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A Compact Multiple Band-Notched Planer Antenna with Enhanced Bandwidth Using Parasitic Strip Lumped Capacitors and DGS-Technique

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Abstract

UWB antenna with dual notched characteristics fed by microstrip transmission line is presented in this paper. The tapered connection between the rectangular patch and the feed line is used to produce a good impedance matching from 2.3 to 11.5 GHz. A dual band frequency notches are achieved using U-DGS loaded with lumped capacitors. The first notch frequency band is achieved using DGS to reduce the interference with WIMAX from 3.3 to 3.7 Ghz. The second notch frequency band is also achieved using U-parasitic strip placed in the ground plan to eliminate the interference with WLAN from 5.2 to 5.9 GHz. Lumped capacitors are combined with the slot due to miniaturize the slot size. The size of the resonator is reduced by more than 40% when lumped capacitors are used. The proposed antenna hasVSWR < 2 except the notched bands. The simulated results confirm that the antenna is suitable for UWB applications.

Keywords: *ultra wide band antenna, parasitic strip lumped capacitors, DGS-Technique*

1. Introduction

The commercial operation of UWB within the range 3.1-10.6 GHz is released by Federal Communication Commission (FCC) [1]. Since then, the design and implementation of UWB systems have been attracted much attention for communication systems. The UWB systems have several advantages such as high data rates, low power consumption, low cost and simple hardware configuration in practical applications [2]. Printed monopole UWB antennas has attracted nowadays because printed antennas have advantages such as easy fabrication, small size, low cost and they can be made compatible to the RF components and be implemented on the same PCB circuitry [3-7].However, There exist some narrow bands for other communication systems such as WiMAX (3.3 to 3.7 GHz) and WLAN (5.15 to 5.825 GHz) over the designated UWB frequency band that causes electromagnetic interference with the UWB systems. In order to reduce the interference, the antenna has to exhibit frequency band notch in those frequency bands. Researchers have proposed several techniques to design the band notched antenna. The conventional method to achieve a notched band can be realized by etching a suitable structure in a UWB antenna [8-13]. Another way is to put parasitic elements near the printed monopole, playing a role as filters to reject the limited band [14, 15]. In this paper, UWB antenna with dual notched characteristics is presented. First, a reference antenna is designed, which exhibits radiating characteristics in the frequency band 2.3-11.5 GHz. Second, parasitic strip in addition to defected ground structure loaded with lumped capacitor is used to achieve the band-notched characteristics. The first notch is achieved at frequency band (3.3-3.7 GHz). The second notch is achieved at frequency band (5.2-5.9 GHz). The detail design of the antenna is introduced.

2. UWB Antenna Design and Configurations

The 2-D layout of the proposed antenna is illustrated in Figure 1. The antenna is fed with a 50-microstrip feed line. The rectangular monopole antenna is printed on substrate

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RO4003 with relative permittivity = 3.38, a dielectric loss tangent = 0.0027 and thickness (h) = 0.813 mm. To improve the bandwidth of the antenna, the tapered connection between the rectangular patch and the feed line is used as shown in Figure 1(a). The dimensions of the patch and the antenna are optimized to achieve maximum bandwidth. Also from Figure 1(b) it is obvious that, the dual band frequency notches are achieved by using first, parasitic U-shape strip which is placed above the resonator at a distance d1. Second, two DGS slots loaded with lumped capacitors which they act as a half wave resonator coupled to monopole antenna. The simulated return loss of the antenna without using parasitic strip and the DGS slots is illustrated in Figure 2. From Figure 2 it is clear that, the UWB monopole antenna has a good matched bandwidth from 2.3 GHz to 11.5 GHz which is suitable for UWB applications.

