A Simple and Compact CPW-Fed UWB Printed Monopole Antenna with Defected Ground Structures

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Abstract

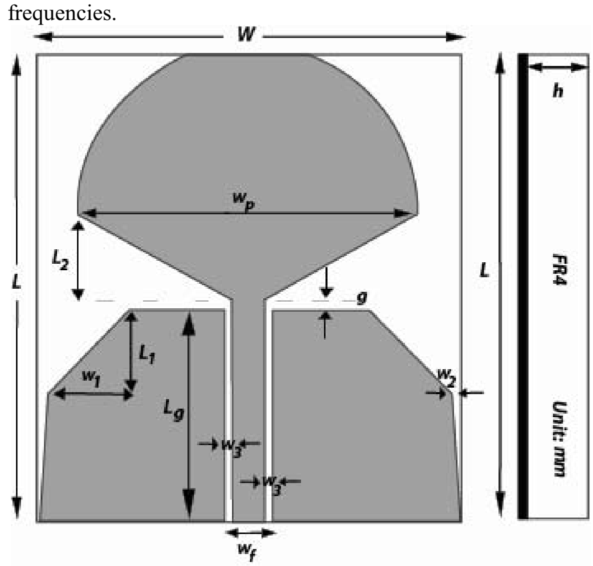
A planar simple and compact monopole antenna for UWB applications is proposed with CPW feeding. The radiating patch of the antenna consists of a top-cut half-circle together with a triangle on the lower edge. The bottom side of the antenna includes a rectangular defected ground plane with two different symmetrical bevels. By cutting out these bevels on the ground plane, bandwidth coverage of the overall UWB range except 5.4-7 GHz frequency band is provided. To enhance input impedance bandwidth characteristics at 5.4-7 GHz frequency band, dimensions of the triangular part on the lower edge of the patch and top-cut half-circle part on the upper edge are optimized. The overall size of the proposed antenna is 22×20×1 mm^3. Simulations are carried out using commercially available ANSYS's HFSS program which uses the finite element method (FEM). Results show that 110% of the impedance bandwidth between 3.6 and 12.2 GHz for VSWR<2 is achieved. Moreover, antenna has a stable omnidirectional pattern at XZ plane over the frequency band. Also, the presented antenna is fabricated on FR4 substrate and it is measured

1. Introduction

Ultrawideband (UWB) technology has taken significant role of the wireless communications world in recent years owing to their attractive features such as ultra-short pulses, high speed data rate, and low power consumption. The bandwidth range of the 3.1-10.6 GHz is specified UWB frequency band by the Federal Communication Commission (FCC) for the commercial purpose in 2002. Broadband planar monopole antennas are frequently used in these systems to satisfy UWB system due to their low profile values, ease of fabrication, large impedance bandwidth and omni-directional radiation pattern. Many novel UWB antenna designs have been developed in the last few years especially with a compact size [1, 7].

There are numerous methods in the literature [8-14] which have been improved to enhance antenna bandwidth and reduce the antenna size. Not only compact planar UWB monopole antennas are considered but also the compact planar UWB monopole antenna with band-notched characteristics at the WIFI/WLAN frequencies [15-20].

In this paper, a novel planar simple and compact CPW-fed monopole antenna for UWB applications is presented. The antenna is designed in order to use in the whole UWB systems which include electromagnetic and biomedical imaging systems, radar applications and GSM communication technologies. It is very applicable for the UWB systems because of its attractive merits such as its compact size, its omni-directional radiation patterns and its low cost planar structure. The overall antenna size is 22×20×1 mm^3. The bevel slots on the upper ground plane and on the lower radiating patch provide broad input impedance bandwidth mainly at the higher frequency band greater than 6.5 GHz. On the other hand, top-cut half-circle shaped part of the patch improves the antenna VSWR characteristics at the lower frequencies.



a.) b.)

Fig. 1. Configuration and parameters of the proposed antenna a.) Top-view b.) Side-view.

