Design of Bandwidth Enhancement CPW-Fed Slot Antennas

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***Abstract* —A multi-band coplanar waveguide (CPW)-fed slot antenna design for wireless/mobile communication applications is proposed. This antenna is designed on single-layer PCB FR4 substrate with permittivity εr=4.4, loss tangent tanδ=0.0245, and thickness h=1.6mm. The antenna consists of T-shaped signal strip and U-shaped conducting strip in the upper side of T-shaped signal strip. With the simple tuning slot parameters of the ground plane, the proposed antenna is suitable for WLAN 2.4/5.2/5.8, WiMAX 2.5/3.5/5.5, and WCDMA 1.92-2.17 GHz operations. The -10 dB bandwidth of the proposed antennas from measurement is about 109.2% (1.85-6.3GHz). The bandwidth enhancement is obtained by choosing suitable combinations of the upper and the lower ground slots. The elaborate analysis of geometrical parameters has been studied to optimize the performance of the designed antennas. The results for return loss, far-field H- and E-plane radiation patterns, gain, and radiation efficiency of the proposed antennas are presented and discussed. The antenna size of radiation area and ground plane is 50×50mm^2. The detailed simulation and experiment are investigated to optimize for broadband operation. The measured results show a good agreement with the simulated results.**

Index Terms—Wireless Local Area Network (WLAN), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX).

I. INTRODUCTION

The increasing need of multi-band antennas is very active because of the continuous demands of various wireless and mobile communications such as the WCDMA in the 1.92-2.17GHz, WLAN in the 2.4-2.4835GHz and 4.9-5.852GHz, and WiMAX in the 2.5-2.69GHz, 3.4-3.69GHz, and 5.25-5.85GHz bands. To achieve a small size, light weight, ease of fabrication but multi-band operation, the applied antenna structures employ CPW-fed antennas due to the fact that CPW-fed antennas have relatively the wider bandwidth the low-cost, feasibility of different frequency bands, and compatibility with surface-mount devices.

In recent years, many researchers have investigated CPW-fed slot antennas [1]-[21]. In [1], a dual-band CPW-fed hybrid antenna consisting of a 5.4 GHz high-band inductive slot antenna and 2.4 GHz low-band F-shaped monopole antenna is proposed. Two printed wide-slot antennas with E-shaped patches and slots for broadband applications are proposed in [2]. In [3], a CPW-fed modified Koch snowflake slot antenna operating over a wide frequency band, covering the 2.4/5.2/5.8 GHz WLAN and 2.5/3.5 GHz WiMAX bands is proposed. To insert a meandering slit at the edge of a rectangular patch, a novel compact dual-band antenna is presented [4]. Additional CPW-fed slot antennas have been proposed [5]-[18].

In this paper, a new configuration to design the multiband antenna has been proposed and implemented. Fig. 1 shows the geometrical configuration of the CPW-fed slot antenna. This antenna is implemented on a FR4 substrate with εr=4.4, loss tangent tanδ=0.0245, and thickness h=1.6mm. The antenna consists of T-shaped signal strip and U-shaped conducting strip in the upper side of T-shaped signal strip. A 50Ω CPW-fed transmission line is used to for the antenna feed; the gap between the feed line is 0.5mm. In order to obtain a good impedance condition, the geometrical configuration of CPW-fed slot antenna is derived by tuning the gap size (L_3) and ground slot (L_{f1}, W_{f1}, L_{f2}, W_{f2}, a1, and a2). The proposed design procedures for specified frequencies and can be validated by simulation and measurement. This paper is organized as follows. Section II briefly describes the multi-band CPW-fed slot antenna. Section III discusses experimental and simulated results for the proposed antenna. Section IV describes design procedures and discusses the simulated results for the multi-band CPW-fed slot antenna. Finally, section V briefly draws some conclusions.

