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A novel design of CPW-Fed UWB antenna with dual band-notched features

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Abstract: A coplanar waveguide (CPW) fed ultra-wideband monopole antenna with dual band-notched characteristics was designed to reject and avoid interference with existing bands at (3.3-3.7) GHz and (5.1-5.9) GHz band for IEEE 802.16 (WiMAX) and IEEE 802.11a (WLAN), respectively. The antenna is characterized by rejection of two distinct bands using U- and L-shaped slots on the radiating plane. The width of slots was 0.5 mm. This compact antenna with dimensions of 0.8×25×29 mm^3 provides a return loss of less than -10 dB and VSWR < 2 in high frequency ranges and in transmission mode. An L-shaped slot was used for band rejection at (3.3-3.7) GHz while two U-shaped slots were used for band rejection at a frequency range of (5.1-5.9) GHz. An optimal result was achieved by changing the position and angle of slots. The substrate with a thickness of 0.8 mm was made of FR4 with a dielectric coefficient of 4.4. According to simulations performed by HFSS, the antenna is able to reject bands at frequency ranges of (3.3-3.8) GHz and (5.05-5.9) GHz. This is a good result and the antenna is able to filter the whole desired range.

Key words: CPW-fed UWB; Dual band; Antena

1. Introduction

Recently, ultra-wideband (UWB) technology has received much attention in communication systems. The advantage of this type of antenna compared to the old type of narrowband wireless communication systems include low energy level required for data transmission, high data rate and simpler hardware structure. Ultra-wideband technology is a novel method for transferring large amounts of data in short distance in difficult electromagnetic conditions. In this technology, transmitters use low radiation power in a very wideband to avoid the negative impact on radio communication system in the frequency ranges. Ultra-wideband technology is one of promising solutions for future communication systems because of high data rates and higher safety for multi-path interference (Mohanan, 2008). The bandwidth of the antenna ranges from (3.1-10.6) GHz as was determined by US Federal Communications Commission (FCC) in 2002. A lot of research has been carried out to increase the bandwidth to achieve ultra-wideband antennas (Liang et al., 2006 and Ntsanderh et al., 2007). The theoretical ultra-bandwidth occupied by UWB gives high transmission capacity as shown by Shannon's channel capacity equation:

$$C = Blog\left(1 + \frac{S}{N}\right) \qquad [1]$$

Where C is the maximum channel capacity, B signal bandwidth, S Signal power and N is the noise power. Within the frequency range of UWB systems, some narrowband telecommunication systems work. The most frequently used narrowband frequency ranges are 3.3-3.7 GHz and 5.1-5.9 GHz respectively for WiMax and WLAN. This may cause electromagnetic interference in the UWB system. To avoid interference of narrowband systems with UWB system, a simple solution is to use UWB antenna with band-notched characteristics in the desired frequency range (Qu et al., 2006; Arash et al., 2013). The desired frequency ranges are developed using slots on the ground plane or antenna radiating patch.

There are different slots to achieve band-notched characteristic in the antenna including U-shaped (Deng et al., 2008 and Ying-song et al., 2011). and L-shaped slots (Ying-song et al., 2011). The slot is used on the ground or radiating plate. However, most antennas are designed for single band rejection (Qu et al., 2006; Hong et al., 2007; Weng et al., 2009). Some used single band rejection of (4.4-6) GHz for the band C for military and satellite applications and for IEEE 802.11a (Ying-song et al., 2011). Studies on dual WiMax band rejection (Arash et al., 2013) revealed the complexity of construction and the lack of uniformity in the return loss. In (Yin et al., 2008; Deng et al., 2008). WLAN band rejection at 5 GHz was obtained using a U-shaped slot with 0.2 mm width on modified ground opposite to feeding area. This results in the complexity of construction. Herein, we introduce an ultra-wideband antenna with dual band-notched characteristics in (3.3-3.8) GHz and (5.05-5.95) GHz which covers the entire bandwidth of WiMax and WLAN. Band rejection is performed by U- and L-shaped slots.

