A CPW-Fed Novel Planar Ultra-Wideband Antenna with a Band-Notch Characteristic

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Abstract. *A coplanar waveguide (CPW) fed novel planar ultra-wideband antenna with a band-notch characteristic is presented. The proposed antenna consists of a rectangular metal radiation patch and a tapered arc-shaped ground plane. To achieve ultra wideband, three modifications are introduced, the first one is to remove a 90-degree fan angle on the upper corners of the patch, the second one is to shape the bottom of the patch into an arc, and the third modification is to remove a small fan angle on each side of the ground plane near the feeding line. Simulation results show that the proposed antenna operates over 3.0 to 23 GHz for VSWR < 2. By embedding a C-shaped slot in the radiating patch, a frequency band notch between the bandwidth of 5 to 6 GHz for Wireless LAN (WLAN) will be obtained. All simulations in this work were carried out by using the electromagnetic software Ansoft HFSS 11. Compared with the recently proposed antennas, this antenna has advantages in wide bandwidth, good band-notch characteristic, compact in size and easy design. Details of the proposed antenna are presented, and simulated results show that the antenna has stable radiation patterns and good gain flatness over its whole frequency band.*

Keywords

Coplanar waveguide (CPW), ultra wideband (UWB), planar UWB antenna, C-shaped slot, band-notched characteristic.

1. Introduction

Since the first Report and Order by the Federal Communications Commission (FCC) authorized the unlicensed use of UWB which must meet the emission masks on February 14, 2002, both industry and academia have paid much attention to R&D of commercial UWB systems [1]-[3]. In UWB systems, antenna design is one of key technologies, and a suitable UWB antenna needs to fulfill requirements set by UWB technology and by portable devices alike, such as ultra wide bandwidth, directional or omnidirectional radiation patterns, constant gain and group delay over the entire band, high radiation efficiency and small size. Meanwhile, planar UWB antenna fed with a microstrip line or a coplanar waveguide (CPW) has received much attention due to its advantages such as wideband characteristic, bidirectional radiation patterns. Especially, it is easy to integrate the CPW-fed antennas with a UWB chip. Many CPW-fed antenna configurations have been proposed and developed [3]-[7]. However, these antennas for UWB communication also need a band-rejection filter to avoid interference with existing wireless networks with standards such as IEEE 802.11a in USA (5.15 GHz - 5.35 GHz, 5.725 GHz - 5.825 GHz) and HIPERLAN/2 in Europe (5.15 GHz - 5.35 GHz, 5.47 GHz to 5.725 GHz) [4]-[7]. To avoid adding new circuits to the communication system, band-notching technique can be applied directly to various UWB planar antennas by loading the UWB antenna with a resonant slot at the center frequency of the stop band. Different configurations of this slot have been introduced for this purpose such as U-shape [4], C-shape [5], spoon-shape [6] and V-shape [7].

In this paper, a CPW-fed novel planar ultra-wideband antenna with a band-notch characteristic is introduced. In order to obtain ultra wideband and rejected band characteristic, some modifications about the antenna are introduced and a C-shaped slot is inserted in the radiating patch. The simulated results show that the proposed antenna presents a very wide impedance bandwidth and a band-notch characteristic. Sec. 2 presents the details of the antenna structure and the design procedure. Sec. 3 analyses the radiation patterns and current distribution. The curve of frequency-gain is also given. Finally, the conclusion is presented in Sec. 4.

