



A New Ultra Wide Band Antenna Design with Dual Band for WLAN and WiMAX Applications

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Abstract. In this paper, a compact microstrip-fed planar ultra-wideband (UWB) monopole antenna with dual band for Wireless Local Area Network (WLAN) and worldwide interoperability for microwave access (WiMAX) application is presented. The proposed design consists of a circular radiating patch and a partial ground plane. A T-shaped slot resonator and four rectangular shaped slot resonators are respectively etched in the radiating patch and partial ground plane for WiMAX band (3.3–3.8 GHz) and WLAN band (5.1–6 GHz). The proposed antenna is printed on the FR4 substrates and is optimized by ANSOFT High Frequency Structure Simulator (HFSS).

Keywords: UWB antenna · WLAN · WiMAX · T-shaped slots · Slotted ground pane

1 Introduction

Since the Federal Communication Commission (FCC) allocates rules for the commercial use of ultra-wideband (UWB) in 2002 [1], the feasible design and the implementation of UWB system becomes a very competitive topic for both academic and industrial communities of telecommunications.

In particular, as a key component of the UWB system, an extremely broadband antenna will be launched in the frequency range from 3.1–10.6 GHz, which has attracted significant research power in the recent years [2]. The major Challenges of a UWB antenna design include the UWB performances of the impedance matching, radiation stability, the compact appearance of the antenna size, and the low manufacturing cost for consumer electronics applications [3].

However, the frequency spectrum of UWB systems will cause interference to the existing WLAN (Wireless Local Area Network) and WiMAX (Worldwide interoperability for Microwave Access) networks operating, respectively, at 5.1–6 GHz and 3.3–3.8 GHz. Thus, the best antenna for dual band applications should have dual bands at (3.3–3.8 GHz) and (5.1–6 GHz) to avoid interference. Some antennas with this characteristic have been reported in the published literature [4]. A recent report [5] describes an antenna designed by the use of the slots to obtain dual band characteristic.

The multi-band antennas have aroused high interest in recent years for its application to multimode communication systems [6, 7]. Printed monopole antennas are very popular candidates for these applications, because of their low cost and process simplicity. The currently popular designs suitable for WLAN operation in the 5.2/5.8 GHz (5.15–5.35 GHz/5.725–5.825 GHz) bands and the WiMAX applications (3.3–3.8 GHz) have been reported in [8, 9].

In this paper, a novel dual-band circular antenna is proposed in the first part. In the second part, a dual-band is also achieved by embedding T-shaped inserted in the radiation patch and modified four rectangular slots in the ground plane.

2 Antenna Configuration

The geometry and the configuration of the proposed antenna with partial plane is illustrated in Fig. 1. The antenna is fed with a 50 Ω micro-strip line and fabricated on the FR4 substrate with a thickness of 1.6 mm and a relative permittivity of 4.4. The shape of the radiating element is circular with a radius of “R” and a modified ground plane with four rectangular slots. The radiator fed by a micro-strip line is printed on the top side of the substrate, while the partial ground plane of size W * G is printed on the bottom side of the substrate. The radiating element is fed by 50 Ω micro-strip transmission line and has a center width $w = 3$ mm, which is terminated with a sub miniature A (SMA) connector for measurement purposes.

On the bottom of the antenna, four rectangular slots are embedded on the partial ground plane. The gap between the radiating patch and ground plane is h. T-shaped slot is etched on the element radiation.

3 Antenna Design and Parametric Study

3.1 UWB Monopole Antenna Configuration

The T-slot is embedded in the radiating patch in order to get an UWB can yield an ultra wideband. A circular monopole is used as the base antenna [10] and to obtain better

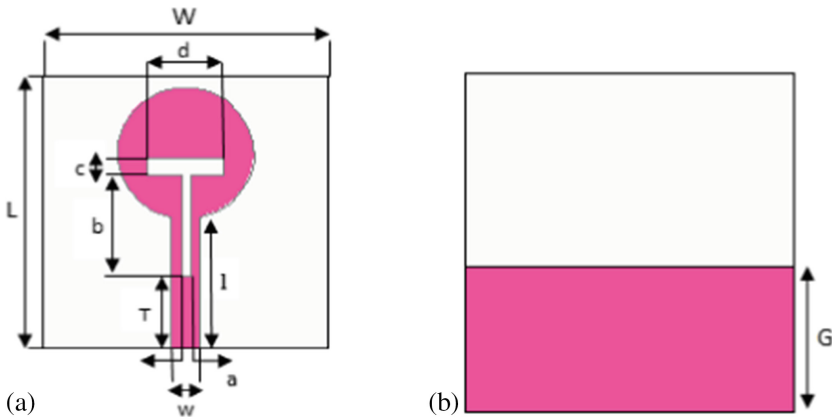


Fig. 1. Geometry of the proposed antenna UWB: (a). front view; (b). back view.

