Ultra-Wideband Antenna Using CPW Resonators for Dual-Band Notched Characteristic

Y. F. Weng, S. W. Cheung and T. I. Yuk
Department of Electrical and Electronic Engineering
The University of Hong Kong
Hong Kong
E-mail: [yfweng, swcheung, tiyuk]@eee.hku.hk

Abstract—**This paper presents the design and results of a compact Ultrawideband (UWB) monopole antenna with a dual-band notched characteristic. The antenna consists of a semi-circular radiator and a dual-coplanar-waveguide (CPW) resonator to produce two notched bands at the center frequencies of 3.5 and 5.5 GHz in the UWB region. The computer simulation results of the Voltage-Standing-Wave Ratio (VSWR), radiation pattern and peak gain of the antenna agree well with the measurements.**

Keywords - Coplanar Waveguide Resonator, monopole antenna, ultrawideband (UWB) antenna, band notched.

I. INTRODUCTION

In 2002, the US-FCC assigned the frequency band of 3.1-10.6 GHz for UWB communication systems [1]. The advantages of the Ultrawideband (UWB) communication system mainly include: high data rate (more than 100Mb/s) for short ranges, low power consumption and easy connection among a large number of multimedia devices such as PCs, high-definition TVs, digital cameras, etc. As a result, the UWB is attracting considerable interests and research activities in recent years. Compact size, low cost and good performance, e.g. non-dispersive, omnidirectional radiation pattern and relatively uniform gain, are all important criteria for UWB antennas and this have brought many opportunities and challenges to the antenna designers.

In the US-FCC allocation of frequency band for UWB applications, there are already several other existing communication systems, e.g. IEEE 802.11a WLAN in the frequency band of 5.15-5.825 GHz and the IEEE 802.16 WiMax mainly operating in frequency band of 3.3-3.6 GHz. These systems may potentially interfere with the UWB systems. Thus UWB antennas with band-notched characteristic are necessary to ease this potential problem. Different antenna design methods have been proposed to produce the band-notched characteristic in the UWB band [2-10]. Among these designs, etching different kinds of slots on the patch or ground of the antennas is most often used [2-4]. Other methods include adding parasitic elements, using folded strips to the antennas [5] and etching split-ring resonator (SRR) or complementary split-ring resonator (CSRR) on the radiator [6-8]. Embedding resonated cell in microstrip line or coplanar waveguide can also effectively filter the undesired bands [9-10], but the antennas have only one notched band from 5.15 GHz to 5.85 GHz.

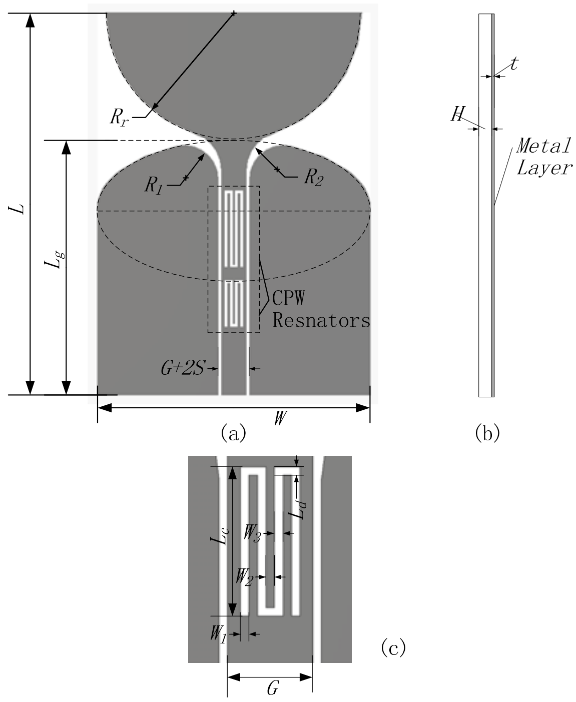

Fig. 1 (a) Layout and (b) side view of antenna with single CPW resonator, and (c) layout of CPW resonator.

In this paper, a dual-band CPW resonator consisting of two CPW resonators connected in series is proposed to achieve a dual-band notched characteristic for an UWB antenna. An UWB antenna with the dual-band CPW is designed and studied by using the computer simulation tool CST MWS 2009 [13] and the Satimo Starlab measurement system [14]. Results show that the dual-band notched antenna can operate in a band from 2.16 GHz to over 12 GHz with Voltage-Standing-Wave Ratio (VSWR) ≤2 and the radiation pattern is almost omnidirectional over the entire UWB band.