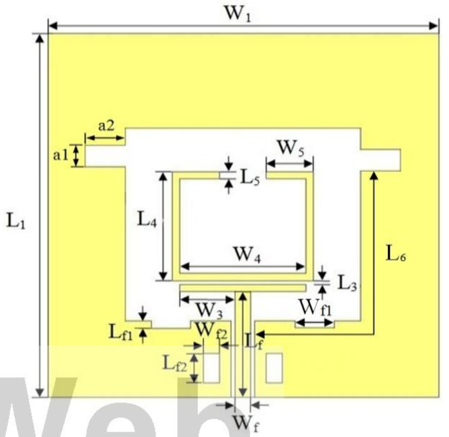

Fig. 1 The configuration of the multiband CPW-fed slot antenna.

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Table I The geometric parameters of this antenna. (unit: mm)

L_1	50	W_1	50
L_2	30	W_2	30
L_3	0.5	W_3	7
L_4	15	W_4	16
L_5	1	W_5	6
L_f	14.5	W_f	2
L_{f1}	1	W_{f1}	4
L_{f2}	4	W_{f2}	1
a1	4	a2	6

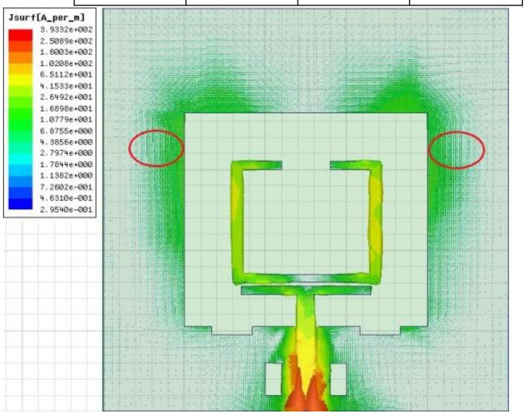


Fig. 2(a) The current distribution of the proposed antenna at 3.5GHz without the ground slots.

II. DESIGN OF MULTI-BAND CPW-FED SLOT ANTENNA

The T-shaped signal strip of the CPW-fed slot antenna is devised the bandwidth ranges which covers 5.2/5.8 GHz (WLAN) bands. By adding an extra U-shaped conducting strip, the dual-band resonant frequency at 2.4 GHz (WLAN) of the antenna is obtain to keep good impedance bandwidth and stable radiation characteristics. The upper frequency band effect of this antenna is improved by the slot of the ground plane. The dimensions of the geometric parameters are shown in Table I.

The comparison of the simulated current distribution at 3.5 GHz of the proposed antenna without and with the upper ground slots is shown in Fig. 2(a) and Fig. 2(b). The simulated current distribution of the proposed antenna at 3.5 GHz is shown in Fig. 2(a). The tuning of the multiband antenna is obtained by adjusting the size of the ground slots to produce the required frequency response characteristic; the strong power of the current distribution at 3.5GHz is mainly in the T-shaped signal strip, U-shaped conducting strip, and the grounded parts on both sides of the circles in Fig. 2. The quarter wavelength of 3.5GHz is calculated from the feeder line end to the slot ground plane distance. The length L_6 is about 33mm. As a result, the upper ground slots method are used to generate another discontinuous effects of the current path and to generate additional 3.4 to 3.6GHz (WiMAX) frequency band. The simulated results in Fig. 2(b) clearly show to verify the validity of the study.

The parameters of a1 and a2 are employed to obtain WiMAX (3.5 GHz band). Many values of a1 and a2 are studied and return loss is shown in Fig. 3 (a), (b) and (c). Fig. 3 shows results for the slot of the ground plane a1 vary from 3 to 5 mm and a2 vary from 5 to 7 mm. It is clear from the Fig. 3 that varying the slots of the ground plane causes the variation of resonant frequencies at 3.5 GHz band. On the other hand, varying the slot parameters of a1 and a2 do not affect other bands. In the case with a1=4 mm and a2=6 mm, it is clear found that the simulated return loss > 10 dB can obtain nearly 3.05 GHz (from 1.85 to 4.9 GHz) in the lower frequency band and 1.5 GHz (from 4.9 to 6.4 GHz) in the upper frequency band, as shown in Fig 3 (b). The return loss is 26dB and 22dB in the lower and upper frequency band, respectively. More elaborate effects of varying the two parameters of a1 and a2 are examined in Fig. 3.

