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FREQUENCY AND TIME DOMAIN CHARACTERISTIC OF A NOVEL NOTCH FREQUENCY UWB ANTENNA

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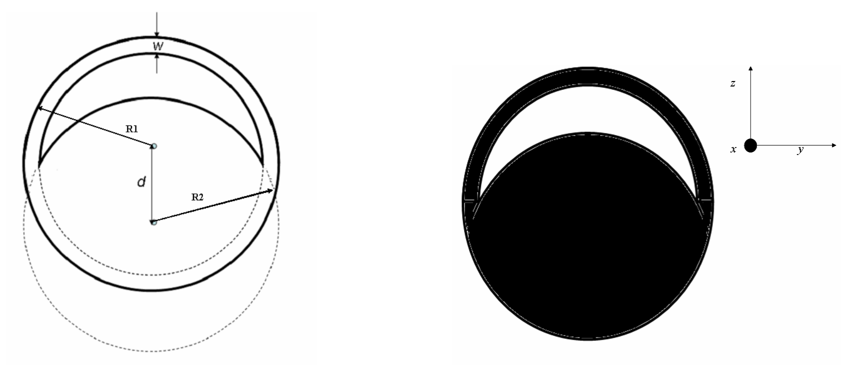
Abstract—An ultra-wideband (UWB) monopole antenna with a band-notch characteristic is presented which needs only two parameters to tune the notch frequency. The proposed monopole antenna is embedded with a crescent slot, whose length is determined by parametric study. By adjusting the slot length, the notched frequency band within the antenna's operating bandwidth can be easily controlled. Also, the time-domain behaviours are discussed and the fidelity factor is calculated.

1. INTRODUCTION

Tremendous effort has been made by researchers to develop and explore new UWB antennas since Federal Communications Commission (FCC) allocated the frequency band of 3.1 to 10.6 GHz for the operation of devices in the new communication technology. To satisfy such a requirement, various wideband antennas have been introduced [1–8]. This frequency range can cause interference to the existing wireless communication systems such as the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15–5.35 GHz and 5.725–5.825 GHz bands [9, 10]. To overcome this problem, these frequency bands have to be filtered via various methods which have been introduced recently. Cutting a slot on the planar monopole antenna is one of the methods which have taken great attention [11–14]. In this method, the size and the place of the slot on the antenna plays very important role in the determination of the frequency center and the bandwidth of the notch. In the other words, in the design of the notch frequency UWB antenna, some parameters such as width and length of the slot must be tuned in a way that notch happens at the desired frequency band. Less number of the parameters can lead to a more practical antenna. There is another important issue which must be considered in the design of notch frequency UWB antenna. Time domain behaviour of the UWB antenna with a notch frequency may distort time domain behaviour of the original antenna. The antenna, hence, should be designed with care to avoid undesired distortions. In other words, a good time domain performance is a primary requirement of UWB antenna.

In this paper, a novel notch frequency UWB antenna is proposed which needs only two parameters to tune the notch frequency. Furthermore, the influence of the creating a frequency notch in frequency domain of the antenna on the time domain behaviour of the antenna is investigated extensively. Fidelity factor which describes the transient characteristics of the antenna is calculated by the use of virtual probe situated in the far field of the transmitting antenna. Also the fidelity factor has been obtained by the use of two similar antennas in the simulation.



(a) (b)

Figure 1. Geometry of the antenna.

