptyset = 0$ (E-plane) in elevation cut (x-z plane), and in elevation cut (y-z plane) with $\emptyset = 90$ is shown in Fig. 6a and Fig. 6b respectively. From the Fig.s, it can be seen that the radiation patterns are similar to omnidirectional radiation, and there are nulls around 90° and $-90°$

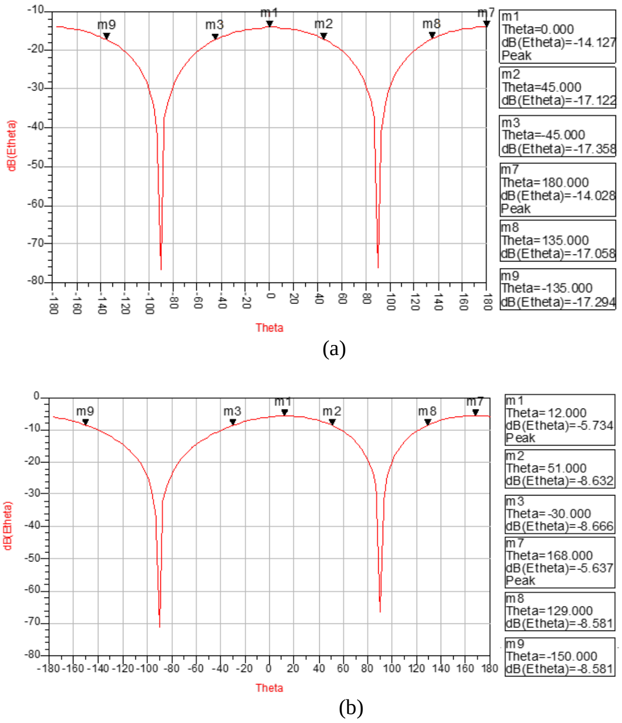


(a)

(b)

Fig. 6 Field pattern at 2.5 GHz in (a) x-z plane with $\emptyset = 0$ (b) y-z plane with $\emptyset = 90$

Beamwidths of the antenna at 2.5 GHz is displayed in Fig. 7.



(a)

(b)

Fig. 7 Beamwidths of the antenna at 2.5 GHz at (a) $\emptyset = 0$ (b) $\emptyset = 90$

From Fig. 7, at the resonant frequency 2.5 GHz with $\emptyset = 0$, it can be observed that the half power beamwidth (HPBW) is 90° for forward and backward directions, and the first null beamwidth (FNBW) is 180°; and at $\emptyset = 90$ plane, the half power beamwidth (HPBW) is 81°.

B. *Antenna characteristics at 4.3 GHz*

Fig. 8 shows the 3D pattern of the radiation pattern of the antenna at 4.3 GHz.

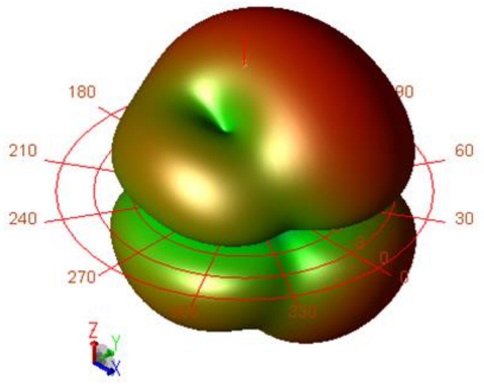


Fig. 8. 3D radiation pattern of the antenna at 4.3 GHz

The parameters of the antenna, radiated power, directivity, gain, and efficiency are tabulated in Table VI.

TABLE VI
PARAMETERS OF THE SIMULATED ANTENNA AT 4.3 GHZ

Parameter	Value
Radiated power (mW)	1.702
Directivity (dBi)	5.264
Gain (dBi)	3.599
Efficiency (%)	68.153

At 4.3 GHz, the field pattern with $\emptyset = 0$ (E-plane) in elevation cut (x-z plane) is shown in Fig. 9.

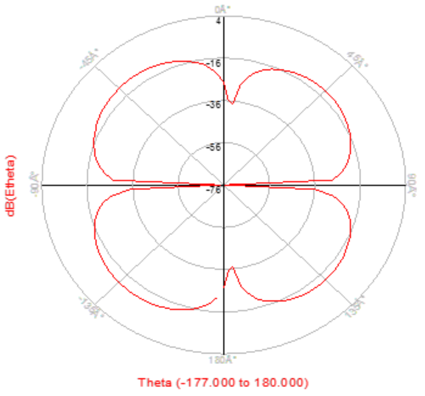


Fig. 9 Field pattern at 4.3 GHz in (a) x-z plane with $\emptyset = 0$

Fig. 10 illustrated the field pattern at 4.3 GHz in elevation cut (y-z plane) with $\emptyset = 90$.