II. Antenna Design

Structure of antenna

In our design, we propose to use a semi-circular radiator fed by a 50-Ω CPW to minimize the antenna size for applications in wireless devices. Figure 1 shows the layout of our design which is fabricated on a Rogers PCB, RO4350B, with a transverse dimension of 32 mm × 35 mm and having a relative dielectric constant ε_r = 3.48, thickness 0.762 mm and loss tangent 0.0037 for the substrate. The width of the CPW, *G*, and the distance between the feed line and ground, *S*, are 3 mm and 0.3 mm, respectively, in order to have a characteristic impedence of 50 Ω. The ground plate is a rectangle plus a half ellipse with a ratio of 0.5 to reduce the beam tilt of the antenna [9]. The small area connecting the CPW and the semi-circular radiator is critical for impedance matching and so is smoothed by using two arc shapes with a radius of R_1 and R_2. Detail dimensions of the single notched band antenna are listed in Table 1.

TABLE I. ANTENNA DIMENSIONS

Parameter	***Value(mm)***	***Parameter***	***Value(mm)***
L	35	L_d	0.3
W	32	W_1	0.3
L_g	20	W_2	0.3
R_r	15	W_3	0.3
R_1	4	G	3
R_2	4.5	S	0.3
t	0.0035	L_c[a]	5.3
H	0.762	L_c[b]	9

a. Notched band at 5.5GHz
b. Notched band at 3.5GHz

Dual-band CPW Resonator

CPW resonator is a basic component in CPW circuits. Different types of $\lambda/2$-open-ended CPW resonators and $\lambda/4$-CPW resonators have been used to design bandstop filters [13-14]. However, the sizes of these types of CPW resonators are too large and so difficult to integrate into the RF front ends of wireless devices. Here we propose a new structure of CPW resonator with a much smaller size as shown in Fig. 1 (c). One of the CPW resonator is etched with a distance of 8 mm from the bottom of ground. The separation between the two CPW resonators is 2mm. The resonance of the CPW resonator is determined by the length L_c and the small gap L_d as shown in Fig. 1(c).

Simulation results on the VSWR with different values of L_c and L_d in the CPW resonator using CST MWS 2009 [11] are shown in Figs. 2 and 3, respectively. It can be seen that the resonance frequency varies with L_d and L_c, but the VSWR values in the other UWB band remain almost the same. This property provides a great freedom to the designers to vary the frequency of the notched band for the antennas. Thus in our proposed antenna, we use two CPW resonators connected in series, a dual-band CPW resonator, as shown in Fig. 1 to create two different notched bands.

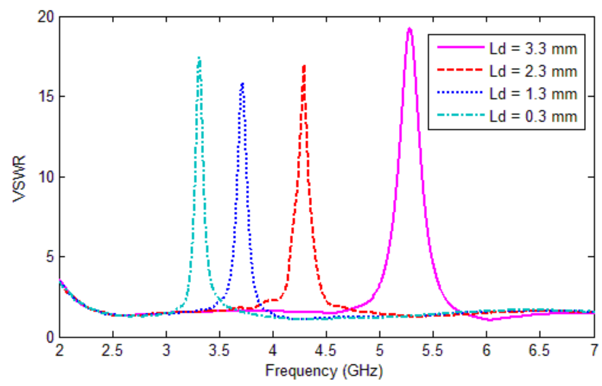

Fig. 2 VSWR for different values of L_d, with L_c = 9 mm, W_1 = W_2 = W_3 = S = 0.3 mm and G = 3 mm.

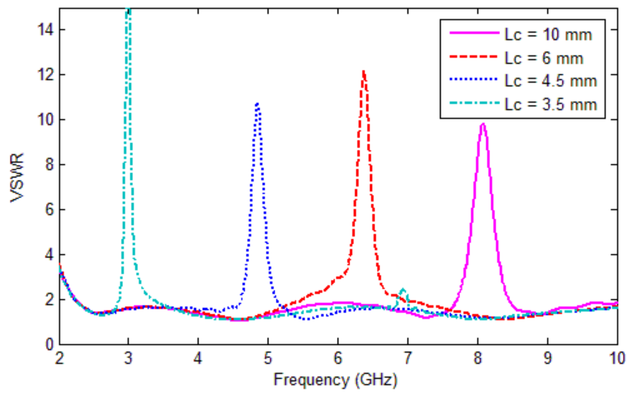

Fig. 3 VSWR for different values of L_c, with L_d = W_1 = W_2 = W_3 = S = 0.3 mm and G = 3 mm.

