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Compact UWB Antennas with Inverted E- and F-Shaped Slots for Bandnotch Characteristics

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Abstract—A compact microstrip notched ultrawideband patch antenna (UWB) with inverted E- and F-shaped slots is presented. By introducing a new inverted E-shaped notch in the radiating plane, band-notch about 2.68 to 3.55 GHz is achieved. A new type of Defected Ground Structure (DGS) in the ground plane is employed to extend the lower limit of the bandwidth so as to cover ISM 2.4 GHz WLAN-frequency band. The proposed antenna offers 126% bandwidth overall dimension of $13 \times 17 \times 1.6\,\text{mm}^3$. The experiment results indicate that the proposed antenna can meet the requirement for UWB communication with size miniaturization.

1. INTRODUCTION

With the drastic increase of market demand as well as rapid development of wireless communication, low power and high data rate communication systems have become the technologies in wireless communication. In this regard, the ultrawideband (UWB) technology is considered as the latest and most popular short range wireless communication technology [1]. Most recent applications of UWB are target sensor data collection, precision locating and tracking applications in which UWB transmits large amounts of digital data and very short pulses (in nanosecond or less) over a wide spectrum frequency bands. Some techniques have been achieved due to improved bandwidth, including the use of trident-shaped feeding strip and a tapered impedance transformer and embedding a pair of notches in two lower corners of the patch and the notch structure in the upper edge of the ground plane [2, 3]. Wireless applications of UWB systems such as WLAN IEEE 802.11a (5.725–5.825 GHz), WIMAX IEEE 802.16 (5.25–5.85 GHz), C-band (5.47–5.725 GHz or 5.725–5.875 GHz) and Extended C-band (6.425–6.725 GHz) have been used for different approaches. The UWB systems will cause interference with these existing narrowband communication systems. Therefore, filtering these frequencies on other applications are mentioned to destroyed this interference. For reducing or avoiding the potential interference between UWB systems and the narrow systems, the band-notch filters should be applied in the antenna.

Various types of band-notch techniques have been studied [4–11], such as using H-shaped conductor-backed plane [12], modifying two U-shaped slots on the patch [13], inserting two rod-shaped parasitic structures [14], using spurlines [15], embedding resonant cell in the microstrip feed-line [16], utilizing a small resonant patch [17], and using an MAM and genetic algorithm [18]. However, these antennas have both large radiator and size.

In this paper, a new slot structure patch antenna is presented for band-notch UWB operating characteristics. The bandwidth of the proposed antenna is increased by using DGS in the ground plane. In addition, the proposed antenna is designed to have a rejection frequency bands by introducing a new inverted E- and F-shaped notch in the radiating plane. This design has a compact size of $13 \times 17\,\text{mm}^2$ and the thickness of 1.6 mm which gives a low profile antenna to cover the UWB band with band-rejection capability. In addition, the proposed antenna is compact compared to the designs recently reported

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in [19–25]. The band notching is achieved by embedding nearly inverted F-shaped slot in radiating patch to eliminate frequency band of 3.1 GHz to 3.8 GHz, and inverted E-slot in the microstrip patch has also eliminated two frequencies band including 2.68 to 3.55 GHz and 4.5 to 5.8 GHz.

2. ANTENNA DESIGN AND PARAMETRIC STUDY

The geometries of the proposed notched ultrawideband antenna are shown in Figure 1. This structure is constructed on an FR4-epoxy substrate with thickness $h = 1.6$ mm, dielectric constant $\varepsilon_r = 4.4$ and loss tangent 0.002. Dimension of the substrate is $17 \times 13\,\text{mm}^2$. The patch is fed by microstrip optimized line Length feed (Lf) and width feed (Wf).

The introduction of DGS affects the current distribution in the ground plane which improves the impedance bandwidth of the antenna. The bandwidth of the proposed E-shaped antenna is increased by using DGS in the ground. The UWB range frequency has gained by elliptical patch antenna. Furthermore, the antenna, which has inverted F-shaped slot on the patch and the same ground, is presented and achieves a band-notch which is 3.1 to 3.8 GHz. The geometry of front view for inverted F-shape defected on patch antenna and front view of elliptical patch antenna for getting UWB rang are shown in Figure 2. The parametric study is carried out to investigate the performance of the antenna with an F-shaped slot on the patch. During the investigation, one parameter has an elliptical shape fixed while others have been changed. As the result, the proposed antenna with an inverted E-shaped slot on the patch is produced, shown in Figure 3. Shorter "d" leads to better band notch

