A Band-Notched Square Monopole Antenna designed for Bandwidth Enhancement in UWB Applications

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Abstract **─** In this letter, a square monopole antenna has been designed for ultrawideband (UWB) applications having variable notch frequency characteristic. The proposed antenna consists of the small square radiating patch with two rectangular slots, which provides a wide usable fractional bandwidth from 3.1 to 14.4 GHz. The proposed antenna is simple and has a very small size of 10×15 mm^2. The bandwidth of the proposed antenna is wider than that of the antenna that has already been introduced in references. Experimental results show that the proposed antenna could be a good candidate for ultrawideband (UWB) applications.

Index Terms **─** Small square monopole antenna, ultrawideband (UWB).

I. INTRODUCTION

Recently, the ultrawideband (UWB) technology has been prominently developed and used. UWB systems for commercial purposes require small antennas that are not costly and also have omnidirectional radiation patterns as well as a large bandwidth [1]. Obviously simple structure, small size and low cost fabrication process are desired features of a planar monopole antennas which make it utilize in promising applications such as satellite communications. Taking into account all the aforementioned interesting characteristics, planar monopoles are extremely appropriate to be used in modern UWB applications and hence, so many activities focus on them. In UWB communication systems, designing compact antennas that can provide wideband characteristic in the whole operating frequency band is one of the state-of-the art concerns [2]. Utilizing UWB antennas with high gain characteristic is necessary for both military and commercial applications. Such applications require an antenna with compact and thin antenna configuration. Consequently, a multitude of planar monopoles with different geometries has been experimentally characterized [3–4] and in order to obtain the optimum planar shapes numerous automatic design methods have been developed [5, 6].

The frequency range for UWB systems between 3.1 and 10.6 GHz may interfere with the existing wireless communication systems, for example the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15–5.35 GHz and 5.725–5.825 GHz bands, so the UWB antenna with a band-stop performance is required. Recently, to generate the frequency band-notch function, a novel UWB monopole antenna with controllable band notch Characteristics [6] and a compact design and new structure of monopole antenna with dual band notch characteristics [7] have been used. In this letter, a novel band-notch monopole antenna is presented that can be used for ultrawideband (UWB) applications. The size of the designed antenna is smaller than that of the antennas reported recently [6], [7].

In this work, a simple notch band antenna is presented. Basically, effects of printed square radiation surface parameters have been studied, comprehensively. Also, investigation on the defective ground has been performed in order to improve the impedance bandwidth and notch frequency. Indeed, the antenna has an impedance bandwidth of 13 GHz across an appropriate average gain of 5 dB. An experimental effort has been made in order to confirm the simulation results. Accordingly, the VSWR>2 bandwidth of the notch frequency is almost 1 GHz from 5 GHz to 6 GHz with the gain of nearly -7 dB.

II. ANTENNA DESIGN AND CONFIGURATION

Figure 1 shows the configuration of the proposed monopole antenna with tunable notch frequency. The antenna consists of a simple square patch with two rectangular slots on sides and a defective ground plate. The proposed antenna is fed by a 50 Ω feed-line printed on FR-4 substrate with the thickness of 1.6 mm, permittivity 4.4, and loss tangent 0.0018. The width of the microstrip feed line is fixed at 1.5 mm. To explain the performance of the antenna, the design has been improved evolutionary, as depicted in Fig. 3. The primary structure is displayed in step 1. Thereafter, the ground has defected in step 2 in order to improve impedance matching. Indeed, the electrical charges

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on ground plane distribute uniformly and a great enhancement capacitance between the feed line and ground will be achieved at high frequencies. Accordingly, due to the current distribution on ground and feed line, an improvement in high frequency bandwidth is yielded. As can be found in Fig. 4, the advancement makes the bandwidth be broadened from 5 GHz to 13 GHz. In the last step, to obtain significant notch frequency bandwidth, the proposed antenna is attained by etching two slots on sides of radiation surface. In fact, in order to achieve the desired notch, the current distribution on radiation surface should be adjusted. Consequently, the parameters of the antenna have prepared the main objective of the study.

The truncated ground plane plays an important role in the broadband characteristics of this antenna because it helps the patch be matched with the feed line in a wide range of frequencies. This is mainly because of neutralization of the inductive nature of the patch by the capacitive load created by the truncation in order to produce nearly pure resistive input impedance [8]. The two rectangular notches are used to control the impedance bandwidth and VSWR level by modifying the capacitance between the patch and the ground plane. The optimal dimensions of the designed antenna are specified in Table 1.