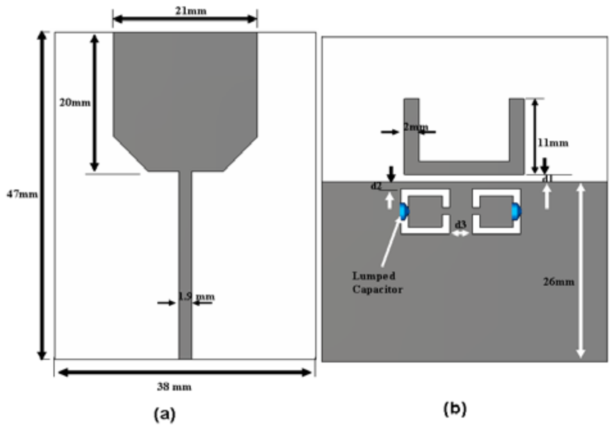


Figure 1. Geometry of proposed UWB antenna (a) Top view (b)back view

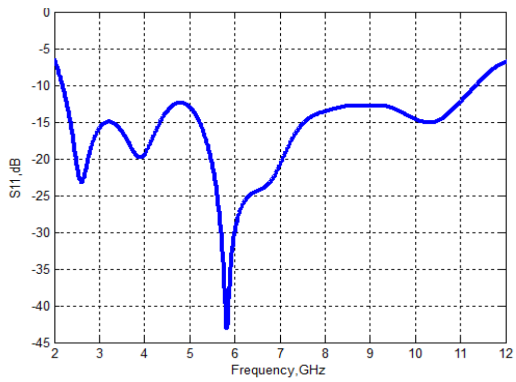


Figure 2. Simulated return loss of UWB antenna without using parasitic strip and DGS slots

3. Parametric Results

The U-shaped parasitic strip is designed to provide notched band at 5.4 GHz for WLAN system. The U-shaped strip behaves as a filter to eliminate the desired band. The notched band frequency is adjustable by varying the length and location of the parasitic strip above the ground plane d1. In order to know the effect of the U-shaped strip on the antenna performance, a parametric study of the UWB antenna with U-shaped parasitic strip only is conducted. Basically, the length of the resonator acts as the inductance. Therefore, when the length of the resonator increases the resonance frequency of the notch decreases. First, the length of U-shaped strip is optimized to operate at centered frequency of 5.4 GHz as demonstrated on Figure 1(b). Second, the effect of the position of the resonator above the ground plane on the antenna return loss is studied as shown in Figure 3. From Figure 3 it is obvious that, when the distance d1is increased above the ground plane the effect of the U-shaped strip on the return loss wasn't appear. Therefore, the optimized place to the U-shaped strip was 1 mm above the ground plan to achieve the required notched frequency band. The two DGS slots also plays role of a filter as U-shaped strip. The two DGS slots dimensions are optimized to operate at center frequency of 5.2 GHz as shown in Figure 1(b). Several parametric analyses are carried out on the DGS slots position. First, the effect of the distance of the two DGS slots below the top of ground plane d2 on the antenna return loss is conducted as illustrated in Figure 4. It is clear that, when the two slots are moved away from the top of the ground plane the notched frequency is vanished. So, the distance d2 is optimized to be at the distance equal to 1 mm below the top of ground plane. Second, the effect of the distance between the two slots d3 on the antenna return loss is carried out as shown in Figure 5 .It is noticed that, when the distance between two antenna is increased from 3mm the notch level is decrease and the bandwidth of the notch is also decreased .So the distance d3 is optimized to be 3 mm to achieve the best performance.

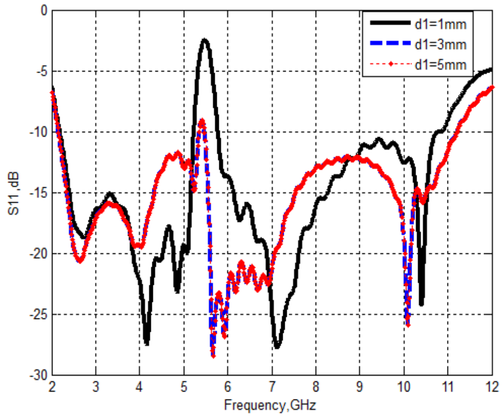


Figure 3. Simulated return loss of UWB antenna at different distances above ground plane (d1)

