UWB Antenna Designing: Challenges and Solutions

Dinesh Yadav, and Vivekanand Tiwari

Abstract— Ultra wide-Band (UWB) technology is one of the most promising solutions for the rapid development in the field of wireless communication due to high-speed data rate, large bandwidth and excellent immunity to multipath interference. In this context, the UWB antenna design plays a unique role because it behaves like a band pass filter and reshapes the spectra of the pulses, so it should be designed to avoid undesired distortions. Some of the critical requirements in UWB antenna design are: UWB antenna should operate over entire UWB allocated by FCC (3.1-10.6 GHz ultra-wide bandwidth), directional or Omni-directional radiation patterns, constant gain and group delay over the entire band, high radiation efficiency and low profile. This paper reviews the state of the art in UWB antenna fundamental techniques, comparison between different UWB antenna designs and proposed new class of UWB microstrip patch antenna.

Keywords— UWB (Ultra-wide band), Microstrip patch Antenna, Planar Antenna.

I. Introduction

ULTRA Wide Band (UWB) technology is one of the most promising solutions for communication systems due to its high speed data rate and excellent immunity to multipath interference. So, UWB technology has been used in the areas of radar, remote sensing and military communication during the past years. In February 2002, the Federal Communication Commission (FCC) allocated an unlicensed band of 7.5 GHz, i.e. from 3.1 GHz to 10.6 GHz for indoor UWB wireless system. Industrial standards such as IEEE 802.15.3a (High data rate) and IEEE 802.15.4a (very low data rate with ranging) based on UWB technology have been introduced. UWB technology is defined by the FCC as any wireless scheme that occupies a fractional bandwidth more than 500 MHz or 20% of absolute bandwidth given in the FCC report 2002 [1]. The essence of ruling is that power spectral density (PDS) of the modulated UWB signal must satisfy the spectral masks specified by spectrum regulating agencies. For indoor communications, maximum power spectral density of -41.3 dBm/MHz is allowed in the frequency band between 3.1GHz to 10.6 GHz. Outside of that band, no intentional emissions are allowed. Similarly, outdoor communication between mobile devices is allowed in 3.1GHz to 10.6 GHz range, though the mask for spurious emission is different.

Dinesh Yadav is a research scholar at Manipal University Jaipur, India (phone: +919829574400; e-mail:dinesh.yadav@jaipur.manipal.edu).

Dr. V. N. Tiwari is Professor at Manipal University Jaipur, India. (e-mail: vivekanand.tiwari@jaipur.manipal.edu)

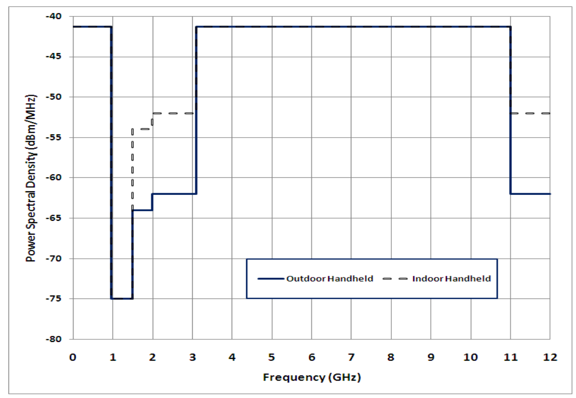


Fig. 1 FCC spectral mask for indoor and outdoor handheld applications

The spectral mask for indoor and outdoor handheld applications and different frequency spectrum specified by FCC in the United States is shown in Fig. 1 and Fig. 2.

