Ultra Wideband Monopole Antenna Excited by a Capacitive Coupling Feed with Double Band Notch Function

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***Abstract*— This paper presents the results of a new monopole antenna that exhibits 2.75-10.7 GHz performance. The proposed antenna consists of a radiating patch with notches excited by capacitive coupling feed. Also, the antenna's truncated ground-plane incorporates a central notch. This modification significantly improves the antenna's impedance bandwidth by 118% over an ultra-wideband frequency range. These characteristics make the proposed antenna an excellent candidate for numerous UWB applications and next generation communication systems. The key physical parameters affecting the antenna's frequency characteristics have also been investigated in order to determine optimum antenna performance. The antenna's simulated return-loss, and *E*-plane and *H*-plane radiation patterns show very good correlation with the requirements of UWB applications.**

***Index Terms*—** monopole antenna, notch filter, capacitive coupling, UWB

I. INTRODUCTION

Ultra-wideband (UWB) technology has undergone many significant developments in recent years. However, there still remain many challenges in making this technology live up to its full potential. The work in this area has gained impetus with the Federal Communication Commission (FCC) permitting the marketing and operation of UWB products within the band 3.1 GHz to 10.6 GHz. This technology employs short duration pulses that result in very large or wideband transmission bandwidths. With appropriate technical standards, UWB devices can be operated using spectrum occupied by existing radio services without causing interference, thereby permitting scarce spectrum resources to be used more efficiently. However, this wireless communication technology still needs to be improved further to satisfy the insatiable demand for higher resolution and higher data rate requirements. One key component necessary to fulfill these requirements in UWB system is a planar antenna that is capable of providing a wide impedance bandwidth. The antenna needs to operate over the ultra-wideband, as it is defined by the FCC. In addition, it needs to provide omni-directional radiation coverage over the entire UWB frequency range. Other aesthetic features sought from the antenna include being light weighted, small in size, and having a low profile.

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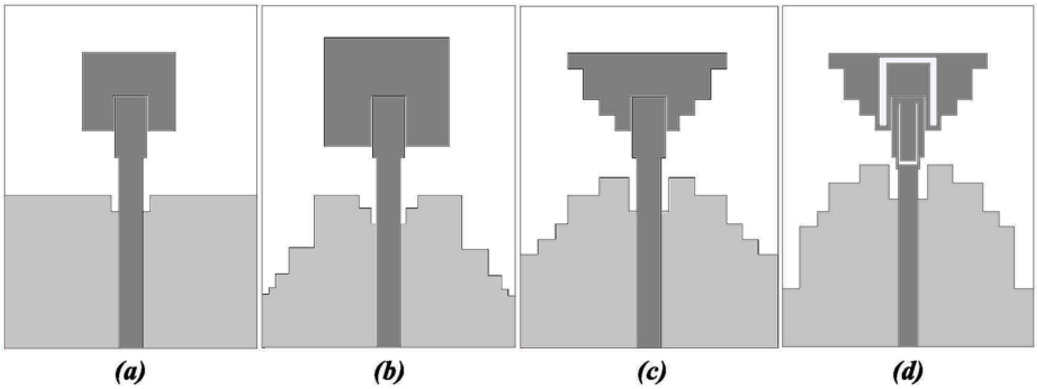
Several monopole configurations have been investigated for wideband applications thus for, which include the following structures: circular, square, elliptical, pentagonal, hexagonal etc. [1]–[6]. Among the proposed wideband antennas include the printed planar monopole antenna, which is a promising candidate for future applications due to its remarkably compact size, stable radiation characteristics and ease of construction. The triangular monopole antenna mounted above a ground-plane was first proposed in [7], and its impedance bandwidth is found to be dependent on the feeding gap, and the antenna's flare angle. A typical bandwidth of this antenna is approximately 30% [8]. Some variants of this type of antenna in an effort to increase its bandwidth have been studied, i.e. the tap monopole antenna [9], and the staircase bow-tie monopole antenna [10]. Although these techniques enhance the antenna's bandwidth, the results show their bandwidth is limited to less than 100%. Another way which is proposed for increasing the impedance bandwidth of the triangular monopole is achieved by modifying its ground-plane [1]. Among the various planar monopole antennas of configurations, only a few triangular monopole antennas have been investigated for UWB applications [11-14].