2. ANTENNA DESIGN

As it is shown in Fig. 1, the antenna which is the intersection of a ring and a disk with the same radius ($R1 = R2 = 10.5$ mm), is etched on 0.78 mm thick single sided RT Duroid 5870 ($\varepsilon_r = 2.33$) substrate and placed vertically 0.5 mm above the 80×80 mm ground plane. The centre frequency and the bandwidth of the notch can be controlled by the width of the ring (w) and the distance between entres of the ring and disk (d). To investigate the effect of these two parameters on the behaviour of the antenna by CST software, first parameter w is assumed to be constant (9.4 mm) and then d is changed from 15 to

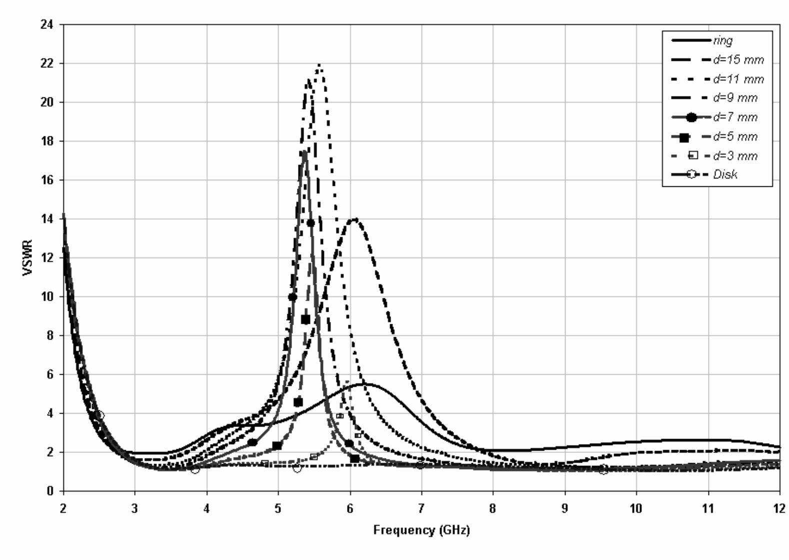


Figure 2. Simulated VSWR versus frequency for fixed w and various d.

3 mm. As it shown in Fig. 2, when the distance between two centres are too far in a way that the disk completely is eliminated from the geometry of the antenna, antenna has a wideband frequency notch, though it doesn't show satisfied performance in the other frequencies.

By decreasing the distance, the notch frequency shifts toward the lower frequencies until $d = 9$ mm then the notch frequency shifts toward the higher frequencies and the bandwidth of the notch decreases. It seems the notch frequency oscillates in the limited frequency band. As a second step of the parametric study, the distance of the two centres is kept constant ($d = 4.5$ mm) then w is varied between 3 and 0.2 mm. When the width of the ring is too tick (3 mm), the size of the slot is too small, so the antenna doesn't show notch behaviour. By decreasing the width, the notch appears and shifts toward lower frequencies and the bandwidth of the notch increases. As it shown in Fig. 3, when $w = 2$ mm notch frequency is around 6.65 GHz with 13.8% bandwidth. When w reaches to 0.2 mm notch frequency happens at 4.64 GHz with 18.4%.

The antenna dimensions regarding to the parametric study, was finalized and fabricated. Fig. 4 shows the measured and simulated S_{11} and VSWR of the antenna. For comparison, the simulation has been done with two different softwares. The measurement result has been shifted to the lower frequencies in contrast with the simulation

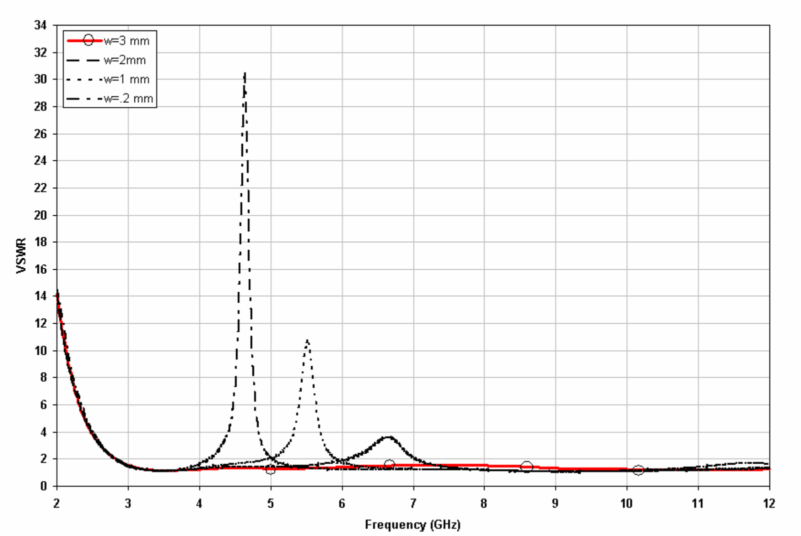


Figure 3. Simulated VSWR versus frequency for fixed d and different w.

