An Improved CPW-Fed Printed UWB Antenna With Controllable Band-notched Functions

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***Abstract*— A newly designed printed slot antenna is presented that incorporates variable two band-notched functions for ultra-wideband (UWB) applications. The two band notches of this coplanar waveguide (CPW) fed antenna are achieved by an M-shaped slot (MSS) embedded in the radiating element and a C-shaped strip (CSS) close to ground plane, therefore two very narrow rejected properties in the wireless local area network (WLAN) band (5.15-5.825 GHz) and worldwide interoperability for microwave access (WiMAX) operation in the (3.3-3.7GHz) are obtained. The rectangular aperture is etched in the square ground plane. It has a determinative role in antenna's impedance bandwidth (IBW) enhancement; moreover, by adjusting carefully it leads to wide IBW. Based on simulated results it covers the frequency range 2.4–12.9 GHz with VSWR ≤ 2, which corresponds to a fractional bandwidth of 137% excluding the rejected bands. Numerical and measured results are presented to understand its behavior. The volume of the proposed antenna is 25 × 25 × 0.8 mm^3.**

***Index Terms*—** Slot antenna; ultra-wideband antenna; WLAN; WiMAX; band-notched function

I. INTRODUCTION

In recent years, the development of ultra-wideband (UWB) antennas facilitating high data transmission rates and low power consumption, and simple hardware configuration in communication application has received attention [1–17]. The Federal communication commission (FCC) allocated the frequency band 3.1– 10.6 GHz for commercial UWB systems in 2002 [2,13,14].

Despite the approval of the FCC for the UWB to operate 3.1– 10.6 GHz, it may be necessary to avoid potential interferences with other existing communication systems, such as Worldwide Interoperability for the Microwave Access (WiMAX) operating at 3.3–3.7 GHz; Wireless Local Area Network (WLAN) is operated at 5.15–5.825 GHz [3–11]. Therefore, UWB antenna with notched characteristics at these frequency bands is required. The conventional methods are cutting a slot (U-shaped, arc shaped, T-shaped slot) on the patch [5,9]. Inserting a slit on the patch [14], another way is

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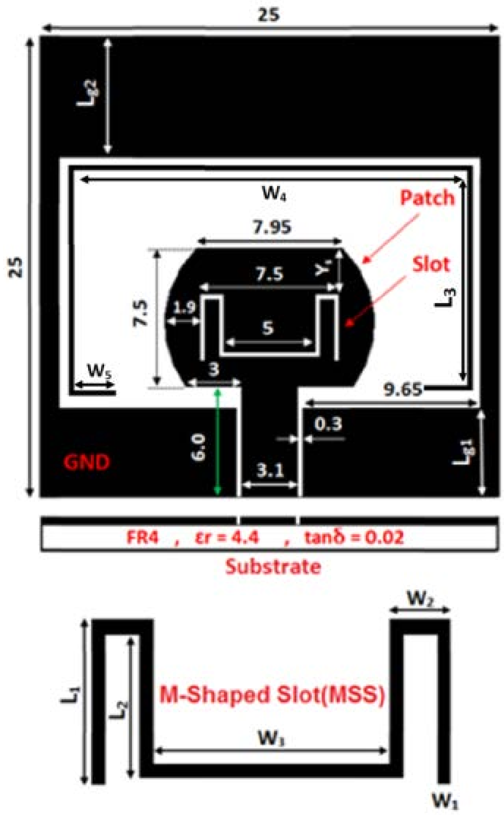

Fig.1. Geometry of the proposed antenna, L_{g1} = 4.8, L_{g2} = 6.5, Y_s = 2.5, L_1 = 3.6, L_2 = 3.4, L_3 = 13, W_1 = 0.25, W_2 = 1.25, W_3 = 5, W_4 = 22 and W_5 = 2. (Optimized dimensions in mm).

putting parasitic elements as filters are existing to reject the electromagnetic interference (EMI). In this letter, we describe a cpw-fed UWB antenna with dual band-notched characteristic. To achieve the two notched frequency bands, a M-shaped slot (MSS) embedded in the radiating element and a C-shaped strip(CSS) close to ground plane are used. Numerical and experimental results are presented to understand its behavior. The simulated and measured results show that the proposed antenna has a wide impedance bandwidth, omnidirectional patterns, and dual band-notched characteristics.

II. ANTENNA DESIGN AND SIMULATION

Fig. 1 shows the configuration of the proposed UWB monopole antenna which consists of 50Ω CPW transmission line and a strip width of 3.1mm with gap width of 0.3mm. An antenna structure consists of a semi-circle exciting stub with MSS and an inverted CSS near the top edge of the aperture. Two main factors that have been aimed in the proposed antenna design are:

I) achieving wide impedance bandwidth

II) filtering the WLAN& WiMAX bands.