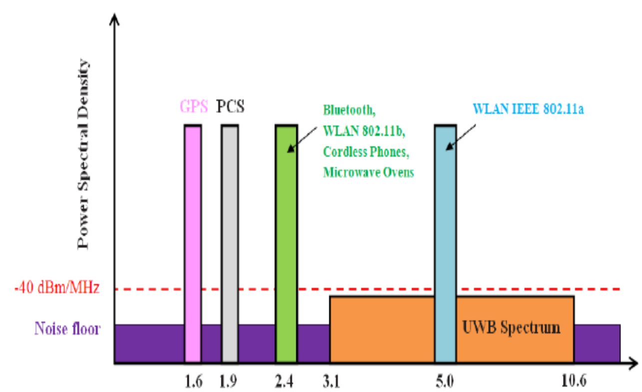


Fig. 2 Different frequency spectrum including Ultra Wide Band

II. Characteristics Of UWB Antennas

UWB system has wide impedance bandwidth, steady directional or omnidirectional radiation pattern, constant gain in desired direction, constant desired polarization, high radiation efficiency, linear phase response, Small size, low profile and embeddable, low cost and low complexity (installation, fabrication, materials and maintenance). UWB systems operate at low power transmission levels; channel capacity is proportion to the bandwidth (means data transfer rate as high hundreds of Mbps or several Gbps). UWB signal do not cause significance interference to the other wireless systems. UWB provides high secure and high reliable communication solutions.

III. Motivation For Uwb Antenna Design

Ultra Wide Band (UWB) technology is considered to be attractive by many researchers, scientists and engineers and a promising technology for high-speed, high data rates and short-range indoor wireless communications. This is especially true when the US Federal Communication Commission (FCC) permitted using the frequency band from 3.1GHz to 10.6 GHz for UWB radio applications in 2002 [1].

Currently, there is a great interest in UWB system design and implementation in both academic research and industry areas. The concept of UWB radio was first developed several decades ago exactly in the late 1960's. The U.S. Department of Defense first founded the term 'ultra-wideband' in 1989 [2]. In the beginning, UWB was mainly for military purposes such as radar applications which use wideband signals in frequency domain or very short duration pulses in the time domain to get fast, reliable and accurate information about moving targets such as missiles.

Extensive work has been has been done to improve the performance of UWB antenna since last decade and still work in progress. In the UWB frequency band (3.1 GHz -10.6 GHz), some narrow band systems such as Wi-MAX (3.4 GHz - 3.69 GHz), WLAN (5.15 GHz - 5.35 GHz, 5.725 GHz - 5.825 GHz) and HIPERLAN (5.45 GHz - 5.725 GHz) exist. These narrow band wireless systems generate interference with UWB systems. To minimize the interference between the UWB systems and narrow band systems, UWB antennas with band notched characteristics have been proposed by the researches.

IV. Different Uwb Antenna Designs

With the increasing popularity of UWB systems, there have been many developments in the design of UWB antennas. Enactment of a UWB system is facing many challenges and one of these challenges is to develop a suitable antenna that can work over entire UWB bandwidth. This is because the antenna is an essential part of the UWB system and its performance affects the system. In recent years, there are many antenna designs that can achieve wide bandwidth to be used in UWB systems such as the Vivaldi antenna, bi-conical antenna, log periodic antenna and spiral antenna as shown in Fig 3. A Vivaldi antenna [3]-[7] is designed antenna for UWB operations. A Vivaldi antenna has a directional radiation pattern and so this antenna is not suitable for either indoor wireless communication or mobile/portable devices because it need omni-directional radiation patterns to enable easy and efficient communication between transmitters and receivers in all directions. Mono-conical and bi-conical antennas [8]-[10] have bulky structures with 16 large physical dimensions which limit their applications. Also, log periodic [9], [11] and spiral antennas [12]-[15] are two different UWB antennas that can operate in the 3.1-10.6 GHz frequency band but are not suitable for indoor wireless communication applications or mobile/portable devices. This is because they have large physical dimensions as well as dispersive characteristics with frequency and severe ringing effect [11].

So researchers are more interested in UWB indoor wireless communications and mobile/portable devices that can overcome all these shortcomings. This candidate is the planar or printed monopole antenna [16]-[38]. Printed monopole antennas [16]-[24] with different shapes of polygonal (rectangular, trapezoidal, circular, elliptical…etc.) have been proposed for UWB applications as shown in Fig 4.

