Vertical UWB CDM Antenna with Integrated Band Notched Filtering

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Abstract - A compact vertical circular disc monopole (CDM) antenna with U-shape slot and inverted U – shape slot (radius, a=1.5cm, thickness, t=0.02cm, height gap, h=0.01cm and the ground plane size of 14cm^2) is presented in this paper. The CDM antenna has been reported to yield wide-impedance bandwidth, good radiation efficiency and one of the best candidates for ultra wide band (UWB) antenna system. The antenna was designed and simulated by using CST software and copper is used as the material. The designed antennas satisfy the -10 dB return loss requirement in the frequency band between 2GHz – 10 GHz, while showing the band stop characteristic in the frequency band of 5 GHz.

Keywords: Vertical CDM Antenna; U-Shape Slot; Inverted U-Shape Slot; UWB Antenna; Band Stop Characteristic

1. Introduction

The investigation on UWB antenna design has been an interesting study topic amongst communication engineer's world wide. This is due to some of its unique features such as transmitting and/or receiving very short time durations of electromagnetic energy and avoiding frequency dispersion and space dispersion. Today, many methods were developed to realize conventional UWB antennas [1-4] in the frequency range between 3.1GHz and 10.6GHz.

The CDM antenna is originally proposed by S. Honda etc. al. (1992) and P. P. Hammoude and F. Colonel (1993). The investigations were continued by Kumar and Ray in 1998 and 2003. They concluded that the CDM antenna is one of the strongest contenders in terms of impedance bandwidth and radiation efficiency [5-6]. The other advantage such as circular polarization (CP) and easy construction is the main reason why the CDM antenna is used in this study.

The UWB service however overlaps with wireless LAN, IEEE802.11a band (5.15GHz-5.825GHz) and could cause severe interference. To overcome this problem, band stop filter can be added to the system as shown in figure 1(a). This system consists of a UWB antenna connected via a transmission line to a frequency band-notched filter (micro-strip filter) component. However this system is not a cost effective and inefficient. To solve this problem, UWB antenna with good notched filtering characteristic is used as shown in figure 1(b). Several UWB antennas with notched filtering characteristic have been proposed [7-10].

In this paper, the design of the vertical UWB CDM antenna with integrated band notch filtering is presented. To achieve the wideband characteristic, a circular disc with ground plane is used. Notched filtering characteristic is achieved by attaching a U shape or inverted U shape slot in the circular disc. This kind of band notched UWB antenna requires no external filters and thus greatly simplifies the circuit design of the communication system. The design was properly calculated and design simulation was carried out using CST software to verify the performance.

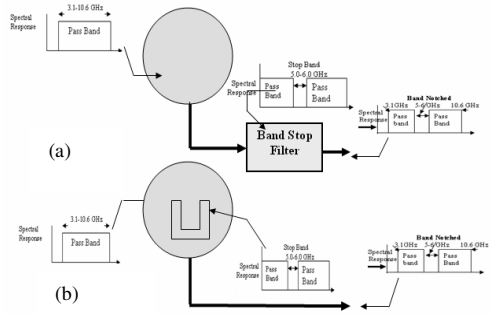

Figure 1: (a) A typical frequency notched UWB antenna system combines a UWB element with a notch filter. (b) UWB antenna with integrated band notch filtering.

2. Specifications

The antenna specifications are as tabulated in Table 1. The wide band frequency, notch filtering characteristic and good radiation efficiency should be considered to design the antenna. The antenna frequency is set to the range of 3.1 GHz to 10.6 GHz

3. Antenna Configuration

Figure 2 depicts the configuration of a vertical UWB CDM antenna with integrated band notch filtering using a copper as antenna material. The antenna is fed at the bottom of the ground plane using SMA connector. The U-shape slot size is optimized and attached to the antenna with a proper calculation and consideration. The antenna dimension and its slot length determine its minimum frequency operation and notch frequency. The relationship is formulated as [6-7]:

$$f_{\min} = \frac{30 \times 0.24}{r + L} GHz \qquad (1)$$

where $r = 2a, L = \frac{a}{4}$ and a is the antenna radius in cm.

$$f_{notch} = \frac{c}{2L + W - 2t} Hz \qquad (2)$$

where c is the speed of light and $0.5 \times f_{notch}$ is the center frequency of the notched band.