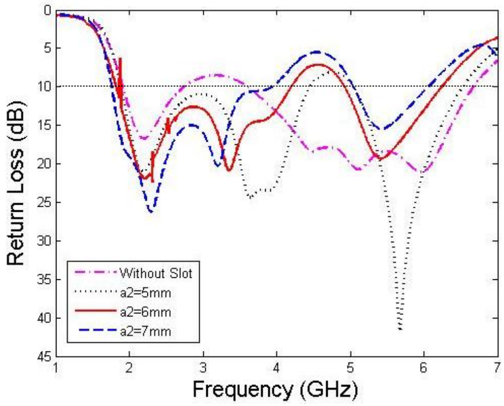


Fig. 3(a) The simulated result of the tuning a2 (a1=3mm).

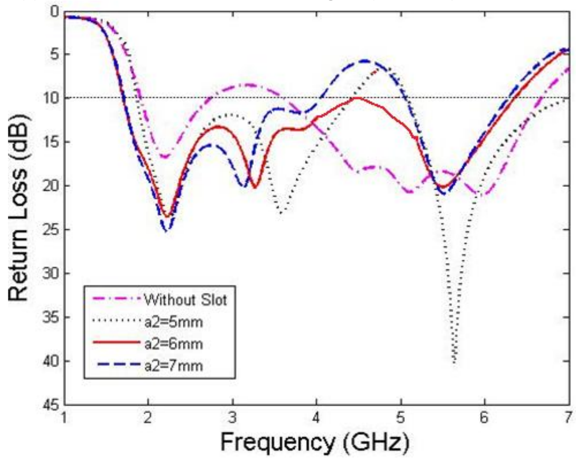


Fig. 3(b) The simulated results of the tuning a2 (a1=4mm).

III. EXPERIMENTAL RESULTS

Fig. 4 shows the physical layout of the proposed antenna, which is built on FR4 substrate having a thickness of 1.6 mm, a relative dielectric constant of 4.4, and loss tangent tanδ=0.0254. The proposed antenna physical size in the study is 50×50 mm^2. We measured the return loss by using an Agilent N5230A network analyzer. The simulated and measured return loss of the proposed antenna is shown in Fig. 5. To make a good comparison, the antenna without the ground slots is also added in Fig. 5; the simulated results are employed the electromagnetic simulation software of Ansoft HFSS (High Frequency Structure Simulator).

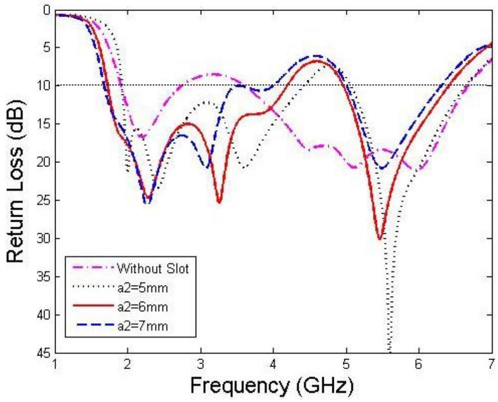


Fig. 3(c) The simulated result of the tuning a2 (a1=5mm).

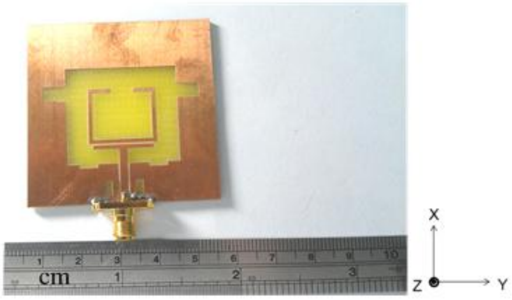


Fig. 4 The photo of the fabricated antenna by a CPW fed.

