A Modified Circular Monopole UWB Antenna with WiMAX/WLAN Dual Band Notch Function

F. Guichi and M. Challal

Abstract—In this paper, a WiMAX/WLAN dual band notched antenna for UWB applications is presented. The proposed antenna is composed of a modified circular patch fed by a 50 microstrip line printed on the upper side of a Rogers AD450 substrate ,and a semi circular ground which is printed on the bottom side of the substrate with defected ground structure underneath the transmission line to cover the UWB. The WiMAX (3.4-4.1 GHz) band is rejected by inserting a narrow circular ring slot on the patch whereas the WLAN (5-6.3 GHz) band is notched using an inverted U shaped slot etched on the ground plane. In order to investigate the performance of the proposed structure ,a parametric study is carried out and the current distributions are simulated at the center frequencies of rejected bands. The antenna covers widely the FCC band allocated to the UWB operation from 2.5 GHzto 14 GHz, and exhibits an omnidirectional radiation pattern in the H-plane and a monopole like radiation pattern in the E-plane. A good agreement between the simulated and measured results indicates that the proposed structure is suitable for UWB systems.

Index Terms—UWB, WiMAX, WLAN, Slot, VSWR, Gain, Radiation pattern.

1 Introduction

Ultra-wideband (UWB) technology has become a very promising candidate for short-range high-speed indoor data communications when the Federal Communications Commission (FCC) has authorized the bandwidth 3.1—$10.6\mathrm{GHz}$ for indoor and outdoor use of this type of technology with a small amount of radiation power smaller than $41.3\mathrm{dBm/MHz}$ [1]. UWB antennas play an important role in such system because it should have omnidirectional radiation patterns, a large bandwidth and a small size to fit in the required space. Microstrip monopole antennas are good candidates for UWB applications owing to their interesting physical features, such as small size, and low cost large impedance bandwidth, and acceptable radiation properties [2]. Due to the very large frequency spectrum that UWB system occupies, sever interferences with other existing narrow band systems such as the wireless local area network (WLAN) operating at 5.15-–5.35 and 5.725—$5.825\mathrm{GHz}$ [3], and worldwide interoperability for microwave access (WiMAX) (3.3-–3.6 and 5.25-–$5.85\mathrm{GHz}$) [4] is challenging task that researchers are facing. In order to reject undesired narrow bands within the UWB pass band, several techniques have been reported in literature such as cutting T-shaped strips in the center of I-shaped structure [5], A pair of split-ring resonators (SRRs) is placed besides the radiating element to realize the band notch function [6], The rejection is achieved using double open-circuited stubs in [7], non uniform short-circuited stub and coupled open-/short-circuited stub resonators [8], closed-loop ring resonators [9], U-shaped stub and a T-shaped stub are embedded in the patch [10]. However, these techniques inevitably exhibit some defects in practical applications and increase the complexity and antenna size. Also Some designs only reject one single band [11].Therefore embedding simple structures either in the ground or in the ground is a simple and effective method to illuminate the interferences.

In this paper, a microstrip monopole antenna with dual band notch property is designed for UWB systems. A narrow circular ring slot is embedded in the patch and an inverted U shaped slot is etched in the ground to reject the WiMAX and the WLAN bands respectively, the length and thickness of the slots are chosen to get narrow rejecting bands with high selectivity. In following sections, the performance of the antenna is explained in detail, simulated and measured results are presented and effects of the key parameters are investigated.

2 Antenna Structure and Design Procedure

The geometry of the proposed antenna is shown in Fig.(1). The antenna is printed on Rogers AD450 substrate with a height of $1.5\mathrm{mm}$ and a relative permittivity of 4.5, it consists of a modified circular shaped radiator fed by a 50Ω transmission line.