VSWR performance over the whole UWB band. Recently, it was demonstrated in [11] that by etching T slot in the radiation patch, the total bandwidth of the monopole antenna can be significantly increased up to 128%. As a result, by inserting a T-shaped slot at the radiating patch and carefully adjusting their parameters (a, b, c, T and d) as shown in Fig. 1, additional resonance can be excited and hence much enhanced impedance bandwidth may be achieved.

The optimum dimensions of designed antenna are shown in Table 1 below.

Table 1. Design specification of the proposed antenna.

Parameters	Values
h	1.6
W	30
L	30
w	3
l	14.5
a	1
b	11
c	2
d	8
G	12.8
e	2
f	9
m	4.8
n	2
g	1
T	8

The proposed antenna structure is simulated using finite element method (FEM) software, HFSS. The return losses S11 for different values of ‘T’ and ‘b’ are shown in Figs. 2 and 3, respectively. It can be seen that the return loss curves have similar shapes for different values of the parameters at low frequencies, but the high-frequency impedance matching and positions of the higher resonances change significantly with the variation of each parameter.

Figure 4 shows the return loss of the proposed antenna with and without slots. We note that this is an ultra-wideband antenna with a bandwidth between 2.7 GHz and 13 GHz. Two resonance modes are observed, one centered around 3.61 GHz and the other around 11.35 GHz. The presence of these resonances can be explained by the presence of the T-shaped slot.

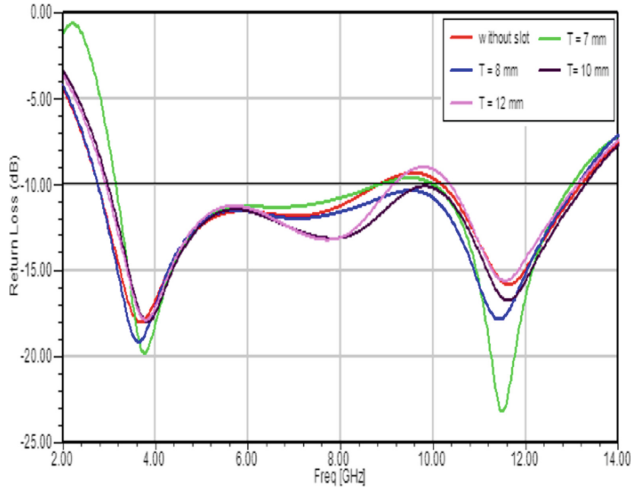


Fig. 2. Simulated return losses for different values of T with fixed values of $a = 1$ mm, $b = 11$ mm, $c = 2$ mm, and $d = 8$ mm.

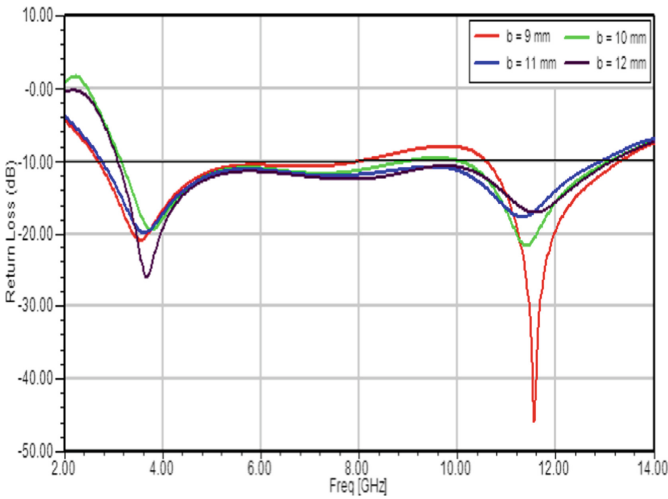


Fig. 3. S_{11} parameter for different values of b with fixed values of $a = 1$ mm, $T = 8$ mm, $c = 2$ mm, and $d = 8$ mm.

