Efficient Design and Analysis of an Ultra Wideband Planar Antenna with Band Rejection in WLAN Frequencies

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The telecommunication industry continues to move towards transferring larger and larger amounts of data in the shortest possible time using wireless technology. To accomplish this goal, it is necessary to operate at higher frequencies and to utilize larger bandwidths. Originally, the main purpose of designing ultra wide band antennas was to fulfill the requirements of radar related systems like the systems used for snow measurement [1].

Using UWB technology was an inexpensive way to design Snow Depth Sensors (SDS) and also Snow Water Equivalent (SWE) measuring systems [1]. Many such radar applications motivated the Federal Communication Commission (FCC) to allocate the 3.1 GHz to 10.6 GHz frequency band to Ultra Wideband devices. This allocation was the starting point for many of innovations based on wide band communications and data transfer. Today, localized communications demand an Ultra-Wideband to enable the transfer of massive data, such as high resolution multimedia content, which is critical in many applications such as hostile environments monitoring systems, hi-tech surgeries and underground communications [2, 3].

Different antenna designs have been proposed to cover the FCC ultra wideband, but two major challenges have always existed for UWB antenna designers: keeping the low profile of the antenna to make it possible to be integrated in portable devices, and dealing with the interference from wireless LAN devices operating at 5.8 GHz.

In this article we propose a printed ultra wide band antenna with a band rejection at WLAN frequencies in order to address both challenges. We also propose an efficient procedure to design and optimize such antennas using a sophisticated high frequency simulator, HFWorks [4]. The proposed antenna is a wineglass-shaped monopole slot fed with a Coplanar Waveguide line. In order to achieve to a band notch at 5.8 GHz, a narrow circular slit has been etched on the radiating element, which creates an open circuit and prevents antenna from radiation at that particular frequency range.

Antenna Design

As mentioned, the antenna proposed here is a microstrip patch antenna fed with a coplanar waveguide (CPW). The radiating element of the antenna is formed of two semicircles; one metallic one and one slot etched on the ground of the coplanar waveguide. The metallic semicircle is the exciting element for the slot semicircles that leads to the radiation of the aperture. The combination of the two semicircles with the CPW line creates a wineglass shaped configuration. This configuration works like a monopole antenna which, when properly dimensioned as in figure 1a, can achieve a bandwidth that covers the whole FCC band, namely from 3.1 GHz to 10.6 GHz.

In [5, 6] and [7], it is suggested to use the following formula to find the approximate aperture size of circular ultra wideband antennas:

$$R_{uwb} = \frac{c}{4f}\sqrt{\frac{2}{1+\varepsilon_{eff}}} \qquad (1)$$

where R_{uwb} is the radius of the aperture, c is the speed of light, ε_{reff} is the effective dielectric constant and f is the lowest frequency of the band, i.e., 3.1 GHz in this case. As the frequency increases, we can see that the radius of the aperture decreases and this is the basic idea behind the ability of the antenna to operate in such a wideband, because the radiating circles will be formed hypothetically inside the main circle.

However, in the proposed design, the story is slightly different, indeed, in order to keep the lowest possible profile by using semicircle instead of the full circle, the mentioned formula would not give us the exact radius. Therefore, finding the correct geometry requires an optimization. The optimization for the proposed antenna has been performed using the high frequency simulator, HFWorks. Using the simulator's built-in multi-configuration tool, a design table has been defined to take different values for the radii of both semicircles, R_{uwb} and Br. Then using the multistudy interface, the design was optimized to fulfill the FCC band requirements. The results of the optimization process are given in Table 1.

R_{uwb} (mm)	Br (mm)	Substrate Thickness (mm)	Permittivity
40	12	0.79	3.48

Table 1. General Dimensions of the UWB Antenna

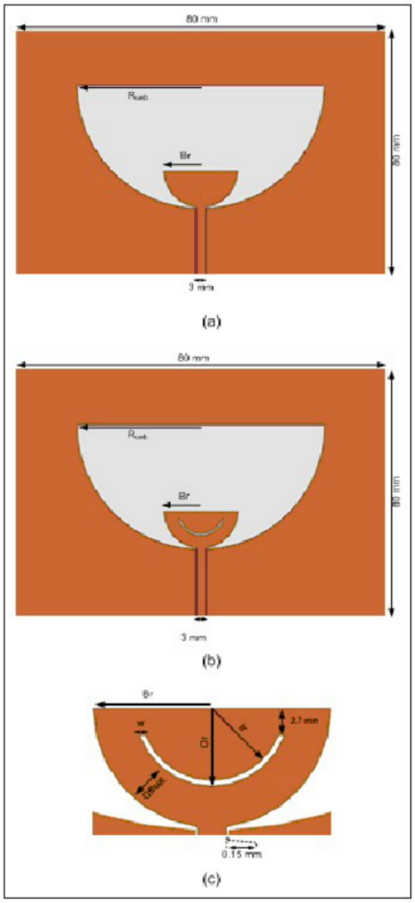

Figure 1 . The UWB antenna (a) The original configuration (b) The proposed configuration (c) The parasitic slit parameters

The next step is to design a sort of filter in order to perform the band rejection in WLAN frequencies. To accomplish this, we can either suppress the metallic semicircle at a certain radius by etching a parasitic slit or suppress the slot semicircle by printing a metallic parasitic arc.