ones. This can be due to difficult adjustment of the distance of the antenna from the ground plane in practice. The simulation result by CST software is more similar to the measurement than HFSS one. The measured radiation patterns in E and H planes at 3.5, 5.5, 8 and 10 GHz frequencies are shown in Fig. 5. Good omnidirectional radiation patterns are almost observed in both E and H planes at all the desired frequencies.

A well-defined parameter named fidelity [5] is proposed to assess the quality of a received signal waveform regarding to the input signal, as given in Equation (1):

$$F = \max\left[\frac{\int_{-\infty}^{+\infty} s_t(t)\, s_r(t+\tau)d\tau}{\int_{-\infty}^{+\infty} |s_t(t)|^2\, dt \int_{-\infty}^{+\infty} |s_r(t)|^2\, dt}\right] \tag{1}$$

where $s_t(t)$ is the source pulse and $s_r(t)$ is received signal by the virtual probes located in the far field of the antenna. The fidelity (F) is the maximum correlation coefficient of the two signals by varying the time delay τ. Indeed, it reflects the similarity between the source pulse and

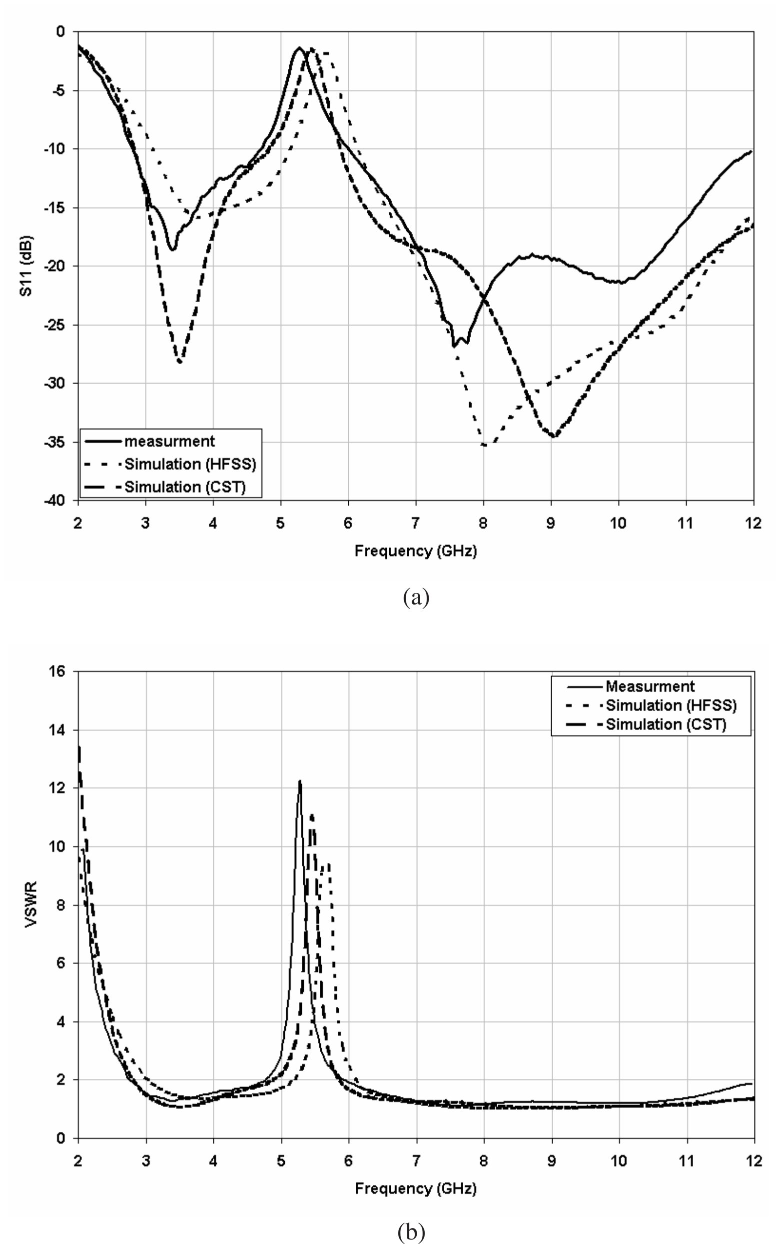
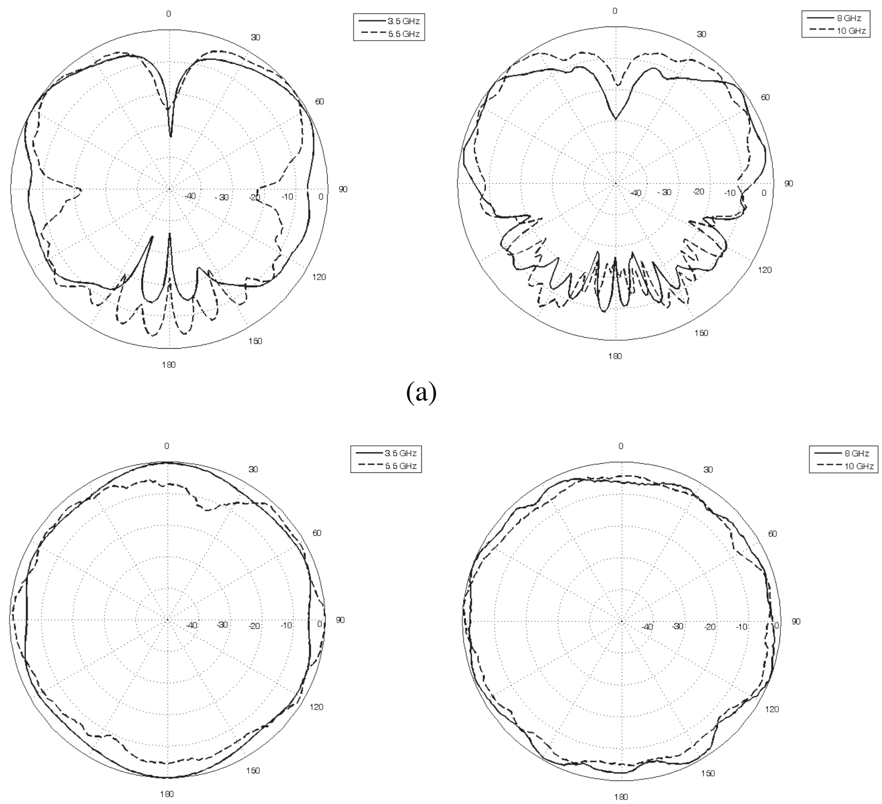


Figure 4. Simulated and measured (a) S_{11} (b) VSWR.



(b)

Figure 5. Measured radiation pattern of the notch frequency antenna at 3.5, 5.5, 8, 10 GHz frequencies in (a) E-plane (b) H-plane.

the received pulse. When the two signal waveforms are identical to each other, the fidelity reaches its peak, i.e., unity, which means the antenna system does not distort the input signal at all. Simulated fidelity factor as a function of ϑ for $\varphi = 0°$ and $\varphi = 90°$ is shown in Fig. 6. For comparison the fidelity factor of an ordinary disk has been plotted at the same figure. Although, the distortion of the transmitted signal was expected due to the existence of the notch in the frequency domain of the antenna, in both planes the fidelity factor of the notch frequency antenna is just slightly lower than disk one and the rate of distortion is not too much.