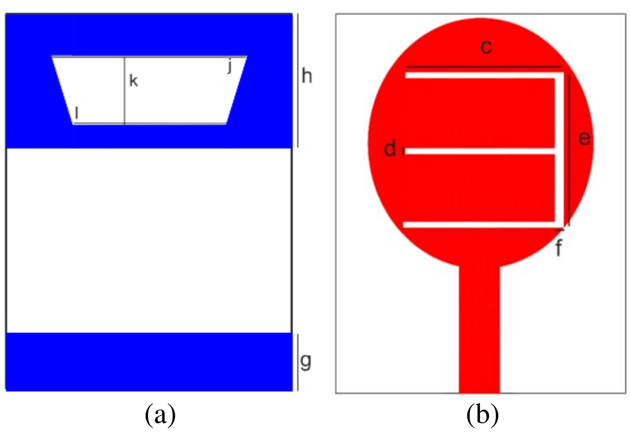


Figure 1. (a) Back view of the proposed antenna with DGS, (b) front view of the proposed antenna containing dual notch band.

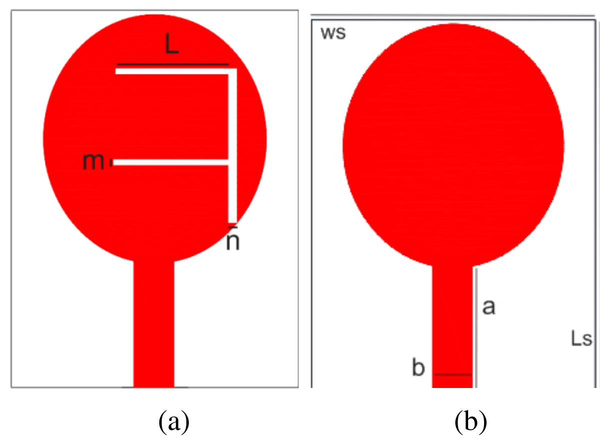


Figure 2. (a) Front view with F-shape defected on patch antenna for obtaining a notch band, (b) front view of the proposed antenna for getting UWB rang.

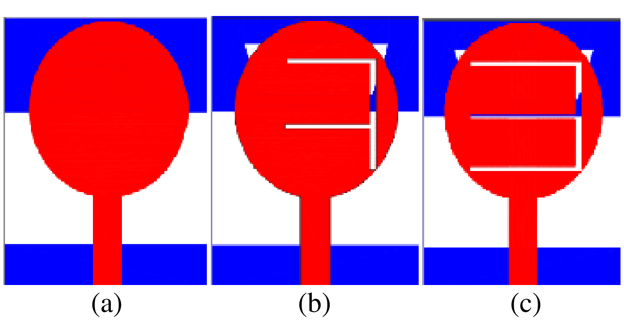


Figure 3. The sequence for getting UWB and band notches.

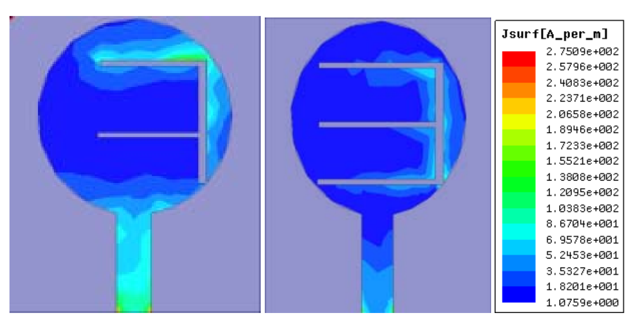


Figure 4. Current distributions for F- and E-shape defected on patch antenna.

characteristics. It is obvious that lower d creates better filtering for two notch-band frequencies. The current distributions of F and E shape defected on patch antenna for getting band-notch characteristics are shown in Figure 4. The effect of parameter "d" variations on the return loss of antenna are depicted in Figure 5. Furthermore, the following optimized parameters have been considered for obtaining the various characteristics as given in Table 1. The dimensions are obtained after performing an optimization.