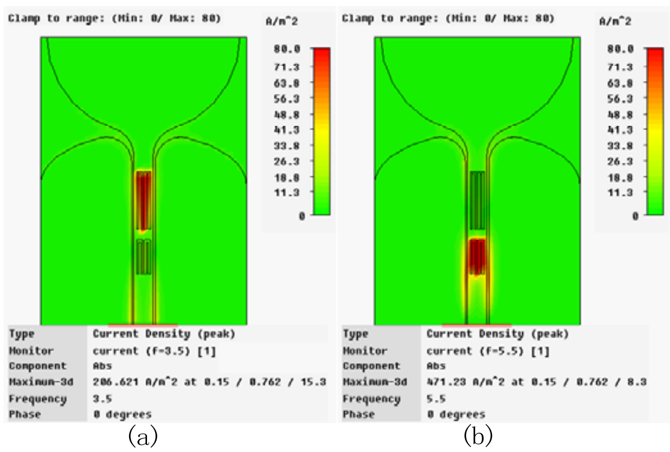

Fig. 4 Distribution of surface current at (a) 3.5 GHz, (b) 5.5 GHz.

To better understand the antenna operation, the distributions of surface current on the antenna at the notched frequencies have been studied using CST MWS 2009 and results are shown in Fig. 4. At 3.5 GHz and 5.5 GHz, Figs. 4(a) and 4(b) show that the energies are confined in the upper and lower CPW resonators, respectively, and are much higher than that in the main radiation element and do not get radiated.

III. Results And Discussions.

The final designs of the antennas, with and without the dual-band CPW resonator (for the notched bands centered at 3.5 GHz and 5.5 GHz), have been fabricated using Rogers PCBs, RO4305B, as shown in Fig. 5. The VSWR and Peak Gain across the UWB band, and the Radiation Patterns at 4.5 GHz, 6 GHz and 9 GHz have been studied by using CST MWS 2009 and measured using the Satimo Starlab measurement system.

The simulation and measurement results of VSWR in Fig. 6 show that there are two notched bands, from 3.26 GHz to 3.75 GHz and 5.02 GHz to 5.90GHz, across the UWB band. The VSWR is substantially higher (VSWR>2) in the notched bands. The results also show that the antenna can work in a frequency band from 2.16 GHz to over 12 GHz for VSWR ≤ 2 which fully satisfy the UWB requirement.

Fig. 5 Photograph of the proposed antennas without and with dual-band CPW resonator for dual-notched bands at 3.5 GHz and 5.5 GHz.

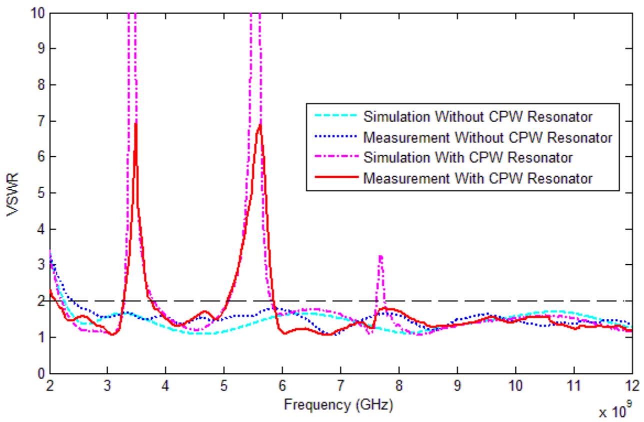

Fig. 6 Simulated and measured VSWR of antenna with and without dual-band CPW resonator.

The simulated and measured radiation patterns of the antenna with the dual-band CPW resonator, at the frequencies of 4.5 GHz, 6 GHz and 9 GHz and in three important cuts, i.e., in the x-z, y-z, x-y planes, are shown in Fig. 7. It can be seen that the measured radiation patterns agree well with the simulated results. For UWB applications, omnidirectional radiation pattern is normally preferred (i.e., in the x-y plane). The results of Fig. 7 show that the radiation patterns at all of the three frequencies satisfy this requirement well.