Table 1. Optimized Antenna Parameters

Parameters	Value	Parameters	Value
L	22 mm	w_2	0.4 mm
W	20 mm	w_3	0.27 mm
h	1 mm	L_g	10 mm
w_p	16 mm	L_1	4 mm
w_f	1.5 mm	L_2	4.02 mm
w_1	4.3 mm	g	0.5 mm

2. Antenna Design and Configuration

Complete geometry of the presented antenna with detailed design parameters are shown in Fig. 1. As a substrate material of the antenna, 1mm thickness of FR4 with a dielectric constant of $\varepsilon_r = 4.4$ and loss tangent of $\tan\delta = 0.02$ is used. Table 1 exhibits the dimensions of the antenna design parameters. The width of the microstrip feed line is fixed at w_f =1.5 mm for 50 Ω impedance, and the length of the feed line is chosen as $L_g + g$ = 10.5 mm. The antenna with an overall size of L (22) × W (20) mm^2 consist of the defected ground plane structure, the modified top-cut half-circle radiating patch, and CPW-fed line. The gap between the ground plane and radiating patch plays an important role to achieve broadband antenna characteristics. The gap adjusts electromagnetic coupling effects between the ground plane and radiating patch, and its optimum value is set to g = 0.5 mm.

The ground plane is formed by two different triangular-shaped slots. The sizes of these triangular-shaped slots are L_1 = 4 mm, w_1 = 4.3 mm, and L_g-L_1 = 6 mm, w_2 = 0.4 mm respectively. They are symmetrically removed with regard to the y-axis from the rectangular-shaped ground plane. Thus the entire UWB range is obtained except for the 5.4-7 GHz frequency band. Triangular-shaped slots with a length of L_2 = 4.02 mm are symmetrically removed from the lower edge of the patch. By removing these slots, input impedance bandwidth characteristics are improved between 5.4 and 7 GHz band.

The proposed antenna is obtained following three design steps. Each of these steps are shown in Fig. 2 and their VSWR characteristics are compared in Fig. 3. The parametric analyzes of the antenna for L_1, L_2, w_1, and w_2 parameters are examined.

3. Results and Discussions

A. The Compact UWB Monopole Antenna

Enhancements of input impedance bandwidth are obtained by modification of both the ground plane and the radiating patch of the antenna. In the first design step, Antenna 1 (see Fig.2) has rectangular radiating patch and ground plane. In this case, electromagnetic coupling is very strong between the ground plane and the radiating patch. The magnitude of the current distribution intensity on the upper side of the ground plane, and on the lower side of the radiating patch are nearly same while the current direction on the upper side of the ground plane, and on the lower side of the radiating patch flow oppositely in the entire UWB except the 5-6.4 GHz frequency band. Therefore, the resultant radiation fields cancel each other at these frequencies.

To enhance the bandwidth of the Antenna 1, a negative-slope triangular-shaped slot is removed from the upper side of the rectangular-shaped ground plane symmetrically with regard to the y-axis and a positive-slope triangular-shaped slot is removed at lower side of the rectangular-shaped radiating patch symmetrically with regard to y-axis. Antenna 2, which is the evolved version of the Antenna 1 as described, is shown in Fig.2. In this case, the magnitude of the current distribution intensity on the upper side of the ground plane and on the lower side of the radiating patch are nearly the same. However, the current direction of both the ground plane and the radiating patch change in a different way. Therefore the resultant radiation fields does not cancel each other. So, Antenna 2 has more VSWR characteristics than the Antenna 1. After all, by this method at the 5.6-7 GHz frequency range, VSWR characteristics do not meet the requirement of UWB systems.

The Antenna 3 shown in Fig. 2 is acquired by replacing the rectangular-shaped radiating patch of the Antenna 2, by a top-cut half-circle shaped radiating patch and by removing an additional triangular-shaped slot from the upper side of the rectangular-shaped ground plane symmetrically with regard to y-axis. By this configuration, obstructive electromagnetic coupling between the ground plane and the radiation patch is prevented. Consequently, configuration of the Antenna 3 works on completely UWB frequency range. Three version of these antenna design steps are shown in Fig. 3.