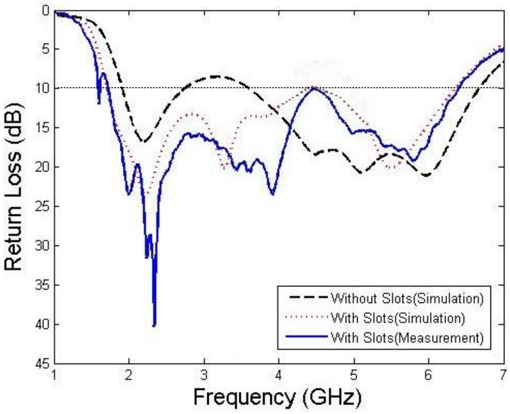
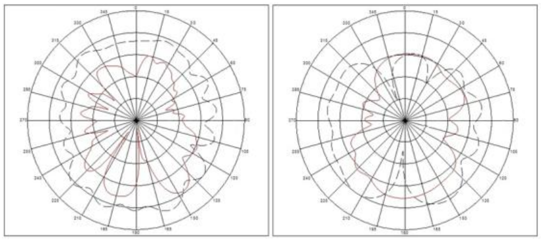


Fig. 5 The simulated and measured magnitude response of the proposed slot antenna.

From the simulated and measured results in Fig. 5, the -10 dB bandwidth of the CPW-fed slot antenna (without the ground slots) is 0.8GHz (1.95-2.75GHz) and 1.3GHz (3.6-4.9GHz) in the lower frequency band and 1.8GHz (4.9-6.7GHz) in the upper frequency band. With the tuning ground slots, the measured result of the proposed antenna gives multiband performance with -10 dB bandwidth of 3.05GHz (1.85-4.9GHz) in the lower frequency band and 1.4GHz (4.9-6.3GHz) in the upper frequency band. In addition, by using the described design method, a multiband antenna is implemented to cover at WLAN 2.4/5.2/5.8, WiMAX 2.5/3.5/5.5, and WCDMA 1.92-2.17 GHz. The measured return loss sinks in 1.92 to 2.17 GHz (IMT-2000) band is below 24 dB, in 2.4 to 2.4835 and 5.2 to 5.8 GHz (WLAN) band is below 40 dB, and in 3.4 to 3.5 GHz (WiMAX) band is below 20.3 dB. The measured results are in good agreement with the simulated results.

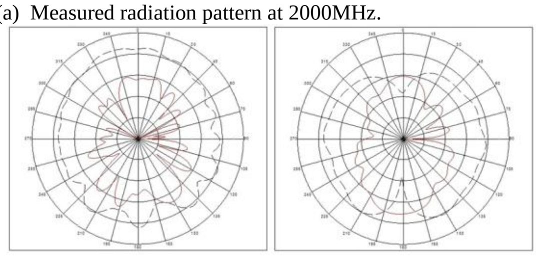
The measured far-field co-polarization and cross-polarization radiation pattern of the proposed slot antenna at the several typical frequencies are presented in Fig. 6. In the H-plane (x-z plane), the radiation pattern is nearly omni-directional at lower and upper frequency bands (2.0, 2.4, 3.5, 5.2, and 5.8 GHz). In the E-plane (y-z plane), the radiation pattern is nearly bidirectional at lower and upper frequency band. Acceptable and stable radiation pattern for the multiband application is obtained for the proposed antenna. Table II shows the measured peak gain, efficiency, and frequency band for the proposed antenna. The measured peak gain with 2.4/3.5/5.2/5.8 bands is obtained for the proposed antenna. The highest gain for the proposed antenna is about 3.6 dBi at 5.8 GHz and highest efficiency is about 68.51% at 3.5 GHz. The size, frequency range and bandwidth with some reports are compared in Table III. In Table III, the bandwidth of the proposed antenna is extended to over 49% of [17]. The size of the proposed antenna reduces up to 30% of [16], 51% of [17], and 75% of [18].



