A Frequency Notched Planar Antenna for UWB Applications

L. Spiteri[1], #C.J. Debono[2], A. Muscat[3]
[1,2,3]Department of Communications and Computer Engineering, University of Malta
Msida, MSD2080, MALTA, [1]leslieg@onvol.net, [2]c.debono@ieee.org, [3]adrian.muscat@um.edu.mt

ABSTRACT: A novel planar ultra wideband (UWB) antenna having a simple design with frequency notching at 5.23 GHz is presented. The antenna parameters are predicted using a 3D-Electromagnetic wave solver. The designed antenna was fabricated on a common FR4 substrate and the input reflection coefficient (S_{11}) was measured confirming the notch at 5.23 GHz. The S_{11} response shows that the available bandwidth (<–10 dB) extends from 3.4 GHz to over 11 GHz with two minor peaks of –8.5 dB at 6.18 GHz and 9.0 GHz. Such a wide bandwidth makes the antenna suitable for applications involving data transfer speeds of around 100 Mbits/s over a range of, typically, 10 m. This is excellent for applications involving, for example, one-room interconnectivity of computers, DVD players, televisions etc.

Key words: *ultra wideband antenna; frequency notching; planar antenna*

1. Introduction

The basic (un-notched) antenna, which is identical to the one illustrated in Fig. 1 except for the rectangular patch above the ground piece on the ground plane, is a planar structure built on a double-sided substrate [1]. The shape adopted is the amalgamation of a semicircle and a triangle both of which have been extensively studied [2 - 3]. The antenna lends itself well to implementation in compact devices as opposed to other proposals found in literature, such as [4 - 5].

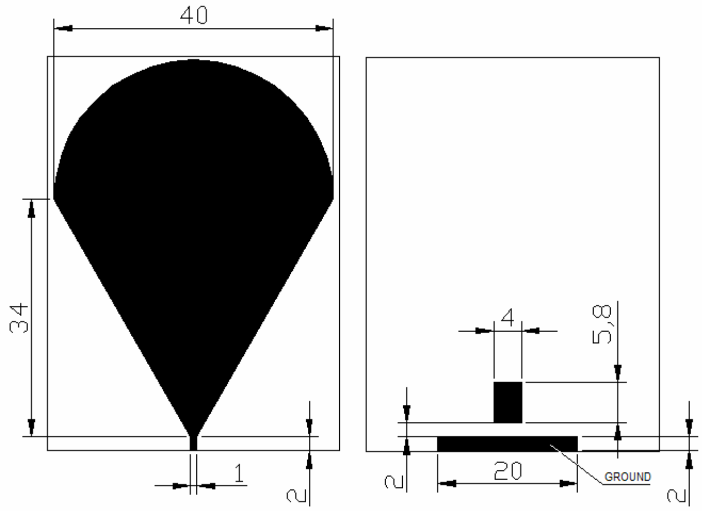

Fig. 1: Antenna (a) and ground plane (b) layout and dimensions

In this paper we present a modification to the structure presented in [1] to include frequency notching. The main dimensions for the structure (apex of triangle, radius of semicircle and width/length of input strip) can be varied either separately or mutually to tune precisely the antenna. Broadly speaking, the length of the triangle and the radius of the semicircle were found to affect the lower and the upper limits of the bandwidth of the antenna, however a strict relationship was not very evident. The width of the input part of the antenna was a very critical parameter in obtaining a good impedance performance over the whole bandwidth of interest. The width of 1 mm was found to exhibit acceptable performance at both the high and low ends of the bandwidth. Additionally this type of layout exhibits a smoothly varying shape (making it resonant at multiple frequencies) and, since it lacks sharp or abrupt changes, reflections are contained. This results in a very good S_{11} response. The shape also has the advantage of making the design compact.

2. Frequency notched antenna

Frequency notching on elliptical and circular dipoles can be implemented by cutting out triangular or elliptical notches [6]. This method of frequency notching was found inadequate when applied to the basic UWB antenna discussed above. Instead, in this case, frequency notching was implemented by the inclusion of a rectangular patch on the underside of the antenna (namely, on the same side of the ground) with the top of the patch shorted to the antenna. It is evident from Fig. 1 that this additional rectangular patch has three principal dimensions, variations of which affect the performance of the antenna in different ways.

The length and width both affect the nominal notch frequency however to a different extent. As the length and the width increase the frequency decreases and the reverse is also true. The patch to ground distance mainly affects the bandwidth of the notch and has a very little affect on the nominal notch frequency: the closer the patch is to the ground plane the wider is the bandwidth of the notch.

3. Simulation Results

Fig. 2 shows the simulation results for three values of patch width, namely 2 mm, 4 mm and 6 mm. From these results it can be seen that the effect of the patch width is to shift the nominal notch frequency to a lower value, as the patch gets wider. In effect, an increase of 4 mm in the patch width causes the notch frequency to decrease by 1.4 GHz (or 0.35 GHz/mm). Other than this effect, simulation results indicate that changes in the patch width affect the overall response very slightly.

