A Compact Quad-Band Microstrip Slot Antenna for WLAN/WIMAX Applications

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Abstract- **A compact quad-band microstrip slot antenna applied to WLAN/WiMAX applications is proposed in this letter. This antenna has a simpler structure than other antennas designed for realizing quad -band characteristics. It is just composed of a microstrip feed line, a substrate, and a ground plane on which some simple slots are etched. Then, to prove the validation of the design, a prototype is simulated. The experimental data show that the antenna can provide four impedance bandwidths of 100 MHz centered at 2.5 GHz, 230 MHz centered at 3.5 GHz, 150 MHz centered at 5 GHz and 450 MHz centered at 5.8 GHz. The proposed antenna has good radiation characteristics, radiation efficiency, improved return loss and low dimensions in the four operating bands. The optimum results of proposed antenna verify and tested in HFSS simulator.**

Keywords – **Microstrip slot antenna, Multi-Band Antenna, quad-band antenna, WLAN/WiMAX, HFSS simulator.**

I. INTRODUCTION

IN MODERN wireless communication systems, multiband antenna with small structure has been playing a very important role for wireless service requirements. Microstrip patch antenna is promising to be a good candidate for these requirements of wireless technology. Microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to its advantages such as low profile planar configuration, low weight, conformal shaping, low fabrication costs, simplicity of manufacture, capability to integrate with microwave integrated circuits technology and their use in multi-frequency band applications. The microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones, pagers, Radar systems and satellite communications systems [16]-[17],etc. Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) have been widely applied in mobile devices such as hand held computers and intelligent phones. These two techniques have been widely recognized as a viable, cost-effective, and high-speed data connectivity solution, enabling user mobility. In practice, IEEE 802.11 WLAN standards consist of 2.4-GHz (2.4–2.484 GHz), 5.2-GHz (5.15–5.35 GHz), and 5.8-GHz (5.725–5.875 GHz) frequency bands. WiMAX standards consist of 3.5-GHz (3.3–3.6 GHz) and5.5-GHz (5.25–5.85 GHz) frequency bands. With the rapid development of the modern wireless communication system, antenna design has turned to focus on wide multiband and small simple structures that can be easy to fabricate.

To adapt to the complicated and diverse WLAN and WiMAX environments, several promising dual-band, triple-band, multiband, monopole, patch antenna designs have already been proposed in [1]–[15]. In [3], a crooked U-slot and a radial stub make the antenna achieve dual-band operations. It has a simple structure to be fabricated easily, but only dual bands can be supplied the same as the antennas in [1] and [2]. In [7]–[9], though the proposed triple-band antennas have good characteristics for both WLAN and WiMAX applications. In [9], A compact triple-band microstrip slot antenna designed to WLAN/WiMAX applications is proposed for provide three impedance bandwidths of 600 MHz centered at 2.7 GHz, 430 MHz centered at 3.5 GHz, and. 1300 MHz centered at 5.6 GHz and simulated in HFSS to analyse the peak Gain, Radiation efficiency and Radiation pattern. In [8] A tri-band slot loaded microstrip antenna is proposed. The tri-band characteristics of antenna are achieved by incorporating a combination of symmetrical Y-shaped and asymmetrical U-shaped slot. The proposed antenna covers the wireless application bands like GPS L1 (1.561- 1.589 GHz), Wi-Fi (2.393- 2.523 GHz), and WiMAX (3.30-3.661 GHz). Simulation is carried out by HFSS software and also compare with CST microwave studio. In [4]–[6], though the proposed monopole antennas have good characteristics for both WLAN and WiMAX applications, they are complicated in structures and large in size. Besides slot and monopole antennas, there are many other general implementations for multiband(tri-band) applications, such as patch antennas[12]–[14], dipole antennas , Planar Inverted F Antenna [16]-[17], and antennas usingdifferent dielectric material [10]-[11], etc. Compared to these regular antennas. The slot antenna fed by microstrip line has better characteristics, including wider bandwidth, less conductor loss, and better isolation between the radiating element and feeding network [15].