For the first purpose, based on electromagnet coupling theory, the rectangular aperture inside the ground plane is playing an important role in the broadband characteristics of this antenna, because it

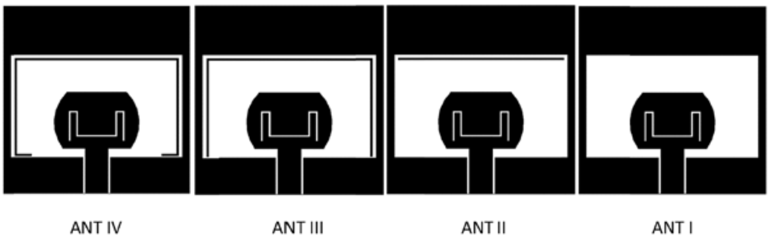

Fig. 2. Design procedure of inverted C-shaped strip in the proposed antenna

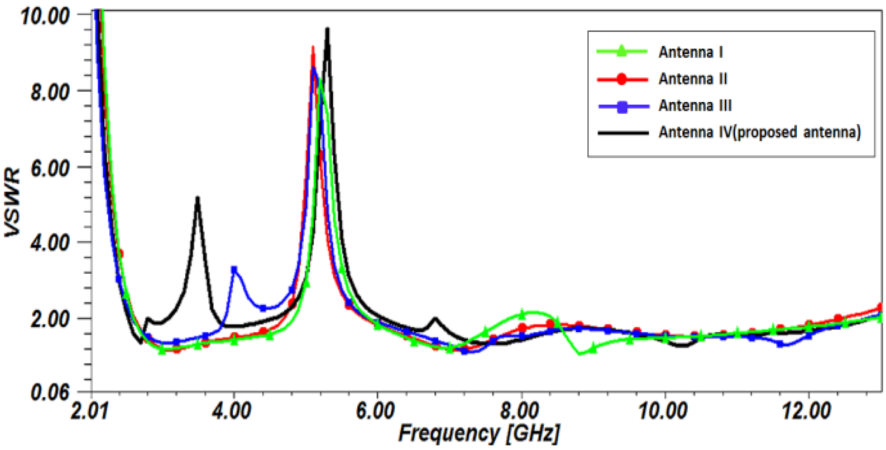

Fig. 3. VSWR responses for the antennas shown in Fig.2

can adjust the electromagnetic coupling effects between the feed-line, patch and the ground plane, and improves its impedance bandwidth without any cost of dimension or expense. In this design, each band-rejected structure of the MSS and inverted CSS is able to provide a single filtering frequency in a certain band and functions as a first order stop filter.

The proposed antenna is constructed from FR4 substrate with thickness of 0.8 mm and relative dielectric constant of 4.4. The antenna's dimensions are 25 mm × 25 mm. The commercial simulation tool Ansoft HFSS was employed to analyze and optimize the design [18].

Fig. 2 presents the design procedure of inverted CSS in the proposed antenna(ANT IV). VSWR plot for the four antennas shown in Fig. 2 is presented in Fig. 3. It is clear that complete CSS cause effective band rejection round 3.5 GHz. It is necessary to control the notched bandwidth to achieve an effective band-notched function in an UWB antenna. Therefore, the rejected bandwidths via the parameters of the band-notched structures are investigated. The variable band-notched characteristics can be controlled by MSS parameters [14].

The proposed antenna's characteristics were investigated by changing one of its parameters at a time, while keeping fixed all others. In this structure the L_1, W_1 and W_3 are critical parameters to control the band-notched and its center frequency. Fig. 4 describes that increasing the L_1, the rejected bandwidth moves to lower frequencies but increasing the W1, the band stop center frequency

