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Groundplane Dependent Performance of Printed Antenna for MB-OFDM-UWB

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***Abstract*— A printed ultra wideband (UWB) antenna suitable for multiband orthogonal frequency division multiplexing (MB-OFDM) UWB is presented in this paper. The proposed antenna covers a wide band from 3.1 GHz to 11.2 GHz. Good performance and low cost production was obtained using FR-4 substrate. An examination of the effects of ground plane dimensions on antenna properties such as gain, bandwidth and radiation pattern is made.**

I. INTRODUCTION

The demand for wireless connectivity has increased dramatically in the last few years. Consumers now want to be able to transfer data between their electronic mobile devices such as, PCs, MP3 players, personal digital recorders, digital cameras and digital camcorders, gaming systems, personal digital assistants (PDAs) and cell phones. But they also need to transfer this data at high data rates demanding a large bandwidth. Today's wireless technology such as LAN (local area network) or WPAN (wireless personal area network) can not support this wide bandwidth.

Ultra-wideband (UWB) technology offers a solution for the necessary bandwidth required for the new electronics devices, as well as offering low cost and low power, with small physical size and high transmission data rates.

The IEEE 802.15.3a task group is developing a high data rate physical layer for WPANs. There are two competitive proposals for this; direct sequence (DS) UWB and multi-band orthogonal frequency division multiplexing (MB-OFDM) UWB.

UWB devices and applications require wideband antennas and the demand for these antennas has increased greatly since the Federal Communication Commission declaration of the bandwidth of 7.5 GHz (3.1 GHz to 10.6 GHz) for commercial applications [1].

The space available for the antenna is different for every device. For example, in a laptop cover, the space can be large but narrow, allowing only a long thin ground plane. In a PDA or mobile phone, the space available for the antenna is much less allowing only very small and compact antennas, making it necessary to use miniaturization techniques to reduce the size of the radiator.

It is well known that the groundplane has significant effects on antenna properties, such as impedance bandwidth, radiation pattern, gain and impulse response [2]–[4].

Small printed antennas have become one of the main areas of UWB antenna research in recent years. This is due to their low-cost and planar structure. Many novel planar geometries have been proposed [5]–[8]. There are many requirements in the specification of UWB antennas [9] and these should not be compromised by groundplane or casing effects. The casing has recently been shown to have significant effects on the impulse response of UWB antennas [10].

This work examines the effects of these printed antennas when located on groundplanes of various sizes, as would be the case in emerging UWB devices. The main focus of this is for the MB-OFDM system, which is more tolerant of antenna dispersion, than DS-UWB and has greater flexibility in adapting to the various national spectral regulatory authorities. It also allows selection of sub-bands to address interference issues, which may arise. The parameters of impedance bandwidth, pattern and gain are examined for the various groundplane shapes.

II. ANTENNA DESIGN AND RESULTS

A. Antenna Geometry

The antenna is printed on double-sided FR-4 substrate of $\varepsilon_r = 4.3$, tan$\delta = 0.02$ and a thickness of 1.52 mm. Fig. 1 shows the geometry of the proposed antenna. The dimensions of the rectangular planar (plate) monopole are $w_p = 13$ mm and $l_p = 14$ mm. It is fed by a microstrip line of width $w_f = 2.5$ mm which is excited by an SMA connector. The feedline is offset by 2 mm from the center of the radiating element. This introduces extra modes and helps to increase the bandwidth. The groundplane ($w_g = 20$ mm, $l_g = 18$ mm) is located on the back of the substrate. The feedgap between the lower edge of the monopole and the upper edge of the groundplane is $h_{gap} = 2$ mm. The overall height of the antenna is $l_s = 34$ mm.

B. Experimental Results

The simulated and measured impedance bandwidth for this antenna is shown in Fig. 2. As we can see, the impedance bandwidth is greater than 10 dB from 3.1 GHz to 10.1 GHz.