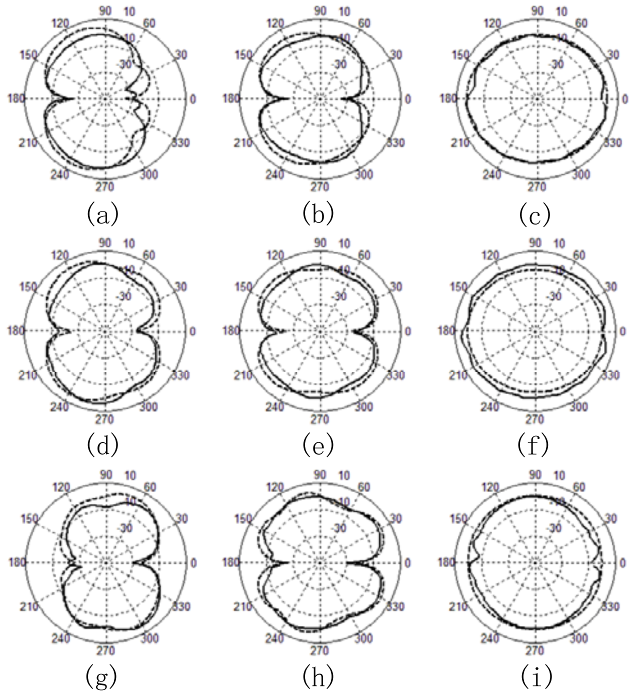

Fig. 7 Simulated and measured radiation patterns with dual-band CPW resonator. Solid lines and dash lines are measured and simulated results, respectively. (a) 4.5 GHz in x-z plane; (b) 4.5 GHz in y-z plane; (c) 4.5 GHz in x-y plane; (d) 6 GHz in x-z plane; (e) 6 GHz in y-z plane; (f) 6 GHz in x-y plane; (g) 9 GHz in x-z plane; (h) 9 GHz in y-z plane; and (i) 9 GHz in x-y plane.

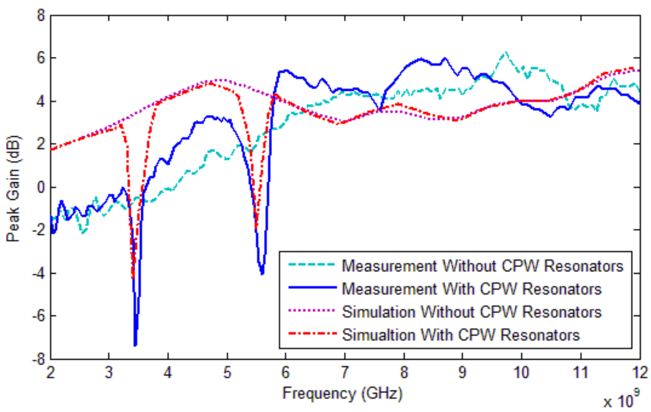

Fig. 8 Simulated and measured peak gain with and without dual-band CPW resonator.

The simulated and measured peak gains of the antenna, with and without the dual-band CPW resonator, in the UWB band are shown in Fig. 8. With the dual-band CPW resonator, the simulation results show that the peak gains around the center frequencies of 3.5 GHz in the WiMax band and 5.5 GHz in the WLAN band drop drastically by about 10 and 8 dB, respectively. While the measured results show the drops are about 6 dB in these two notches. At other frequencies (i.e., from 6 GHz to 12 GHz), the peak gains are in the range from 3 to 6 dB which are higher than those of the antenna without the dual-band CPW resonator.

IV. CONCLUSIONS

In this paper, we have proposed and presented the design of a small-size CPW-fed monopole antenna that exhibits dual band-notched characteristic at the center frequency of 3.5 and 5.5 GHz in the UWB band. The planar monopole antenna consists of a semi-circular shape as the primary radiation element and a dual-band CWP resonator to produce a deep notch at 3.5 GHz of the WiMax band and another deep notch at 5.5 GHz of the WLAN band. Simulated and measured results have shown great agreements. Results have shown that the antenna pattern is almost omnidirectional in the UWB band and the peak gains are quite satisfactory.

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