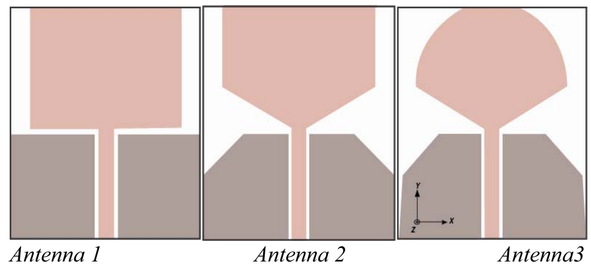


Fig. 2. Three design steps of the proposed compact UWB antenna.

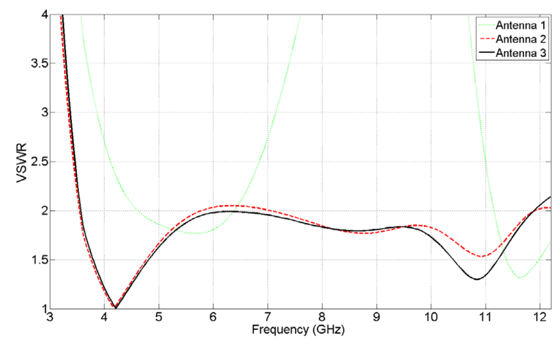


Fig. 3. Comparison of VSWR characteristics for the Antenna 1, 2 and 3.

B. The Parametric Studies

Simulated VSWR curves for different values of the L_1 are shown in Fig.4. As shown in Fig. 4, when the length of L_1 is varied from 2 mm to 6 mm, the lower resonance frequency decreases from 4.5 GHz to 3 GHz, and antennas' behavior at the middle frequency band also differs.

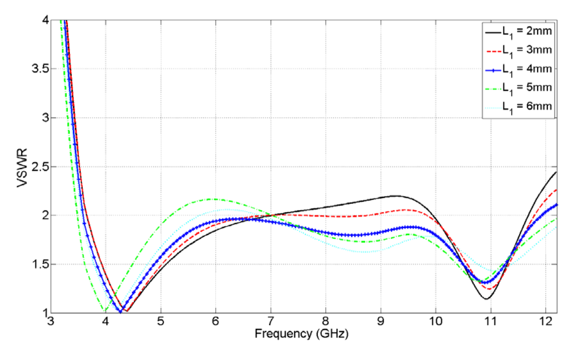


Fig. 4. Simulated VSWR characteristics for different L_1 values.

Fig. 5 shows the simulated VSWR curves with different values of L_2. As shown in Fig. 5, when the length of L_2 changes from 3.02 mm to 5.02 mm, the lower resonance frequency decreases from 4.5 GHz to 4 GHz.

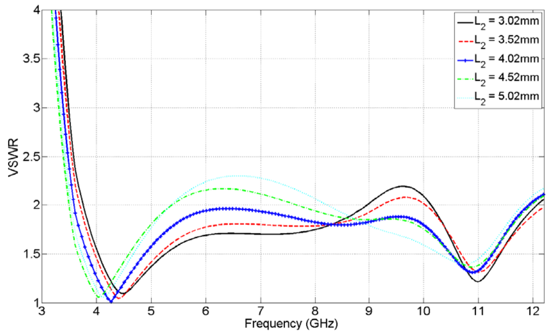


Fig. 5. Simulated VSWR characteristics for different L_2 values.

Fig. 6 shows the simulated VSWR curves with different values of w_1. As shown in Fig. 6, VSWR characteristic is sensible to the length of w_1 change at the 5-8 GHz frequency range.