2. Antenna Design

The geometrical configuration of the proposed antenna is depicted in Fig. 1 and the parameters are summarized in Tab. 1. This antenna is fed by a 50-Ω CPW and has dimension of 28×30 mm that is fabricated on the FR-4 substrate with a thickness (H) of 1.6 mm and relative dielectric constant of 4.4, loss tangent tanδ = 0.02. The proposed antenna is located in x-y plane and the normal direction is parallel to z-axis. The proposed antenna is composed of a rectangular metal radiation patch and a tapered arc-shaped ground plane. Two modifications are

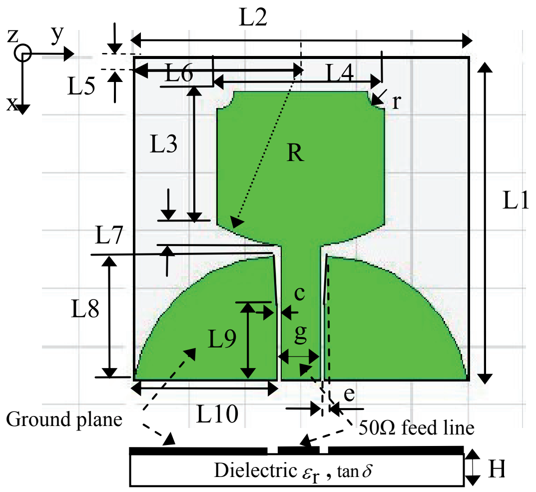


Fig. 1. Configuration of the proposed antenna.

L1	L2	L3	L4	L5	L6	L7	L8
28	30	10.5	15	1.5	15	3	10.8
L9	L10	H	R	r	g	c	e
5.4	12.9	1.6	15	1	3.6	0.3	0.3

Tab. 1. Parameters of the proposed antenna (unit: mm).

introduced on this patch to improve its operating bandwidth. The first one is to remove a 90-degree fan angle on the two upper corners of the patch. The second modification is to shape the bottom of the patch into an arc. The modification of the patch results in a smooth transition from one resonant mode to another. In practical applications, the size of ground plane is finite and the direction of maximum radiation tilts somewhat upwards from the horizontal plane. To reduce this beam tilting, the ground plane of the proposed antenna is designed to have not rectangular but rounded shape [2], and a small fan angle on each side of the ground plane near the feeding line is removed respectively [8]. The arc-shaped patch and tapered ground plane make good broadband impedance matching of the antenna possible [3]. The gap between the feed line and ground plane is 0.3 mm to obtain 50-Ω port impedance. By selecting the optimal parameters mentioned in Tab. 1, the proposed antenna can be tuned to operate within the UWB band. Fig. 2 shows the VSWR which demonstrates very broadband impedance characteristics, covering the frequency range of 3.0 (m1) to 23 (m2) GHz.

when the bottom of the patch is shaped into an arc. On the basis of this, the third line regarding the upper corners modification indicates the bandwidth is further expanded compared with the second line. The fourth line demonstrates that the small angle on each side of the ground plane near the feeding line will affect the characteristic impedance of the CPW line and also explains

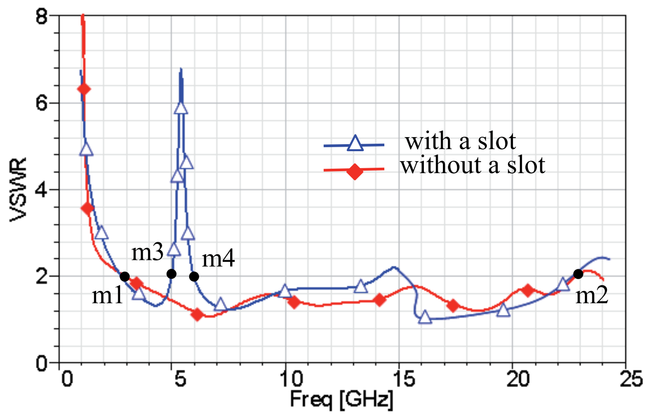


Fig. 2. Simulated VSWR of the antenna without and with a slot.