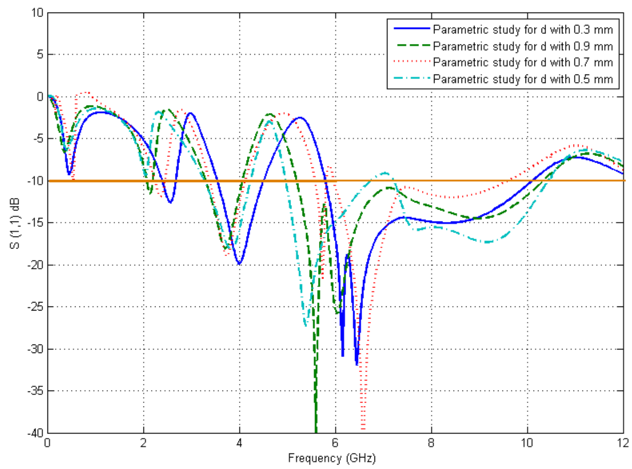
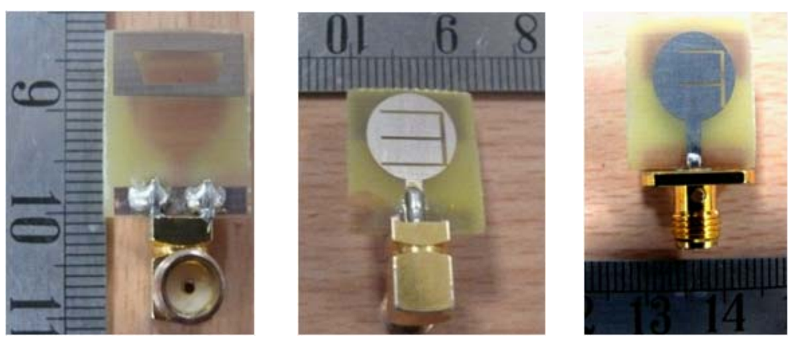


Figure 5. Effect of d changes on the return loss of antenna.



(a) (b) (c)

Figure 6. The view of fabricated antennas (a) back view, (b) front views for inverted E-shaped antenna, (c) front view for inverted F-shaped antenna.

Table 1. Designed parameters for proposed structure.

Parameter	Value (mm)	Parameter	Value (mm)
W_s	13.00	g	2.60
L_s	17.00	h	6.00
a	5.70	i	7.00
b	1.80	j	9.00
c	6.90	k	4.00
d	0.30	l	5.30
e	7.00	m	0.30
f	0.45	n	0.43

3. MEASURED RESULTS AND DISCUSSION

Based on the optimized parameters of the proposed dual band-notched and band-notch UWB microstrip antennas, the presented antennas were fabricated and are shown in Figure 6. The inverted E-slot in the microstrip patch has also eliminated two band frequencies including 2.68 to 3.55 GHz and 4.5 to 5.8 GHz. In addition, this antenna provides frequencies range from 2.39 to 2.7 GHz, so as to cover ISM 2.4 GHz WLAN frequency band. Furthermore, the proposed antenna with inverted F-shaped slot on the patch produces a band-notch from 3.1 to 3.8 GHz in order to eliminate the IEEE 802.16 WIMAX systems, and it can cover other frequency bands such as WLAN, 5.5 GHz WIMAX and C-bands. Figure 7 shows the simulated return loss performance of three proposed antennas. It can be illustrated that the proposed antenna without inverted E-shaped slot on the patch obtains a bandwidth of 3.1 to 10.1 GHz.

Moreover, with using DGS for this antenna, the bandwidth is improved which is about 3.1 to 11.47 GHz. The proposed inverted E-shaped notch antenna is compact in size compared to the design recently reported in [19–26]. The DGS ground structure has improved results for three proposed antennas. The return loss for inverted E-shaped slot with and without DGS is shown in Figure 8. Return losses for both measured and simulated antennas are illustrated in Figure 9, where a good agreement

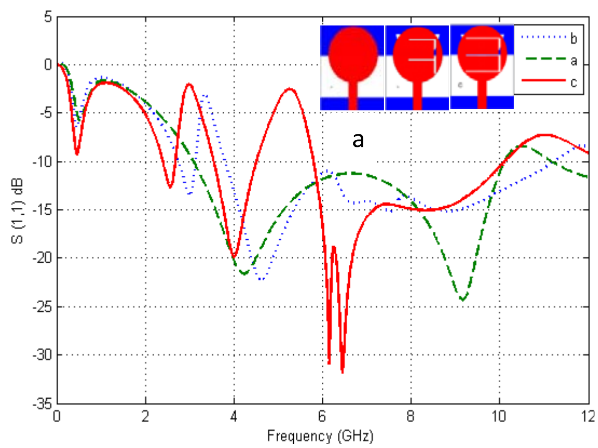


Figure 7. (a) Proposed antenna for getting UWB ranges, (b) inverted F-shaped slot to notch 3.1 to 3.8 GHz, (c) inverted E-shaped antenna to obtain dual notch band.

