A Miniaturized Ultra Wideband Antenna With Single Tunable Band-Notched Characteristics

Ahmed Mostafa Ahmed Salem(1), Shoukry I. Shams(2), A. M. M. A. Allam(3).
(1) Student, German University in Cairo (GUC), Egypt.
(2) T.A., M.sc., IET, German University in Cairo (GUC), Egypt.
(3) Professor, Ph.D, IET German University in Cairo (GUC) Cairo, Egypt.

Abstract—A miniaturized planar ultra wideband (UWB) monopole antenna is presented in this paper. By etching a C-shaped slot in the radiating patch, a band-rejected filtering properties in the WLAN band is achieved. By changing the thickness of the C-shaped slot, the notched frequency changes. An equation is introduced to calculate the thickness of the slot corresponding to a required notched frequency. The proposed antenna is compact in size with an overall dimensions of 20mm × 18mm and it is fed by a 50 Ω microstrip transmission line. The antenna is fabricated on FR4 dielectric substrate with ε_r=4.4 and height h=1.5 mm. There is a good agreement between the measured return loss and the simulated one. The antenna operates in the frequency band 2.8- 12.2 GHz with omnidirectional radiation pattern.

Index Terms—UWB, miniaturized, compact, tunable, C-shaped slot, ultra wideband antennas, band-notched characteristics, microstrip.

I. INTRODUCTION

Since the ultrawideband technology was first approved by the Federal Communication Commission (US-FCC) in 2002 it has advanced with an amazing rate in the last few years. The US-FCC has assigned the frequency band 3.1-10.6 GHz for commercial use of ultrawide band. Many new telecommunication applications and techniques appear everyday using extremly broadband antennas. The main aim of UWB technology is to transmit or receive data with very high data rates over a short-range wireless communication systems using the existing communication standards. It is also used in military applications due to its low probability of being intercepted by undesired receivers which makes it more secure than other communication techniques. One of the problem that UWB technology is facing is the interference with other narrow band technologies operating in a frequency band occupied by the UWB band. Some of the examples of these narrow bands are the WLAN(IEEE802) and HIPERLAN/2 WLAN operating in the 5-6 GHz band. In addition to these technologies come the WiMAX service operating in the 3.3-3.6 GHz band [2]. Using filters is not a practical solution due to the complexity of filters so the proposed antenna will be used as a notch filter.

Broadband planar monopole antennas have received great attention due to their ease of fabrication, acceptable radiation properties and large impedance bandwidth [1][3].

In this paper two microstrip fed ultra-wideband (UWB) antennas are proposed. The first antenna design is a simple UWB antenna which operates in the frequency band 2.8- 12.2 GHz. The second design is similar to the first one but with an additional C-shaped slot on the radiating patch which causes a notched frequency in a specific band depending on the slot thickness. An empirical formula to calculate the thickness of the slot corresponding to a specific notched frequency is proposed. Both antennas are compact having an overall size of 20mm × 18mm and are fed by a 50 Ω microstrip transmission line. The antennas were fabricated on an FR4 epoxy substrate with dielectric constant ε_r=4.4 and a substrate thickness h=1.5mm. Both antennas were simulated, fabricated and measured.

II. ANTENNA DESIGNS AND RESULTS

A. UWB Antenna Design and Results

The geometry of a simple UWB antenna is shown in Figure 1. The antenna was fabricated on an FR4 epoxy substrate with dielectric constant ε_r=4.4 and fed by a 50 Ω microstrip line. The manufacturing of the antenna is very easy and has a low cost. The final parameters are L= 20mm, L_1 = 2mm, L_2 = 4mm, L_3 =10mm, L_4= 4mm, W= 18mm, W_f = 2mm, G= 3.5mm, h= 1.5mm . Figure 2 shows the characteristics of the measured and simulated return loss of the ultra wideband antenna. A relative good agreement in between measurement
Figure 2. Measured Vs simulated return loss of the UWB antenna.