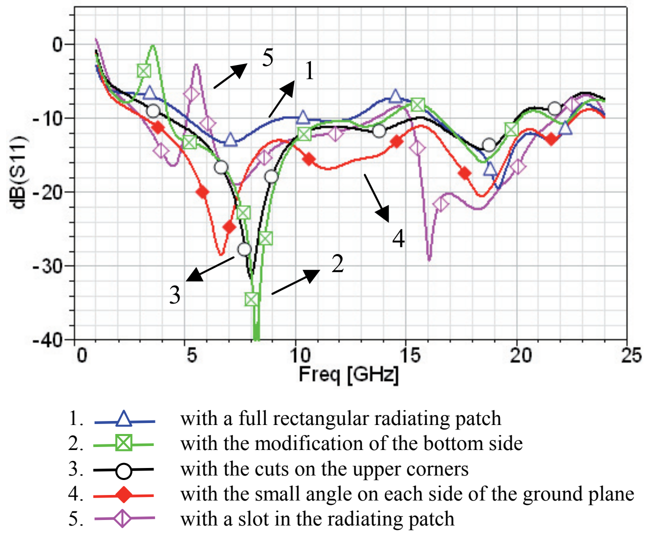


Fig. 3. Simulated reflection coefficient for different shapes of the radiation patch and the ground plane.

bandwidth. The fifth curve reveals that by cutting a C-shaped in the radiating patch, a stop-band has been created.

Fig. 4 shows the geometry of the antenna with a C-shaped slot. The outer radius and inner radius of the slot are R1 and R2. The center of the arc is placed at distance L11, 8 mm from the upside of the patch and the end of the arc is placed at distance L12, 6.7 mm from the upside of the patch. The C-shaped slot has total length 22.5 mm and is close to about one-half wavelength at the center frequency of the desired notched frequency band (the center frequency of the desired notched frequency band is 5.5 GHz, the one-half wavelength can be approximated by: $\lambda/2 = c/2f = 300/11 \cong 27.3$ mm.

The bandwidth and the central frequency of the notched band can be adjusted with ease by proper selection of C-shaped slot parameters. To investigate the effects of the length (L12) variation on the notch bandwidth performance, the VSWR are computed as demonstrated in Fig. 5. When L12 varies from 6.2 to 7.2 mm, the center notch frequency moves toward higher frequency, and the

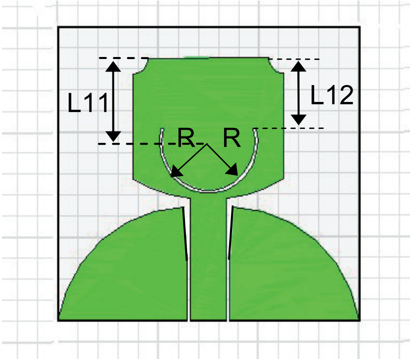


Fig. 4. Geometry of the antenna with a C-shaped slot, R1 = 4.9 mm, R2 = 4.6 mm, L11 = 8 mm, L12 = 6.7 mm.

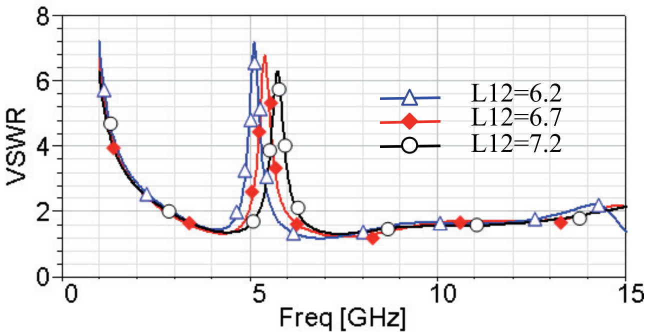


Fig. 5. Simulated VSWR for various L12 in mm with R1 = 4.9 mm and R2 = 4.6 mm.