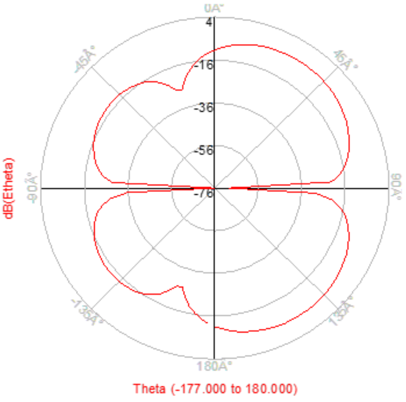
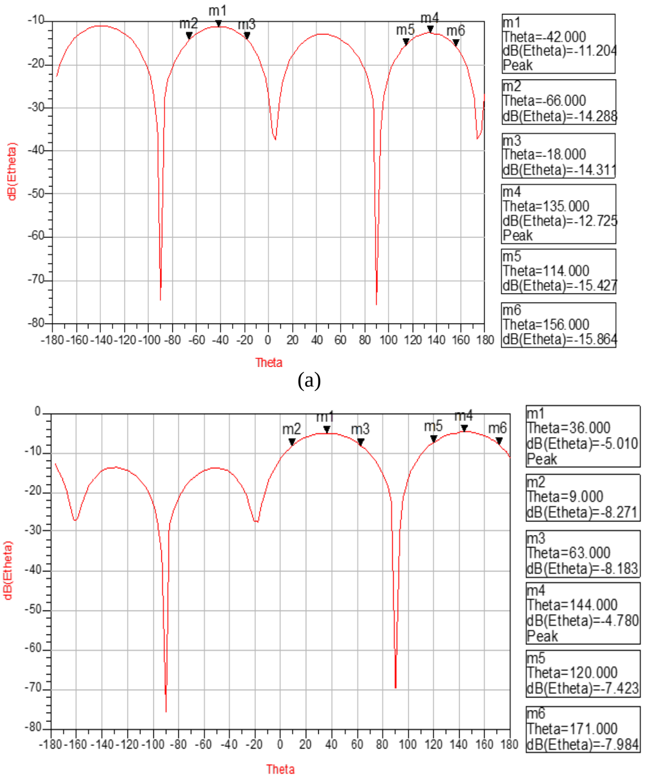


Fig. 10 Field pattern at 4.3 GHz in y-z plane with $\emptyset = 90$

From the Figures (9,10) , it can be seen that the radiation patterns are similar to omnidirectional radiation, and there are nulls around 90° and −90°

Beamwidths of the antenna is shown in Fig. 11 at 4.3 GHz.



(a)

(b)

Fig. 11 Beamwidths of the antenna at 4.3 GHz with (a) $\emptyset = 0$ (b) $\emptyset = 90$

From Fig. 11, at the resonant frequency 4.3 GHz, it can be observed that at $\emptyset = 0$ plane the half power beamwidth (HPBW) is 48° for forward direction and 42° for backward direction; and at $\emptyset = 90$ plane, the half power beamwidth (HPBW) is 54° and 51° for forward and backward directions respectively.

C. *Antenna characteristics at 5.8 GHz*

The 3D illustration of the radiation pattern of the proposed antenna at 5.8 GHz is shown in Fig. 12.

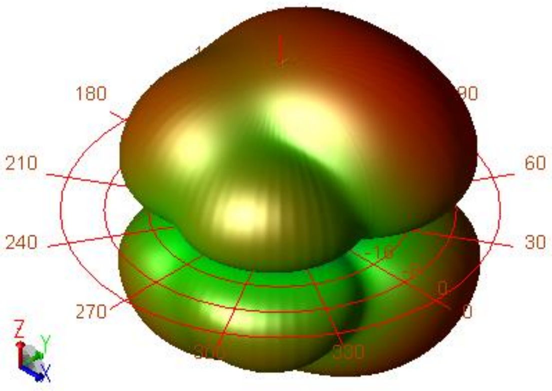


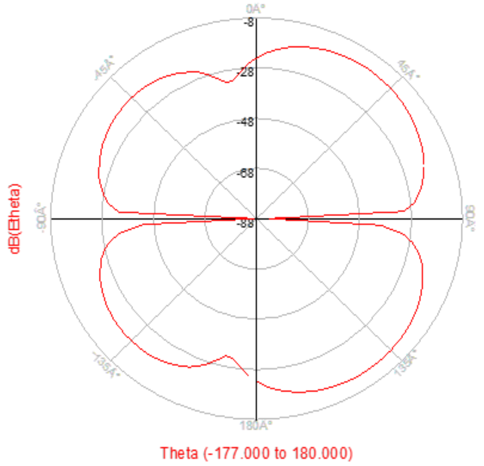
Fig. 12 3D radiation pattern of the antenna at 5.8 GHz

The parameters of the antenna at 5.8 GHz, radiated power, directivity, gain, and efficiency are tabulated in Table VII.