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2. Antenna Design

Fig. 1 shows the UWB antenna designed by HFSS. For simplicity of construction, coplanar waveguide fed was used. The substrate was made of FR4 with a dielectric coefficient of 4.4 and a loss tangent of 0.02. The length and width of antenna is 29 and 25 mm, respectively with a thickness of 0.8 mm. The width of both L- and U-shaped slots is equal to 0.5 mm. The slot width between feed line and ground is 0.27 mm. The width of feed line is 1.5 mm. To design an UWB antenna which does not transmit a certain bandwidth, a semicircle is created in the circular patch. The radius is calculated using the following formula and is proportional to the frequency intended to be filtered.

$$R_n \cong \frac{c}{2\pi f_n}\sqrt{\frac{2}{1+\varepsilon_{reff}}} \qquad (2)$$

Where R_n is the radius of the semicircle and f_n is the filtered frequency.

$\varepsilon_{\mathrm{reff}}$ is defined as follows:

$$\varepsilon_{\mathrm{reff}} = \frac{\varepsilon_{\mathrm{r}}+1}{2} + \frac{\varepsilon_{\mathrm{r}}-1}{2}{}_{2}\sqrt{\frac{1}{\left[1+12\frac{\mathrm{h}}{\mathrm{w}}\right]}} \qquad (3)$$

Where h is the height of substrate and w is the width of transmission line. The radius of semicircle is 3.8 mm. The terminal angles are equal to 175 ° and its center is located in the middle of radiating plate, 0.4 mm below the top of plate. The radius of the second semicircle is 4.8 mm. The terminal angles are equal to 190 ° and its center is located in the middle of radiating plate, 4 mm below the top of the plane. L-shaped slot with a length of 1.7 mm is located on the left corner of the radiating plate with a distance of 1.6 mm from the edge. Its distance from the upper portion of the plate is 0.4 mm. The feed line and ground are coplanar. This will facilitate construction of the antenna.

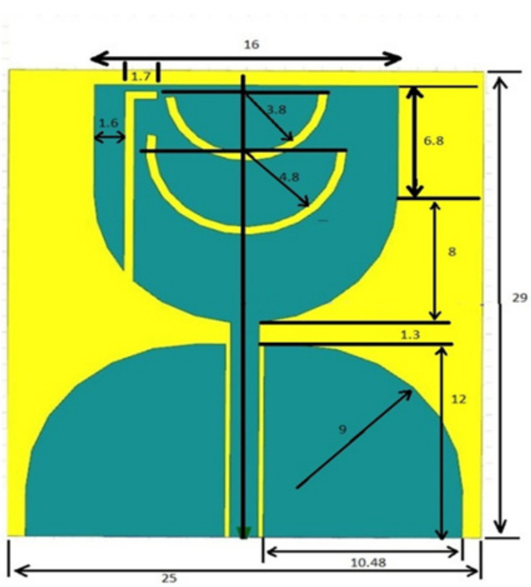

Fig. 1: Geometry of the UWB antenna

3. Simulation Results

Fig. 2 shows the simulation results (return loss=S_{11}) for UWB antenna with band-notched characteristics in the frequency ranges of (3.3-3.8) GHz and (5.05-5.95) GHz. In transmission mode, S_{11}<-10 dB in the whole frequency range for UWB systems. Fig. 3 shows the VSWR diagram for the UWB antenna. VSWR is less than 2 in transmission mode. The design has been able to filter the WiMax and WLAN frequency ranges.