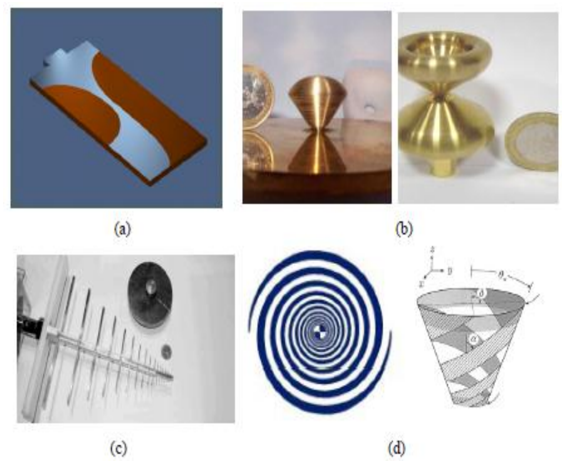
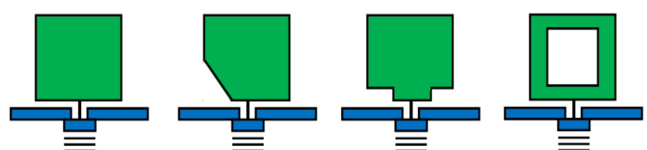
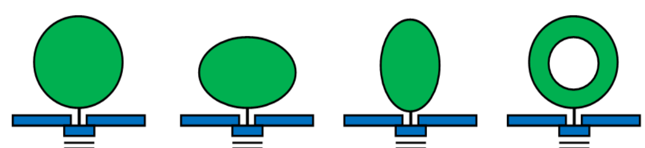


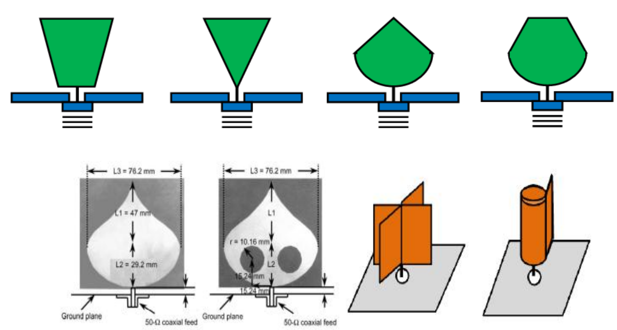
Fig. 3 (a) Vivaldi antenna [4] (b) Mono-conical and bi-conical antenna [9] (c) Log-periodic antenna [9] and (d) Spiral and conical spiral antenna [14]



(a) Rectangular [16]-[19]



(b) Circular and elliptical [20]-[21]



(c) Other shapes [22]-[24]

Fig. 4 Modified shape planar antennas for UWB applications

These proposed antennas have omni-directional radiation patterns, wide frequency impedance bandwidth, easy fabrication on printed circuit boards (PCBs) and printed PCB structure of planar monopole antennas are considered to be promising candidates for applications in UWB communications. Due to ease of fabrication, UWB antenna designs focus on small printed antennas and their ability to be integrated with other components on the same PCBs [25]-[38]. Several realizations of planar PCB or printed antenna deigns shown in Fig. 5.

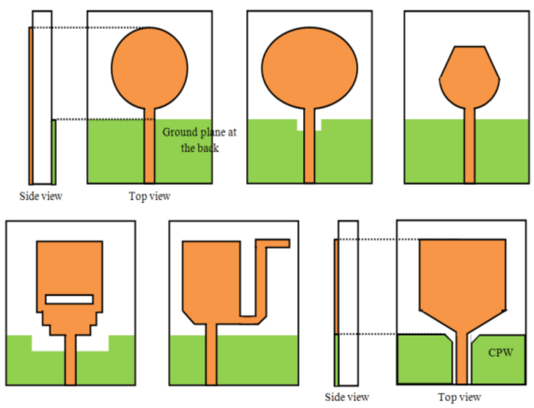


Fig. 5 Planar PCB or printed antenna designs [33]-[38].