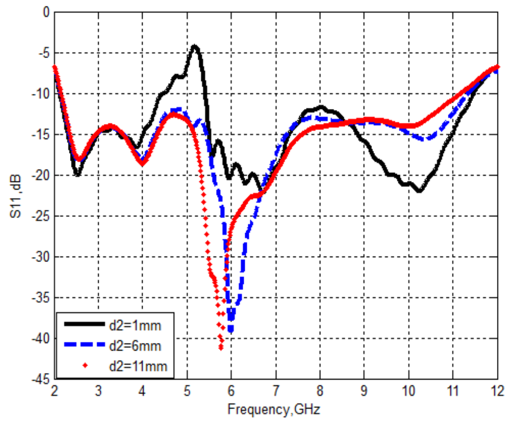


Figure 4. Simulated return loss of UWB antenna at different distances (d2)

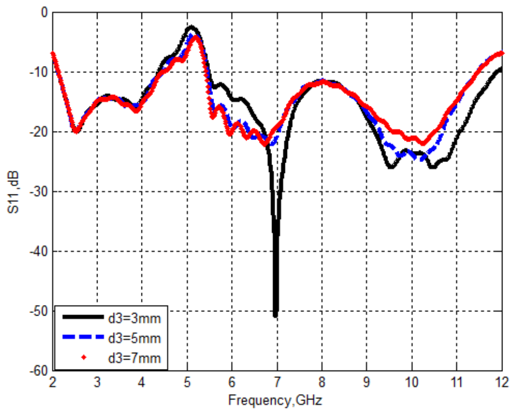


Figure 5. Simulated return loss of UWB antenna at different distances between slots (d3)

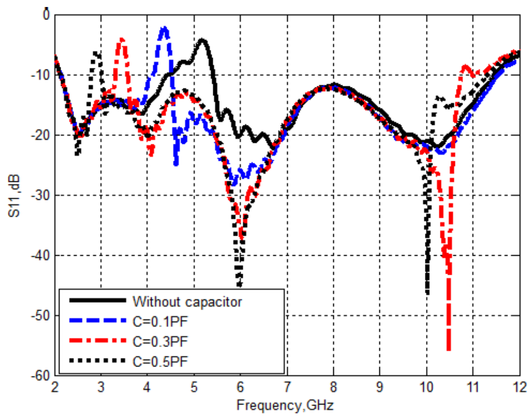


Figure 6. Simulated return loss of UWB antenna at different value of lumped capacitors (C)

Finally, the effect of the capacitance of the lumped capacitor C on the antenna return loss is studied as illustrated in Figure 6. The lumped capacitors are inserted in the two DGS slots at the place which has maximum electric field. The maximum electric field in the slots is concentrated around the arm opposite to the open end as shown in Figure 1(b). So, when lumped capacitor is inserted in this place the total capacitance of the resonator increases which leads to decreases in the resonance frequency of the notch. From Figure 6 it is clear that, the resonance frequency of the notch is decreased from 5.2 GHz without capacitor to 2.8 GHz when the lumped capacitor with C equal to 0.5 pF is used. This means, the lumped capacitor can used to miniaturize the length of the two slots by more than 40%. So, the value of C is optimized to be equal to 0.3 pF.

4. UWB Antenna with Dual Band Notched Filter

The performance of the designed antenna has been validated using the electromagnetic full wave simulations. The commercial software CST microwave studio was employed in the full wave simulations. The distances d1, d2, d3 and the capacitance of the lumped capacitors are optimized depend on the previous discussion in Section III to achieve the required two notches at the desired frequency band. The simulated return loss of the proposed antenna is illustrated in Figure 7. It is obvious that, there are two notches at the desired frequency band. The first notch is caused by the two DGS slots loaded with lumped capacitors which is used for rejecting frequency band of WIMAX from (3.3 GHz -3.7 GHz). As well as the parasitic strip that is used for rejecting frequency band of WLAN from (5.2 GHz -5.9 GHz). The VSWR of the antenna is demonstrated in Figure 8. It is noticed that, the proposed antenna has VSWR < 2. However, the antenna shows an impedance mismatch in the frequency bands 3.3 GHz-3.7 GHz and from 5.2 GHz-5.9 GHz as the VSWR > 2 in these bands.