Figure 5 shows the antenna’s peak gain in the frequency range from 2–14 GHz for the proposed UWB antenna. We can observe that the significant antenna gain increase at 3.61 GHz and 11.35 GHz indicate the effect of band function clearly.

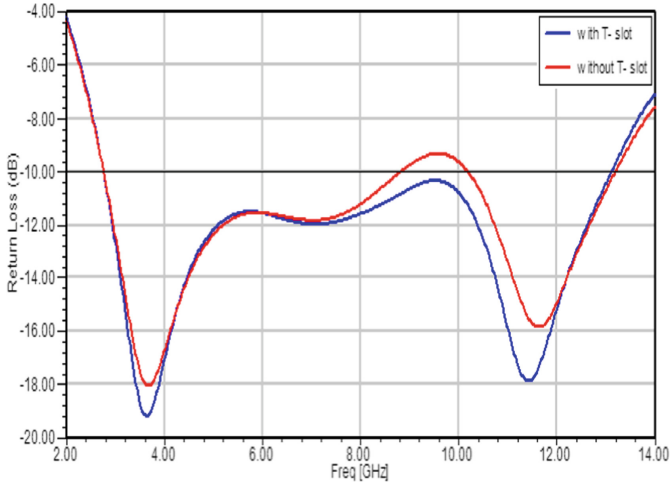


Fig. 4. Simulated return losses of the proposed antenna with and without T-shaped slot. The optimized parameters of the T-slot are: $a = 1$ mm, $b = 11$ mm, $c = 2$ mm, $d = 8$ mm and $T = 8$ mm.

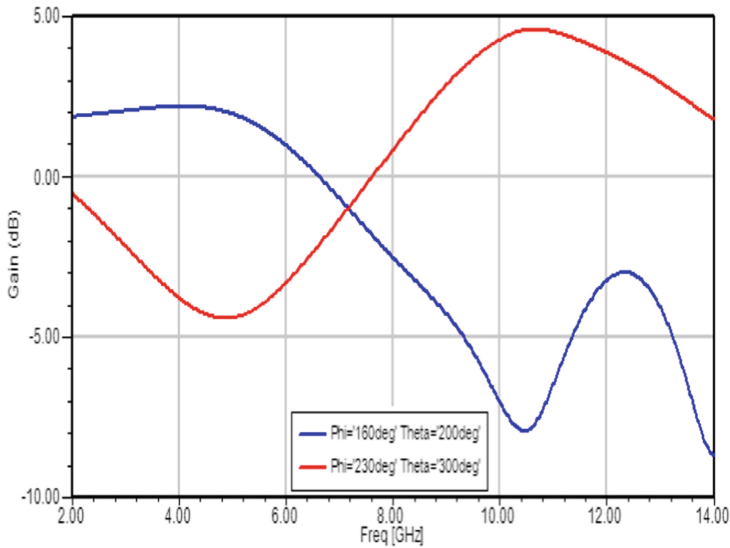


Fig. 5. Simulated gain of the proposed UWB antenna.

Two principal planes are selected to present the radiation pattern of the proposed antenna (Fig. 6). These are called E plane ($\varphi = 0$) and the H plane ($\varphi = \pi/2$). Figure 6 shows the radiation patterns in the H-plane and E-plane of the proposed antenna at frequency 3.61 GHz, 7 GHz and 11.35 GHz. We can see that the radiation patterns in the E plane are nearly almost omni-directional for the two frequencies 3.61 GHz, 7 GHz

and bidirectional for 11.35 GHz. H-plane, the radiation pattern is bidirectional and as a dipole antenna.