In this paper, a compact quad-band microstrip slot antenna is proposed for WLAN and WiMAX applications. The antenna consists of a microstrip feed line, a substrate, and a ground plane on which some simple slots are etched. The rectangular and trapezoid slots are able to achieve dual-band, triple-band frequencies and also provide a broadband operation at high frequency. The additional resonant mode is excited with the use of horizontal strips embedded in the ground plane. Compared to the antennas in [1]–[15], the proposed antenna in this paper not only achieves quad- bands simultaneously, but also has a rather reduced size and simple structure that is easy to fabricate. Meanwhile, the measured results represent that the antenna shows a good multiband characteristic to satisfy the requirement of WLAN in the 2.4/5.2/5.8-GHz bands and WiMAX in the 2.5/3.5/5.5-GHzbands. Details of the antenna design are described in the paper, and simulated results are presented. The simulated results show good agreement with the WIMAX/WLAN requirements.

II. ANTENNA DESIGN

The configuration of the proposed quad-band microstrip slot antenna is shown in Fig 2&4. The proposed antenna may be considered as a transformer of the slot antenna.

Design concept of microstrip line to slot line transition:

Due to the simplicity in design and manufacturing, microstrip line is chosen as the feed line. The microstrip line to slot line transition is considered. The geometry of the transition is shown in Figure-1.

The transition is employing a microstrip line and a slot line crossing each other at a right angle. The microstrip extends about one quarter of a guided wavelength beyond the slot, and the slot extends about a quarter of a guided wavelength beyond the microstrip. In order to obtain a transition that has low return loss over a wide frequency band, the impedances of the microstrip line and the slot line should be matched to each other to minimize the reflections. Large impedance values in order to be able to achieve impedance matching between microstrip line and slot line. The characteristic impedance of a slot line increases with increasing slot width, so the width possible to obtain an impedance value close to 50 limitations, a minimum slot width of 0.254 mm (10 mils) is chosen.

To calculate the characteristic impedance and guided wavelength are as following.

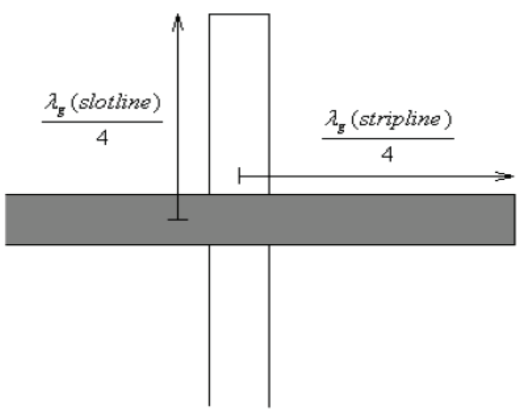


Figure 1 : Orthogonal Microstrip line to slot line transition

The characteristic impedance of a slot line can be calculated as:

$$Z_0 = 60 + 3.69\sin\left[\frac{(\varepsilon_r - 2.22)\pi}{2.36}\right] + 133.5\ln(10\varepsilon_r)\sqrt{\frac{W}{\lambda_0}} +$$
$$2.81[1 - 0.011\varepsilon_r(4.48 + \ln\varepsilon_r)]\left(\frac{W}{h}\right)\ln\left(\frac{100h}{\lambda_0}\right)$$

$$+131.1(1.028-\ln\varepsilon_r)\sqrt{\frac{h}{\lambda_0}}+12.48(1+0.18\ln\varepsilon_r)\left(\frac{\left(\frac{W}{h}\right)}{\sqrt{\varepsilon_r-2.06+0.85\left(\frac{W}{h}\right)^2}}\right)$$

Where h is the height of the dielectric substrate and w is the width of the slot line.

The guided wavelength of the slot line can be found as:-

$$\frac{\lambda_g}{\lambda_0}=1.045-0.365\ln\varepsilon_r+\frac{6.3\left(\frac{W}{h}\right)\varepsilon_r^{0.945}}{238.64+100\left(\frac{W}{h}\right)}-\left(0.148-\frac{8.81(\varepsilon_r+0.95)}{100\varepsilon_r}\right)\ln\left(\frac{h}{\lambda_0}\right)$$

The effective dielectric constant and characteristic impedance of a microstrip line can be calculated as:

For w/h<1:

$$\varepsilon_{eff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{W}}}+0.04\left(1-\frac{W}{h}\right)^2\right]$$

$$Z_c=\frac{60}{\sqrt{\varepsilon_{eff}}}.\ln\left(\frac{8h}{W}+\frac{W}{4h}\right)$$

For w/h>1:

$$\varepsilon_{eff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{W}}}\right)$$

$$Z_c=\frac{120\pi}{\sqrt{\varepsilon_{eff}}}.\frac{1}{\left[\frac{W}{h}+1.393+\left(0.677.\ln\left(\frac{W}{h}+1.444\right)\right)\right]}$$

Where w is the width of the microstrip line.