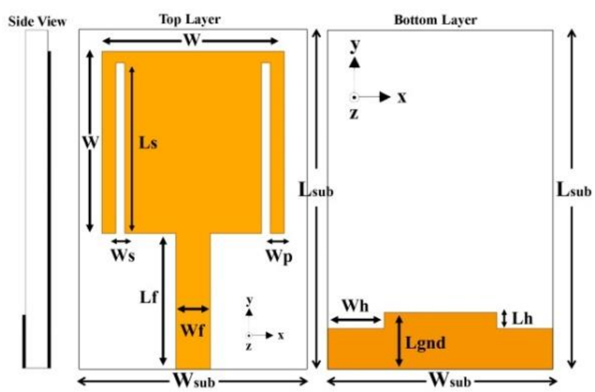


Fig. 1. Geometry of proposed antenna.

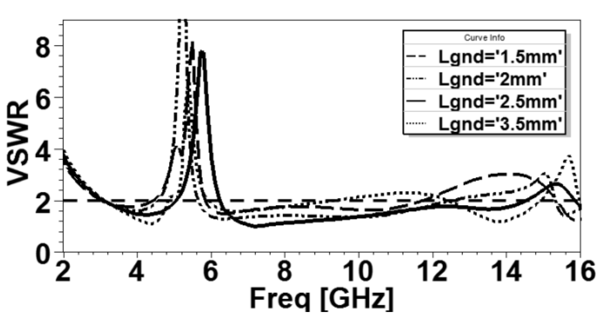


Fig. 2. Simulated VSWR characteristics of proposed antenna with different values of Lgnd length.

Table 1: Optimized parameters of the antenna (Unit: mm)

Wsub	10	Ws	0.4	Ls	7.5
Lsub	15	Lgnd	2.5	Lf	6
W	8	Wp	0.6	Lh	0.7
Wf	1.5	Wh	2.5		

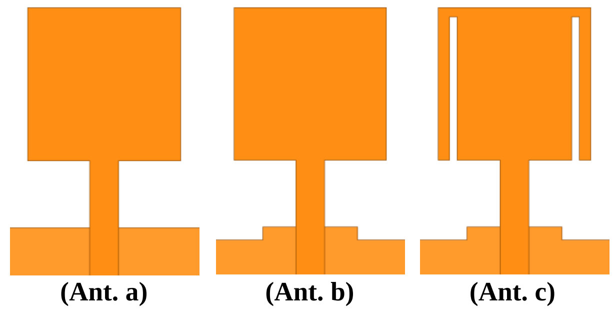


Fig. 3. Different antenna structures: (Ant. a) basic structure (ordinary square antenna); (Ant. b) the antenna with two rectangular notches in the ground plane; (Ant. c) the proposed antenna.

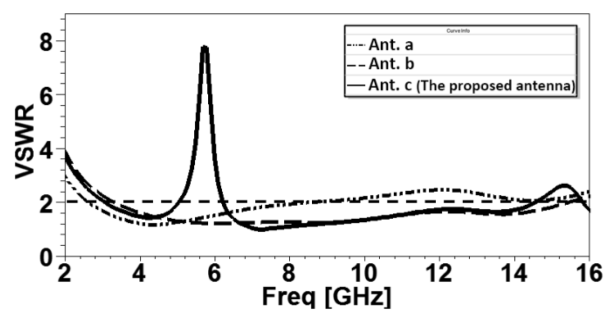


Fig. 4. Simulated VSWR characteristics for antennas shown in Fig. 3.

III. RESULTS AND DISCUSSIONS

Through the result investigation in previous works, attaining high performance in variable notch frequency leads us to study the configuration parameters. The parameters of the proposed antenna have been studied by varying one parameter while the rests are fixed. The procedures of the investigation have totally been carried out through HFSS (High Frequency Simulation Structure) [9].