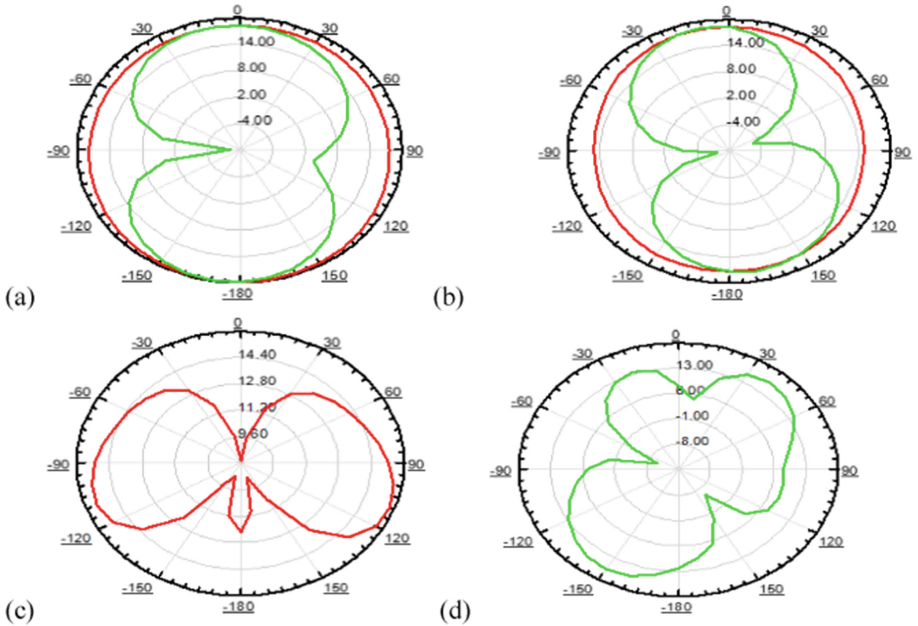


Fig. 6. Simulated radiation patterns of the proposed UWB antenna in the E plane and the H plane at (a). $f = 3.61$ GHz, (b). $f = 7$ GHz, (c, d). $f = 11.35$ GHz.

3.2 Single and Dual Band Antenna

The rapid development of wireless communication urges the need of antennas covering multiple bands with good radiation characteristics. Thus, many researchers have been paying much attention to design this kind of antennas. Wide-band antenna and multi-band antenna designs have become very important for wireless communications. In [12], by the presence of an L-shaped parasitic strips, three resonant modes of the antenna for the 2.6/3.5/5.5 GHz-bands can be excited to meet the WiMAX system. By introducing dual U-shaped strips, multi-resonant modes for WiMAX applications are proposed in [13]. In [14], with the inclusion of an additional small radiation patch, a dual-band antenna designed from 3.1 to 10.6 GHz out of the band 5.0–6.0 GHz can be achieved.

In this section, a novel printed monopole antenna with dual-band is presented to satisfy WLAN (5.1–6 GHz) and WiMAX (3.3–3.8 GHz) applications (Fig. 7). The antenna structure consists of a circular monopole with a micro-strip feed-line and a partial ground plane.

Figures 8, 9 and 10 show the simulated return loss of the proposed antenna with different parameters which affect the dual band characteristics. We can observe that the proposed antenna provides the dual band in the frequency range of 2.6–3.8 GHz with a

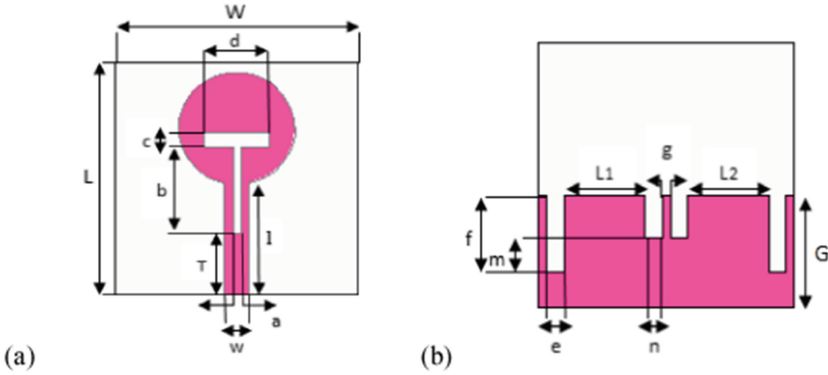


Fig. 7. Geometry of the proposed dual-band antenna: (a). front view; (b). back view

return loss value of about -15.43 dB and $4.5\text{--}8.7$ GHz with a return loss value of about -30.2 dB.