To investigate the performance of the notch frequency antenna as a transmitter and a receiver in a UWB system, a pair of the identical

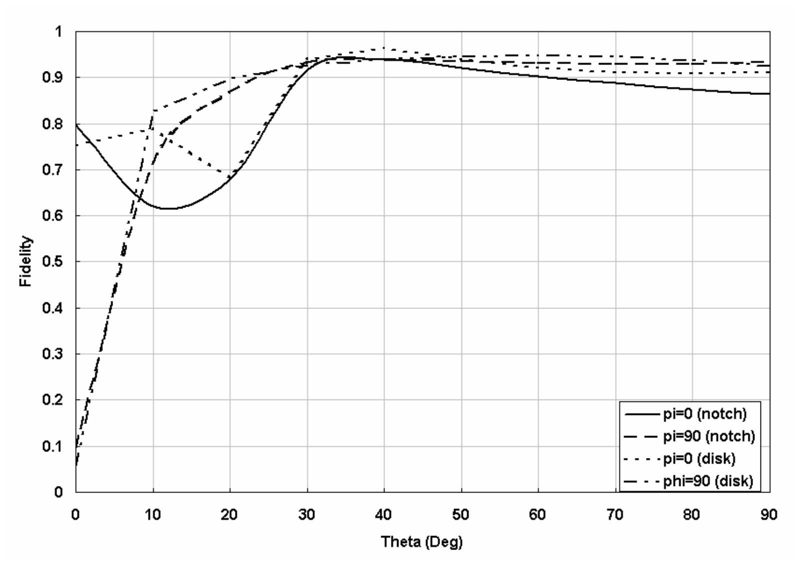


Figure 6. Fidelity factor of the notch frequency antenna for various angles in.

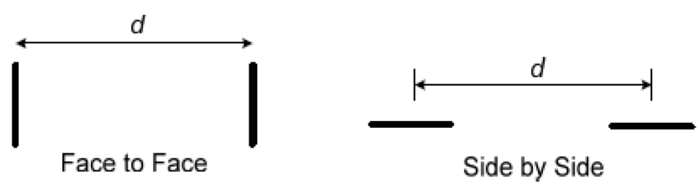
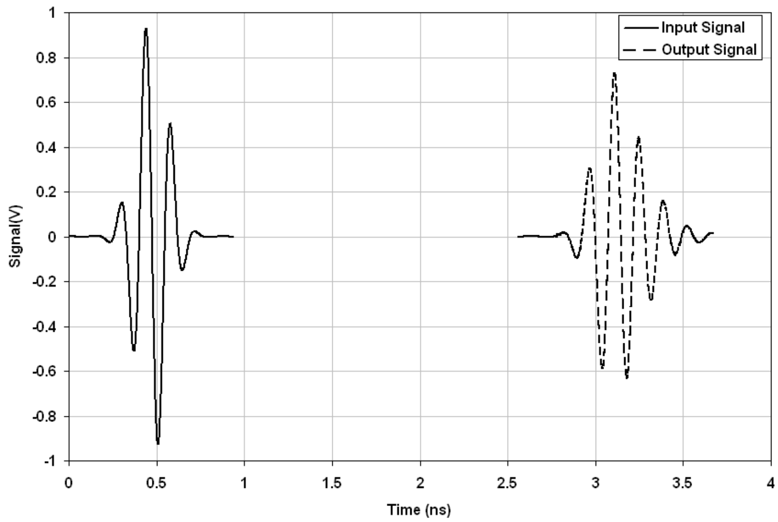
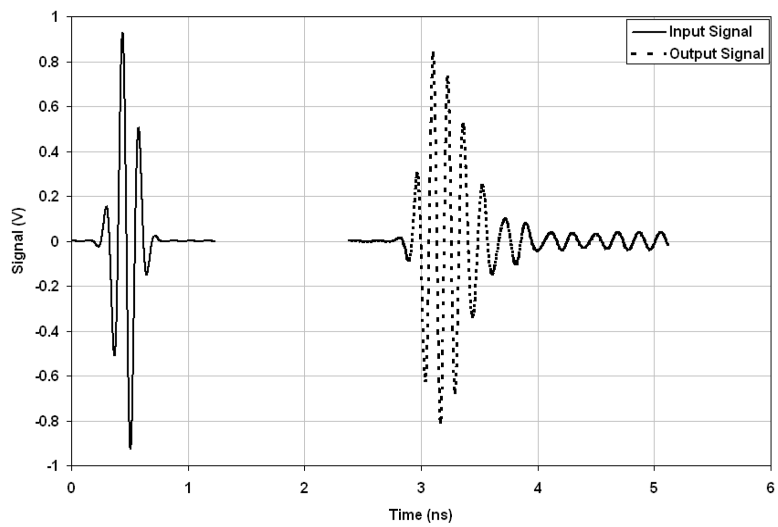