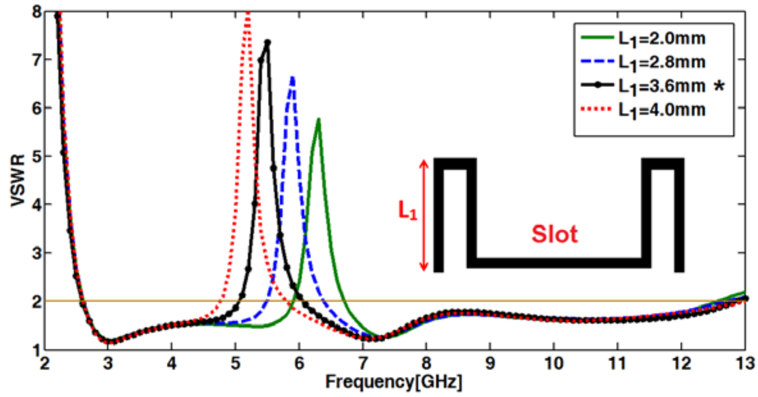

Fig. 4. VSWR responses as a function of L_1 with MSS and without CSS

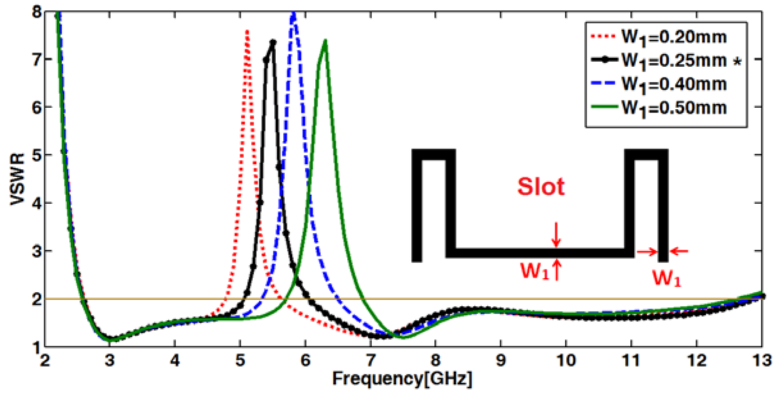

Fig. 5. VSWR responses as a function of W_1 for proposed antenna with MSS and without CSS

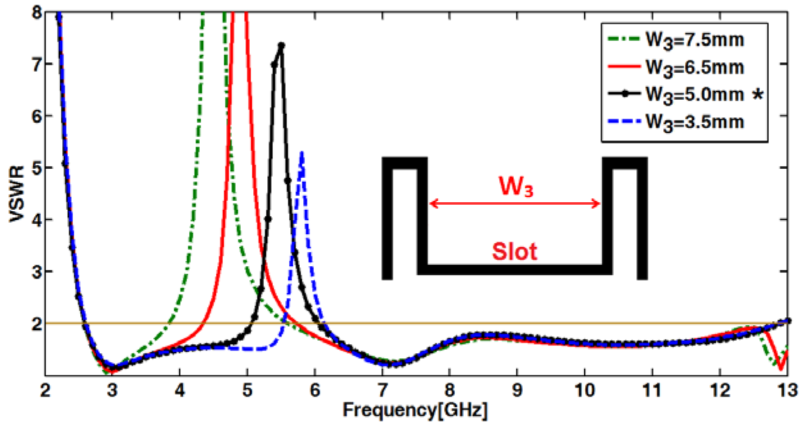

Fig. 6. VSWR responses as a function of W_3 for proposed antenna with MSS and without CSS

moves to higher frequencies, and larger W_3 causes the rejected bandwidth shifts to lower frequencies which are presented in Fig. 5 and Fig. 6, respectively.

Furthermore for creating band-notch function for WiMAX system (3.1-3.7GHz) as clearly illustrated in Fig. 1, the CSS is embedded near the top edge of the aperture. Embedding the CSS, leads to capacitance enhancement, thus saving energy instead of propagating it to hence realize the stop