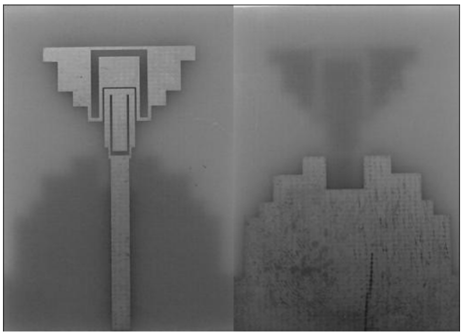
In this paper, we present a new monopole antenna with capacitive coupling feeding that exhibits 2.75-10.7 GHz. The monopole antenna includes notch functions for 3.15-3.85 and 5.15-5.825 GHz. The antenna's ground-plane is truncated and modified. This designed antenna operates over 2.75 to 10.7 GHz with VSWR<2. Unlike other antennas reported in the literature to date, the proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. The monopole antenna is analyzed using Ansoft's High Frequency Simulator (HFSS™) [15]

II. ANTENNA STRUCTURE

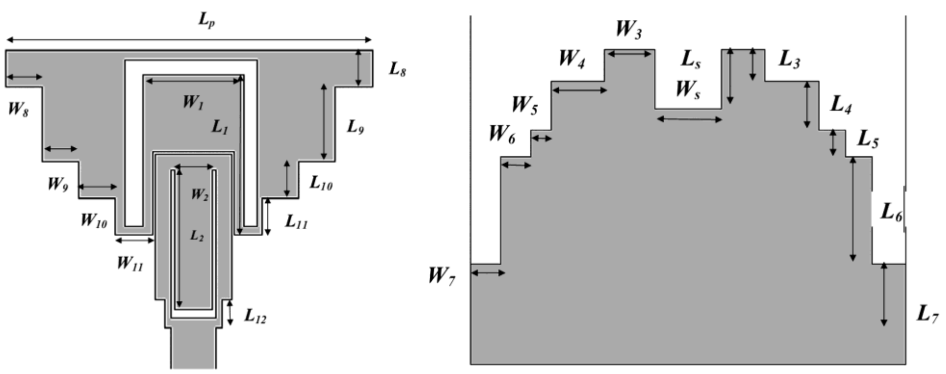
Fig. 1(a) presents the design procedure of the proposed antenna. Fig. 1(b)&(c) show the configuration of the radiating patch of proposed monopole antenna which consists of inverted U shaped notch. The ground-plane is truncated, as shown in Fig. 1, and envelops the feed line to the radiating triangular patch. The ground-plane includes a rectangular notch at its center for impedance matching. The proposed antenna is constructed from FR4 substrate with the thickness of 1.6 mm and relative dielectric constant of 4.4. The proposed antenna excited by using the technique of capacitive coupling on microstrip transmission line. This is used to enhance the impedance bandwidth of the antenna due to increasing the capacitive coupling. The width of the microstrip feedline is fixed at 2.5 mm. The antenna's dimensions are 44 mm × 32.5 mm. The dimensions of the notch ($L_s \times W_s$) embedded in the ground-plane are important parameters in determining the sensitivity of the antenna's impedance match. The proposed shape of the truncated ground-plane acts as an effective impedance matching network to realize an antenna with a very wide impedance bandwidth. This is because the truncation creates capacitive loading that neutralizes the inductive nature of the patch to produce nearly pure resistive impedance present at the antenna's input [3]. As it is shown in Fig.2, introducing U shaped



(a)



(b)