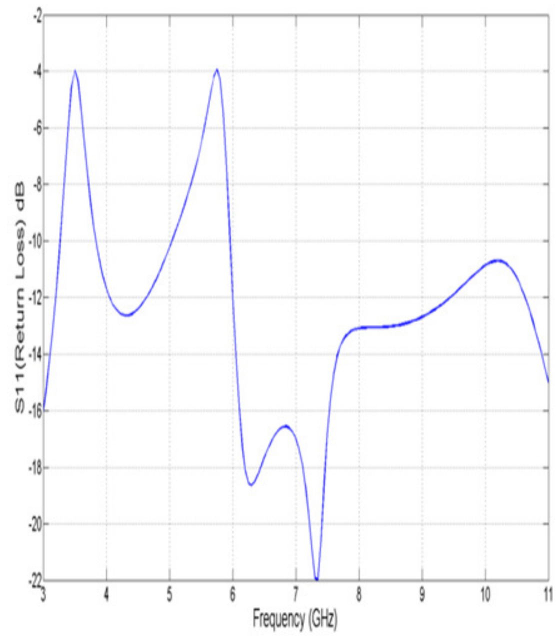

Fig. 2: The return loss of the UWB antenna

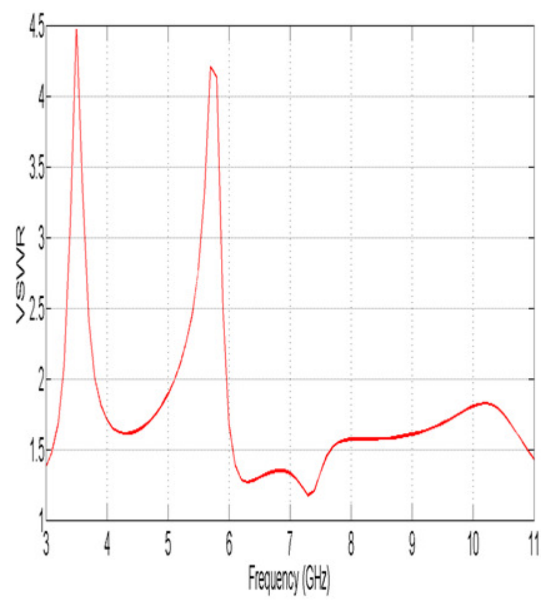

Fig. 3: The VSWR diagram of the UWB antenna

Fig. 4 shows the effect of slots on the simulation results. At each stage, a parameter is eliminated keeping all other parameters constant. The comparative results are shown in the following Fig.

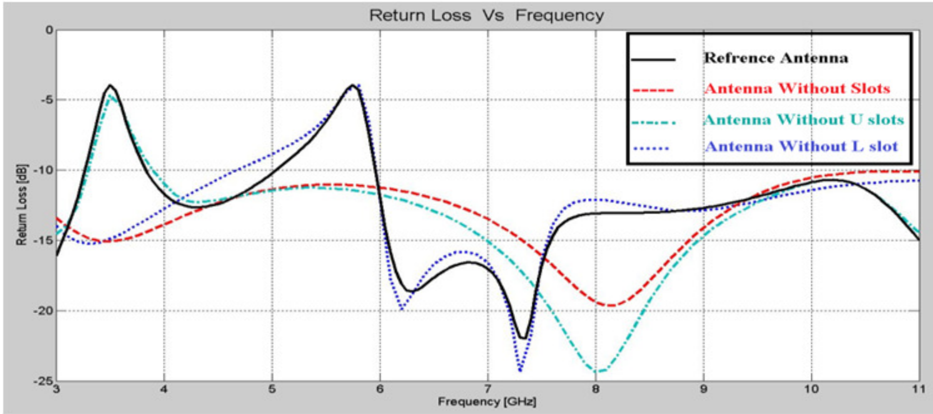

Fig. 4: The return loss of UWB antennas obtained by eliminating different slots

As can be seen, UWB antenna works in all frequency ranges by eliminating all slots and no band rejection occurs as shown by Red line in the diagram. When L-shaped slot is eliminated, no filtering occurs in the frequency range of (3.3-3.7) GHz. The effect of elimination of other slots is also shown.