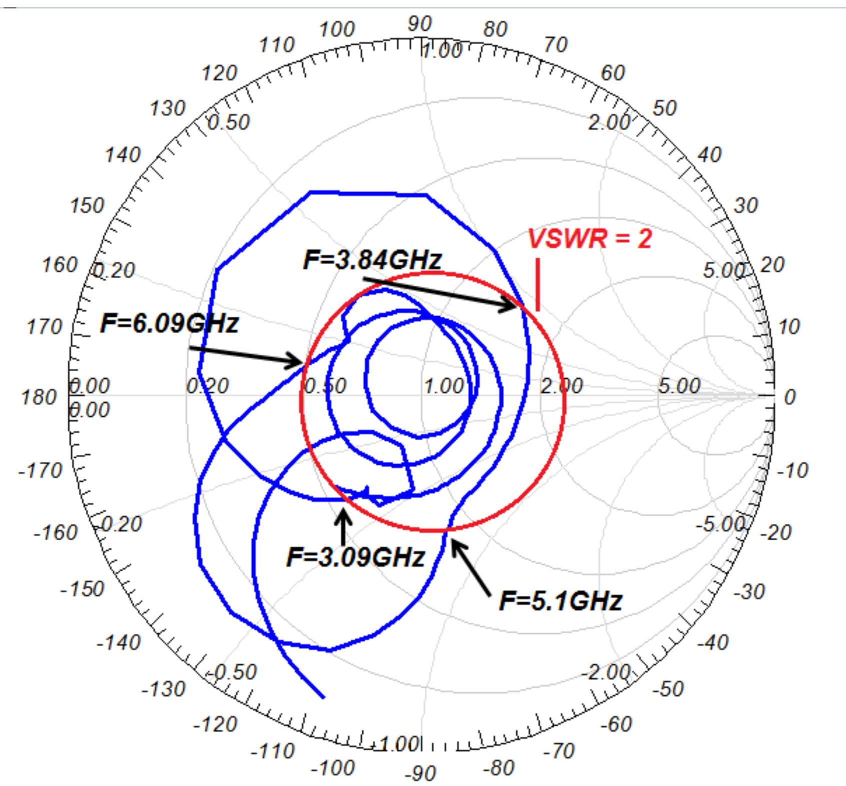

Fig. 7. The simulated input impedance on a Smith chart of the antenna

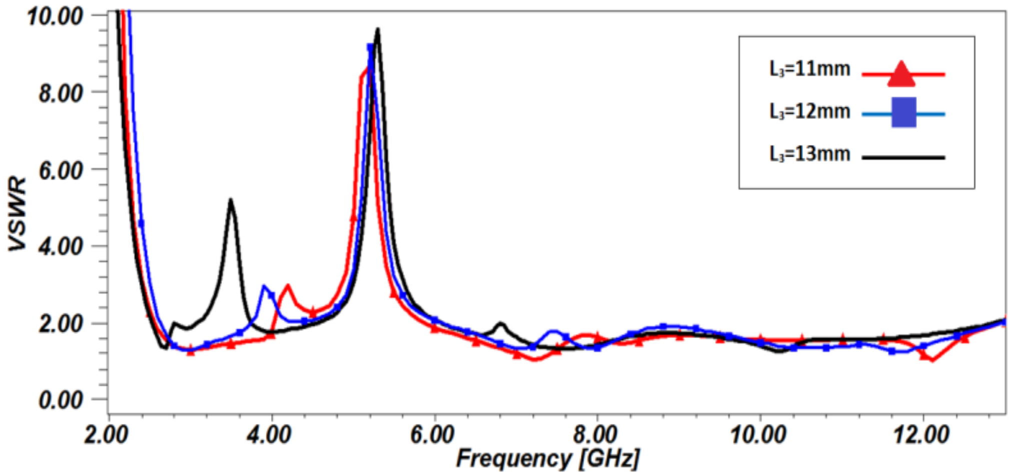

Fig. 8. VSWR responses as a function of W_3 for proposed antenna with CSS and MSS

band. The CSS perturbs the resonant response and also acts as a half-wave resonant structure. This phenomenon can be understood using the Smith Chart plotted in Fig. 7.

The parameter L_3 is the effective parameter to control the first notched bandwidth,to know how the parameter L3 affects the first notched band width, simulated VSWR curves with different values for L3 are shown in Fig. 8. It is clear that with tuning the length of the L_3, suitable notched band for WiMAX (3.3–3.6 GHz) can be obtained. Changing L_3 creates additional surface current

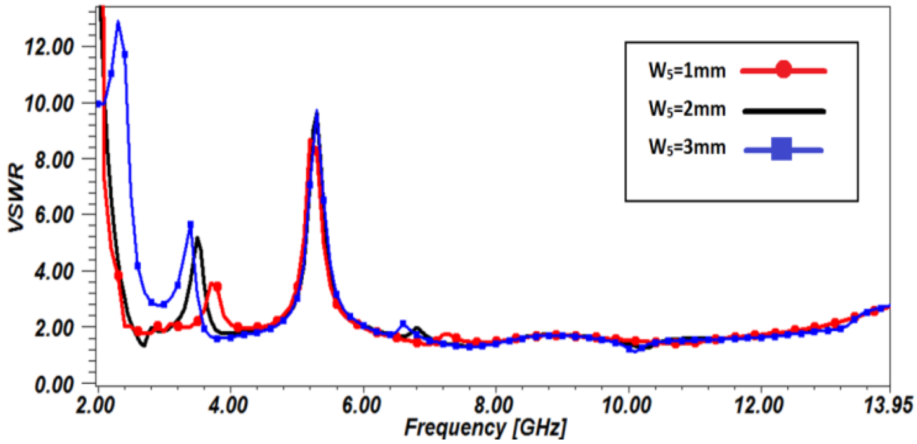

Fig. 9. VSWR responses as a function of W_5 for proposed antenna with CSS and MSS