This paper is basic aimed to design & simulate Compact Quad-band microstrip slot Antenna resonates at 2.5GHz, 3.5GHz, 5GHz and 5.8GHz for Wi-Max/WLAN application with low cost, improved return loss, appropriate bandwidth, and improved radiation efficiency. Table 1: shows Design Parameter of Quad-band Antenna using Bakelite dielectric substrate with reduced size. Multiband Antenna will operate at different center frequencies as well as it has different frequency bands. To provide multifunctional operations for Mobile Communication multiband Antennas are essential. As shown in fig. 2, microstrip quad-band slot antenna consists of a microstrip feed line, a substrate, and a ground plane on which two slots are etched. The proposed antenna has four resonant frequencies 2.5GHZ, 3.5GHz, 5GHZ,5.8GHZand implemented using Bakelite dielectric substrate with dielectric constant ε_r= 4.8.,thickness(t)=1.575mm.

Low dielectric constant leads to a larger antenna size. In order to design a compact antenna, substrates with higher dielectric constants must be used. Size can be further reduced and Radiation efficiency can be improved by using Bakelite dielectric substrate which has dielectric constant of 4.8. Bakelite dielectric material is also cheaper so low cost antenna can be implemented. So next a Quad-band Antenna using Bakelite dielectric substrate is discussed in order to make it compact and cheaper.

The simulation has been carried out by HFSS software. Return loss curve, radiation efficiency, bandwidth, gain, directivity are obtained.. The entire size of the antenna is 30 x 31 x 1.57 mm^3 .(Figure 2)

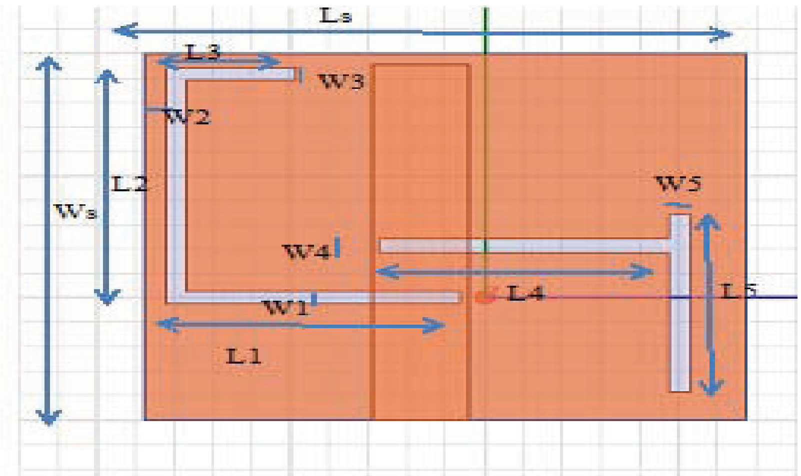


Figure 2: Quad-band Antenna using Bakelite substrate with two slots

Parameter	Value(mm)	Parameter	Value(mm)
LS	30	WS	31
L1	14.17	W1	1
L2	18.3	W2	1
L3	6.7	W3	1
L4	15	W4	1.1
L5	12.6	W5	1.1

Table 1 : Design Parameter of Quad-band Antenna using Bakelite with Two slots

III. Simulation and Result

Result analysis of Quad-band Antenna using Bakelite substrate:

1. Simulated Return loss curve**:**

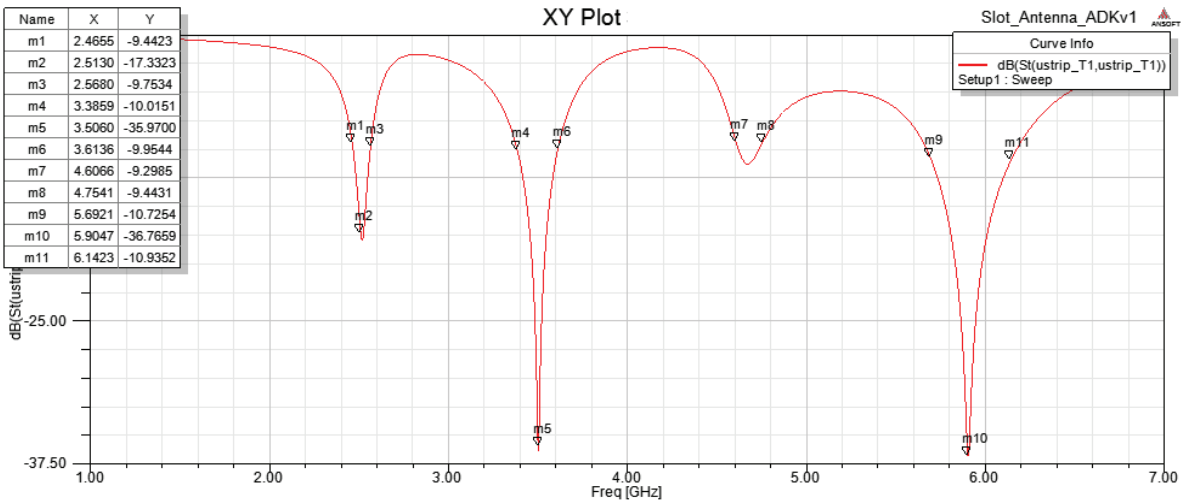
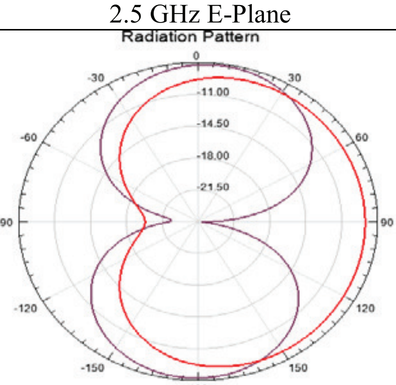
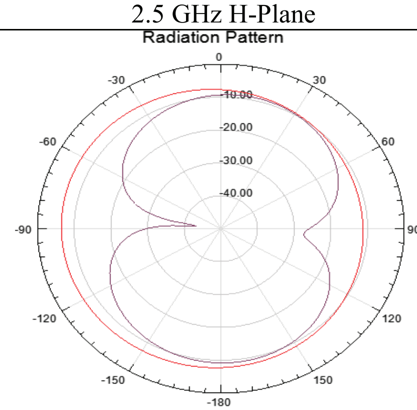


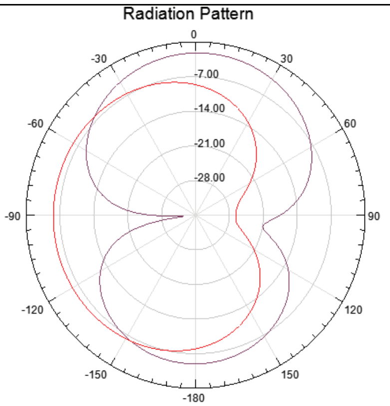
Figure 3 : Simulated Return Loss Curve for Quad-band Antenna using Bakelite substrate

	2.5GHZ	3.5GHZ	4.7GHZ	5.8GHZ
Bandwidth	100MHZ	230MHZ	150MHZ	450MHZ
Return Loss	-17.5dB	-35.9dB	-12dB	-36.76dB

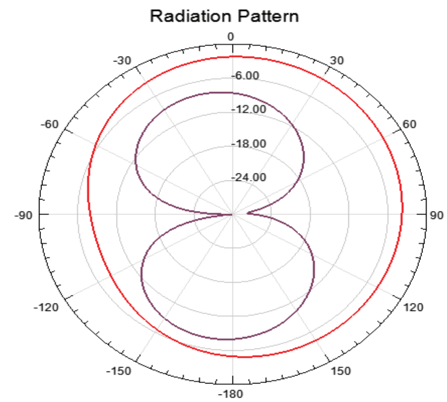
2. Size of Proposed Antenna : 30 x31 mm^2