In UWB band (3.1 GHz to 10.6 GHz), there are several existing Narrow Band communication systems operating below 10.6 GHz and may cause interference with the UWB systems such as Wi-MAX (3.4 GHz - 3.69 GHz), IEEE 802.11a WLAN (5.15 GHz - 5.35 GHz, 5.725 GHz - 5.825 GHz) and HIPERLAN (5.45 GHz - 5.725 GHz) wireless system. To avoid the interference with the existing wireless systems, a filter with band stop characteristics may be integrated with UWB antennas to achieve a notch function at the interfering frequency band [39]-[50]. Fig 6 shows several developed band stop antenna designs [51].

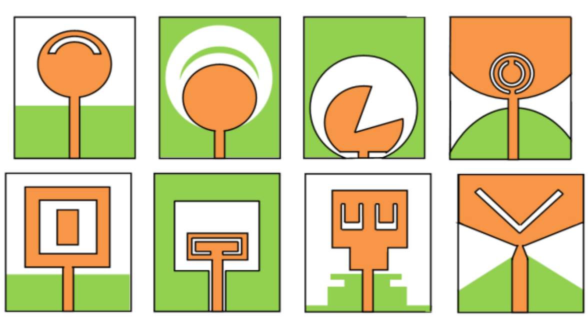


Figure 6 Printed antenna designs with single band-stop functions [39]-[47].

V. CONCLUSION

A wide variety of UWB antenna designs are discussed in this paper. Lot of research has been done in the past years to design conventional antennas for Ultra wideband wireless communication. Some features are common for different antennas, and it is remarkable that, all designs are looking for a wider matching impedance bandwidth without loss of omnidirectional radiation pattern and limiting pulse distortion. Moreover, some designs provide a frequency band notch to avoid WLAN interferences, which will be critical in the future. The planar UWB monopole has several interesting characteristics, among them; the most important are its mechanical simplicity, directional and omnidirectional capability and the matching impedance bandwidth ratio.

REFERENCES

[1] FCC, "First report and order, revision of part 15 of the commission's rules regarding "Ultra-Wideband Transmission Systems FCC" 2002.

[2] Barrett, W. Terence, "History of Ultra Wideband Communications and Radar: Part I, UWB Communications", Microwave Journal, January 1st, 2001.

[3] I. Linardou, C. Migliaccio, J. M. Laheurte and A. Papiernik, "Twin Vivaldi an-tenna fed by coplanar waveguide", Electron. Lett., vol.33, no. 22, pp. 1835–1837, Oct. 1997. http://dx.doi.org/10.1049/el:19971259

[4] E. Guillanton, J.Y. Dauvignac, Ch. Pichot and J. Cashman, "A New Design Ta-pered Slot Antenna for UWB Applications", Microwave Opt. Technol. Lett., vol. 19, no.4, pp. 286–289, Nov. 1998. http://dx.doi.org/10.1002/(SICI)1098-2760(199811)19:4<286::AID-MOP12>3.0.CO;2-0

[5] J. P. Weem, B. M. Notaros and Z. Popovic "Broadband Element Array Considera-tions for SKA", Conf. Proc. Perspectives on Radio Astronomy: Technologies for Large Antenna Arrays, pp.59–67, Dwingeloo, The Netherlands, April, 1999.

[6] E. Gazit, "Improved design of the Vivaldi antenna", IEE Proc. Microw. Antennas Propag., vol. 135, part H, no. 2, pp. 89–92, 1988.

[7] S. G. Kim and K. Chang, "Ultra Wideband Exponentially-Tapered Antipodal Vi-valdi Antennas", IEEE Antennas and Propagation Society Symposium, vo. 3, pp. 2273 – 2276, Monterey, CA, June 2004.

[8] Warren L. Stutzman and Gary A. Thiele, Antenna Theory and Design, 1998, by John Wiley & Sons, INC.

[9] A. Sibille, "Compared Performance of UWB Antennas for Time and Frequency Domain Modulation", 28th URSI General Assembly, NewDelhi, India, 2005.