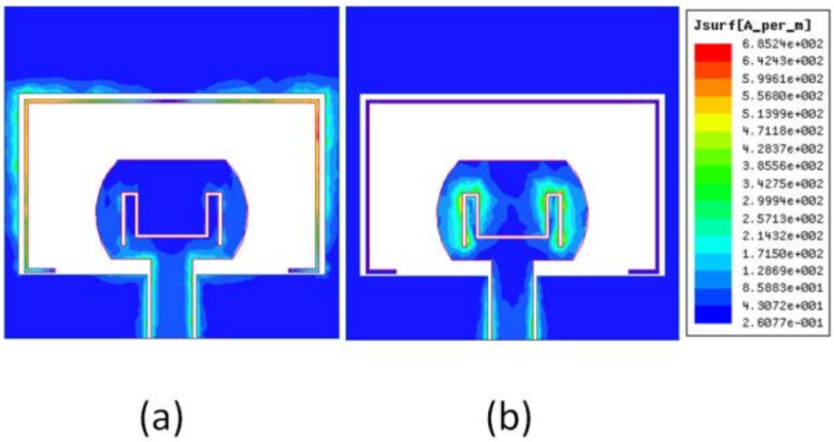

Fig. 10. Surface current distributions at (a) 3.5 GHz and (b) 5.5 GHz

paths in the antenna. Moreover, this CSS structure changes the inductive and capacitive nature of the input impedance, which in turn leads to band rejection on antenna IBW.

Also, the parameter W_5 is basic parameter to control the first notched band, simulated VSWR curves with various values for W_5 are also shown in Fig. 9. It is obvious that changing W_5 has a excessive effect on lower frequencies of the first notched band. Figs. 10(a) and (b) show the current distributions at 3.5 GHz & 5.5 GHz on the proposed antenna. Large current distributions around the CSS and MSS are observed, which cause destructive interference for the excited surface currents in the antenna so that the antenna is non-propagative at those frequencies.

The proposed antenna's far-field radiation patterns with and without MSS & CSS are presented in the two principle planes, (E-plane, H-plane) in Figs. 11, 12, respectively. Fig. 11 shows that the radiation pattern plots at several different frequencies are stable. It is seen that the E-field pattern is omnidirectional at lower frequencies and is near omnidirectional at higher frequencies. Comparing the patterns presented in Fig. 11 (antenna without MSS& CSS) with pattern shown in Fig. 12 (antenna