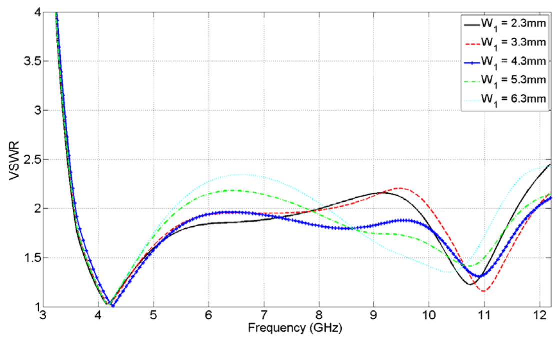


Fig. 6. Simulated VSWR characteristics for different w_1 values.

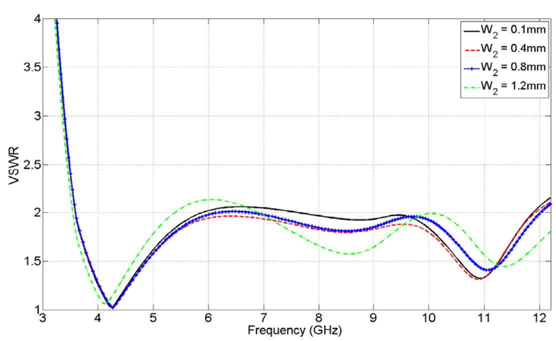


Fig. 7. Simulated VSWR characteristics for different w_2 values.

Fig. 8. Photograph of the fabricated antenna

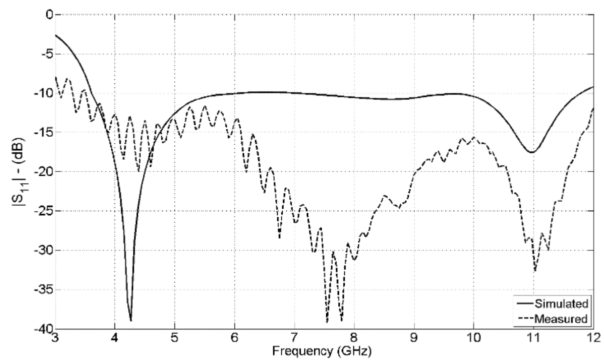


Fig. 9. Simulated and measured $|S_{11}|$ of the proposed antenna

Fig. 7 shows the simulated VSWR curves with different values of w_2. As shown in Fig. 7, w_2, width of the triangular slot on the ground plane directly effects the VSWR characteristic of the antenna at the higher frequencies. The offered antenna is fabricated using the optimum antenna design parameters which is given in Table 1. Realized antenna is shown in Fig.8. In Fig.9 comparison of simulation and measurement results are plotted. A reasonable agreement between simulation and measurement is obtained.

In Fig. 10, antenna radiation patterns at XZ and YZ planes with co- and cross-polarizations are investigated at 4GHz, 7GHz, and 10 GHz, across bandwidth. It can be seen from the figures that antenna exhibits omni-directional radiation pattern at XZ plane. Moreover, very low cross-polarized pattern levels are observed on both plane cuts.

4. Conclusions

A simple planar and small CPW-fed monopole antenna with defected ground structure for UWB applications has been presented and investigated. Design steps of the antenna are given and VSWR characteristics are compared. Also, the simulated antenna is fabricated on FR4 substrate. Then its S11 characteristic is measured and both the simulated S11 result and the measured S11 result are compared too. The effects of the different geometries on the current distribution intensity are also analyzed. It is presented that by removing triangular-shaped slots with proper dimensions from the radiating patch and from the ground plane, a broad impedance bandwidth can be achieved. The effect of the size of these slots are studied and exhibited. The radiation pattern of the antenna has an omni-directional pattern in the XZ plane along the UWB frequency range. The proposed antenna can be used with all UWB systems.