[10] S. N. Samaddar. E. L Mokole, "Biconical Antennas with Unequal Cone Angles", IEEE Transactions on Antenna and Propagation, Vol 46, No 2, pp 181-193, 1998. http://dx.doi.org/10.1109/8.660962

[11] S. Licul, J. A. N. Noronha, W. A. Davis, D. G. Sweeney, C. R. Anderson and T. M. Bielawa, "A parametric study of time-domain characteristics of possible UWB an-tenna architectures", IEEE 58th Vehicular Technology Conference, VTC 2003-Fall, vol. 5, 6-9 October, 2003.

[12] D. J. Sego, "Ultrawide Band Active Radar Array Antenna for Unmanned Air Ve-hicles", Proc. IEEE Nat. Telesyst. Conf., pp. 13–17, 1994. http://dx.doi.org/10.1109/NTC.1994.316703

[13] E. Gschwendtner, W. Wiesbeck, "Ultra-Broadband Car Antennas for Communi-cations and Navigation Applications", IEEE Trans. Antennas Propag., vol. 51, no. 8, pp. 2020–2027, Aug. 2003. http://dx.doi.org/10.1109/TAP.2003.815341

[14] T. W. Hertel and G. S. Smith, "On the Dispersive Properties of the Conical Spiral Antenna and Its Use for Pulsed Radiation", IEEE Trans. Antennas Propag., vol. 51, no. 7, pp. 1426–1433, July 2003. http://dx.doi.org/10.1109/TAP.2003.813602

[15] Z. Lou and J. M. Jin, "Modeling and Simulation of Broadband Antennas using the Time-Domain Finite-Element Method", IEEE Trans. Antennas Propag., vol. 53, no. 12, pp. 4099–4110, Dec. 2005. http://dx.doi.org/10.1109/TAP.2005.859905

[16] M. J. Ammann, "Square planar monopole antenna", Proc IEE National Conf An-tennas Propagat., UK, pp. 37–40, 1999. http://dx.doi.org/10.1049/cp:19990010

[17] M. J. Ammann, "Control of the impedance bandwidth of wideband planar mono-pole antennas using a beveling technique", Microwave Opt. Technol. Lett., vol. 30, no. 4, pp. 229–232, Aug. 2001. http://dx.doi.org/10.1002/mop.1273

[18] S. W. Su, K. L. Wong, and C. L. Tang, "Ultra-wideband square planar monopole antenna for IEEE 802.16a operation in the 2–11 GHz band", Microwave Opt. Tech-nol. Lett., vol. 42, no. 6, pp. 463–466, Sept. 2004.
http://dx.doi.org/10.1002/mop.20337

[19] Z. N. Chen, M. J. Ammann, and M. Y. W. Chia, "Broadband square annular pla-nar monopoles", Microwave Opt. Technol. Lett., vol. 36, no. 6, pp. 449–454, Mar. 2003.
http://dx.doi.org/10.1002/mop.10787

[20] N. P. Agrawall, G. Kumar, and K. P. Ray, "Wide-Band Planar Monopole Anten-nas", IEEE Trans. Antennas Propag., vol. 46, no. 2, pp. 294–295, Feb. 1998.
http://dx.doi.org/10.1109/8.660976

[21] Z. N. Chen, M. J. Ammann, M. Y. W. Chia and T. S. P. See, "Annular planar monopole antennas", IEE Proc. Microw. Antennas Propag., vol. 149, no. 4, pp. 200–203, Aug. 2002.
http://dx.doi.org/10.1049/ip-map:20020701

[22] Z. N. Chen, and Y. W. M. Chia, "Impedance characteristics of trapezoidal planar monopole antennas," Microwave Opt. Technol. Lett., vol. 27, no. 2, pp. 120–122, Oct. 2000.
http://dx.doi.org/10.1002/1098-2760(20001020)27:2<120::AID-MOP11>3.3.CO;2-4

[23] S. Y. Suh, W. L. Stutzman, and W. A. Davis, "A New Ultrawideband Printed Monopole Antenna The Planar Inverted Cone Antenna (PICA)", IEEE Trans. Anten-nas Propag., vol. 52, no. 5, pp. 1361–1365, May 2004.
http://dx.doi.org/10.1109/TAP.2004.827529