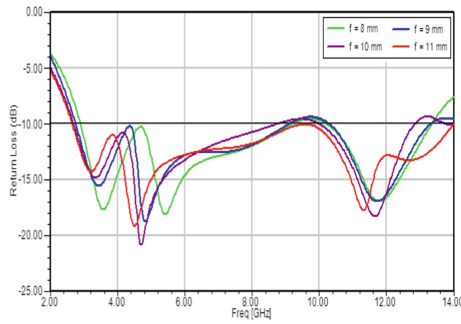


Fig. 8. Simulated return losses for different values of f with fixed values of $e = 2$ mm.

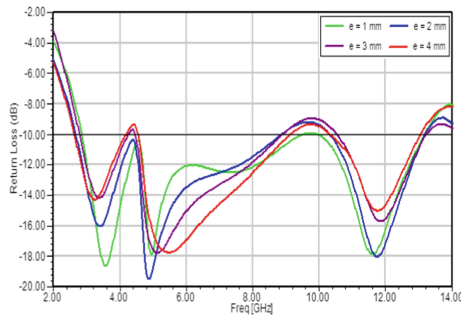


Fig. 9. Simulated return losses for different values of e with fixed values of $f = 9$ mm.

Figures 11, 12, 13 and 14 show the simulated return loss of the proposed antenna with different parameters which affect the dual band characteristics.

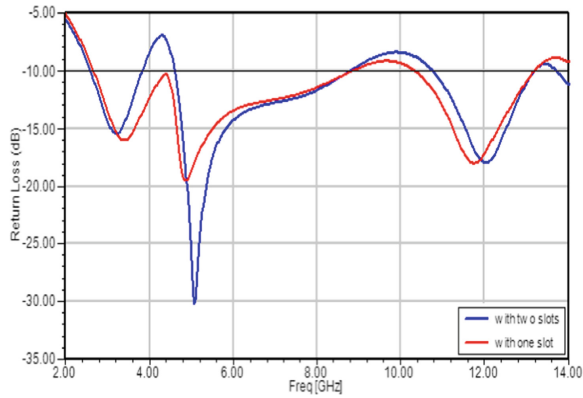


Fig. 10. Simulated return losses of the proposed antenna with one and two slots.

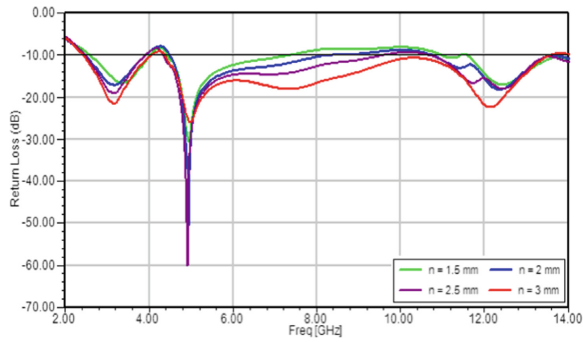


Fig. 11. Simulated return losses of different values for the first slot of n , $m = 4.8$ mm.

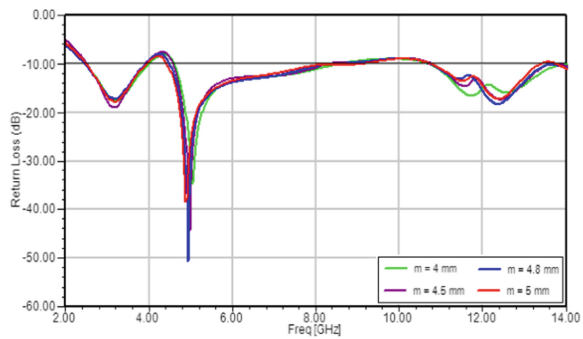


Fig. 12. Simulated return losses of different values for the first slot of m , $n = 2$ mm.

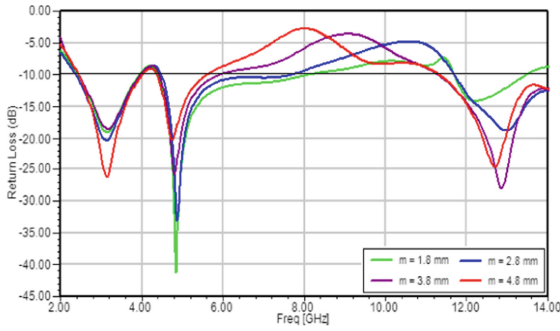


Fig. 13. Simulated return loss of different values to the second slot of m , $n = 2$ mm.