The staircase notch is used to lengthen the path of the current and hence to cover higher frequencies, and a semi circular ground plane with rectangular shaped defect underneath the transmission line to enhance the impedance bandwidth. A thin circular ring slot and an inverted U-shaped slot are inserted to reject both WiMAX and WLAN bands.The design process involves three different evolution stages as depicted in Fig.(2). Initially, the basic structure of this antenna (denoted as Ant1) is discussed in [12], then a circular ring slot is etched on top of the radiator (denoted as Ant2) to create the first band notch 3.4–$3.7\mathrm{GHz}$ for WiMAX. Finally an inverted U-shaped slot is etched on the finite

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ground plane (denoted as Ant 3) to achieve the second band notch for the WLAN band 5–6.3GHz.

3 Results and discussion

Embedded slots act as resonators and the band-notch centre frequency mainly depends on the length of the slot. The length of the slot is about a half of the wavelength corresponding to the desired centre frequency of the rejection band [13]. The required band notch frequencies are $3.4 - 3.7$GHzfor WiMAX band and 5.15–5.825GHz for WLAN band. Hence, the designed centre frequencies of the rejection are set to be at around 3.5GHz and 5.5GHz. The wavelength corresponding to notched frequency λ_r can be calculated by $\lambda_r = \lambda / sqrt(\varepsilon_{eff})$, where ε_{eff} is the effective dielectric constant. The length of the circular ring slot and inverted U-shaped slot can be deduced by equation (1)

$$L_{(slot)} = \frac{c}{2f\varepsilon_{eff}} \tag{1}$$

where c is the speed of light and f is the center frequency of the rejected band

In order to investigate the effect of the slot's length on the center frequency and on the performance of the antenna, both radius of the circular ring slot r and the length of inverted U-shaped slot U in terms of voltage standing wave ratio VSWR, each parameter is varied while the other one is kept constant. All simulation are performed using the IE3D commercial software.

First, when the radius r is increased from 3mm to 6mm as shown in Fig.(3) which represents the simulated VSWR of the proposed structure for different values of r, the center frequency is decreased from 3GHz to 5GHz . This means that the length of the ring and the center frequency of the rejected band are inversely proportional which agrees with equation (1). The value of r to properly reject the WiMAX band is 4mm. After that, the length of the inverted U-shaped slot U is increased from 2mm to 5mm which results in decreasing the center frequency of the rejected band from 10.5GHz to 5.5GHz as shown in Fig.(4), so the appropriate value of U to reject the WLAN band is 5mm.

The optimum dimensions of the proposed UWB antenna and the filtering structure are presented in table 1.

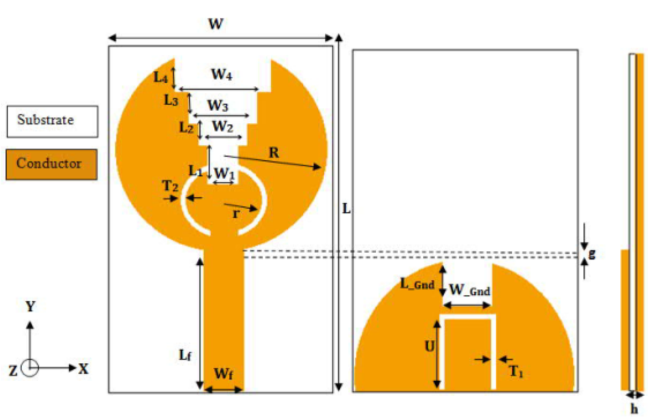

Fig. 1. Geometry of the proposed dual band notch antenna.

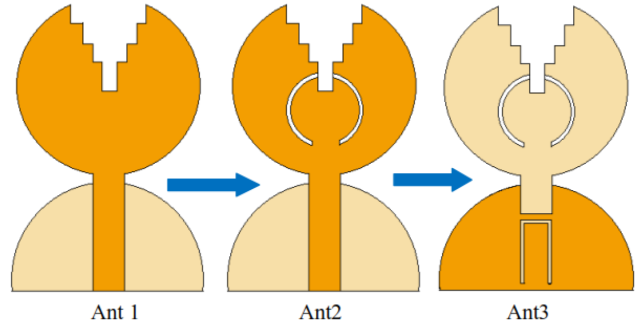

Fig. 2. Design steps of the first proposed dual band notched UWB antenna.