[24] Z. N. Chen, "Broadband Roll Monopole", IEEE Trans. Antennas Propag., vol. 51, no. 11, pp. 3175–3177, May 2003.
http://dx.doi.org/10.1109/TAP.2003.818777

[25] H Deng, X He, S Liu, Y Xie, "A novel Ultra Wideband Planar Antenna," Global Symposium on Millimeter Waves (GSMM), pp. 288–290, April 2008.
http://dx.doi.org/10.1109/GSMM.2008.4534625

[26] S. Cheng, P. Hallbjorner, and A. Rydberg, "Printed Slot Planar Inverted Cone An-tenna for Ultrawideband Applications," IEEE Antennas Wireless Propag. Lett., vol. 7, pp.18–21, 2008.
http://dx.doi.org/10.1109/LAWP.2007.914115

[27] J.-P. Zhang, Y.-S. Xu, and W.-D Wang, "Microstrip-Fed Semi-Elliptical Dipole Antennas for Ultrawideband Communications," IEEE Trans. Antennas Propag., vol. 56, no.1, pp. 241–244, 2008.
http://dx.doi.org/10.1109/TAP.2007.913165

[28] A. Abbosh and M. Bialkowski, "Design of ultra wideband planar monopole an-tennas of circular and elliptical shape," IEEE Trans. Antennas Propag., vol. 56, no.1, pp.17–23, 2008.
http://dx.doi.org/10.1109/TAP.2007.912946

[29] O. Ahmed and A.-R. Sebak, "A Printed Monopole Antenna with Two Steps and a Circular Slot for UWB Applications," IEEE Antennas Wireless Propag. Lett., vol.7, pp. 411–413, 2008.
http://dx.doi.org/10.1109/LAWP.2008.2001026

[30] O. Ahmed and A.-R. Sebak, "A Novel Ultra-Wideband Printed Monopole Anten-na", XXIX General Assembly of the International Union of Radio Science (URSI), Chicago, USA, 2008.

[31] O. Ahmed and A.-R. Sebak, "A Novel Maple Leaf Shaped Printed Monopole An-tenna for UWB Wireless Communications", IEEE International Symposium on An-tennas and Propagation and USNC/URSI National Radio Science Meeting (AP-S/URSI), San Diego, USA, 2008.

[32] N. C. Azenui, and H. Y. D. Yang, "A printed crescent patch antenna for ul-trawideband applications," IEEE Antennas Wireless Propag. Lett., vol. 6, pp. 113–116, 2007.
http://dx.doi.org/10.1109/LAWP.2007.891522

[33] 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 Propag., vol. 53, no. 11, pp. 3500–3504, Nov. 2005.
http://dx.doi.org/10.1109/TAP.2005.858598

[34] C. Y. Huang and W. C. Hsia, "Planar elliptical antenna for ultra-wideband com-munications," Electron. Lett., vol. 41, no. 6, pp. 296-297, Mar. 2005.
http://dx.doi.org/10.1049/el:20057244

[35] C.-H. Hsu, "Planar multilateral disc monopole antenna for UWB application," Microwave Opt. Technol. Lett., vol. 49, no. 5, pp. 1101–1103, May 2007.
http://dx.doi.org/10.1002/mop.22353

[36] S. H. Choi, J. K. Park, S. K. Kim, and J. Y. Park, "A New UWB Antenna for UWB Applications," Microwave Opt. Technol. Lett., vol. 40, no. 5, pp. 399–401, May 2004.
http://dx.doi.org/10.1002/mop.11392

[37] Z. N. Chen, T. S. P. See, and X. Qing, "Small printed Ultrawideband antenna with reduced ground plane effect," IEEE Trans. Antennas Propag., vol. 55, no. 2, pp. 383–388, Feb. 2007.
http://dx.doi.org/10.1109/TAP.2006.889823

[38] M. A. Peyrot-Solis, G. M. Galvan-Tejada, and H. Jardon-Aguilar, "A novel planar UWB monopole antenna formed on a printed circuit board," Microwave Opt. Tech-nol. Lett., vol. 48, no. 5, pp. 933–935, May 2006.
http://dx.doi.org/10.1002/mop.21523