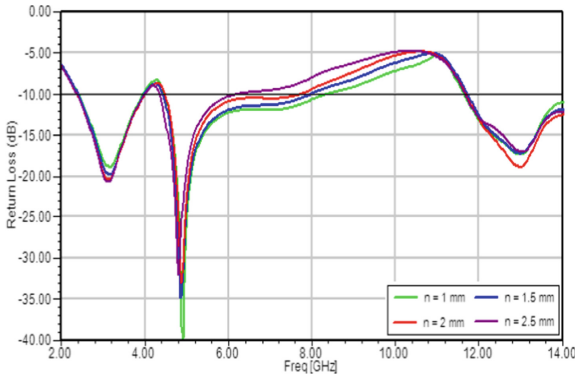


Fig. 14. Simulated return loss of different values to the second slot of n , $m = 2.8$ mm.

From Fig. 15 we observe the simulated VSWR of the dual band antenna with slots. The $VSWR \leq 2$ for the proposed antenna is from 3 to 3.4 GHz and 4.7 to 5.1 GHz.

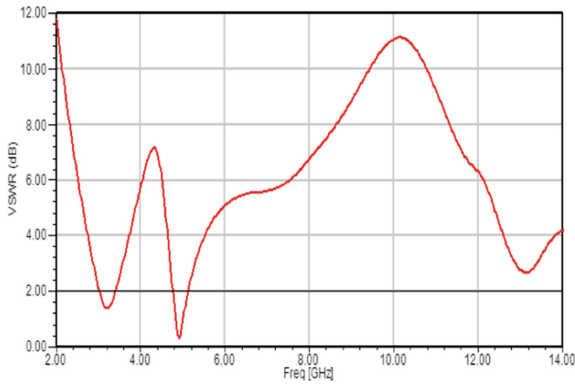


Fig. 15. Simulated VSWR of the proposed antenna.