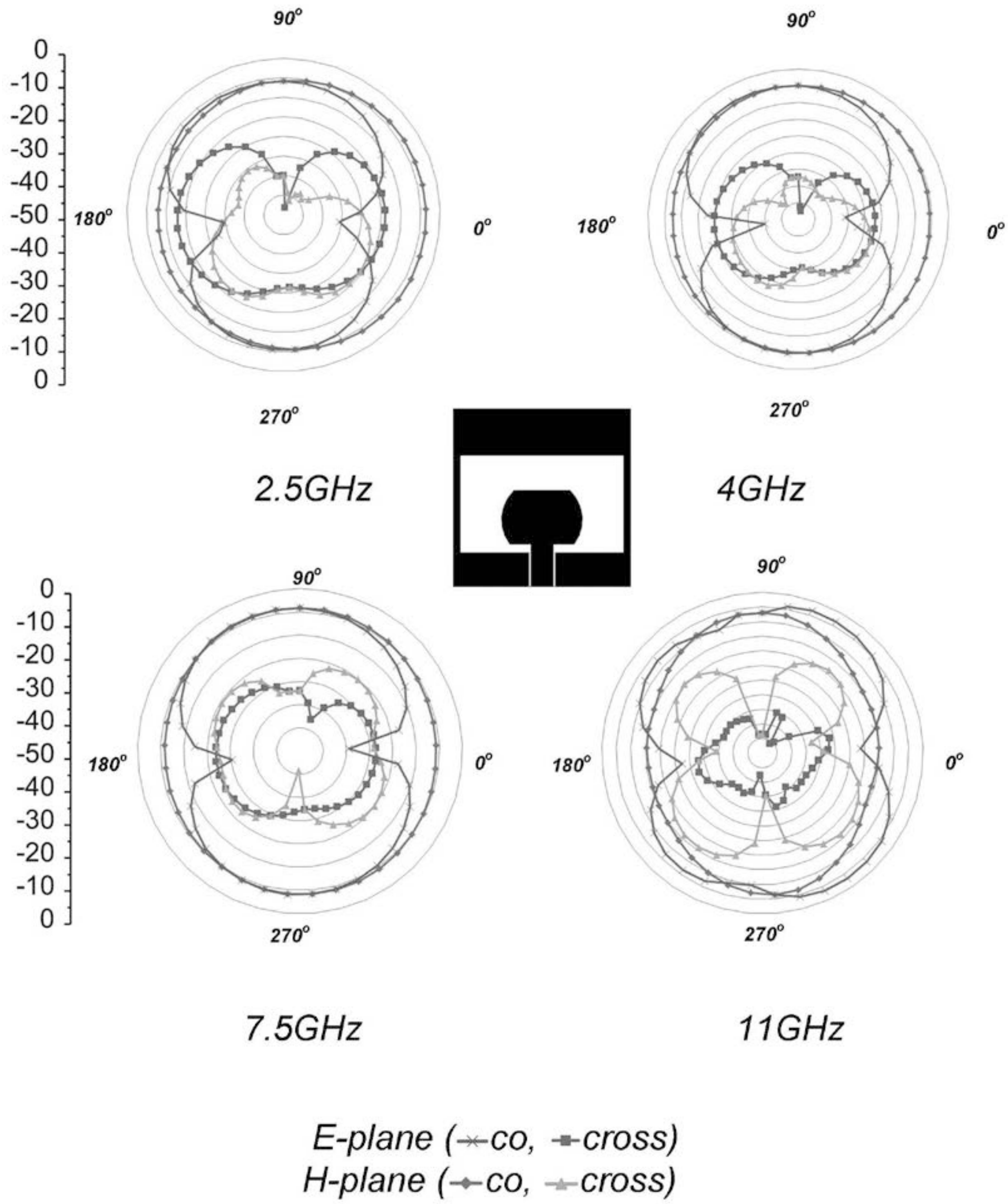

Fig. 11. Radiation patterns of the proposed antenna without MSS & CSS

with MSS&CSS), it can be seen that putting MSS&CSS for filtering interfering bands didn’t cause any large variance in the radiation pattern of the antenna.

Fig. 13 presents a comparison of simulated and measured S_{11} characteristic for proposed monopole antenna. This figure shows the proposed monopole antenna has a very large impedance bandwidth, 2.4-12.9 GHz for which the return-loss characteristic is less than -10 dB. This performance exceeds the UWB as defined by FCC. Fig. 13 also shows good agreement between the simulated and