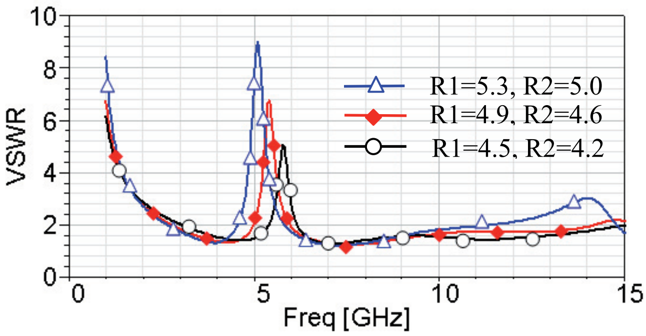
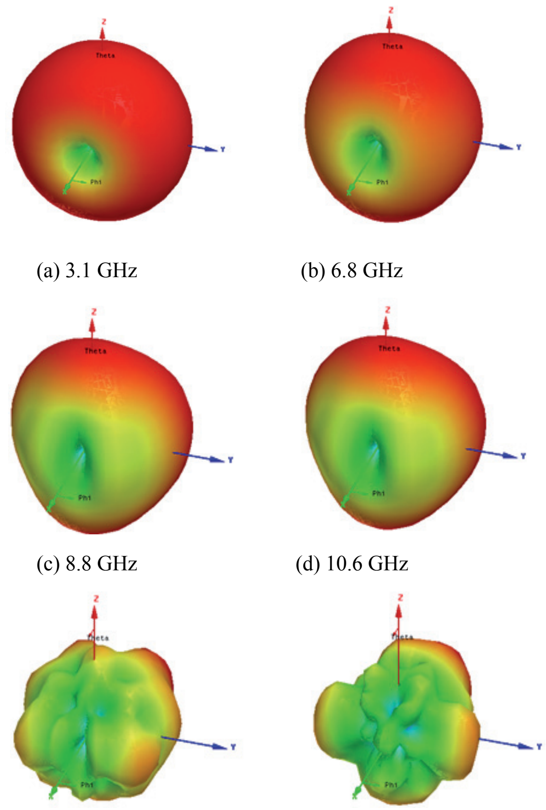


Fig. 6. Simulated VSWR for various R1 and R2 in mm with L12 = 6.7 mm.

edge of low frequency and the bandwidth are nearly unchanged. Fig. 6 shows the simulated VSWR for various outer radiuses (R1) and inner radiuses (R2) of the C-shaped slot with the width of the slot fixed at 0.3 mm. As the parameters R1 and R2 are increased simultaneously, the central frequency of the notched band is decreased and the bandwidth is broadened.

3. Antenna Simulation Results

In this section, full wave analyses of the proposed antennas in frequency domain are obtained by using the electromagnetic software Ansoft HFSS 11 which is based on finite element analysis. The simulated VSWR of the proposed antenna without and with slot are shown in Fig. 2. It is apparent that the proposed antenna can cover the frequency band 3.1 to 10.6 GHz released by FCC for a UWB system for VSWR < 2 and stop the band 5.0 (m3) to 6.0 (m4) GHz.



(a) 3.1 GHz (b) 6.8 GHz

(c) 8.8 GHz (d) 10.6 GHz

(e) 16.8 GHz (f) 22.5 GHz

Fig. 7. Simulated radiation patterns at specific frequencies.

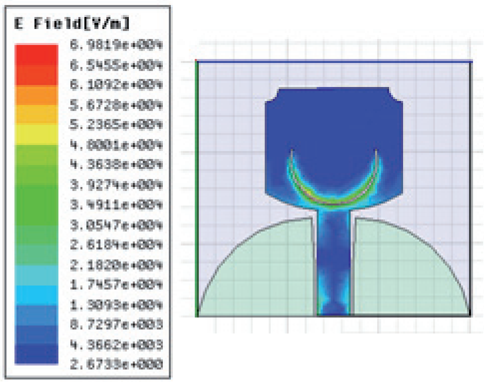


Fig. 8. Simulated current distribution of the antenna at 5.5 GHz.