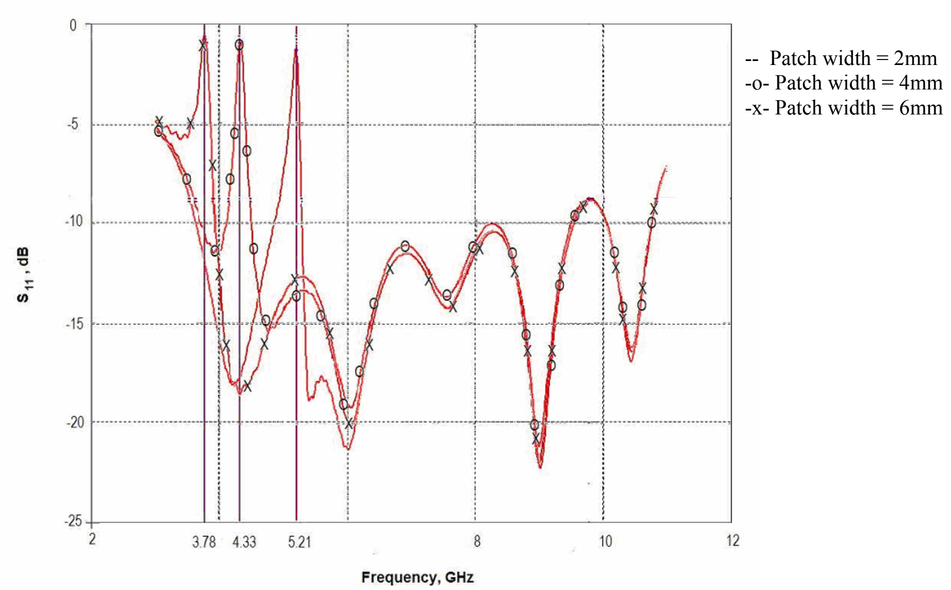

Fig: 2: S_{11} response for notched antenna with patch width as parameter

Fig. 3 illustrates the effect that the patch length has on shifting the nominal notch frequency: the longer the length, the lower is the nominal notch frequency. These simulation results indicate that a change in length of 0.7 mm has the effect of shifting the notch frequency by 400 MHz, which is equivalent to 0.57 GHz/mm. This means that the nominal notch frequency is more sensitive to changes in the length of the patch than to changes in its width.

Prototyping results indicated that a patch having a width of 4 mm and a length of 5.8 mm gives the required antenna parameters. This result was used in developing the main antenna and ground plane, whose dimensions are shown in Fig. 1. The simulation results for the S_{11} response, shown in Fig. 4, show that the nominal notch frequency is located at 4.14 GHz and there are three points at which the response exceeds –10 dB (albeit only marginally). This response is adequate considering that the structure is operating with a 109% fractional bandwidth and when compared to other simple structures such as microstrip designs [7 – 8].