We opted for the first approach and have created a parasitic slit on the semicircular metallic patch like the one shown in Figure 1b. This slit creates an open circuit at the hypothetical arc, which was exciting the slot to radiate at 5.8 GHz, the central frequency of wireless LANs. This open circuit prevents the antenna from being impedance matched at those frequencies and this way the WLAN frequencies are rejected. Figure 1c shows the different parameters to deal with in the optimization process, particularly the couple *(Offset,w)* that controls the position and the width of the slit.

The following equation was used in order to determine O_r and I_r for a given *(Offset,w)* configuration.

$$\begin{bmatrix} Or \\ Ir \end{bmatrix} = \begin{bmatrix} 1 & -1 \\ -\frac{1}{2} & -\frac{1}{2} \end{bmatrix}^{-1} \begin{bmatrix} w \\ Offset - Br \end{bmatrix} \qquad (2)$$

Results

A three dimensional model of the antenna has been developed using the high frequency finite element simulator, HFWorks. A parametric study has been performed using the multi-configuration, multi-study scheme of the simulator in order to optimize the thickness *(w)* and the location *(Offset)* of the parasitic slit etched on the metallic semicircular patch. Figure 2 shows the shift of the rejected band by changing the location of the slit for a constant width *(w)*. As we can see the behavior of the rejected band, confirms the hypothesis about the locus of the excitation for different frequencies within the band.

Table 2 gives the final values for the thickness and the locus of the parasitic slit. The combination of Table 1 and Table 2 gives the final geometry of the antenna.

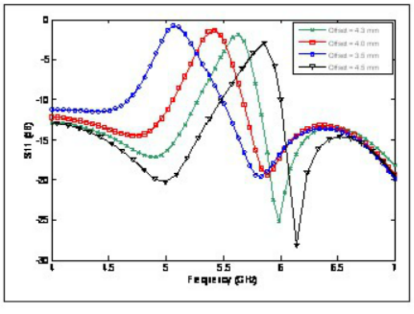

Figure 2. The variation of return loss during the optimization process (HFWorks)

Offset (mm)	w (mm)	Or (mm)	Ir (mm)
4.5	0.5	7.75	7.25

Table 2. The final dimensions of the parasitic slit

Figure 3 shows the return loss of the proposed antenna. We can clearly see that the whole FCC band is covered and only 5.8 GHz with a 200 MHz of bandwidth is rejected.

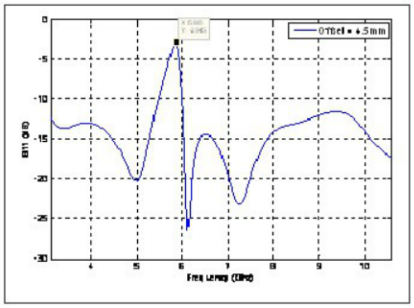

Figure 3. The return loss of the proposed antenna over the FCC band (HFWorks)

Figure 4 shows the radiation pattern at two different points within the bandwidth. As it can be seen in this figure, the omnidirectional pattern of the antenna has been preserved all across the band.

Conclusion

An Ultra Wideband antenna has been proposed in this article that rejects the WLAN frequency band of 5.8 GHz with 500 MHz bandwidth. The procedure of designing the antenna in the first place and creating a band notch in the operating band of the antenna in the second place has been explained. The optimized antenna which covers the FCC UWB band of 3.1 GHZ to 10.6 GHz has been simulated and optimized using a FEM high frequency simulator and the corresponding results have been reported. The antenna keeps the omnidirectional pattern all along the operating band.

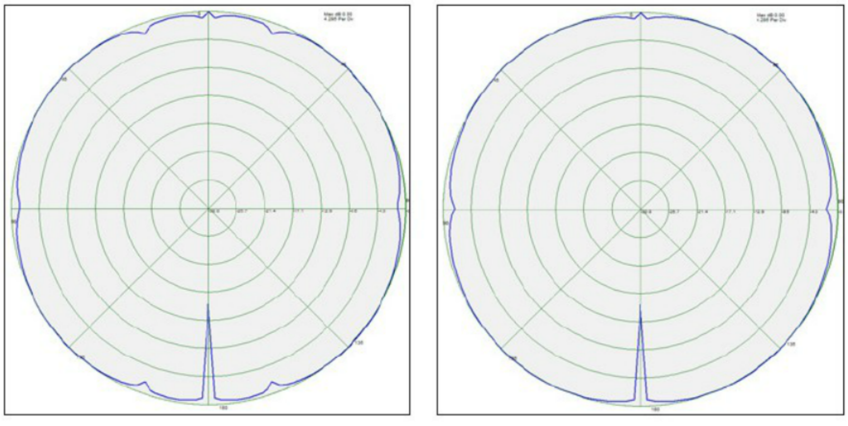

Figure 4. The radiation pattern of the proposed antenna (HFWorks) (left) at 7 GHz (right) at 3.1 GHz

References

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