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Advancement in Ultra Wideband Antennas for Wearable Applications

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Abstract- There has been a tremendous rumble in UWB research after the U.S. Federal Communications Commission (FCC) allocated a frequency range with a bandwidth of 7.5 GHz from 3.1–10.6 GHz for UWB applications. Ultra wideband (UWB) technology was earlier limited to special applications, primarily in the military area and there primarily to electronic warfare. The antennas were usually horn antennas or modified, ridged horn antennas, sometimes in combination with reflectors. Wearable intelligent textile system is an innovative fast growing field in application oriented field. In recent years, body-centric wireless communication becomes an important part of fourth generation mobile communication systems (4G). Utilization of wearable textiles in the antenna segment has been seen on the rise due to the recent miniaturization of wireless devices. Wearable and fabric-based antennas have become one of the dominant research topics in antennas for body-centric communications. The review presented here intended to disclose the unconventional antenna technology including UWB technology for wearable applications. Contributions by various researchers have been compiled keeping in mind background of UWB technology, the wearable antenna, and specification of the antenna, material for the antenna and analysis that must be done to design proper UWB wearable antennas for various applications.

Index Terms— Body-centric communications, UWB, UWB wearable antenna, Wearable Antenna, 4G.

1 INTRODUCTION

ANTENNA becomes a part of electrical devices in wireless communication system after late 1888; Heinrich Hertz (1857–1894) were first demonstrated the existence of radio waves [1]. The UWB technology opens new door for wireless communication system, since the current wireless system increasing exponentially. The appearance of wearable intelligent textile systems revealed the necessity for WBAN (Wireless Body Area Network) system to provide standalone outfit in recent years. This network enables wearable computer devices to interact with each other and exchange digital information using the electrical conductivity of the human body as a data network [2]. While talking about wireless body area networks, suddenly it comes into mind that how the signals would be communicated? Well, an antenna, which is a fundamental part of the network, is the answer for this. Textile antenna is one of the most fascinating and cutting edge research areas of modern era. It provides a wearable interface between human and the machine. Since we are talking about wearable antennas, it is necessary to mention here that antennas for such applications should possess certain properties like light weight, conformal design, low cost, easy system integrable etc. So the design should be such that antennas performance is not deteriorated even if they are bent. UWB radio applications has gain much attention to wireless personal area networks, which address short-range, ad-hoc, and high-rate connectivity among portable electronic devices.

The Federal Communication Commission (FCC) releases ultra-wide band (UWB) from 3.1GHz-10.6 GHz in 2002 for the use of indoor and hand-held systems [3]. Since then UWB antennas have gained enormous attention in both academia and industry for applications in wireless transmission systems. Figure-1 shows spectral mask for UWB applications specified by FCC.

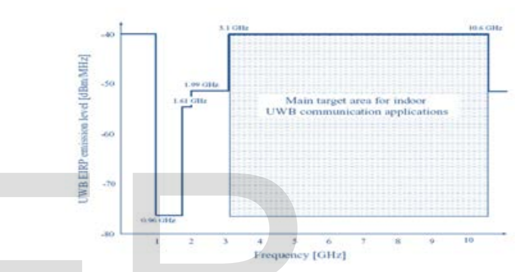

Fig.1: FCC spectral mask for Indoor UWB Application

In Impulse-Ultra wideband (I-UWB) technology a very low power pulse is sent whose power is always kept below the noise threshold and also this system does not uses any carrier for transmission.

Generation of UWB pulse has been described in [4]. The transmission bandwidth for such system is more than 20% of its center frequency (>500 MHz) [5], [6]. In short, the antennas to be designed for UWB systems should have sufficiently broad operating bandwidth for impedance matching and high-gain radiation in desired directions. The UWB spectral mask was defined to allow a spectral density of -41.3 dBm / MHz throughout the UWB frequency band.

2 UWB REQUIREMENT AND SPECIFICATION

Various studies have been devoted to evaluating the performance of UWB antennas (Agrawal et al., 1998; Amman & Chen, 2003; Hertel & Smith, 2003; Klemm et al., 2005; MaTG & Jeng, 2005).

The UWB antenna must achieve almost a decade of impedance bandwidth, spanning 7.5 GHz.

The UWB system must provide:

- Broad operating bandwidths for impedance matching,
- High gain transmissions in the desired direction,
- Stable transmission patterns and gains,
- Consistent group delays,

- High transmission efficiency, and
- Low profiles.

The design considerations of the UWB antennas and source pulses are based on investigating S parameters, transfer functions, systems efficiency, group delay and fidelity.