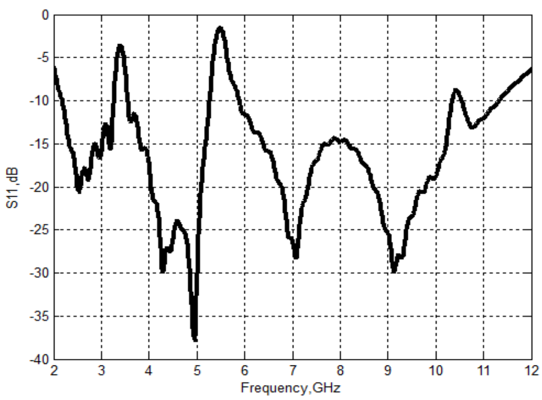


Figure 7. Simulated return loss of the proposed UWB antenna

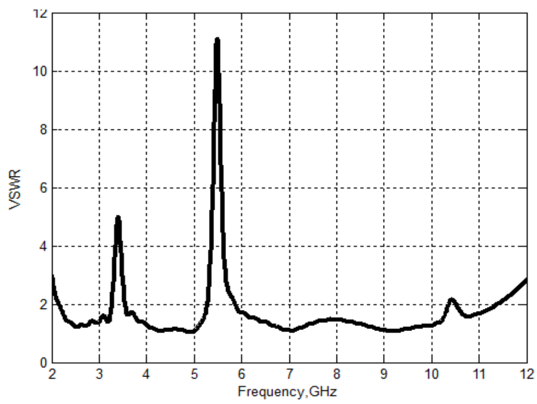
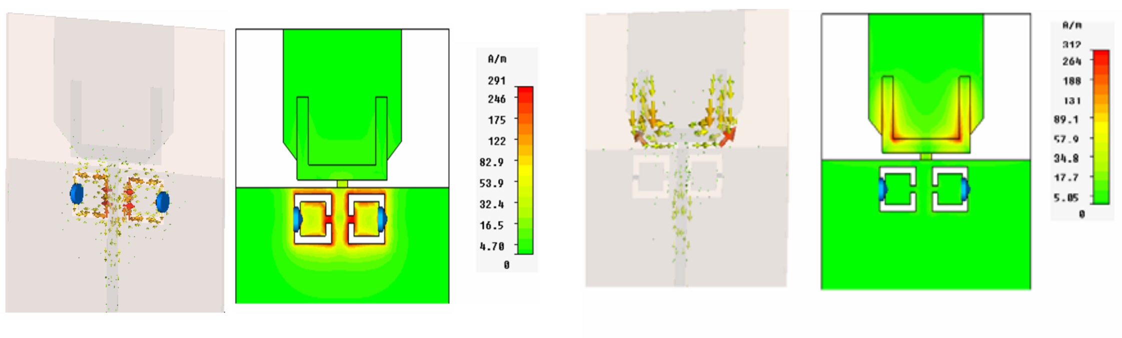


Figure 8. Simulated VSWR of the proposed UWB antenna



(a) (b)

Figure 9. Simulated surface current distributions of proposed UWB (a) at f=3.4GHz (b) at f=5.4GHz

In order to understand the behavior of the band-notched characteristics, the simulated current distributions at 3.4 and 5.4 GHz for the proposed antenna are investigated as shown in

Figure 9. It is noticed that from Figure 9(a) the surface current is concentrated around the two slots with lumped capacitors at 3.4 GHz which is the center of WIMAX frequency band. Also from Figure 9(b) it is obvious that the surface current is concentrated around the parasitic strip at 5.4 GHz which is the center of the WLAN frequency band. From two figures it is concluded that the antenna didn't radiate at these frequency bands. The E-plane (x-z plane) and H-plane (y-z plane) radiation patterns are presented at three frequencies; 3 GHz, 7 GHz, and 9 GHz as shown in Figure 10. The patterns obtained The E-pattern seems to be bi-directional while the H-pattern seems to be omni-directional. The realized gain of the proposed with frequency is shown in Figure 11. From Figure 11 it is obvious that, The average peak gain of the proposed antenna is around 3.3 dB over the all operating frequency band except the two frequency band notches which has reduction on its gain.