W_1 = 5.5 mm
L_1 = 9 mm
W_2= 2 mm
L_2 = 8 mm
L_8 = 2 mm
W_8 = 2 mm
L_9 = 2 mm
W_9= 4 mm
W_{10} = 2 mm
L_{10} = 2 mm
L_{11} = 2 mm
W_{11} = 2 mm
W_{12} = 1.5 mm
L_P = 20mm

(c)

Fig. 1. (a) Design procedure of the antenna (b) Photograph (c) radiation patch and ground plane of the proposed antenna.

slot on the radiating patch and feed line also carefully adjusting its dimensions result in filtering the 3.15-3.85 and 5.15-5.825 GHz WLAN bandwidth. The improvement in impedance match over the UWB bandwidth is attributed to the phenomenon of defected ground structure (DGS) with slots that create additional surface current paths in the antenna. Moreover, this ground-plane structure changes the inductive and capacitive nature of the input impedance, which in turn leads to change in bandwidth [16-18].

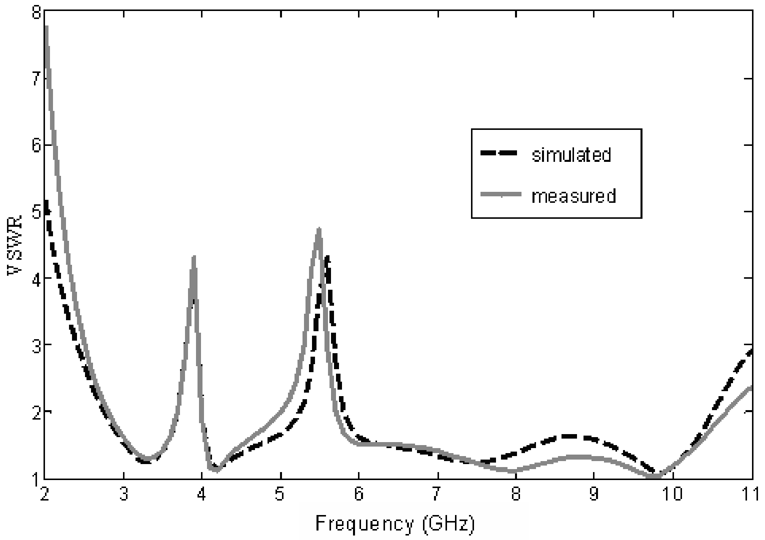


Fig. 2. VSWR of the proposed antenna

The proposed antenna is investigated by changing one parameter at a time, while fixing the others. To fully understand the behavior of the antenna's structure and to determine the optimum parameters, the antenna was analyzed using Ansoft's high-frequency structure simulator (HFSS™). The optimum magnitudes of the physical parameters of the proposed antenna are shown in Fig. 1, which achieves a very wide impedance bandwidth from 2.75 to 10.7 GHz with VSWR<2.

III. RESULTS AND DISCUSSIONS

Fig. 2 shows measured and simulated VSWR characteristics of the proposed antenna. As observed in Fig. 2, the successive modifications improve the bandwidth of the triangular monopole antenna. The inclusion of notches in the radiation patch and feed line also modifying the ground-plane has a significant effect on increasing its bandwidth also filtering the WLAN band.

In this study, in order to filter the WLAN frequency bandwidth and reduce the electromagnetic interference between UWB and WLAN systems, U shaped slots are embedded on the radiating patch and feed line of the proposed antenna, as depicted in Fig. 3. indicates the effect of adding a U shaped slot on the patch. This phenomenon occurs because the slot acts as current perturbation on the radiating patch. Fig. 4 presents the effect of adding a U shaped slot on the feed line of the antenna.

Fig. 5 presents the peak gain of the proposed antenna. As it is obvious the gain level of the antenna is stable except the WLAN frequency band which causes reduction of interference of the systems.