As a future work, the presented antenna will be rearranged in order to have a band-notch function at the WLAN frequencies (5.1 – 5.8 GHz). It can be provided by several methods which is used in the literature such as adding parasitic patch, removed various shaped slots, inserting various shaped slits etc. Thus the interfere which is occurred at the WLAN frequency band in the UWB systems is going to be prevented via using the mentioned ways.

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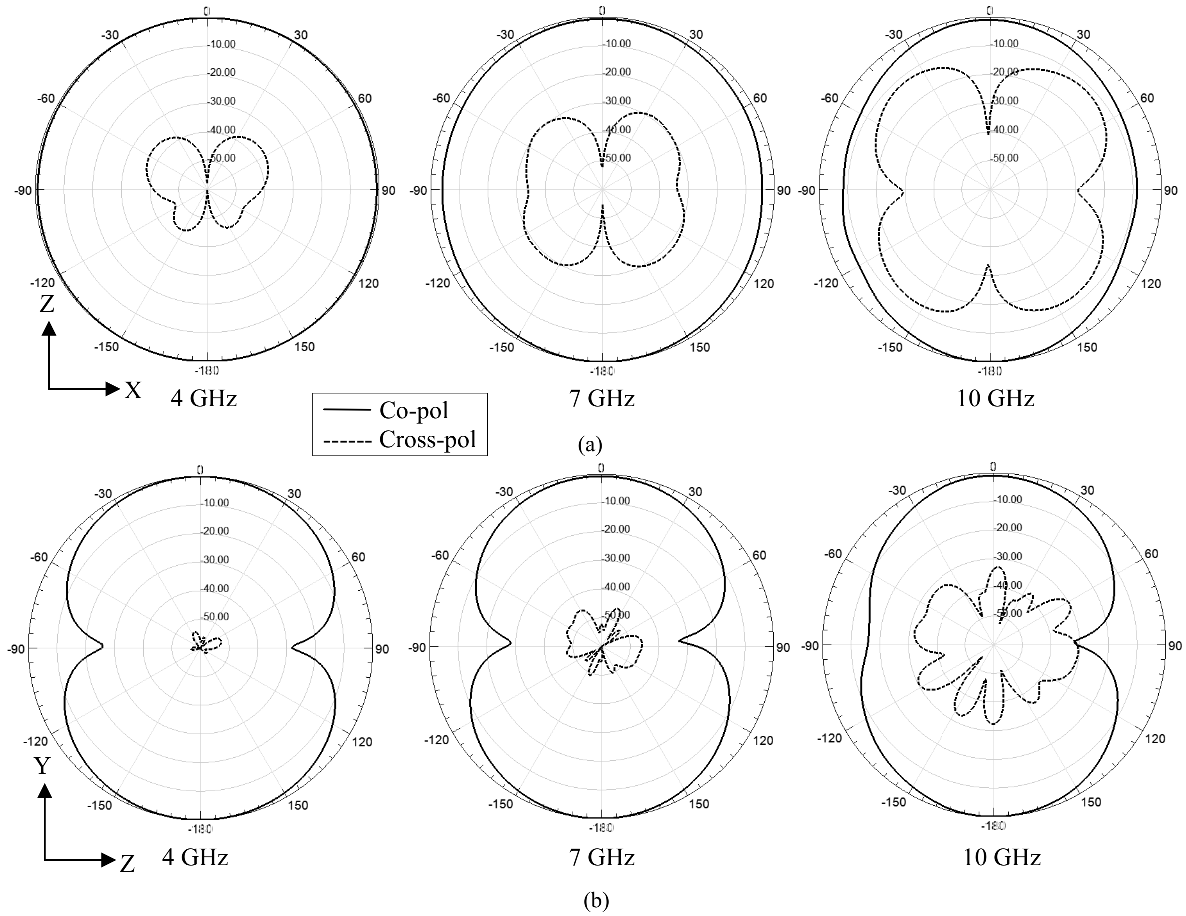

Fig. 10. Radiation pattern of the antenna at 4GHz, 7GHz, and 10 GHz for (a) XZ plane (b) ZY plane