Hence, dimension of UWB antenna with minimum frequency of 3.1GHz and 5 GHz notch frequency can be determined. According to (1) antenna radius $a = 1.5cm$ is used in this study and ground plane size of 14cm^2 is considered. The U shape slot needed to deliver notching effect at 5.5GHz are L=1.1cm, W=1.0cm and t=0.2cm. The completed parameters of the antenna design with its simulated picture are as illustrated in Figure 2 (a-c).

Table 1: Specifications on the vertical UWB Slotted CDM antenna

Specifications	
Frequency Bands	3.1 – 10.6 GHz
Band Stop Frequency	5.5 GHz
Slot 1	U 1.CDMSlotU1(W=0.9cm,L=1.0cm,t=0.2cm) 2.CDMSlotU2(W=1.0cm,L=1.1cm,t=0.2cm) 3.CDMSlot3(W=0.9cm,L=1.3cm,t=0.2cm)
Slot 2	Inverted U 1.CDMInvertedU1(W=0.9mm,L=1.0cm,t=0.2cm) 2.CDM-InvertedU2(W=1.0cm, L=1.1cm, t=0.2cm) 3.CDM-InvertedU3(W=0.9cm, L=1.3cm, t=0.2cm)
Radiation Pattern	Omni directional

4. Simulation Results and Discussion

Figure (3) – (5) and Table (2) – (3) shows the result for simulation in VSWR, S-parameter, VSWR bandwidth and radiation characteristics for CDM antenna and slotted CDM (U and inverted U).

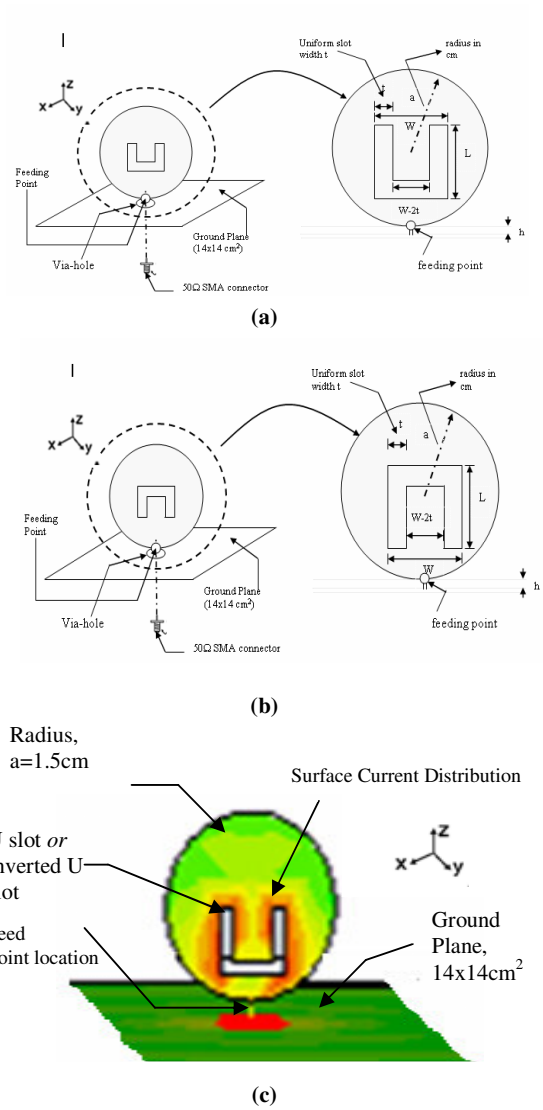

Figure 2: (a) The designed of the slotted CDM antenna 1 and its geometry, (b) The designed of the slotted CDM antenna 2 and its geometry and (c) The simulated of the slotted CDM antenna 1.

4.1 Voltage Standing Wave Ratio (VSWR)

The graph in Figure 3 shows the VSWR versus frequency (GHz) for CDM antennas with slot and without slot. The graph for CDM antenna without slot covers frequency range from 2.5 GHz to above 11GHz while the band notched antenna with U shape slot, CDM-SlotU2 covers frequency range from 2.13GHz to 8.8GHz, except frequency of 5.5 GHz. As a result, the

notched bandwidth of the antenna with the U shape slot satisfies the requirement for exempt from interference with existing wireless system (IEEE802.11a).