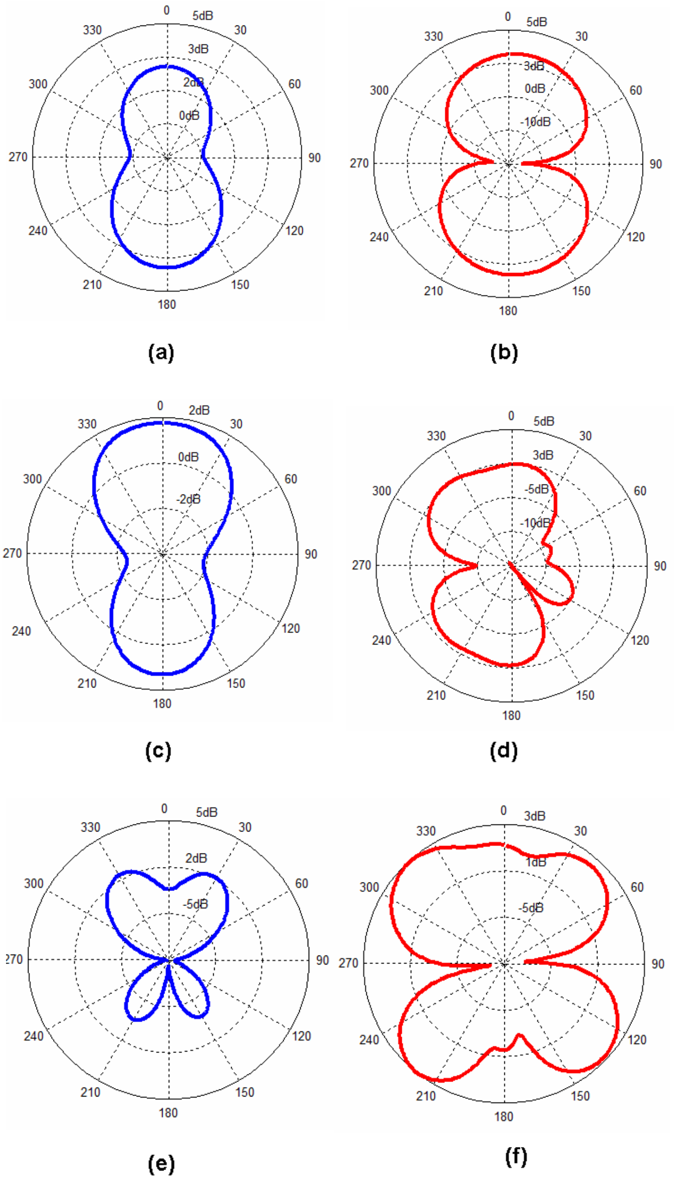


Figure 10. Simulated directive gain of the proposed antenna at different frequencies (a) E-plan at 3GHz (b) H-plan at 3GHz (c)E-plan at7GHz (d) H-plan at 7GHz(e) E-plan at 9GHz (f) H-plan at 9GHz

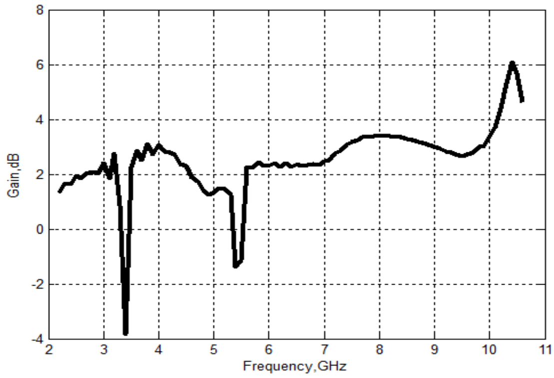


Figure 11. Simulated gain of the proposed UWB antenna with notched bands.

5. Conclusion

Ultra wide band antenna with dual band notch characteristics has been introduced. A dual band frequency notches have been achieved by using U-shaped parasitic strip and defected ground structure loaded with lumped capacitors. The first notch frequency band has been achieved using defected ground structure loaded with lumped capacitors to reduce the interference with WIMAX from 3.3 GHz to3.7 GHz. The second notch frequency band has been achieved using U-shaped parasitic strip which is placed above the ground plan to eliminate the interference with WLAN from 5.2 GHz to 5.9 GHz. The proposed antenna operated at the range from 2.3 GHz to11.5 GHz with VSWR < 2 except the notched bands. The simulated results confirm that the proposed antenna is suitable for UWB applications.

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