Figure 7. Antenna orientation (top view).

antenna has been placed in 75 cm distance from each other (antennas are in the far field of the each other) in two different orientations in the free space as it shown in Fig. 7. One of the antenna acts as a transmitter and the other one is a receiver. The Fidelity factor for each case has been calculated according to the Equation (1) and summarized in Table 1. The time domain received and transmitted pulses for front to front case for both disk and notch frequency antennas are shown in Fig. 8. Due to the free space loss the received signal attenuate very much which makes difficult to indicate in the figure. Because of that the amplitude of the received signal has been multiplied by 500. As it shown in Fig. 8(a) and (b), the received signal by notch frequency antenna has been dispersed and distorted in comparison with the disk antenna which confirms the fidelity factor results.



(a)



(b)

Figure 8. Transmitted and received signals for face to face case (a) Disk antenna (b) Notch frequency antenna.

Table 1. Fidelity factor between transmitted and received signals.

	Simulation (disk-identical)	Simulation (notch-identical)
Face to Face	0.95	0.79
Side by Side	0.97	0.87

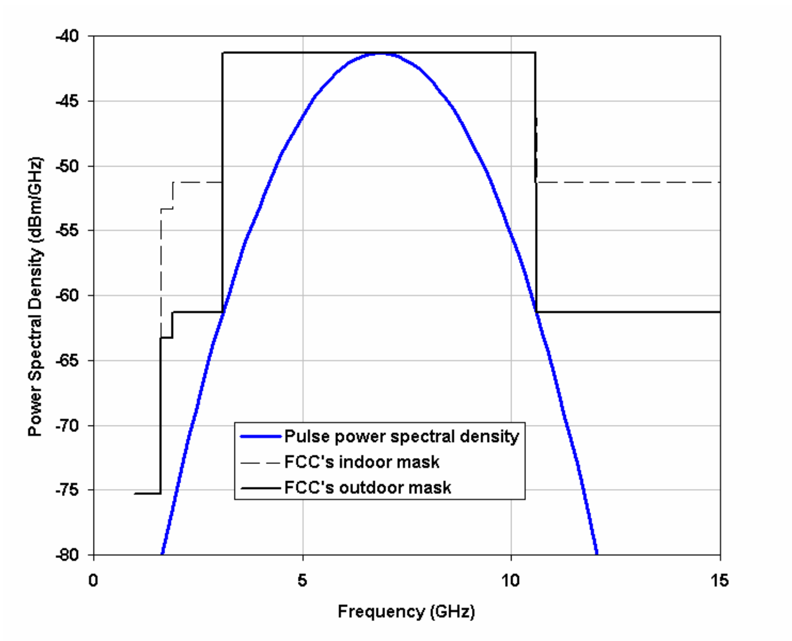
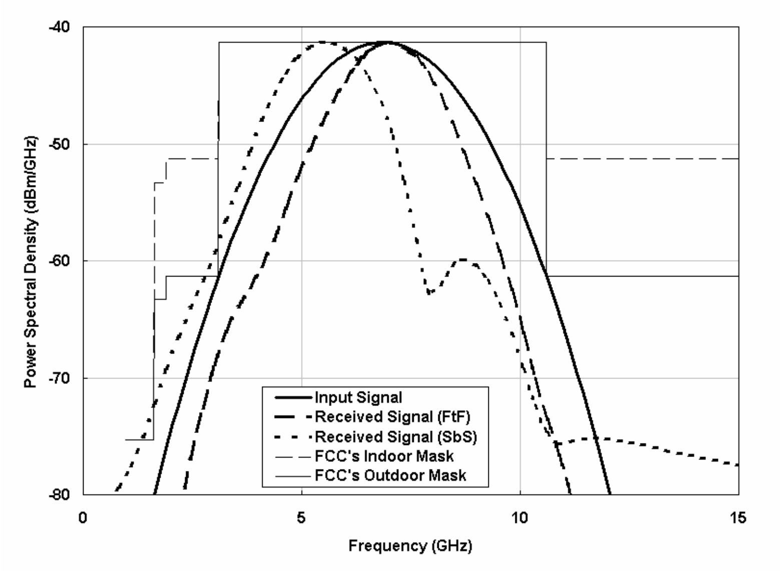
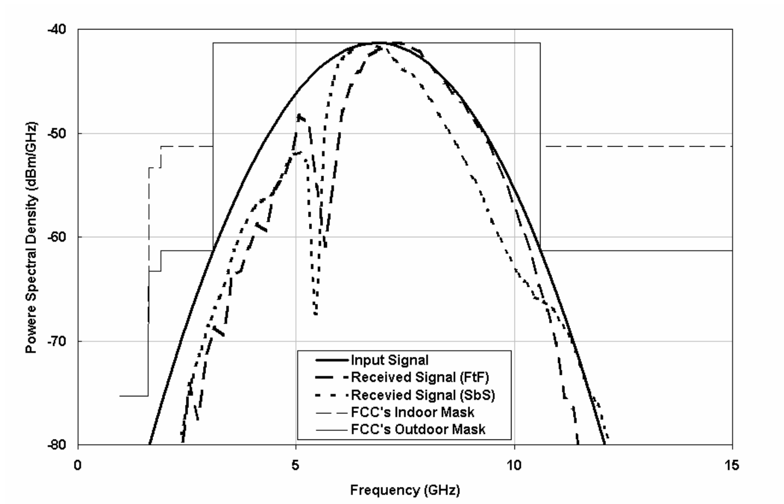


Figure 9. Power spectral density of the transmitted signal.