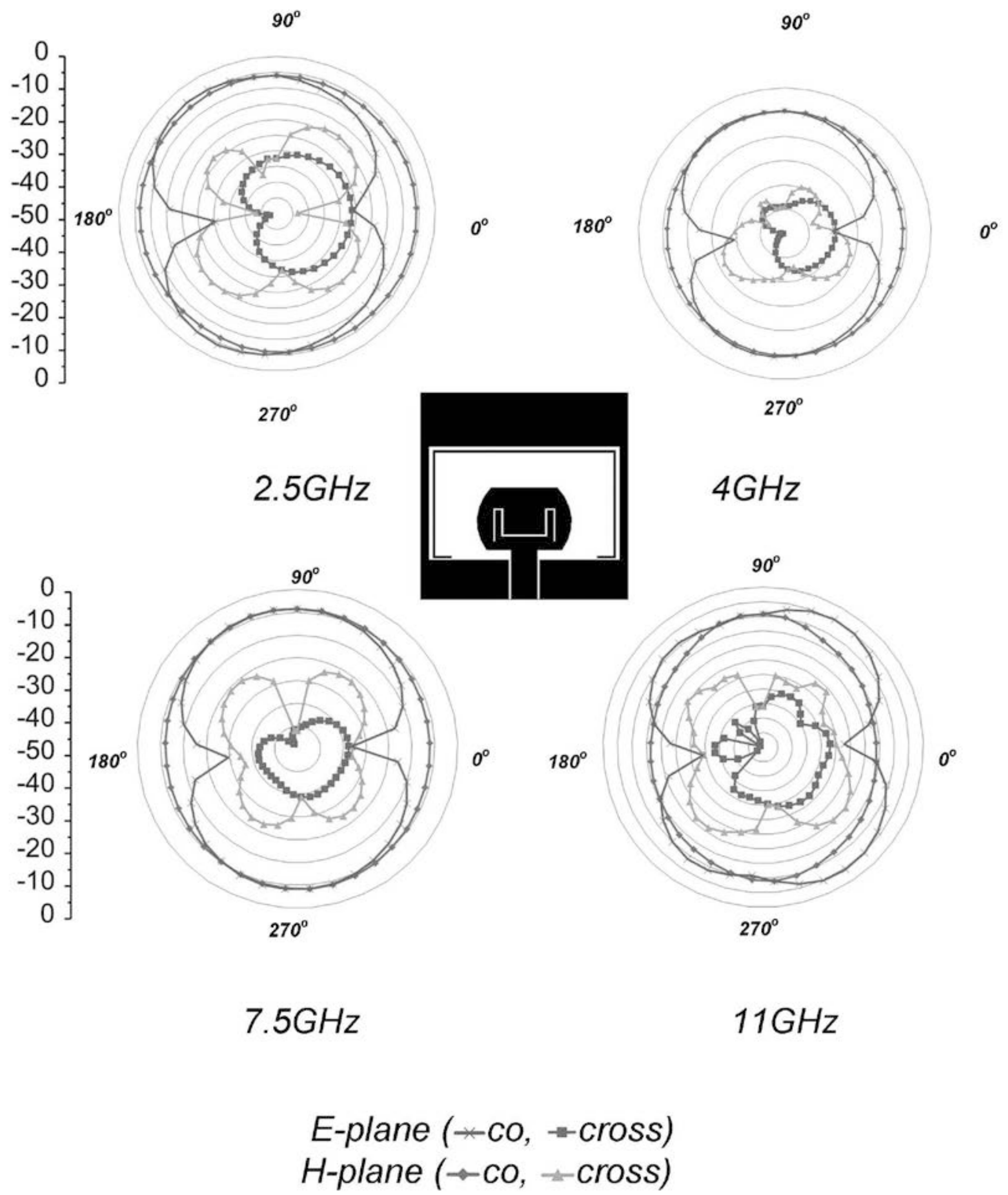

Fig. 12. Radiation patterns of the proposed antenna

measured results. The disparity between the two responses is attributed to manufacturing tolerance and imperfect soldering effect of the SMA connector.

Fig. 14 shows the gain of the proposed antenna. Sharp gain decreases happen on the vicinity of 3.5 and 5.5 GHz bands, but for other frequencies outside the rejected bands, the antenna gain is nearly constant in the entire UWB band. Table I presents a summary of charectristics of proposer antenna comparing [9,10 and 12]. It is observed that the proposed antenna has compact size and large IBW.

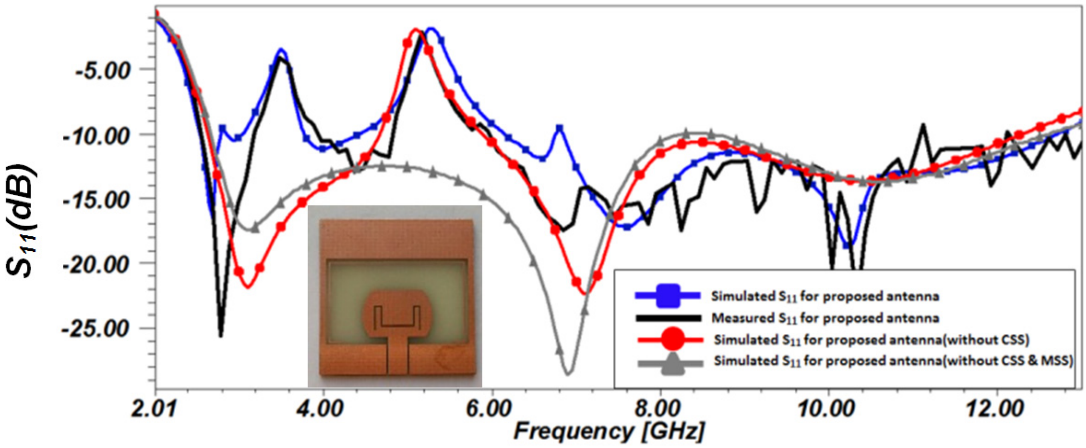

Fig. 13. Measured and simulated S11 response of the proposed optimized antenna

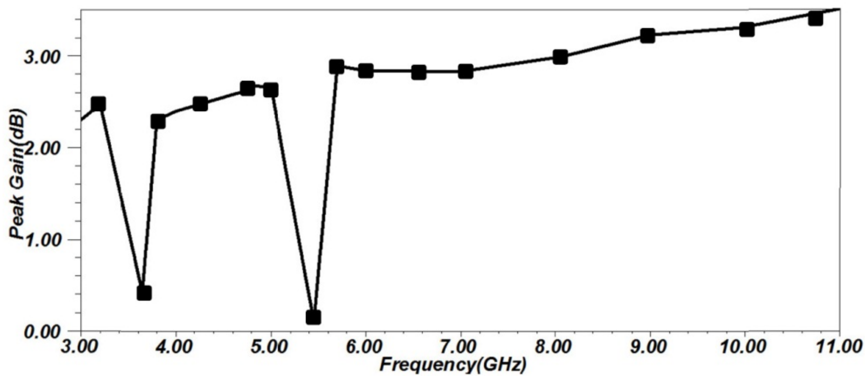

Fig. 14. Gain of the proposed antenna

Table I. Summary of charectristics of proposed antenna and antennas in references [9,10,12]