3 DESIGN PARAMETERS FOR UWB WEARABLE ANTENNA

There are 14 parameters to be considered while designing the conventional antenna (radiation diagram, directivity, gain, equivalent receiving area, diffraction area, input impedance, radiation resistance, equivalent height, bandwidth, polarization, front-back ratio, antenna ratio, thermal noise, efficiency). When we talk about design of UWB antenna for wearable applications certain parameter need to be calculated in addition to conventional parameters like transfer function, group delay etc.

For wearable antennas integrated into clothing Microstrip antennas have been preferred among the candidates [7], [8]. In such uses Microstrip antennas with flexible conductors and substrates are needed and this has led to an increased demand for electrical technical textiles (ETTs). Microstrip antennas [9] have some significant advantages for on-body wearable applications the three major ones being their ease of construction, their cost effectiveness and an associated metallic ground plane that when used between the body and the radiating elements can significantly reduce energy absorbed by the body. But Microstrip antennas are low bandwidth and relatively large in size.

Typically for flexible and wearable antennas the substrate materials chosen have been textiles or plastics. Textiles tend to low relative permittivity (<2) and suffer somewhat from trapped air which may have variable electrical characteristics due to water content. Plastics, for example polypropylene, are not well suited to wearing close to the skin and also have relatively low permittivity (<2). Neoprene [10] is a material commonly seen in scuba diving suits but more recently in sporting attire. It is durable, has good thermal properties and is generally consistent in density. It also has a permittivity greater than 4. It is a good choice for wearable antennas.

Liquid crystal polymer (LCP) is an emerging candidate for its flexible, light weight, low loss factor and low cost characteristics [11]. LCP is a recyclable organic substrate with a uniform relative dielectric constant of 2.9-3.1 over the entire radio frequency (RF). It has an extremely low water absorption factor of 0.004 and low dissipation factor of 0.002, which make LCP an ideal choice for circuits operating in different conditions and environments. UWB antennas for body-centric wireless communications have been presented extensively in the open literature [12]–[15]. But very few people have discussed about conformal antennas, especially about the bending effect of antenna for UWB body centric communications. In [14] discussion about the bending effect of single band meander antenna on LCP is made at 5 GHz. Effect of bending on UWB antenna performance using a copper film and a AgHT-8 film as substrate is presented in [15].

UWB antennas should be effective in transmitting, compact, non dispersive, and have a good wide impedance bandwidth properties, these features are desirable for both indoor and outdoor hand-held UWB applications. To satisfy such requirements, various types of planar monopole antennas have been developed for UWB communications over the last few years. Also, variety of bandwidth enhancement techniques have been reported, to improve the impedance bandwidth of these antennas, such as the use of the multiple feeds techniques [16], beveling radiating element [17], a beveling ground pattern [18], offset feeding techniques [19], feed gap optimization [20], ground plane shaping [21], a notched ground plane [22]-[24] and so on.

Following section provides the detail about development of various techniques proposed by different authors during last few years. Various designs & theirs implementation for different applications have been compiled. All these are presented to show that how UWB technology is being taken up by various researchers and what are the future scope of work in this technology and its implementation.

4 DEVELOPMENT OF UWB WEARABLE ANTENNAS

During early 1930s many wide band antennas had already been reported. All were Non-planar wideband antennas. Later, various antennas at different frequency bands like UHF, VHF etc. were introduced having planar designs and suitable for integration with ICs. Various Ultra wideband antennas have been categorized in four forms based on four corners of Figure-2

1. Multiband, Omni UWB Antennas
2. Multiband, Directional UWB Antennas
3. Omni, Impulse Radiating UWB Antennas
4. Directive, Impulse Radiating UWB Antennas

Details of the category can be found in [25].

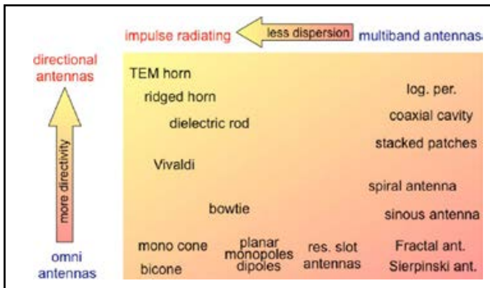

Fig-2: UWB antenna classification according to directivity and signal radiation characteristics

During last few years researchers have been working on various aspects in wearable antenna designs. Some researchers have proposed flexible antennas which can be easily integrated into clothing [10], [13], [26]-[29]. In the year 2007, B. Sanz-Izquierdo proposed a novel "Compact UWB Wearable Antenna", suitable for wireless on body applications. In this paper Circular metal nail were employed