In order to modify the antenna design, a parametric study is performed. Figure 2 demonstrates the effect of the Lgnd variation on impedance bandwidth. As Lgnd increases, the upper bound of the impedance bandwidth increases as well. Indeed, the capacitance property between the ground and the patch amplifies as Lgnd increases. However, the Lgnd=2.5 mm intensifies the capacitor among the ground and gaps at sides of the patch. Therefore, this phenomenon interference the main capacitance and consequently the resonant frequency decrease to 14 GHz. It has been worth noting that the noticeable performance of the antenna is varying the notch frequency. Accordingly, two parameters (Wh and Lh) have been studied in order to attain the objective. As shown in Fig. 6 (a), the notch frequency increases as Wh raises to 3.5 mm. Also, the increment of Lh increases the frequency notch as well. In spite of notch frequency variations, other frequencies in bandwidth are extremely stable. Besides, one should be noted that the notch frequency has been altered through ground parameters. This feature leads us to design antenna leaning on just ground defection. Nevertheless, owing to the intact radiation surface, the gain will not change at all.

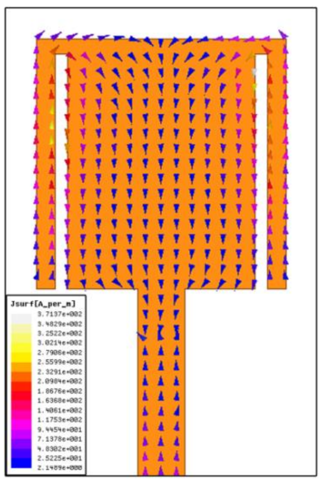
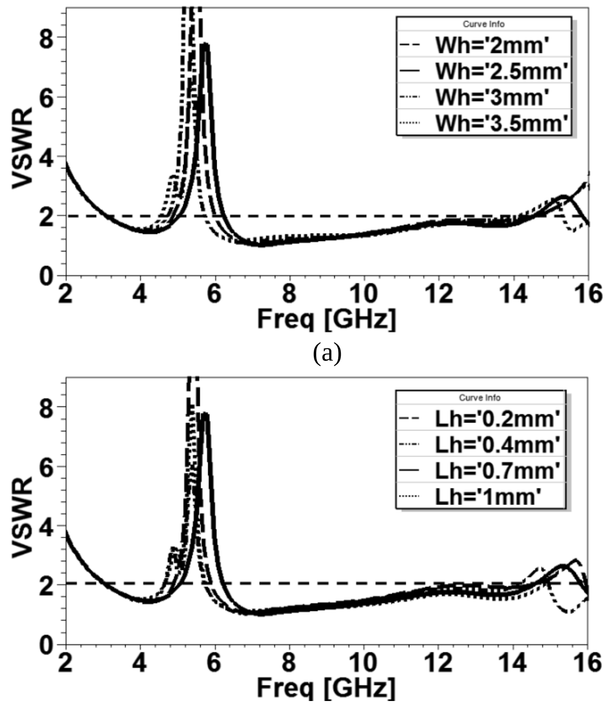


Fig. 5. Simulated surface current distributions on the radiating patch for the proposed antenna at 5.5 GHz.

Although the variation of prior parameters effects on notch frequency, the influences of other parameters should be studied as well. Notch frequency is significantly altered as the Ls varies from 6 mm to 7.8 mm. Since the frequency is proportional to the inverse of length ($f \propto \frac{1}{Ls}$), the frequency variation is rather considerable. According to the Fig. 7 (b), the frequency shift is approximately 1 GHz. As can be seen in Figs. 7 (b), 7 (c), the slight increase in notch frequency caused by Ws and Wp is almost none-uniform. The variations are almost 0.25 GHz for both Ws and Wp. As illustrated in Fig. 4, the additional two rectangular slots in the radiating patch are playing an important role in the band-stop characteristics of this antenna. Consequently, the band-stop performance is improved, especially at the central band-notch frequency. The simulated current distributions on the radiating patch for the proposed antenna at 5.5 GHz are presented in Fig. 5. It can be observed in Fig. 5 that the current is mainly concentrated on the edges of the interior and exterior of the two rectangular slots at 5.5 GHz. It is obvious that the current distributions direction on slot edges is opposite. Therefore, the inductance decreases and the resonance frequency known as notch frequency are obtained. Worth noting that signal which is transmitted through the feed line cannot reflect the main source.



(a)

(b)

Fig. 6. Simulated VSWR characteristics of the proposed antenna: (a) with different values of Wh (Lh is fixed at 0.7 mm); (b) with different values of Lh (Wh is fixed at 2.5 mm).