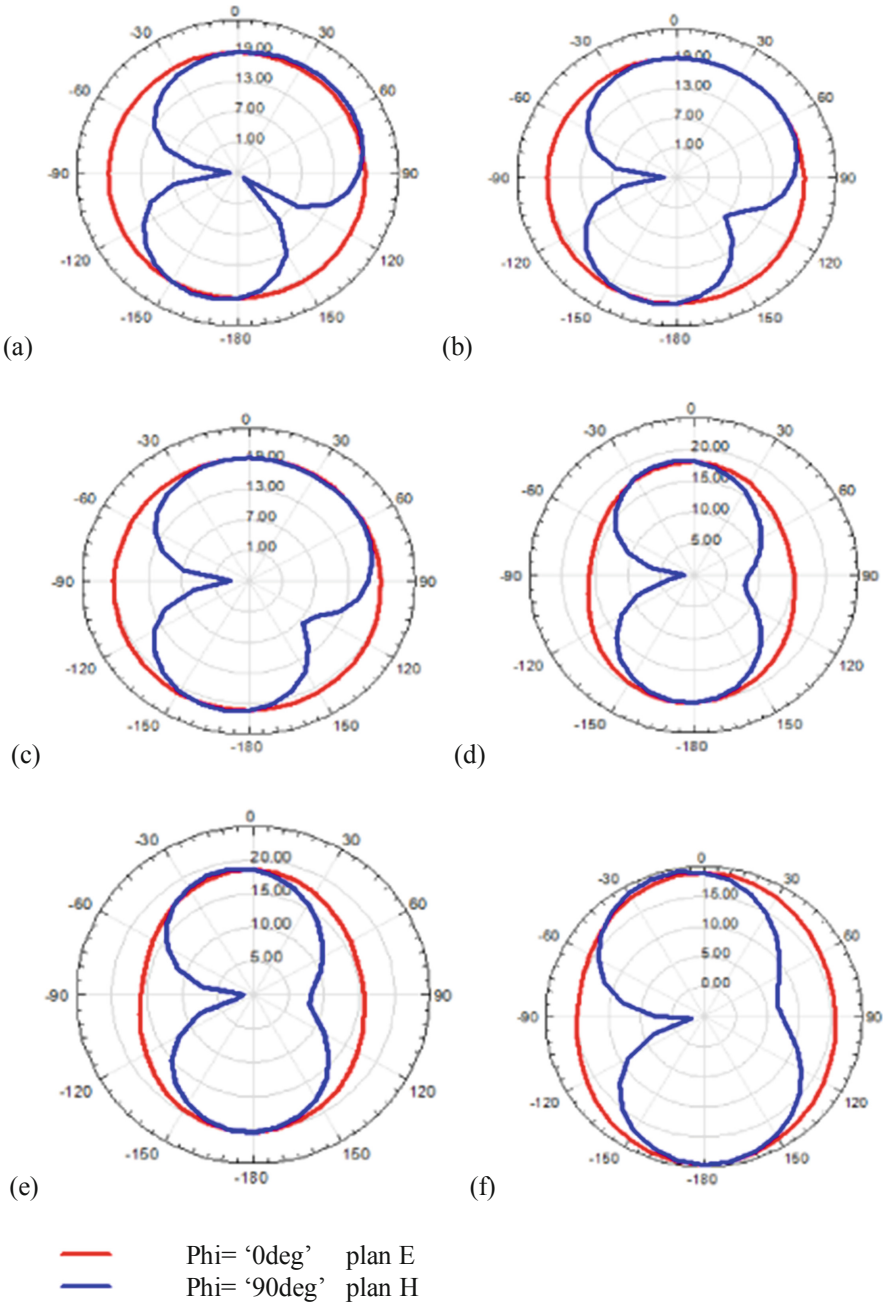


Fig. 16. Simulated radiation patterns of the proposed antenna in the E plane and the H plane at (a). $f = 2.5$ GHz, (b). $f = 3.2$ GHz, (c). $f = 3.3$ GHz, (d). $f = 4.9$ GHz, (e). $f = 5.1$ GHz, (f). $f = 5.82$ GHz.

Two principal planes are selected to present the radiation pattern of the proposed antenna. These are called E plane ($\varphi = 0$) and the H plane ($\varphi = \pi/2$). Figure 16 shows the radiation patterns in the H-plane and E-plane of the proposed antenna at frequency 2.5 GHz, 3.2 GHz, 3.3 GHz, 4.9 GHz, 5.1 GHz and 5.82 GHz. We can see that the radiation patterns in the E plane are almost omni-directional for the three frequencies. H-plane, the radiation pattern is bidirectional and as a dipole antenna.

Figure 17 shows the antenna’s peak gain in the frequency bands of 2–14 GHz for the proposed antenna. We can observe that the significant antenna’s gain increase at 3.3 GHz and 5.1 GHz clearly indicates the effect of band function.

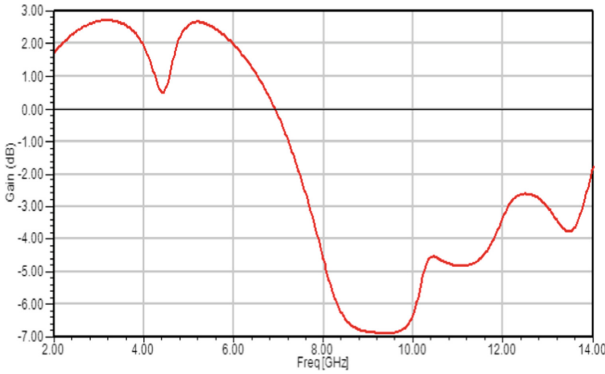


Fig. 17. Simulated gain of the proposed dual band antenna.

Figures 18 and 19 show the simulated return losses for the proposed antenna with varying T, L1 and L2.

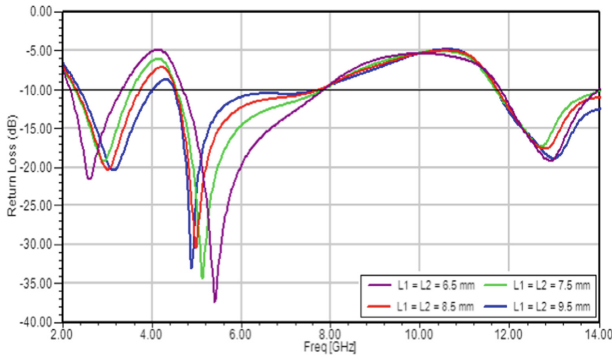


Fig. 18. Simulated return losses of different values of L1 and L2.