The spectrum of the antenna in Fig. 2 shows many resonances. These resonances correspond to the different modes of field distribution. Fig. 6 shows the simulated current distribution at the frequencies of 3 GHz, 5 GHz, 8 GHz, and 10 GHz. Fig. 6 shows a strong current distribution located around the top notch in the radiating patch, as well as the current flow directed towards the corners of patch. This indicates that the modifications in the truncated ground-plane excite resonance modes at a

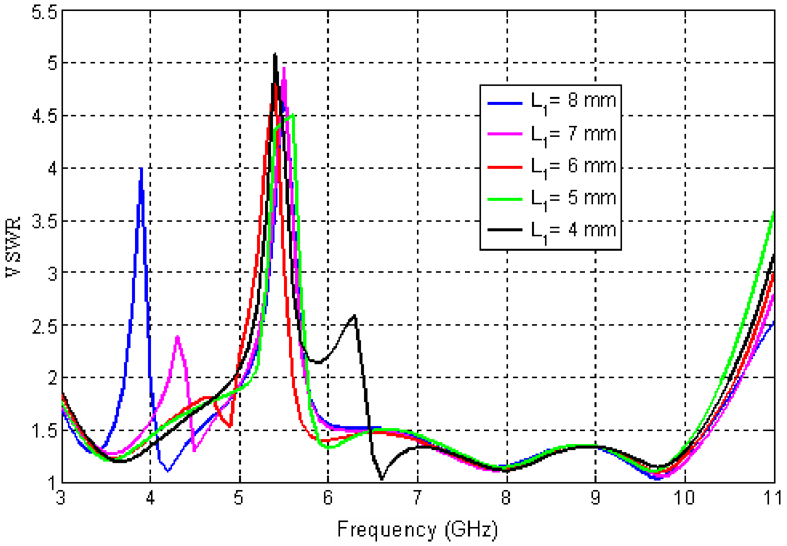


Fig. 3. Simulated VSWR of the proposed antenna for different values of L_1

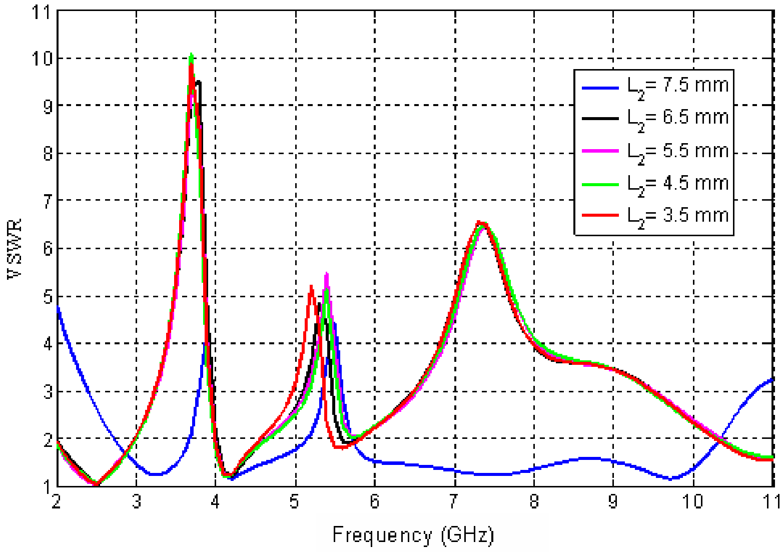


Fig. 4. Simulated VSWR of the proposed antenna for different values of L_2

higher frequency, which effectively extend the antenna’s bandwidth, and also embedding a U shaped notch acts as a filtering function by affecting the current distribution.