H-plane E-plane

- - - (co-pol) —(cross-pol)

Fig. 6(a) Measured radiation pattern at 2000MHz.



H-plane E-plane

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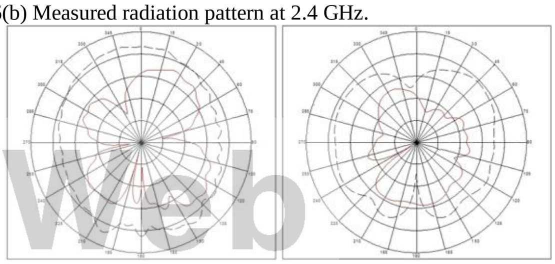
Fig. 6(b) Measured radiation pattern at 2.4 GHz.



H-plane E-plane

- - - (co-pol) —(cross-pol)

Fig. 6(c) Measured radiation pattern at 3.5 GHz.

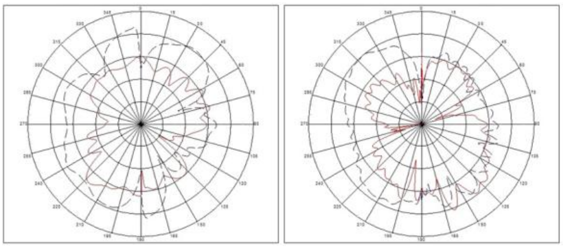

H-plane E-plane
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Fig. 6(d) Measured radiation pattern at 5.2 GHz.

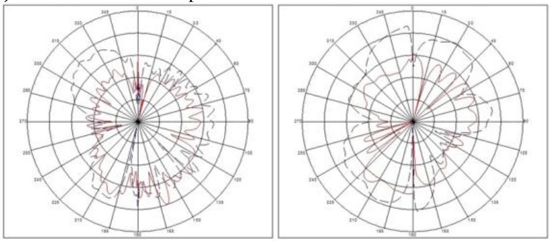
H-plane E-plane
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Fig. 6(e) Measured radiation pattern at 5.8 GHz.

Table II Frequency band, gain, and efficiency of the proposed antenna.

Freq.(GHz)	Gain(dBi)	Total Radiation Efficiency (%)
2.4	2.17	61.26
3.5	1.79	68.51
5.2	3.3	66.88
5.8	3.6	48.1

Table III The size, frequency range and bandwidth of the proposed antenna and other reports.

CPW-fed slot antenna	size	Frequency range	Bandwidth
Proposed antenna	50mm×50mm	1.85-6.3GHz	109.2%
[16]	60mm×60mm	1.85-7.54GHz	121%
[17]	72mm×72mm	1.56-2.88GHz	60%
[18]	100mm×100mm	2.79-9.48GHz	110%

III. CONCLUSION

A novel multi-band configuration of CPW-fed slot antenna using T-shaped signal strip and U-shaped conducting strip has been proposed and implemented. The effects of the various geometrical parameters on the proposed antenna are studied. The -10 dB bandwidth of the proposed antennas from measurement is about 109.2% (1.85-6.3GHz). The bandwidth enhancement is obtained by choosing suitable combinations of the upper and the lower ground slots. The elaborate analysis of geometrical parameters has been studied to optimize the performance of the designed antennas. The results for return loss, far-field H- and E-plane radiation patterns, gain, and radiation efficiency of the proposed antenna are investigated and discussed. With the simple tuning slot parameters of the ground plane, the proposed antenna is suitable for WLAN 2.4/5.2/5.8, WiMAX 2.5/3.5/5.5, and WCDMA 1.92-2.17 GHz operations. The measured results show a good agreement with the simulated results.

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