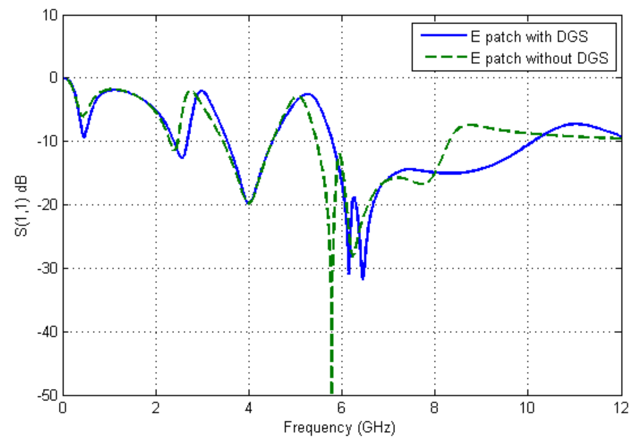


Figure 8. The inverted E shaped antenna with and without DGS.

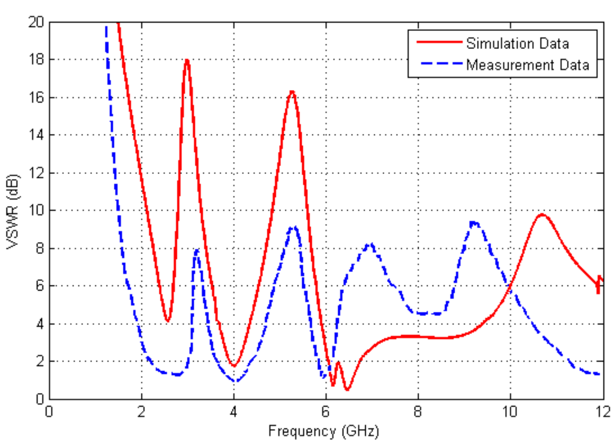


Figure 9. VSWR for E-shaped slot for both measurement and simulation data.

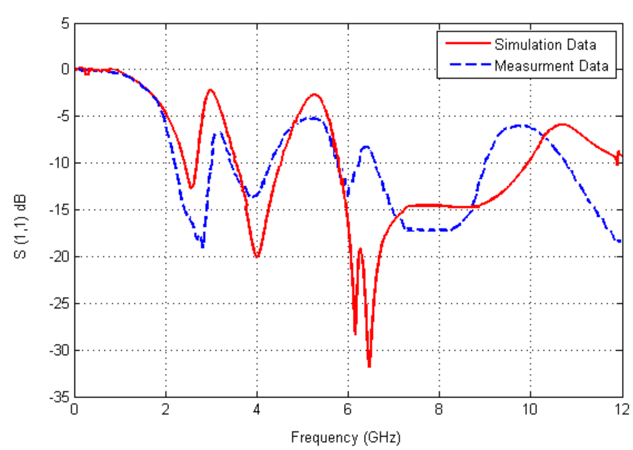


Figure 10. Return loss for E-shaped slot for both measurement and simulation data.

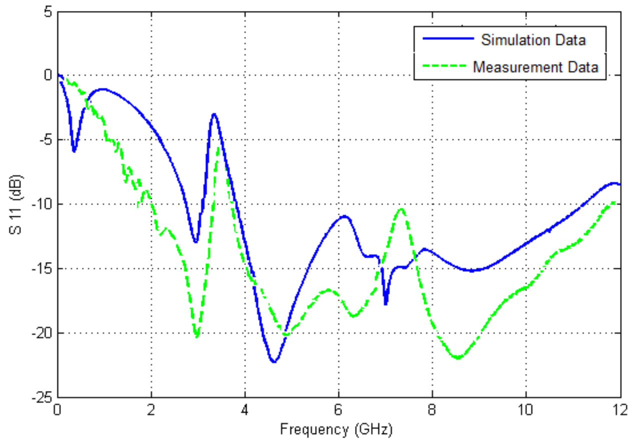


Figure 11. Return loss for F-shaped slot for both measurement and simulation data.