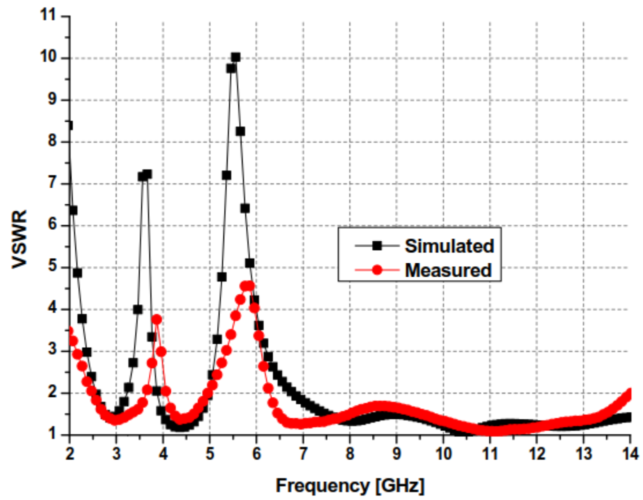

Fig. 3. Simulated VSWR versus frequency of the proposed structure for various r.

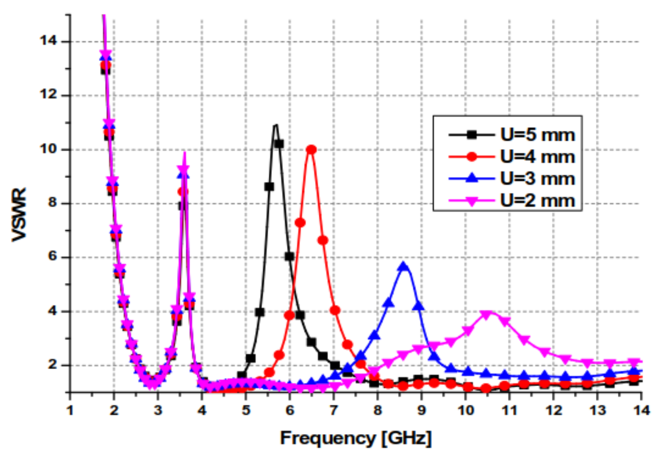

Fig. 4. Simulated VSWR for different antenna structures.

Fig.(5) represents the simulated VSWR of UWB antenna without notch characteris-tics (named Ant1) where the condition VSWR < 2 is satisfied from 2.5GHz up to 12GHz which means that the FCC spectrum is widely covered. For Ant2, it is clear that the $VSWR > 2$ for 3.3 – 3.7GHz, that means a single band notch is achieved. The last antenna (named Ant3), there is dual band notches where the $VSWR > 2$ from 3.3–3.7GHz and from 5.2–7GHz. To

TABLE 1
Conductivities and time constants of the soil components studied.

Parameter	Value (mm)	Parameter	Value (mm)
W	23	T_1	0.5
L	32	T_2	0.2
R	10	W_1	2
g	0.5	W_2	4
W_f	3	W_3	6
L_f	12	W_4	8

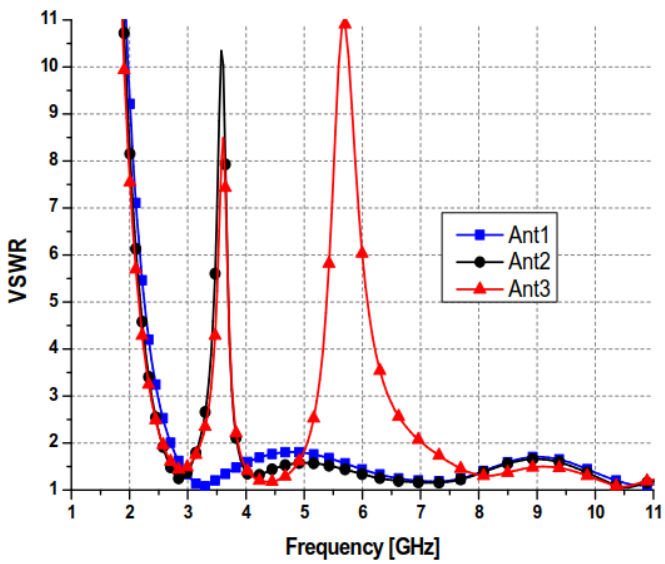

Fig. 5. Simulated surface current distributions at (a)3.5GHz and, (b)5.5GHz.