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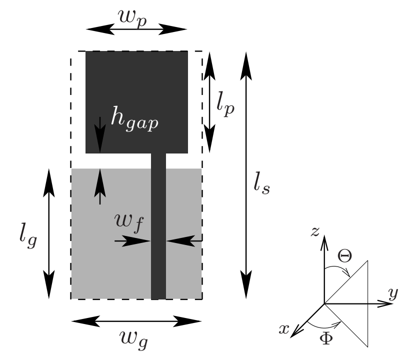

Fig. 1. Antenna geometry with substrate surrounding the radiator.

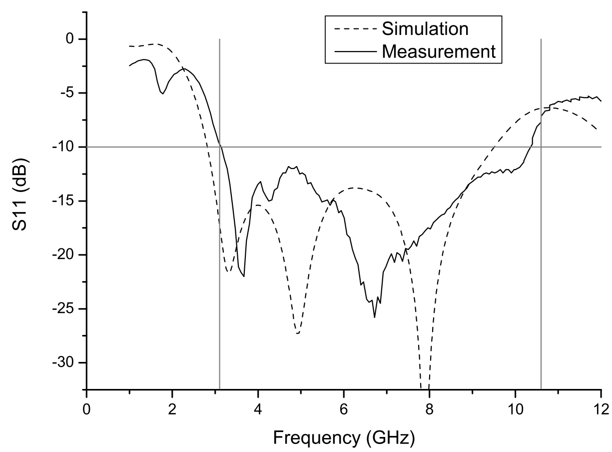

Fig. 2. Simulated and measured return loss of the printed antenna in Fig. 1.

C. Refinement of the Antenna Geometry

In order to further increase the efficiency and impedance bandwidth of this antenna and meet the requirement of the FCC, a technique of removing the substrate surrounding the plate was used. The new design is shown in Fig. 3. The radiator element has the same dimensions as the design shown in Fig. 1. The white arrows indicate where the substrate was trimmed.

Fig. 4 shows the simulated and measured impedance bandwidth of the proposed antenna design. A 10 dB return loss is realized from 3.1 GHz to 11.2 GHz, which covers the entire ultra-wide band (from 3.1 GHz to 10.6 GHz).

III. Groundplane Modifications

Due to the small size of the above mentioned antenna, it can be easily integrated into a mobile device. However the space available for the antenna is different in every electronic device. A laptop cover is big enough to allow a larger groundplane. Therefore, the groundplane width and height was extruded. The impedance bandwidth, radiation patterns and gain effects are examined.

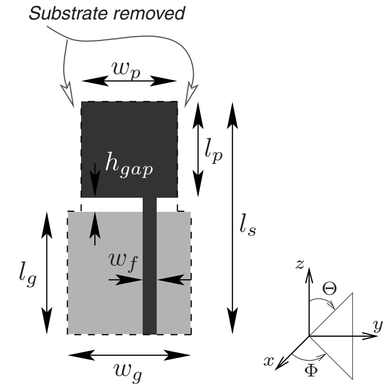

Fig. 3. Geometry of the proposed UWB antenna with substrate removed from radiator plate.

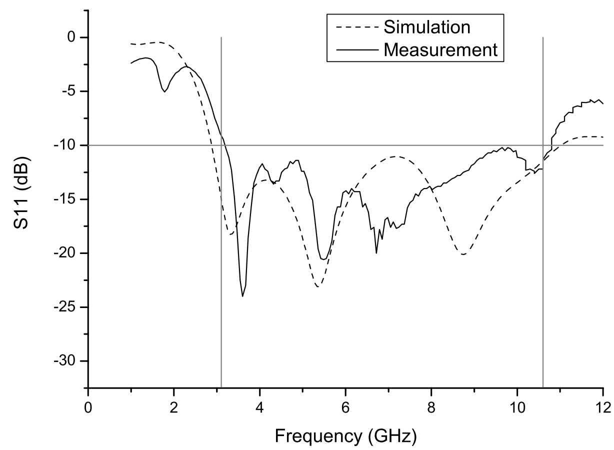

Fig. 4. Simulated and measured return loss of antenna with substrate removed.