Figure 19 shows that the center frequency of the dual band at 3.2 GHz and 4.9 GHz is increased as T decreases. Furthermore, we can observe in Fig. 18 that the length of T obviously affects the impedance matching. The simulated impedance of the proposed

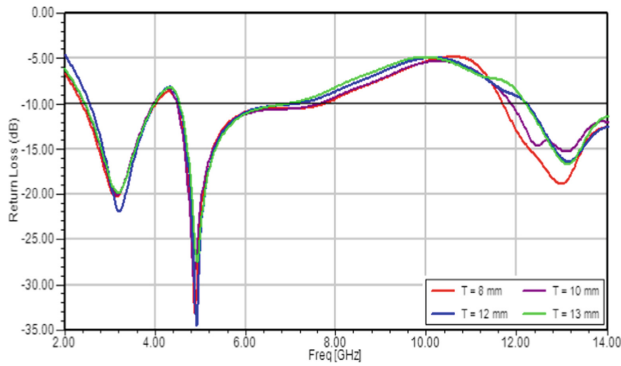


Fig. 19. Simulated return losses of different values of T .

antenna shows that the return loss decreased in the WiMAX and WLAN bands. By properly tuning the dimensions $L1$, $L2$ and spacing T . It is empirically found that band broadening can be optimized with choosing the dimensions: $T = 12$ mm, $L1 = 9.5$ mm and $L2 = 9.5$ mm.

Figure 20 shows the simulated return loss of the proposed antenna with the optimal parameters which affect the dual band characteristics. We can observe that the proposed antenna provides the dual band in the frequency range of 2.5–3.99 GHz with a return loss value of about -22 dB and 4.5–6.6 GHz with a return loss value of about -34.44 dB.

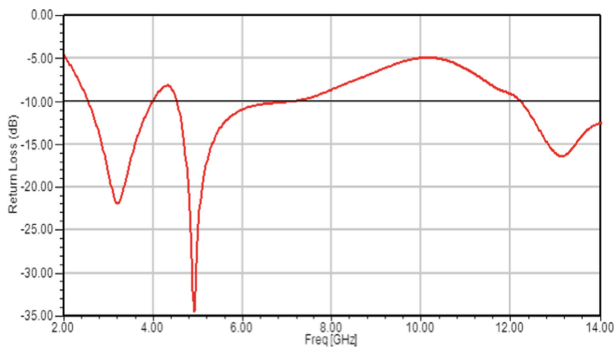


Fig. 20. Simulated return losses of the final proposed antenna.

After completing the parametric study of the proposed antenna, we present in Fig. 20, the final optimization of S_{11} for the base and the proposed antenna. The antenna in the circular patch with slots allows getting a dual band antenna. For the obtained antenna, we get two modes of resonance centered on the 3.2 GHz frequency and 4.9 GHz.

In Fig. 21, we represent the variations of the reflection coefficient S_{11} by using both the software HFSS and CST to validate our results.

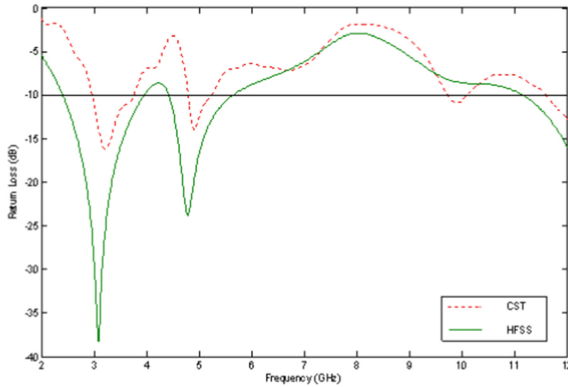


Fig. 21. Return loss for the antenna design, from 2 to 12 GHz.

4 Conclusions

A new design of a compact planar circular antenna's ultra wide band antenna with dual band for WLAN and WiMAX has been proposed and discussed. The circular patch antenna ring ultrawide-bandwidth radiating between 2.7 GHz and 13 GHz, a wide impedance bandwidth 131%. Dual bands antenna is achieved by etching four rectangular slots on the partial ground plan and a T-shaped slot in the radiation element. It has a dual bands frequency with 2.5–3.99 GHz and 4.5–6.6 GHz (WLAN and WiMAX technology). The proposed antenna indicates not only a dual band frequency but also a good radiation performance, while retaining the small volume of $30 \text{ mm} \times 30 \text{ mm} \times 1.6 \text{ mm}^3$. These features are very attractive for WLAN and WiMAX applications.

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