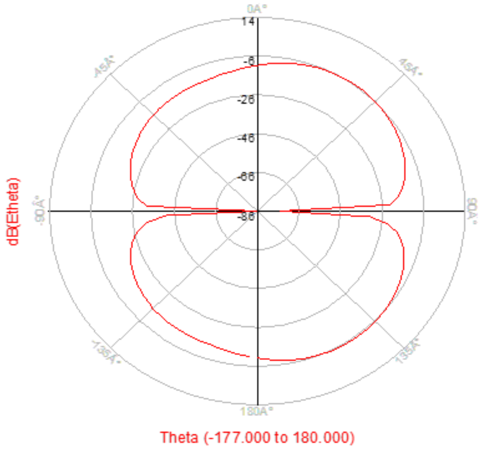
TABLE VII
TABLE 4. PARAMETERS OF THE SIMULATED ANTENNA AT 5.8 GHZ

Parameter	Value
Radiated power (mW)	1.661
Directivity (dBi)	6.551
Gain (dBi)	4.807
Efficiency (%)	66.934

At 5.8 GHz, the two field patterns with $\emptyset = 0$ (E-plane) in elevation cut (x-z plane), and in elevation cut (y-z plane) with $\emptyset = 90$ is shown in Fig. 13a and Fig. 13b respectively. From the Fig.s, it can be seen that the radiation patterns are similar to omnidirectional radiation, and there are nulls around 90° and −90°



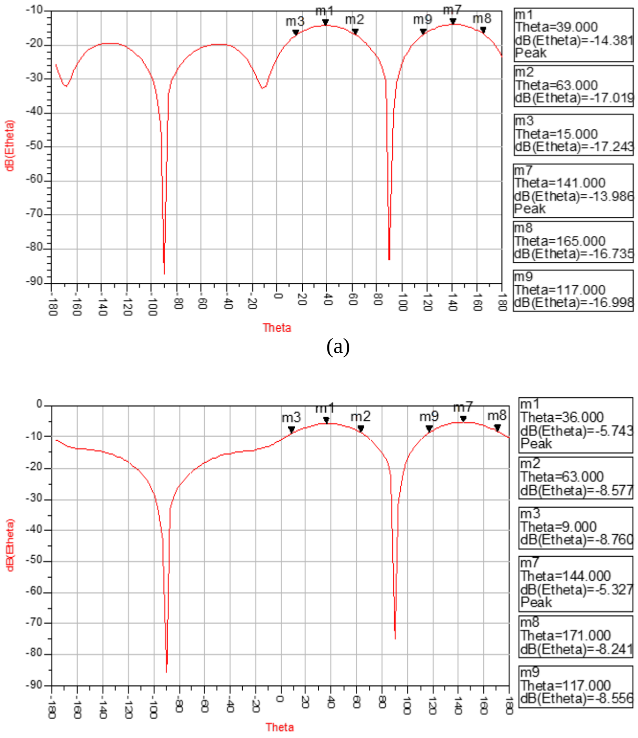
(a)



(b)

Fig. 13 Field pattern at 5.8 GHz in (a) x-z plane at $\emptyset = 0$ (b) y-z plane with $\emptyset = 90$

Half power beamwidths of the antenna at 5.8 GHz is displayed in Fig. 14.



(a)

(b)

Fig. 14 Beamwidths of the antenna at 5.8 GHz at (a) $\emptyset = 0$ (b) $\emptyset = 90$

From Fig. 14, at the resonant frequency 5.8 GHz, it can be observed that the half power beamwidth (HPBW) is 48° for forward and backward directions; and at $\emptyset = 90$ plane, the half power beamwidth (HPBW) is 54°.

The comparison between the proposed antenna and other antennas that published in [7-9] is made in Table VIII.

Table VIII shows that the proposed antenna has a compact size compared with the other antennas, and it has acceptable gain, directivity and impedance bandwidths for WiMAX, RADALT, and WLAN bands.

TABLE VIII
COMPARSION THE PROPOSED ANTENNA WITH OTHER ANTENNAS

Gain (dBi)	Directivity (dBi)	BW (%)	Size	frequency (GHz)	Published Antenna
3.48	4.11	31.90	41×49	2.5	[7]
6.00	--	22.20	39.6×44.9	4.3	[8]
6.11	6.28	5.92	30×30	5.8	[9]
3.26	3.60	5.47	38.5×32.5	2.5	Proposed antenna
3.60	5.26	13.25		4.3	
4.81	6.55	25.76		5.8	

III. CONCLUSION

In this paper, a CPW-fed triple-band slotted antenna was proposed to operate at three wireless communication bands, WiMAX IEEE802.16 (2.5-2.69 GHz) band, RADALT (4.2-4.4 GHz) band, and WLAN IEEE 802.11a (5.15-5.825 GHz) band. The antenna was simulated using ADS Momentum software on FR-4 substrate with 4.4 dielectric constant and 1.58 mm thickness.

Based on the simulated results, it can be conclude that, the simulated antenna has three resonant frequencies at the desired values 2.5 GHz, 4.3 GHz, and 5.8 GHz. At the resonant frequencies, the return loss is better than -10 dB, and VSWR is less than 2, these results indicate that this antenna has a good impedance matching. The proposed antenna has total efficiency 92.497% at 2.5GHz, 68.153% at 4.3 GHz, and 66.934% at 5.8 GHz, also it has similarly omnidirectional radiation pattern in E-plane and H-plane.

Therefore, the simulated results show that the proposed CPW-fed triple-band slotted antenna can be operated with good performance at the desired wireless communication bands.

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