A. Change of Groundplane Width

Fig. 5 shows the geometry of the antenna with the groundplane extended in width. Only the width is modified, all other dimensions remain the same. The width was varied between 10 mm and 200 mm, which is realistic for these devices.

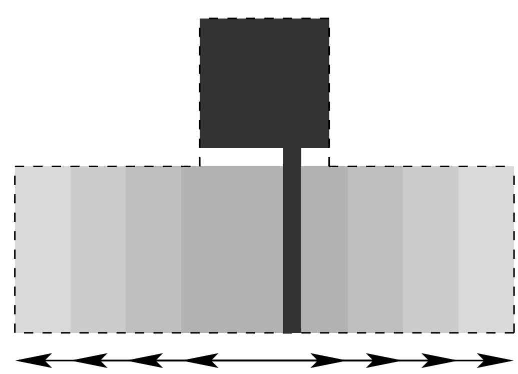

Fig. 5. Geometry of the antenna with modified groundplane width.

The modification of the groundplane width has very little effect on the return loss of the antenna. Therefore, in Fig. 6 we only show a few sample plots for widths, w, of 10, 20, 90, 150 and 200 mm. The UWB band is achieved for all widths from 20 mm up. It can be seen that the UWB bandwidth is lost for a very small groundplane.

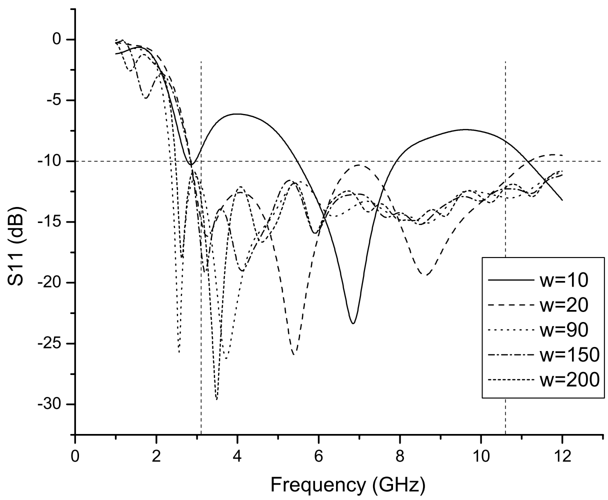

Fig. 6. Return loss for different width groundplanes.

A plot of the variation of maximum antenna gain is shown in Fig. 7 for the width varying from 20 mm to 200 mm. It can be seen that the gain variation across the UWB band is relatively constant for small values of width (± 0.5 dB for $w = 20$ mm), but wider groundplanes increase the gain variation.

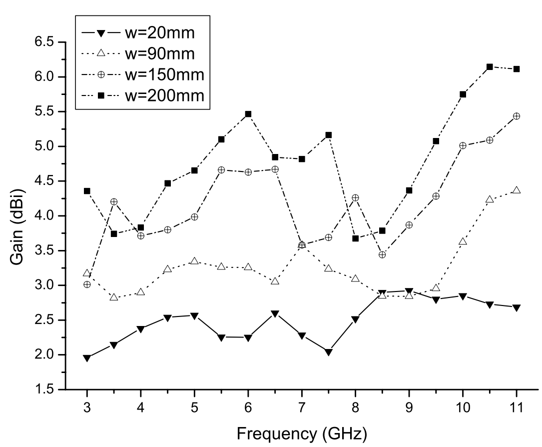

Fig. 7. Gain variation over the UWB band for different groundplane widths.

Radiation patterns were simulated in CST-MWS and shown in Fig. 8–11. The patterns are shown for groundplane width of 20, 90, 150 and 200 mm. As we can see, the patterns are almost omnidirectional for the low frequencies of 3.1 GHz and 5 GHz, but this omnidirectionality is lost for higher frequencies and more noticeably for larger groundplanes.