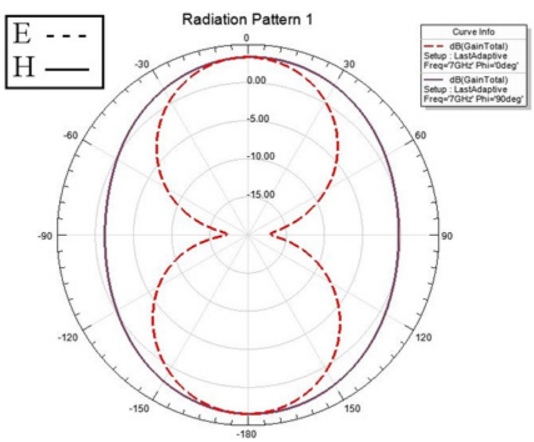

Fig. 5: The radiation pattern in E and H planes at 7 GHz

Fig. 5 shows antenna gain in E and H planes at 7 GHz. As seen, the maximum antenna gain at transmission frequency of 7 GHz is about 3.5 dB. Fig. 6 shows antenna gain at 5.7 GHz in the range of frequency rejection. The maximum gain at 5.7 GHz is about 2 dB.

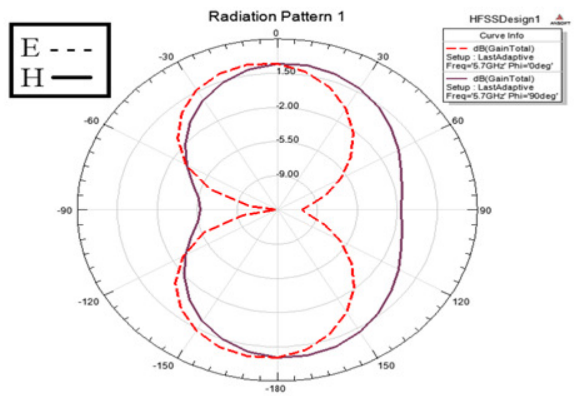

Fig. 6: The radiation pattern in E and H planes at 5.7 GHz

Fig. 7 shows antenna gain (in dB) at (3-11) GHz.

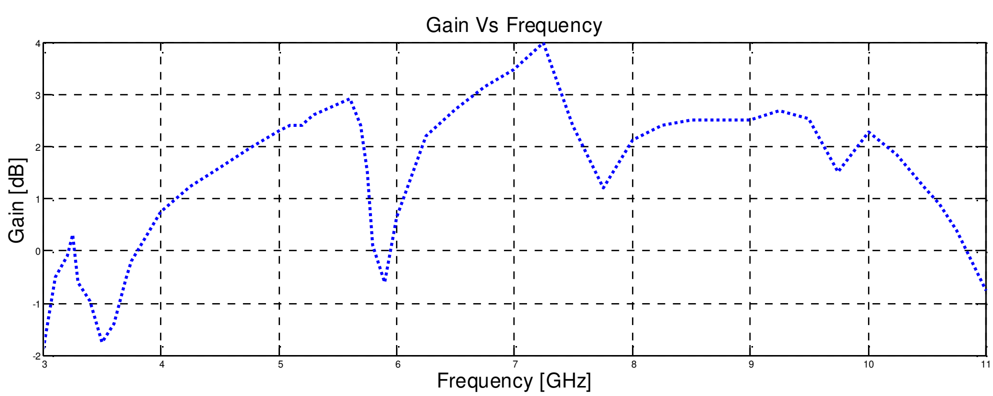

Fig. 7: Antenna gain (dB) at a frequency range of (3-11) GHz

4. Conclusion

As shown, the return loss of antenna in transmission mode is low (S_{11}< -10 dB). The gain of antenna with an optimal radiation pattern is about 3 dB. The antenna is not able to provide an optimal radiation pattern in frequency ranges of 3.3-3.8 and 5.05-5.95 GHz with low gains of less than -1 dB and 2 dB, respectively. This high return loss (-4dB) is desirable for band rejection. Because of CPW feeding, the ground and radiating patch are coplanar. Thus, the construction cost is optimal and it can be constructed as single-layer PCB. When the antenna is fed by a micro strip line, disturbance may occur because the substrate is fed on both sides. However, the problem is resolved by CPW feeding, because the ground and slot-bearing radiator plane are coplanar.

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