further inspect the operating mechanism of the proposed antenna namely Ant3 and the effect of both circular ring and inverted U-shaped slots, the current distribu-tions are simulated at both center frequencies of the notched bands 3.5GHz and 5.5GHz as depicted in Fig.(6). It is observed that the current flow is mainly concentrated around the filter structure (interior, exterior circular shaped and inverted U-shaped slots) and they are oppositely directed between the interior and exterior edges. The resultant radiated field cancel out and provides high attenuation near the notch which guarantees that the WiMAX and WLAN band are well filtered.

4 Fabrication and Measurement

To validate the simulation results, the proposed UWB antenna was fabricated and tested as shown in Fig.(7). The fabricated structure performances were measured using a Rohde & Schwarz R&S®ZNB vector network analyzer (VNA) operating in the frequency band 100kHz–-20GHz.

The measured and simulated VSWR are presented in Fig.(8). It can be observed that the measured and simulated results are in good agreement and the proposed structure covers the whole UWB band from 2.5GHzto 14GHz. Furthermore, Two band notches are realized 3.4–4.1GHz and from 5–6.3GHz to suppress interferences with WiMAX and WLAN .Basically, there is a small variation in the measured results which is possibly due to manufacturing tolerances, change of substrate constant and the SMA port mismatch.

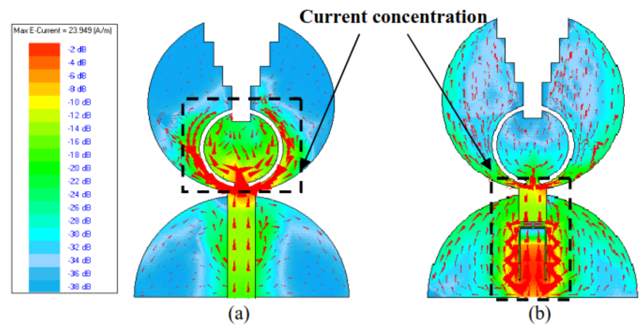

Fig. 6. Fabricated prototype of the first proposed dual band notched UWB antenna

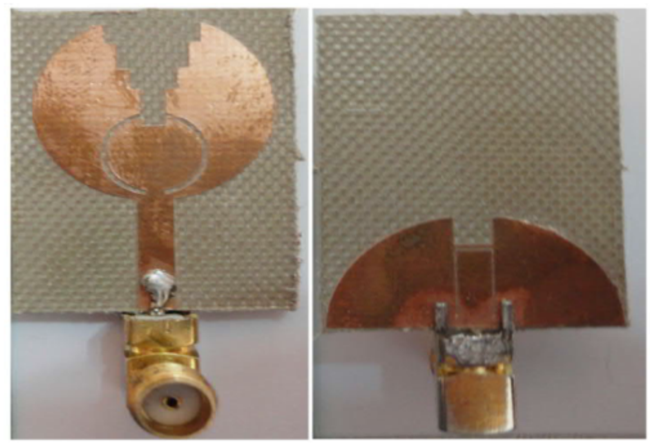