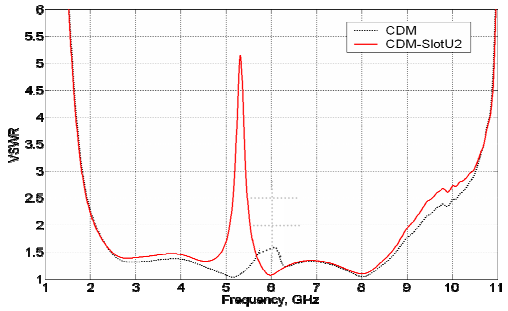

Figure 3: VSWR plots for CDM (.....) and CDM-SlotU2 (_____)

4.2 S-parameter

The graph of the S-parameter (S11/dB) versus frequency, (GHz) for CDM (no slot), CDM-SlotU2, and CDM-SlotU3 was shown in Figure 4. The results show the size of slot which consists of W, L and t is significantly effect the notch frequency, $f_{notched}$ means the length of the slot can be used to select the notch band. The best value of U-slot and inverted U slot is CDM-SlotU2 and CDM-SlotInvertedU2 (Refer to Table 3) which satisfies the requirement of the study. The detail analysis of these antennas was summarized in Table 2 and Table 3.

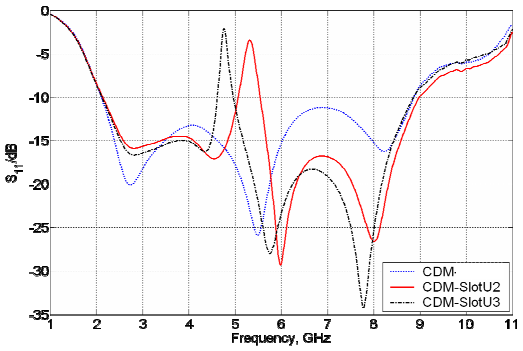

Figure 4: S11/dB versus frequency (GHz) plots for CDM (.....), CDM-Slot2 (_____) and CDM-Slot3 (……..).

4.3. VSWR Bandwidth

The frequencies calculated using the equation from [1] and [2] for the CDM antenna are shown in Table 2 and Table 3. For CDM-SlotU1, CDM-SlotU2 and CDM-SlotU3 antennas, by comparison with the simulation frequencies, the calculation agrees within 1.4% for lower frequency prediction and 1.7 % for the notch frequency respectively. The result of lower frequency is agreed with reference [6] which found $\pm 8\%$ differences between calculation and measurement.

Table 2: VSWR bandwidth of a CDM antenna with U shape slot (CDM-SlotU1, CDM-SlotU2 and CDM-SlotU3).

Conf.	*Freq. range For VSWR <2 (GHz)*	*Lower freq. for VSWR <2 (GHz) (a)Theor. (b)Simul.*	*Bandwidth ratio*	*Notch Freq.(GHz) (a)Calculation (b)Simulation (a)*	*(b)*
CDM	2.10 – 9	(a) 2.13 (b) 2.10	1: 4.29	-	-
CDM-SlotU1	2.10-8.8	(a) 2.13 (b) 2.10	1:4.19	6	5.98
CDM-SlotU2	2.10-8.8	(a) 2.13 (b) 2.10	1:4.19	5.4	5.5
CDM-SlotU3	2.10-8.8	(a) 2.13 (b) 2.10	1:4.19	4.84	4.89

Meanwhile, for CDM-InvertedU1, CDM-InvertedU2 and CDM-InvertedU3 antennas, by comparison with the simulation frequencies, the calculation agrees within 1.4% for lower frequency prediction and 1.7% for the notch frequency respectively.

The results were shown by utilizing the U slot and inverted U slot can give same result for notch frequency band.

Table 3: VSWR bandwidth of a CDM antenna with Inverted U shape slot (CDM-InvertedU1, CDM-InvertedU2 and CDM-InvertedU3).