The simulated VSWR curves with different values of Wh and Lh length in the ground plane are plotted in Fig. 6. Figure 7 shows the effect of varying the Ws, Ls, and Wp length in the radiating patch on the impedance bandwidth. The simulated VSWR curves with different values of Ws are plotted in Fig. 7 (a). The optimized length is selected to be 0.4 mm. Figure 7 (b) shows the effects of Ls on the impedance matching. The simulated VSWR curves with the optimal Ws and Ls for various Wp are plotted in Fig. 7 (c). In order to confirm the simulation results, a prototype of the antenna has been fabricated, as displayed in Fig. 8. Figure 8 presents the photograph of a prototype printed monopole antenna on an FR-4 substrate with the SMA connector. Figure 9 shows the simulated and measured radiation pattern in frequencies 4, 7, 10, and 14 GHz in H-plane (xz plane) and E-plane (yz plane). The half power bandwidths (HPBWs) of the antenna are almost 23º and 26º in E- and H-plane for 4 GHz, respectively, as shown in Fig. 9 (a). Also, it can be seen that the HPBWs are 21º and 25º for

10 GHz. Obviously, since the antenna is printed on a defective ground, the broadside pattern will be deflected forward slightly. VSWR characteristics of the proposed antenna are shown in Fig. 10. As shown in Fig. 10, the fabricated antenna has the frequency band of 3.1 extending to more than 14.4 GHz with a rejection band around 5–6 GHz. Figure 11 shows the effects of two rectangular slots, on the maximum gain in comparison to the antenna without the aforementioned slots.

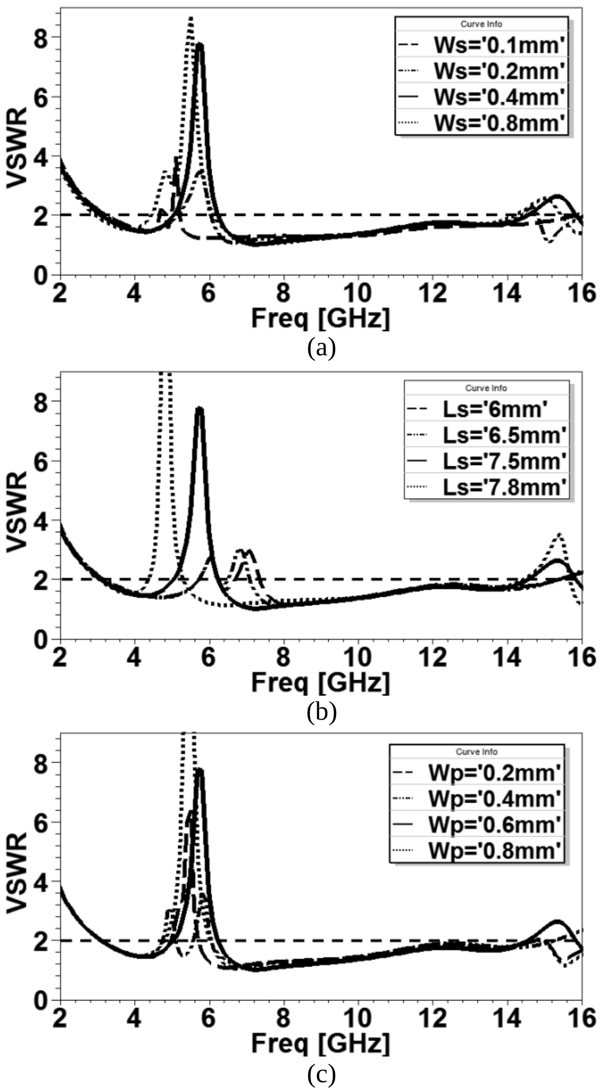


Fig. 7. Simulated VSWR characteristics of the proposed antenna: (a) with different values of Ws (Ls is fixed at 7.5 mm); (b) with different values of Ls (Ws is fixed at 0.4 mm); (c) with different values of Wp (Ws is fixed at 0.4 mm and Ls is fixed at 7.5 mm).

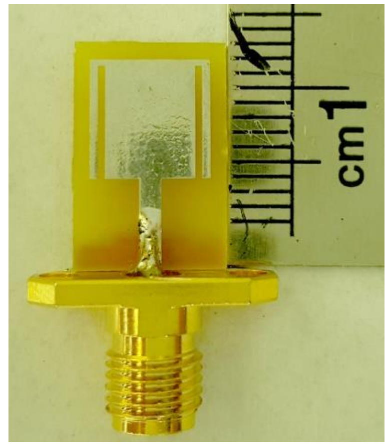


Fig. 8. Photograph of the realized antenna.