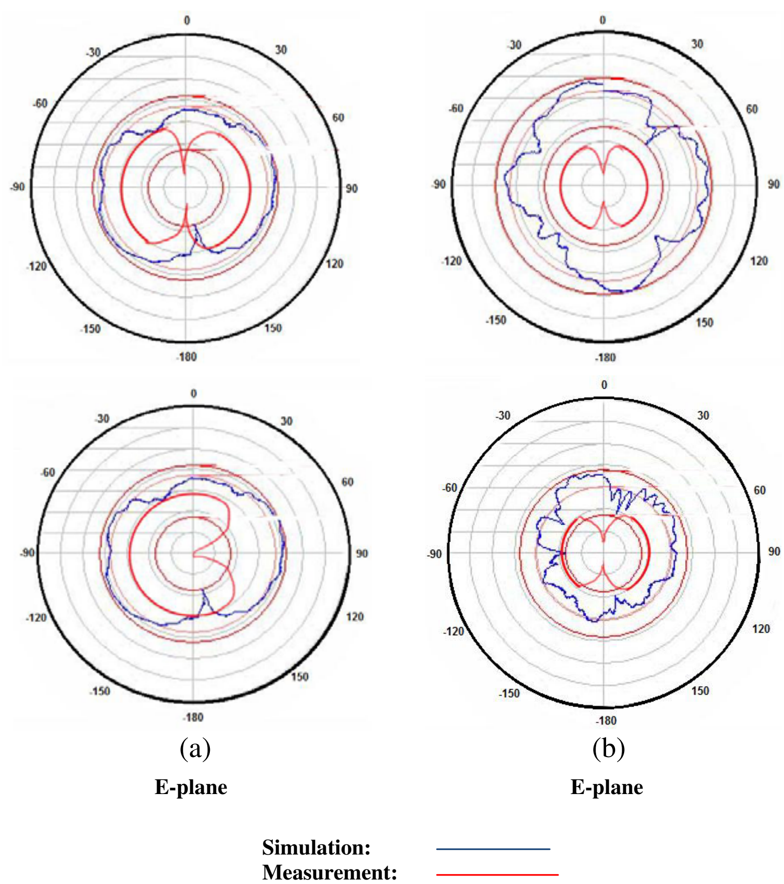


Figure 12. Simulated and measured radiation patterns of (a) proposed inverted E-shaped antenna for frequencies 2.4 GHz, 4.0 GHz, (b) proposed inverted F-shaped antenna for frequencies 3.0 GHz, 4.9 GHz.

between simulated and measured results is observed. The VSWRs for both measured and simulated inverted E-shaped antennas are shown in Figure 10. Although there is a little disagreement between simulated and measured VSWRs through the whole band, the result is quite satisfactory. In addition, the return loss for the inverted F-shaped antenna is shown in Figure 11. The simulation and measurement radiation patterns of the proposed E and F antennas in E-plan (or y-z) at frequencies 2.40 and 4.02 GHz for inverted E-shaped antenna and frequencies 3 and 4.9 GHz for inverted F-shaped antenna are depicted in Figure 12. The presented E-shaped antenna has a VSWR lower than 2 ($S_{11} < -10$ dB) from 2.38 to 10.41 GHz. For better comparison, the result of VSWR for both measured and simulated inverted E-shaped slot on the patch is shown in Table 2.

Table 2. VSWR measured and simulated results for inverted E-shaped antenna.

VSWR			
Frequency (GHz)	2.40	4.02	6.03
Simulation Value (dB)	4.10	1.76	0.49
Measurement Value (dB)	1.26	1.68	0.34
Different Value (dB)	2.84	0.08	0.15

4. CONCLUSION

In this paper, a compact planer notched UWB antenna is designed and discussed for UWB operation. In the design, the inverted E-shaped slot on the patch, using DGS based on the new shape and elliptical patch antenna, is designed and optimized to be used for wireless communication system. The dual band-notch, which is about 2.68 to 3.55 and 4.5 to 5.8 GHz in the design, removes unwanted frequency bands while maintaining an ultrawideband bandwidth performance. The size reduction of the antenna is also achieved, and the result is impressive due to its improved bandwidth which covers large frequency range from 2.38 GHz to 10.41 GHz (about 126%) having return loss less than -10 dB. VSWR is nearly under 2 which is very good for wireless application. The characteristics of compact size, low profile, and simple structure make the proposed antenna suitable to use for the UWB wireless communication applications.

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