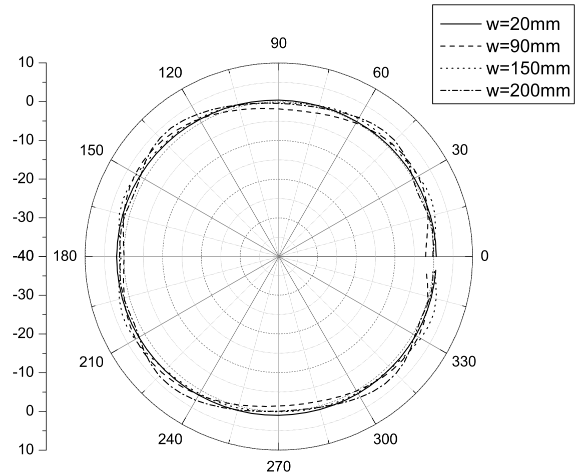

Fig. 8. Radiation pattern for the xy plane at 3.1 GHz. Groundplane of width 20, 90, 150 and 200 mm.

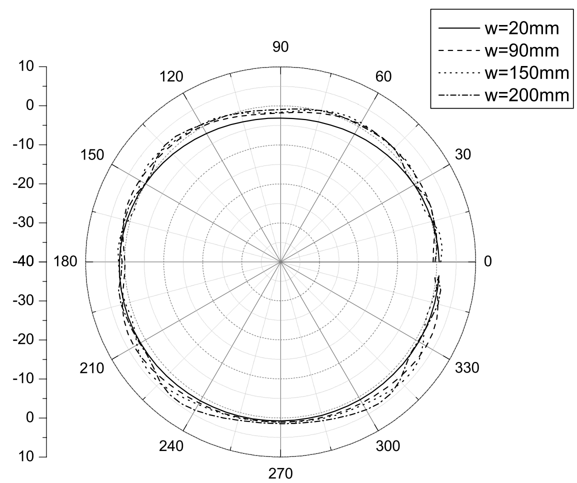

Fig. 9. Radiation pattern for the xy plane at 5 GHz. Groundplane of width 20, 90, 150 and 200 mm.

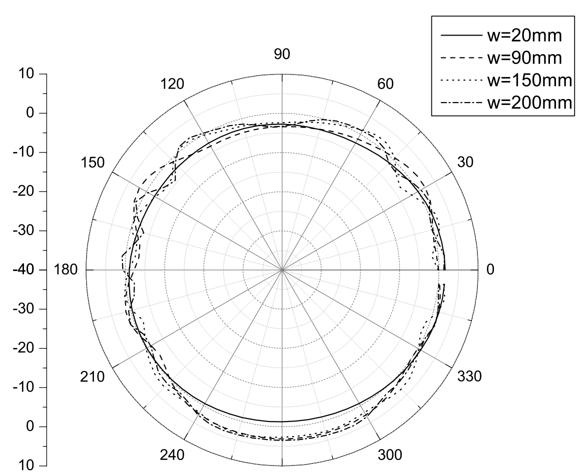

Fig. 10. Radiation pattern for the xy plane at 8 GHz. Groundplane of width 20, 90, 150 and 200 mm.

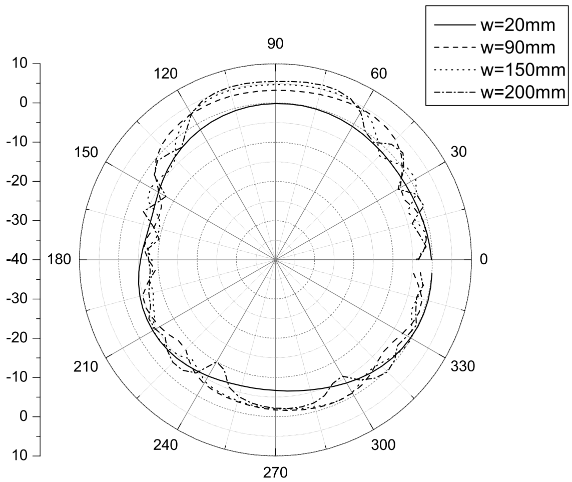

Fig. 11. Radiation pattern for the xy plane at 10.6 GHz. Groundplane of width 20, 90, 150 and 200 mm.