B. Single Band-Notched UWB Antenna Design and Results

To reduce the interferences from the IEEE802.11a and HIPERLAN/2 WLAN systems, the band-notched function is desirable in the UWB system. Figure 4 shows the geometry and dimensions of the UWB antenna with filtering property operating in the 5–6 GHz band. By etching a C-shaped slot in the radiating patch of the UWB antenna, a frequency band notch is created. The C-shaped slot exact dimensions are as follow C1= 8.56mm, C2=2.44 mm, C3= 3.67 mm and its thickness (ww) is equal to 1.15 mm for 5-6 GHz band notched characteristics.

The simulated radiation patterns of the band notched antenna at 6 GHz are shown in Figure 8 and Figure 9. The radiation pattern shows omnidirectional characteristics.

C. Design equation.

The notched frequency in the band notched antenna can be tuned by changing the thickness of C-shaped slot etched in the radiating patch. It is to be noted that the thickness of the slot is directly proportional to the filtered frequency.

In order to get an equation to calculate the exact thickness needed to filter a specific frequency, the return loss curves shown in Figure 8 are plotted for different values of the C-shaped slot thickness. The slot thickness was varied from 0.1 mm to 1.4 mm with a step of 0.05 mm. Each thickness resulted in a different frequency band rejection. Finally the empirical formula shown below is introduced to determine the exact thickness of the C-shaped slot corresponding to a frequency located in the band range from 3.5 to 6.3 GHz.

\[
S_{thick} = -0.12 \times \sin \left( \left( \frac{F_{notched} - 3.5}{5} \right) \frac{4\pi}{5} \right) + \frac{F_{notched}}{2.1} - 1.56
\]  

(1)

Figure 9 shows two curves representing the relationship between the C-shaped slot thickness versus the notched frequency. The first curve was plotted using the exact dimensions from the previous simulation. The second one represents the empirical equation.

The measured and simulated return loss of the UWB antenna with single band notched frequency is shown in Figure 5. It is found that the antenna is operating in the 2.8-12.2 GHz frequency band and the radiation is suppressed in the 5-6 GHz frequency band. The VSWR shown in Fig. 6 shows a good agreement with the return loss.

Figure 7 shows the simulated current distributions at different frequencies. In Figure 7(a) at 8 GHz frequency the current distributions flow in the same direction. At 5.5 GHz as shown in Fig. 7(b), the current distribution around the C-shaped slot flows in opposite directions. Similarly the current distribution along the patch and the feeding line flow in opposite directions. In this case, the radiating fields cancel each other which causes the antenna to be non radiating at that frequency. Large reflection at the desired notched frequency are created by the impedance nearby the feed-point which has significantly changed. Figure 12 shows the top and the bottom view of the band notched antenna.

and simulation can be observed. The antenna operates in the 2.8 to 12.2 GHz frequency band. Figure 3 shows the top and the bottom view of the fabricated UWB antenna.
Figure 4. Band notched antenna.

Figure 5. The return loss of the band notched antenna.

Figure 6. VSWR of the band notched antenna.

Figure 7. (a) Current distribution at 8 GHz. (b) Current distribution at 5.5 GHz.

Figure 8. VSWR for different C-shape slot thicknesses.

Figure 9. The C-shaped slot thickness Vs the notched frequency.
III. Conclusion

UWB systems face a problem of interference with other narrow band systems. To minimize this interference, a miniaturized UWB antenna with a tunable frequency band rejection is proposed and discussed. An empirical equation is given to calculate the dimension of thickness of the C-shaped slot in the antenna design which will correspond to a specific notched frequency. Omnidirectional radiation patterns are obtained. One of the antennas is fabricated without a C-shaped slot to obtain UWB characteristics without band rejection. The other one was fabricated with a C-shaped slot to have a band rejection at 5.5 GHz. Both antennas were simulated, fabricated and measured.

REFERENCES