3. Radiation Pattern: at different centered frequency of proposed antenna the characteristic of radiation pattern is achieved in E-plane and H-plane as shown in table 3 -

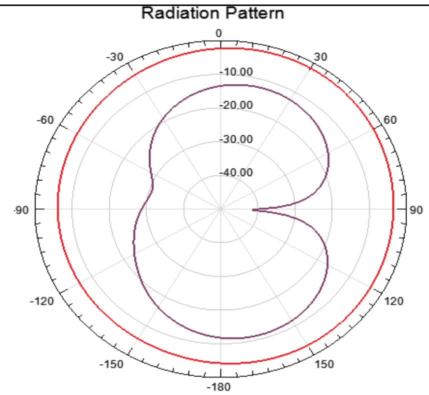
2.5 GHz E-Plane	2.5 GHz H-Plane
	
3.5GHz E-Plane	3.5GHz H-Plane



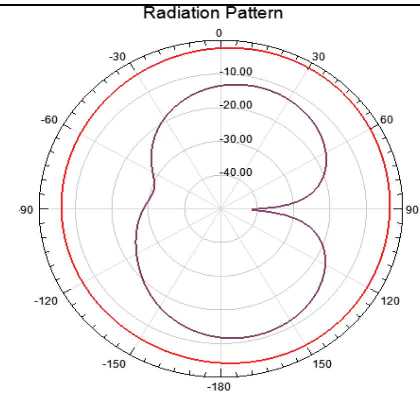
4.7GHz E-Plane



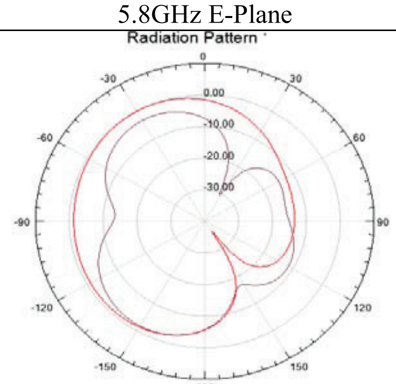
4.7GHz H-Plane



5.8GHz E-Plane



5.8GHz H-Plane



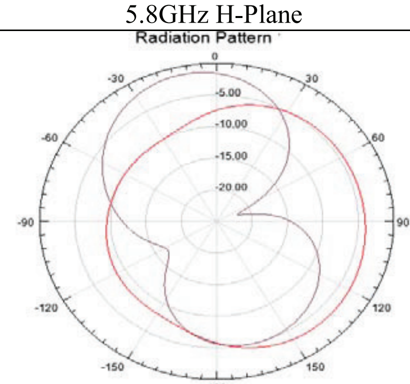


Table 3 : Radiation Pattern

4. Radiation efficiency, Peak Gain & Peak Directivity

PARAMETER	5.8GHZ	4.7GHZ	3.5GHZ	2.5GHZ
Radiation efficiency	97.30%	97.31%	97.46%	95.44%
Peak Gain	8.13dB	3.36dB	2.28dB	5.69dB
Peak Directivity	2.62	1.51	1.26	0.55

Table 41 : Result of Quad-band Antenna using Bakelite with Two Slot

IV.CONCLUSION

In this letter, a compact quad-band slot antenna for WLAN/WiMAX applications is presented. Compared to many antennas proposed in recent papers [1]–[15], this antenna is designed based on a rather simple structure and suitable for all frequency bands of WLAN and WiMAX applications simultaneously. The proposed antenna can be considered to achieve multiband just through etching slots on the ground plane, so it can be much easier to fabricate. The simulated results show that the obtained impedance bandwidths are 100MHz (2.51–2.59 GHz), 230MHZ (3.42–3.59 GHz), 150MHz (4.73–5.31 GHz) and about450MHz (5.65–5.97 GHz), respectively with good return loss, enough for WiMAX/WLAN applications. The bandwidth and Resonant frequencies can be easily tuned by variation of slot width and length respectively. In addition, the proposed antenna has good radiation characteristics, radiation efficiency and low dimensions in the four operating bands, so it can emerge as an excellent candidate for multiband generation of wireless. Proposed antenna simulated in HFSS Simulator. The optimum results of proposed proposed antenna verify and tested in HFSS simulator.

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