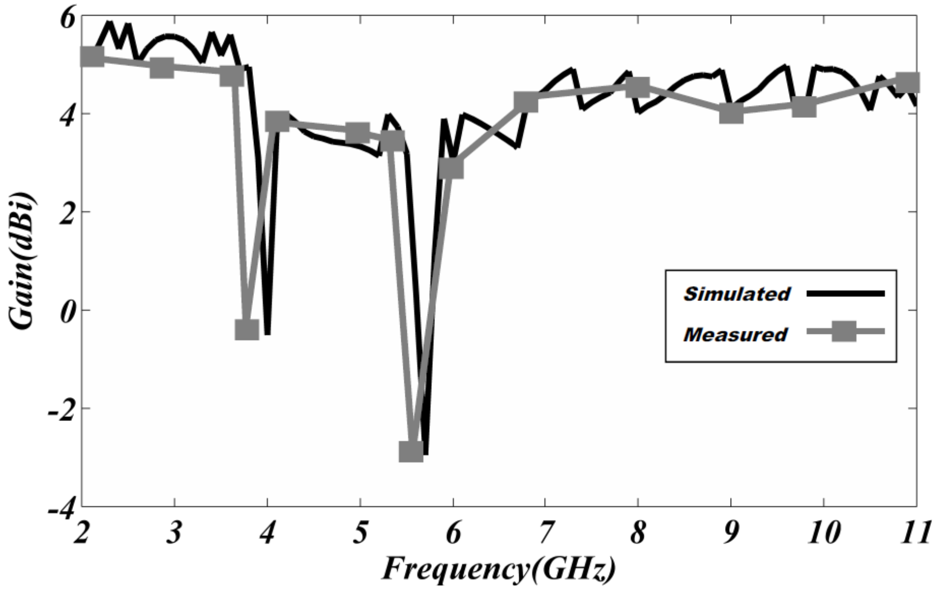


Fig. 5. Mesured and Simulated gain of the proposed antenna

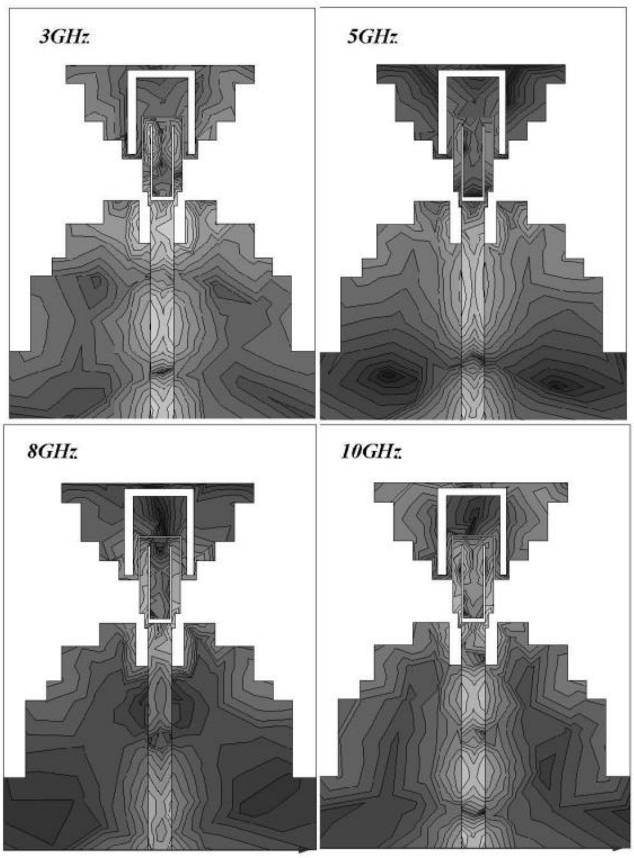


Fig. 6. Simulated current distributions for the proposed antenna at various freqeuncies