[39] Chih-Yu Huang, Wei-Chun Hsia, and Jieh-Sen Kuo, "Planar ultra-wideband an-tenna with a band-notched characteristic," Microwave Opt. Technol. Lett., vol. 48, no. 1, pp. 99–101, Oct. 2006.
http://dx.doi.org/10.1002/mop.21274

[40] M. Naghshvarian-Jahromi, "Compact UWB bandnotch antenna with transmission-line fed," Progress In Electromagnetics Research B, vol. 3, pp. 283–293, 2008.
http://dx.doi.org/10.2528/PIERB07121407

[41] C.-Y. Huang, S.-A. Huang, and C.-F. Yang, "Band-Notched Ultra-Wideband Cir-cular Slot Antenna With Inverted C-Shaped Parasitic Strip," Electron. Lett., vol. 44, no. 15, pp. 891–892, July 2008.
http://dx.doi.org/10.1049/el:20081143

[42] C.-J. Pan, C. Lee, C.-Y. Huang, and H.-C. Lin, "Band-notched ultra-wideband slot antenna," Microwave Opt. Technol. Lett., vol. 48, no. 12, pp. 2444–2446, Oct. 2006.
http://dx.doi.org/10.1002/mop.21958

[43] J. Kim, C.S. Cho and J.W. Lee, "5.2 GHz notched ultra-wideband antenna using slot-type SRR," Electron. Lett., vol. 42, no. 6, pp. 315–316, Mar. 2006.
http://dx.doi.org/10.1049/el:20063713

[44] H. W. Liu, C. H. Ku, T. S. Wang, C.F. Yang, "Compact monopole antenna with band-notched characteristic for UWB applications", IEEE Antennas Wireless Propag. Lett., vol. 9, pp. 397–400, 2010.
http://dx.doi.org/10.1109/LAWP.2010.2049633

[45] Y. C. Lin and K. J. Hung, "Compact Ultrawideband Rectangular Aperture Anten-na and Band-Notched Designs," IEEE Trans. Antennas Propag., vol. 54, no. 11, pp. 3075–3081, Nov. 2006.
http://dx.doi.org/10.1109/TAP.2006.883982

[46] M. Ojaroudi, G. Ghanbari, N. Ojaroudi, C. Ghobadi, "Small square monopole an-tenna for UWB applications with Variable frequency band-notch function", IEEE An-tennas Wireless Propag. Lett., vol. 8, pp. 1061–1064, 2009.
http://dx.doi.org/10.1109/LAWP.2009.2030697

[47] B. Ahamadi, R. F. Dana, "A miniaturized monopole antenna for ultrawideband applications with band-notch filter", IET Microwave antennas Propagations, vol.3, pp.1224–1231, 2009.

[48] S. W. Qu, J. Li, and Q. Xue, "A Band-notched Ultrawideband Printed Monopole Antenna," IEEE Antennas Wireless Propag. Lett., vol. 5, pp. 495–498, Dec. 2006.
http://dx.doi.org/10.1109/LAWP.2006.886303

[49] C.-Y. Hong, C.-W. Ling, I.-Y. Tarn, and S.-J. Chung, "Design of a Planar Ul-trawideband Antenna with a New Band-Notch Structure," IEEE Trans. Antennas Propag., vol. 55, no. 12, pp. 3391–3397, 2007.
http://dx.doi.org/10.1109/TAP.2007.910486

[50] Y.-L. Zhao, Y.-C. Jiao, G. Zhao, L. Zhang, Y. Song, and Z.-B. Wong, "Compact Planar Monopole UWB Antenna with Band-Notched Characteristic," Microwave Opt. Technol. Lett., vol. 50, no. 10, pp. 2656–2658, Oct. 2008.
http://dx.doi.org/10.1002/mop.23717

[51] Osama Haraz and Abdel-Razik Sebak, "UWB Antennas for Wireless Applications" E- Book.