B. Change of Groundplane Height.

Fig. 12 shows the geometry of the antenna with the groundplane extended in height. Only the height of the groundplane, l, is changed and with it the overall height of the antenna. All other dimensions remain the same.

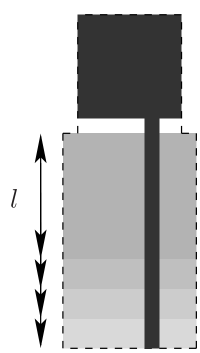

Fig. 12. Geometry of the antenna with modified groundplane height.

There are two design limitations, a bandwidth of 7.5 GHz (between 3.1 GHz and 10.6 GHz) or more and a lower edge frequency of 3.1 GHz or less. Fig. 13 shows the behaviour of the lower edge frequency and the bandwidth with change of groundplane height. The groundplane height, l, was varied from 10 mm to 150 mm. It can be seen that the lower edge frequency varies in a cyclic fashon with change of groundplane height. The bandwidth is also slightly dependent on this parameter. The smallest groundplane height for full UWB coverage is between 14 mm and 22 mm. Further heights where this criteria is met are 65, 110 and 150 mm. As can be seen from Fig. 13, some values of groundplane height place limitations on both lower edge frequency and bandwidth. Thus, the groundplane dimensions need to be carefully examined as an integral part of the antenna.

A plot of the variation of maximum antenna gain is shown in Fig. 14 for the groundplane height varying from 18 mm to

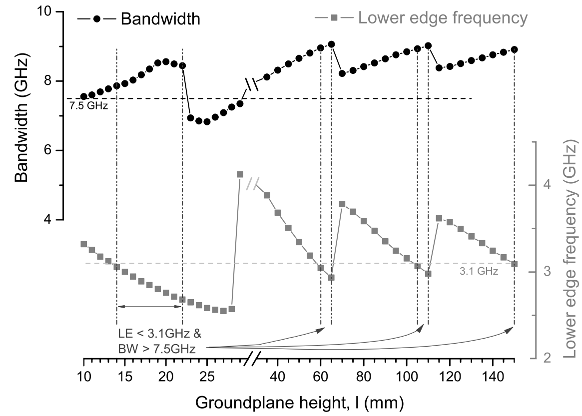

Fig. 13. Lower edge frequency and impedance bandwidth (10 dB RL) for different groundplane heights.

150 mm. It can be seen that the gain variation across the UWB band is relatively constant for small values of height (± 0.5 dB for $h = 18$ mm). Longer groundplanes however, show higher gain for frequencies below 6 GHz but the gain decreases for frequencies higher than 6 GHz.

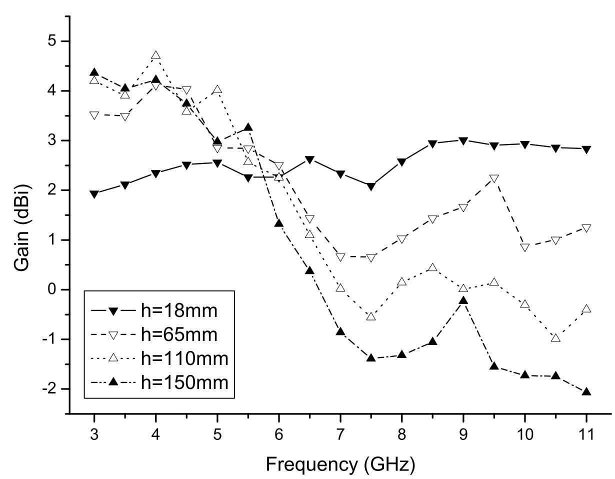

Fig. 14. Gain variation over the UWB band for different groundplane heights.