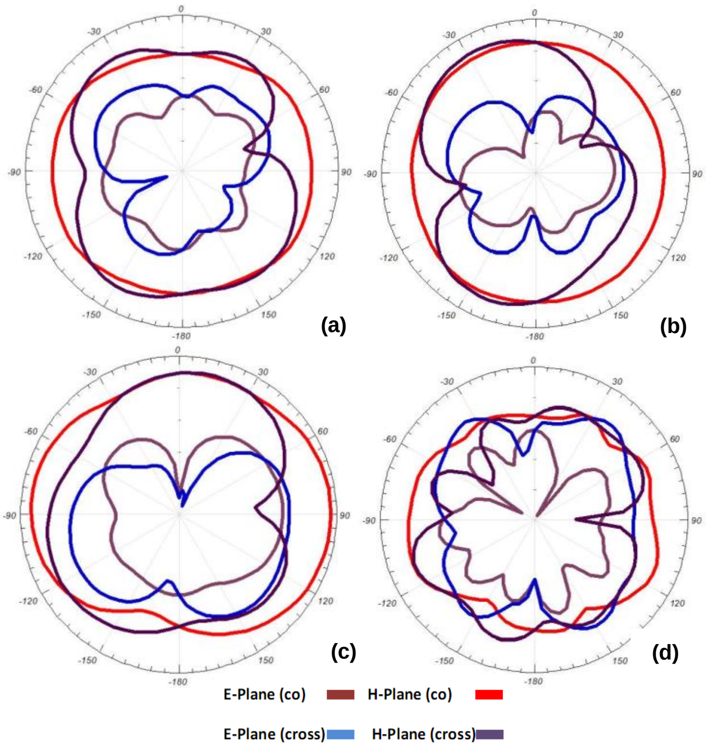


Fig. 7. measured radiation patterns of the proposed antenna(a) 3 GHz, (b) 6 GHz, (c) 8 GHz and (d) 10 GHz.

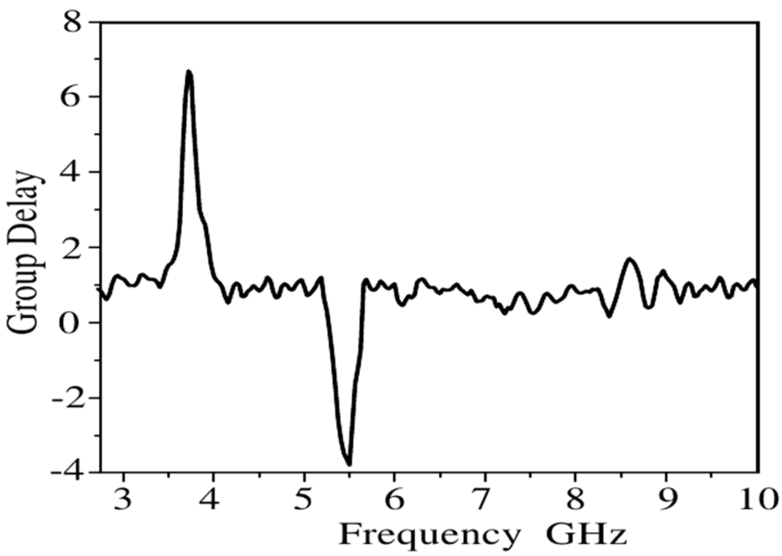


Fig. 8. Group delay of the proposed antenna

Although the proposed antenna's far-field radiation patterns are simulated in the two principle planes, *y-z* plane for the *E*-field and *x-z* plane for the *H*-field. Fig. 7 shows that the radiation pattern plots at several different frequencies are stable. It is noticed that the *E*-field pattern is omni-directional at lower frequencies and is near omni-directional at higher frequencies.

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 assess these parameters two identical fractal antennas proposed here were mounted 60 cm from each other, which corresponds to approximately six wavelengths at the lower frequency of the band of operation and in the antenna's far-field region. The group delay measurement is shown in Fig. 8. This varies between around ±1 ns but rise up to 6.8 ns and drop down to 3.8 ns at round 5.5GHz as a result of band notch structure.

IV. CONCLUSION

In this paper, a modified triangular monopole compact planar antenna is proposed which exhibits multi-octave bandwidth performance and completely satisfies the requirements for UWB applications. The results show that the impedance bandwidth of the proposed antenna is significantly improved with modification on the radiating patch. The proposed antenna exhibits an impedance bandwidth of 118% over a very wide frequency range from 2.75 to 10.7 GHz with return-loss better than -10 dB. Also, results show good radiation patterns within the UWB frequency range.

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