Conf.	*Freq. range For VSWR <2 (GHz)*	*Theor. Lower freq. for VSWR <2 (GHz)*	*Bandwidth ratio*	*Notch Freq.(GHz) (a)Calculation (b)Simulation (a)*	*(b)*
CDM	2.10 – 9	(a) 2.13 (b) 2.10	1: 4.29	-	-
CDM-InvertedU1	2.10-8.8	(a) 2.13 (b) 2.10	1:4.19	6	5.98
CDM-InvertedU2	2.10-8.8	(a) 2.13 (b) 2.10	1:4.19	5.4	5.5
CDM-InvertedU3	2.10-8.8	(a) 2.13 (b) 2.10	1:4.19	4.84	4.89

4.4 Radiation Pattern

Figure 5 plots the simulated E-plane, H- plane and its equivalent three dimensional (3-D) radiation patterns at 3GHz and 5GHz with omni directional behavior.

5. Summary

The vertical UWB CDM antenna with U-shape and inverted U as a slot is simulated, analyze and simplified the common frequency band notched UWB antenna system. The simulation results show that the frequency characteristic and the radiation pattern behavior are satisfying the targets. Utilization of a CDM antenna with U-shape slot and inverted U would be easy for fabricating the antenna and for reducing the losses antenna that could occur at the time of measurement.

The antenna gap, h, antenna radius, a and the length of the ground plane, L is used to increase the S-parameter as well as a bandwidth (BW), hence satisfy the targets. Meanwhile, by utilizing the length of the slot U or inverted U can achieve the notch frequency requirement.

The simulation results show the agreement between calculation to predict the lower frequency and notch frequency operation. The antenna of CDM-SlotU2 and CDM-InvertedU2 provides bandwidth ratio of 1:4.82 for VSWR < 2 with notch frequency at 5.5GHz respectively.

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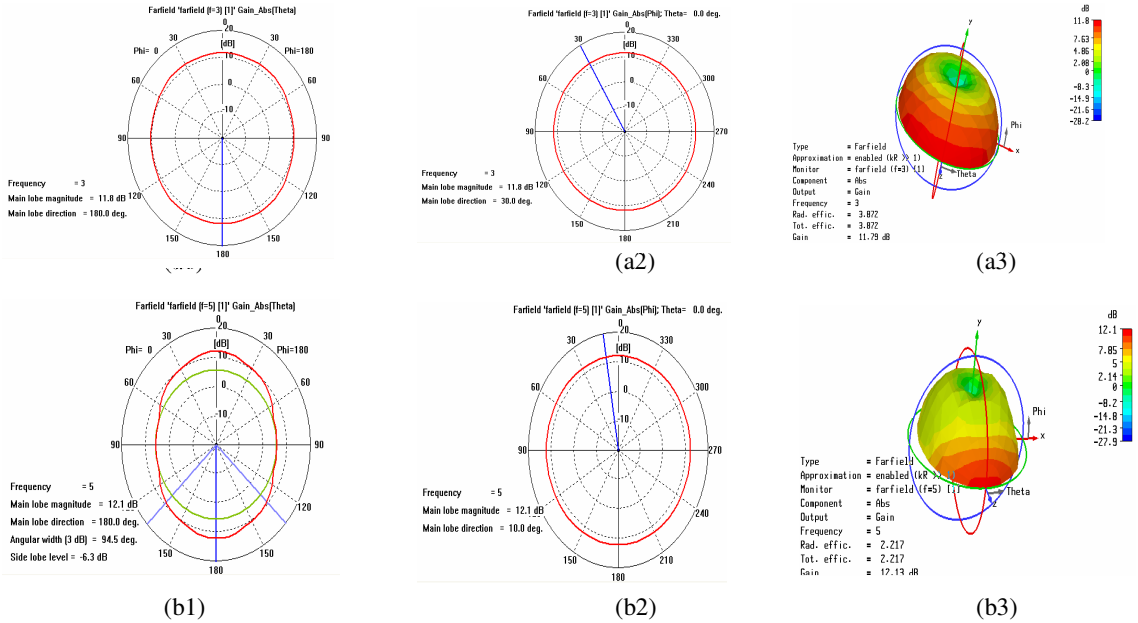

Figure 5: Radiation patterns of the slotted CDM antenna. (a1) E-Plane in 3GHz, (a2) H-Plane in 3GHz (a3) 3-D in 3GHz, and (b1) E-Plane in 5GHz, (b2) H-Plane in 5GHz, (b3) 3-D in 5GHz.