Radiation patterns for various groundplane heights are shown in Fig. 15–18. The groundplane heights examined are 18, 65, 110 and 150 mm.

These patterns remain almost omnidirectional up to 8 GHz. This omnidirectionality is lost only at the highest frequency examined (10.6 GHz).

IV. Conclusion

A very small and low cost UWB printed antenna has been presented. A prototype was built and tested. Simulation and measurements results are in good agreement. The dependence of the groundplane dimensions are examined in terms of impedance bandwidth, radiation patterns and gain. It was found that the antenna bandwidth is dependent on groundplane size and the UWB band is not fully covered for some

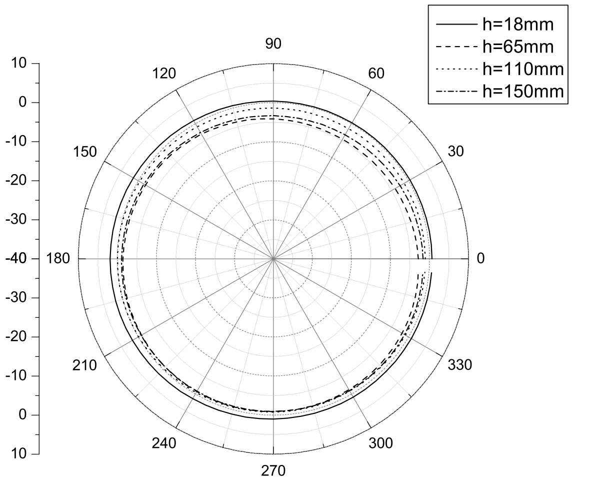

Fig. 15. Radiation pattern for the xy plane at 3.1 GHz. Groundplane of height 18, 65, 110 and 150 mm.

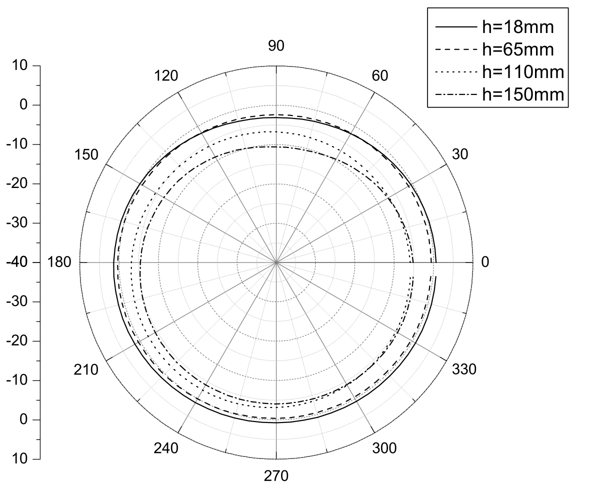

Fig. 16. Radiation pattern for the xy plane at 5 GHz. Groundplane of height 18, 65, 110 and 150 mm.

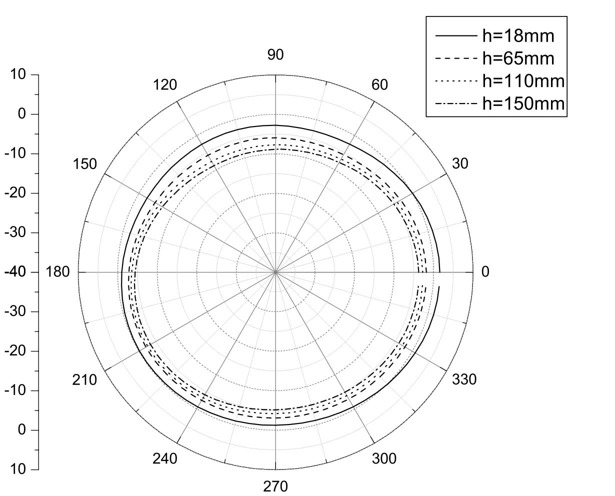

Fig. 17. Radiation pattern for the xy plane at 8 GHz. Groundplane of height 18, 65, 110 and 150 mm.