Reference	B.W (GHz) VSWR = 2	B.W (%) VSWR = 2	1st Rejection Band (GHz)	2nd Rejection Band (GHz)	UWB Coverage	SIZE (mm)
[9]	2.97-10.7	113	3.3-3.6	5.2-5.8	Yes	20 × 20
[10]	3.1-11	112	3.4-3.6	5.1-5.9	Yes	30 × 34
[12]	2.75-10.7	118	3.15-3.85	5.15-5.825	Yes	44 × 32.5
Proposed Antenna	2.4-12.9	137	3.1-3.7	5.15-5.85	Yes	25 × 25

Fig. 15 presents the efficiency of the proposed antenna, which is approximately over 75%. The efficiency of the antenna decreased consumedly at notch bands as shown here. At the first notch, efficiency reduced to about 22% at 3.8 GHz. Also at the second notch frequency, the antenna efficiency reduced to 30% at 5.7GHz.

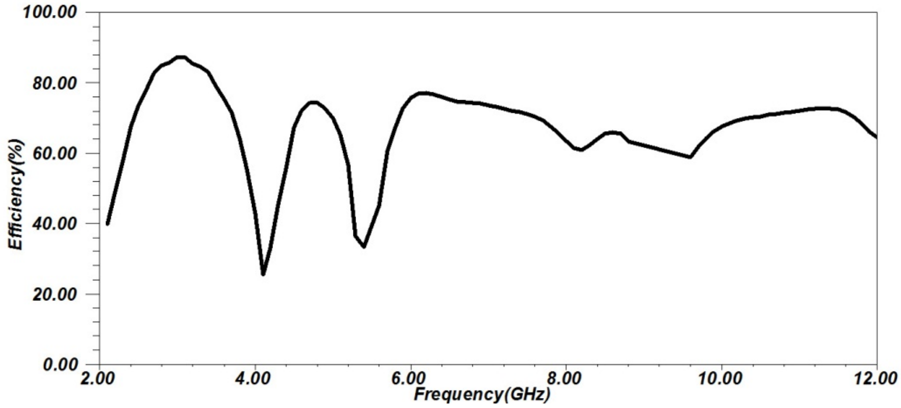

Fig. 15. Efficiency of the proposed antenna

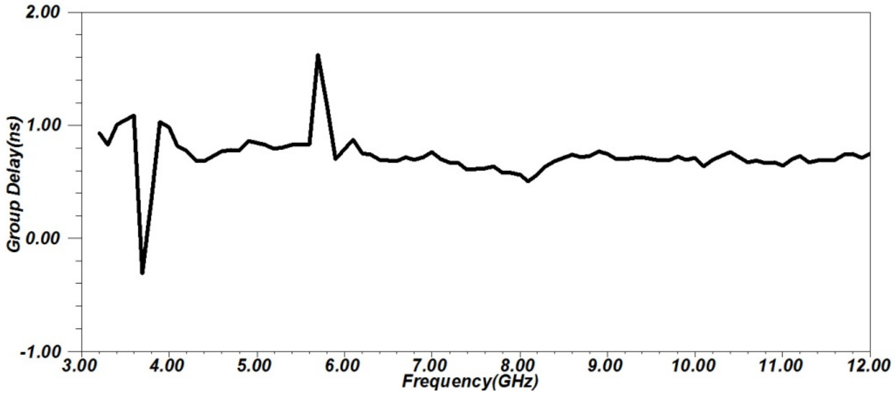

Fig. 16. Group delay of the transfer system.

Reflection coefficient, gain, efficiency and radiation pattern are important parameters of UWB antennas. Other important parameters include system transfer function and group delay. Ideally, group delay in UWB applications should be constant over the entire bandwidth as well. To achieve the group delay characteristic, the distance between the two antennas was 30 -cm, which attain field position of the antenna. The group delay is about 1 ns across the frequency band except in the notched bands shown if Fig. 16. For the rest of the frequency band, the group delay characteristic is rather smooth, showing that the antennas have good linear transmission performances.

III. CONCLUSION

In this article, a compact planar monopole antenna is proposed that exhibits 2.4-12.9 GHz bandwidth and easily satisfies the requirements for UWB applications. The antenna has inherent band-notch characteristics which is necessary to solve the interfering problem between WiMAX(3.1-3.7GHz) and WLAN(5.15-5.85GHz) with the UWB spectrum. To obtian the two stopped bands, two specific form of an M-shaped slot (MSS) and C-shaped strip(CSS) are inserted in the radiating element and ground plane. Numerical and experimental results are presented to understand fabricated aprototype behavior. The measured results show good radiation patterns within the UWB frequency range.

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