Since, UWB systems may cause interferences to other wireless systems since they operate over a large frequency range, which covers many bands being used. Thus, the emission limit is a crucial consideration for the design of both source pulses and UWB antennas. As indicated in Fig. 9 input signal comply with FCC's emission mask. The power spectrum density of the received signals in both orientations (Fig. 7) for both disk and notch frequency antenna has been depicted in Fig. 10. In addition to the impact of the notch which is observed in Fig. 10(b), reduction of the bandwidth of the power spectrum in both cases can be seen in comparison with power spectrum of the input signal.



(a)



(b)

Figure 10. Power spectral density of the transmitted signal (a) Disk antenna (b) Notch frequency antenna.

3. CONCLUSION

A new notch frequency antenna was studied. By use of the parametric study, it was shown that the location of the slot is very crucial in the design of the notch frequency antenna. The designed antenna was fabricated and measured. The measurement results showed good agreement with the simulation results. The results show an impedance bandwidth of 3.1 to 12 GHz or 3.87:1 with WLAN band notched at 4.75 to 5.9 GHz band. Also, the extensive investigations were carried out to extract the time-domain behavior of the notch frequency antenna. It seems despite of the appearing of the notch in the frequency domain, the distortion of the transmitted and received signal is low which makes it suitable to use as a UWB antenna.

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