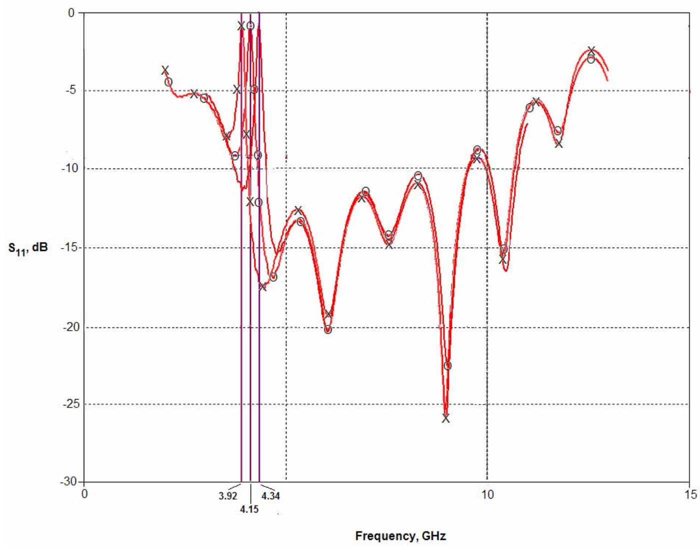

Fig 3: S_{11} response for notched antenna with patch length as parameter

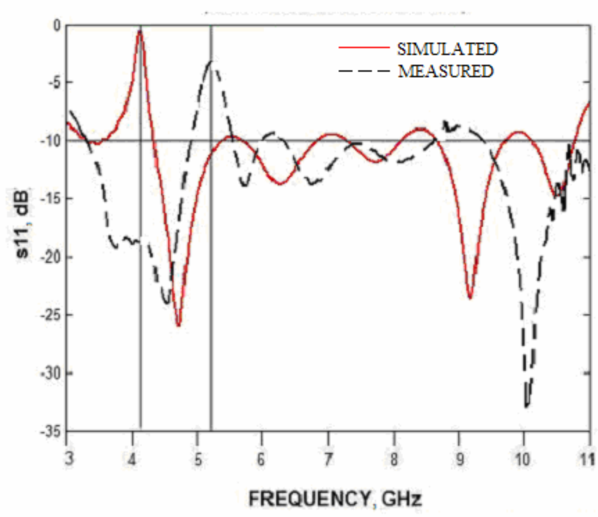

Figure 4: Simulated and measured S11 results for notched UWB antenna with patch length of 5.8 mm

4. Experimental Results

The antenna prototype was constructed on FR4 substrate having a thickness of 1.5 mm and a dielectric constant of 4.8. Measurements were carried out using an HP8510C network analyzer. Fig. 4 depicts an overlay of the experimental and simulated S_{11} response of the final prototype antenna built with a patch having a length of 5.8 mm and a width of 4 mm. The following are the salient points of the response:

- 3.3 GHz lowest –10 dB frequency.
- Notch frequency of 5.23 GHz.
- Return loss at notch –3.22 dB (equivalent to a VSWR of 5.22).
- Beyond the notch the return loss peaks marginally (approximately -8.2 dB) above the –10 dB line at 6 GHz and 9 GHz (in this case the VSWR is approximately 2.2).

From Fig. 4, it is also clear that the simulation results and experimental results agree closely as regards the general shape of the response. It is however visible that there is a frequency shift, equivalent to approximately 1.0 GHz, between the two responses. This shift is attributed to the simulator as various prototypes having different notch frequencies have been manufactured to investigate this shift and all presented similar differences between simulations and measurements.

Several other simulations were done and prototypes were built in order to test experimentally the effect that the patch dimensions have on the overall S_{11} response. The responses clearly highlighted that, as the notch frequency gets high, the S_{11} response shifts upwards: when the notch frequency increases beyond approximately 5.1 GHz, the S_{11} response exceeds –10 dB, that is, obviously, undesirable.

5. Conclusion

A planar antenna of simple and low cost construction, and with dimensions which make it suitable for use in portable devices, has been presented. The proposed structure is frequency notched to make it compliant with 802.11a devices. The notch introduces adequate attenuation such that the additional attenuation required by the 802.11a standard can be implemented by electronic filtering. Compared with other UWB antenna designs reported in literature [6] and [9], the characteristics obtained through this solution measure up to similar antennas well. Measurements have also demonstrated that the return loss of the antenna remains quite stable even when the antenna was manually handled. Of special note is that the notch frequency did not shift under such circumstances. This makes the antenna structure ideal for applications in handheld devices.

References

[1] Spiteri L., Debono C.J., and Muscat A.: 'A Planar Antenna for UWB Applications,' Proc. of the 6th Int. Conf. on Microwaves, Radar and Communications (MIKON 2006), Krakow, Poland, 2006
[2] Schantz H.G.: 'Planar Elliptical Element Ultra-Wideband Dipole Antennas', Proc. of the IEEE Antennas and Propagation Society Int. Symp., vol. 3, p. 44, June 2002.
[3] Yazdandoost K.Y. and Kohna R.: 'Ultra Wideband Antenna', IEEE Communications Magazine, vol. 42, pp. 29 – 32, June 2004.
[4] Schantz H.G.: 'UWB Magnetic Antennas', Proc. of the Proc. of the IEEE Antennas and Propagation Society Int. Symp., vol. 3, pp. 604 – 607, June 2003.
[5] Yang T., Suh S-Y., Nealy R., Davis W.A, and Stutzman W.L.: 'Compact Antennas for UWB Applications', Proc. of the IEEE Conf. on Ultra Wideband Systems and Technologies, pp. 205 – 208, November 2003.
[6] Schantz H.G.: 'Frequency Notched UWB Antennas', Proc. of the IEEE Conf. on Ultra Wideband Systems and Technologies, pp. 214 – 218, November 2003.
[7] Balanis, C.A., 'Antenna Theory: Analysis and Design', 2nd Edition, John Wiley & Sons Inc., Ch 14, pp. 722, USA, 1997.
[8] Yarovoy, A.G., Pugliese, R., Zigderveld, J.H., and Ligthart, L.P., 'Antenna Development for UWB Impulse Radio', Proc. of the 34th European Microwave Conference, pp. 1257 - 1260, Amsterdam, 2004.
[9] Wong, K-L, 'High-Performance Ultra-Wideband Planar Antenna Design', Dept of Electrical Engineering, National Sun Yat-Sen University Kaohsiung, Taiwan, 2005.