Fig. 7. Simulated and measured VSWR of proposed dual band notched UWB antenna

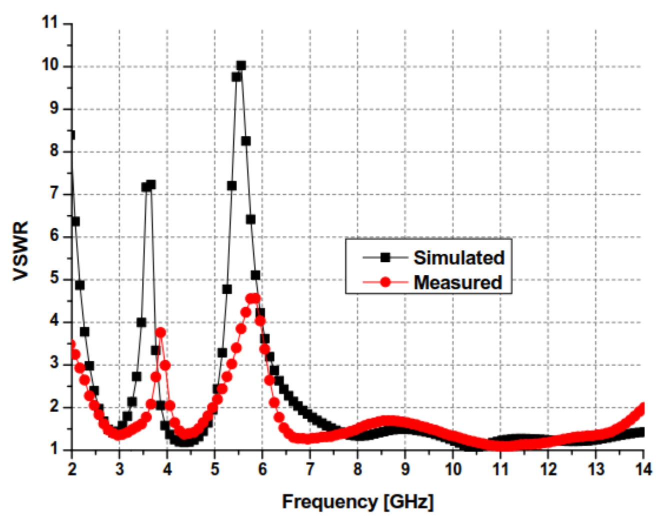

Fig. 8. Fabricated prototype of the first proposed dual band notched UWB antenna

The measured and simulated radiation patterns in the E-plane and H-plane at the frequencies of 4.5GHz and 9.1GHzof the UWB band are illustrated in Fig.(9). The radiation patterns in the H-plane (yz plane) are nearly omnidirectional for three frequency bands and monopole radiation in the E-plane (xz plane). The peak gain with and without band notches are presented in Fig.(10) where the

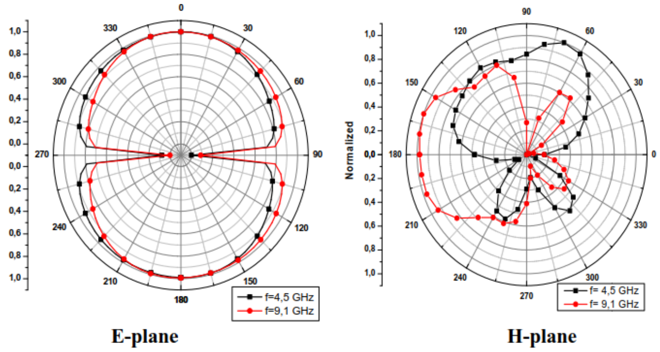

Fig. 9. Measured gain of the first proposed dual band notched UWB antenna.

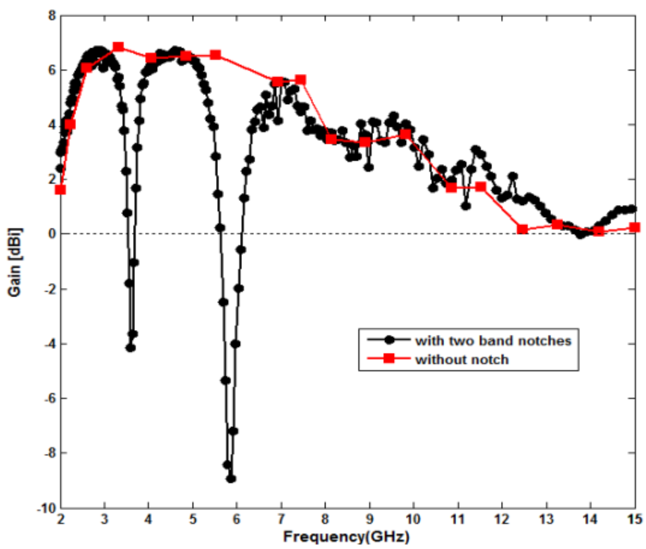

Fig. 10. Measured gain of the first proposed dual band notched UWB antenna.

gain varies from 2dBi to 7dBi.

5 Conclusion

A dual band notch UWB antenna has been designed, fabricated and tested. In this proposed design, two types of slots have been used to reject both WiMAX and WLAN bands in order to reduce interferences. The length of the slots controls the centre frequency of the rejected band which is verified by carrying a parametric study.The measured results have shown a satisfactory agreement with the simulated ones. The developed antenna covers the frequency band from 2.5GHz to 14GHz with two rejected bands are realized 3.4–4.1GHz and from 5–6.3GHz.It exhibits good radiation patterns in both E and H-planes and high gain about 7dBi. Thus, these interesting characteristics make the proposed antenna suitable for the intended application.

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