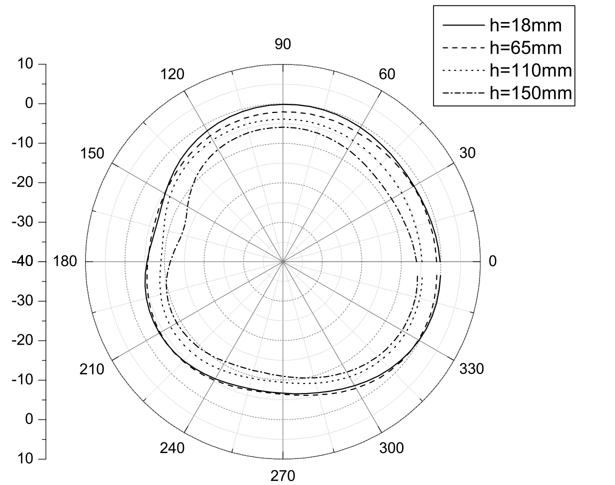

Fig. 18. Radiation pattern for the xy plane at 10.6 GHz. Groundplane of height 18, 65, 110 and 150 mm.

groundplanes sizes. Pattern distortion was found be minimal particularly for smaller groundplane sizes and at lower frequencies, which makes the antenna suitable for MB-OFDM with carrier band base systems. The gain remained relatively constant across the UWB band for smaller groundplane sizes. Gain variations approach ± 2 dB for wider and ± 3.5 dB for longer groundplanes.

Acknowledgment

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References

[1] Federal Communications Commission, *First Order and Report, Revision of Part 15 of the Commissions Rules Regarding UWB Transmission Systems*, FCC 02–48, April 22, 2002.

[2] M. J. Ammann and M. John, "Optimum Design of the Printed Strip Monopole," *IEEE Antennas & Propagat. Mag.*, vol. 47(6), pp. 59–61, Dec. 2005.

[3] A. T. Arkko, "Effect of Ground Plane Size on the Free-Space Performance of a Mobile Handset PIFA Antenna," *IEE Intl. Conf. Antennas & Propagat. (ICAP)*, vol. 1, pp. 316–319, 2003.

[4] H. Poor, *An Introduction to Signal Detection and Estimation*, New York: Springer-Verlag, 1985, ch. 4.

[5] J. Liang, C. C. Chiau, X. Chen and C.G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Trans. Antennas & Propagat.*, vol. 53(11), pp. 3500–3504, Nov. 2005.

[6] Z. N. Chen, M. J. Ammann, X. M. Qing, X. H. Wu, T. S. P. See and A. Cai, "Planar Antennas: Promising Solutions for Microwave UWB Applications," *IEEE Microwave Magazine*, vol. 7(6), pp. 63–73, Dec. 2006.

[7] X. H. Wu and Z. N. Chen, "Comparison of planar dipoles in UWB applications," *IEEE Trans. Antennas & Propagat.*, vol. 53(6), pp. 1973–1983, June 2005,

[8] A. M. Abbosh, M. E. Bialkowski, M. V. Jacob, J. Mazierska, "Design of a Planar UWB Antenna with Signal Rejection Capability in a Narrow Sub-band," *IEEE 63rd Vehicular Technol. Conf. Spring*, pp. 2645–2648, 2006.

[9] H. G. Schantz, *Ultra-Wideband Antenna Design and Applications*, Artech House, Norwood, MA, 2005.

[10] D. Manteuffel, "Considerations on Antennas and Propagation Aspects for UWB Consumer Applications," *LAPC - Loughborough Antennas and Propagation Conference*, pp. 145–150, April 2006.