The 3D plots of simulated radiation patterns at specific frequencies about the antenna without a slot are illustrated in Fig. 7. The E (x-y plane) and H (y-z plane) fields in the figures reveal that at lower frequencies they have nearly perfect omnidirectional radiation patterns, but the radiation pattern degrades sharply at higher frequencies (such as 22.5 GHz). The proposed antenna has an acceptable quasi omnidirectional radiation pattern required to receive information signals from all directions.

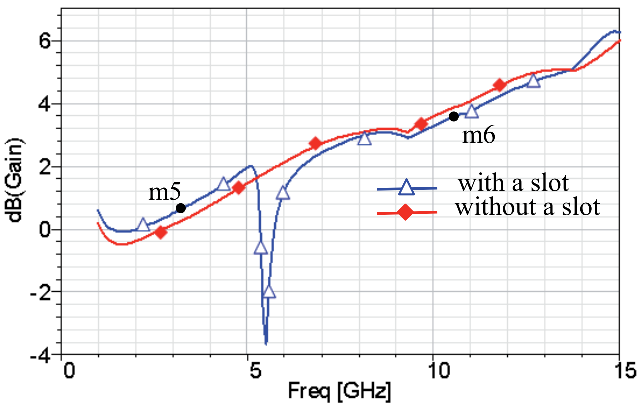


Fig. 9. Simulated gain of the antenna without and with a slot.

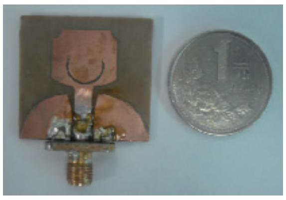


Fig. 10. Photograph of the fabricated antenna.

Antenna	Simulated Bandwidth (GHz)	Simulated Notch Bandwidth (GHz)	Antenna size (mm^2)	Gain (dB)
This work	3.0 - 23	5.0 - 6.0	28 × 30	0.2 - 3.9 *
[4]	3.8 - 12.0	5.1 - 6.2	28 × 29	-4.5 - 3.5
[5]	3.1 - 11	5.0 - 6.0	26 × 30	1.5 - 4.6
[8]	3.1 - 10.6	5.12 - 6.05	35.2 × 28.18	0.42 - 4.2
[9]	3.1 - 12	5.15 - 5.85	24 × 35	< 4

(*: 0.2 - 3.9 dB is covering the frequency range of 3.1 - 10.6 GHz)

Tab. 2. Comparison between recently proposed antennas and this antenna.

The simulated current distribution at 5.5 GHz is shown in Fig. 8. It reveals that the currents mainly concentrate over the area of the slot in the radiation patch. A comparison of simulated gain of the proposed antenna without and with slot is shown in Fig. 9 and indicates gain variation from 0.2 (m5) dB to 3.9 (m6) dB in the frequency range of 3.1 to 10.6 GHz and a sharp notched band suppressed by the slot between 5 and 6 GHz is seen. The photograph of the manufactured antenna including coaxial feeding port is shown in Fig. 10 and a future measurement work will be carried out. When comparing the results to the performance of some UWB antennas presented in Tab. 2, the following features of the implemented antenna can be highlighted: wide impedance bandwidth, good band-notch characteristic, compact in size and good gain flatness.

4. Conclusion

In this paper, a CPW-fed novel planar ultra-wideband antenna with a band-notch characteristic was presented. One quarter of circle was simulation removed from both two upper corners of the rectangular UWB antenna combined with an arc-shaped bottom and with a tapered arc-shaped ground plane. The simulation result of the VSWR demonstrates that the antenna has very broadband impedance which covers the frequency range of 3.0 to 23 GHz. By embedding a C-shaped slot in the radiating patch, a frequency band notch between the bandwidth of 5 and 6 GHz for Wireless LAN (WLAN) has been obtained. Simulated and analyzed in detail in this paper, the proposed antenna could be a good candidate for UWB applications.

Acknowledgements

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