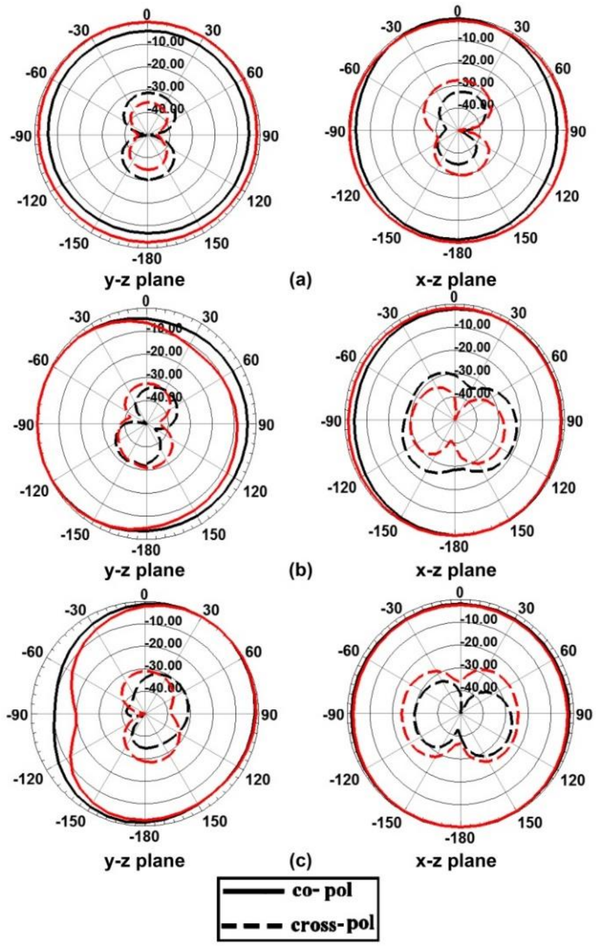


Fig. 9. Simulated and measured radiation patterns in: (a) 4, (b) 7, and (c) 10 GHz frequencies.

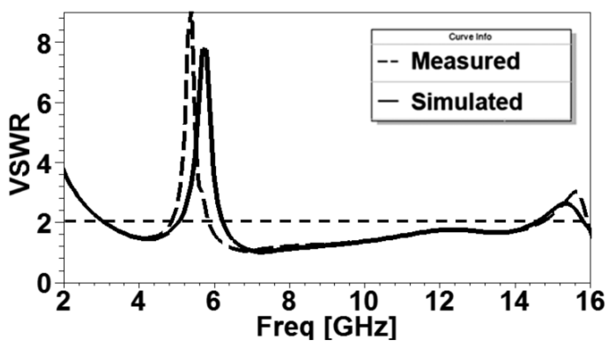


Fig. 10. Measured and simulated VSWR for the proposed antenna.

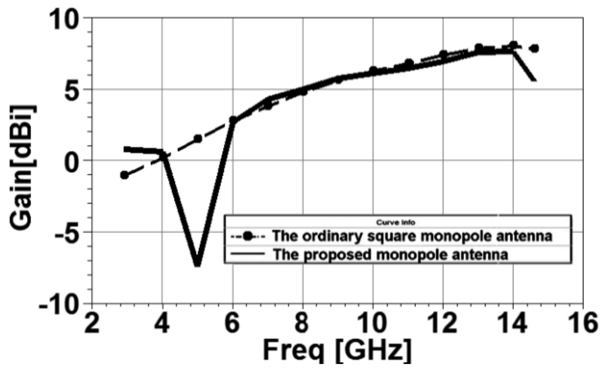


Fig. 11. Measured antenna gain of the proposed antenna.

In this study, bandwidth could be enhanced after inserting two slots in the ground plane of the proposed antenna as displayed in the figure. The main function of the slots here is to create a new path for the surface current that is able to make another resonance and hence, the bandwidth can be increased [10], [11].

In order to confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the measurement process be performed carefully.

IV. CONCLUSION

In this letter, a newly-designed band-notched square monopole antenna is proposed for UWB applications. The proposed antenna has a simple configuration and it is easy to fabricate. The proposed antenna is small in size (10x15 mm^2) and the bandwidth of the proposed antenna is wider than that of the antennas reported in references. The proposed antenna has the frequency band of 3.1 to over 14.4 GHz with a rejection band around 5–6 GHz. The sizes of two rectangular slots for obtaining the wide bandwidth have been optimized by parametric analysis. Experimental results show that the proposed antenna could be a good choice for UWB application.

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