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in some buttons to create the radiating element of the antenna. Proposed antenna was intended for textile jackets where the button structure could be easily camouflaged and disregarded as a plastic button. Although the proposed antenna had good return loss characteristics, good radiation pattern but when employed practically the radiation pattern and matching deteriorated. The biggest challenge in designing UWB antenna is achieving the wide impedance bandwidth while maintaining high radiation efficiency. Another requirement is linear phase for optimal wave reception, which would correspond to a near constant group delay [30]. In [30], a novel optimization method for the design of antennas for UWB wireless communication systems was presented. The optimization was based on the time domain characteristics of the antenna. The correlation factors obtained for several angles were used as the optimization goals in the optimization procedure. The optimization of the antenna was performed by genetic algorithm (GA) search concepts. Generation of short electromagnetic pulse has been a challenge to research community. Before, Mithilesh kumar, Ananjan Basu, S, K. Koul proposed a new technique for the generation of such pulse [4], there were only a few practical circuits proposed for the same [31]-[35]. In the conventional methods of pulse generation, when ultra-short pulses are to be generated, they have to be generated after passing pulses through a differentiator and wave shaping circuits. But, it has been shown that they are distorted in amplitude because such pulses are highly sensitive to rise and fall time [4]. The authors in this paper proposed The HEMT-based circuit which gave the simplest circuit compatible with MMIC. Figure-4 provides the circuit proposed by the authors.

Fig. 3. UWB pulse generation circuit proposed by [4]

In the year 2010, an review on UWB antennas were presented by Qammer H. Abbasi, which was published in Proceedings of 2010 IEEE International Conference on Ultra-Wideband (ICUWB2010) [36]. In this paper various section included UWB antennas to be deployed in body-centric communications, overview of UWB on body measurement techniques and characterization of UWB on-body channels, UWB on-body channel characterization using numerical modeling, UWB on-body system modeling. The authors had given an exhaustive review on UWB antennas.

In this paper, recent advancements have been compiled, which provide the work proposed in various areas of UWB deployment especially in and after year 2010.

In the year 2010, a compact and conformal UWB antenna for wearable application was proposed by Md. Hasanuzzaman Sagor [37]. Proposed design, antenna and results are given in Figure-4. In this paper authors demonstrated the possibility of using LCP as emerging candidate for wearable antennas to overcome both frequency and time domain performance deterioration during bending because of subject postures and motion.

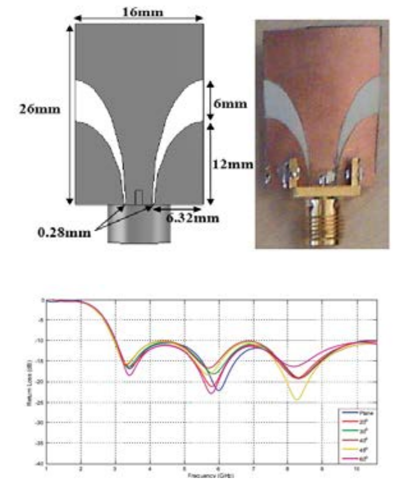

Fig. 4: Compact UWB antenna proposed by [37]

In this year only, Mai A. R. Osman [38] presented a textile antenna as shown Figure-5.

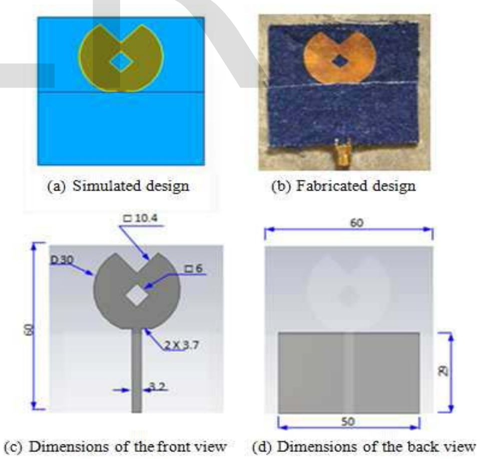

Fig. 5 UWB Wearable Textile Antenna prototype &geometry in [38]

Radius of the radiating element was calculated by

$$a = \frac{87.94}{f_r\sqrt{\varepsilon_r}}$$

Where a is the radius of the circular patch antenna in millimeter. Other parameters have usual meanings. The radiating element with radius of 15 mm and a rotated square slot of 6 mm x 6 mm at the centre of the circular patch was used in the paper.

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For design and tuning of UWB antennas full wave EM simulation based tuning is the only available method for different types. Unfortunately, direct EM-based optimization is normally impractical because of its high computational cost. Various metaheuristic approaches such as genetic algorithms or particle swarm optimizers, while being able to handle some issues of EM-based design (e.g., multiple local optima), are characterized by huge computational overhead.

Surrogate-based optimization techniques such as space mapping or simulation-based tuning are more efficient computationally. However, they are not particularly suitable for antenna design. Space mapping normally requires a fast underlying coarse model, typically a circuit equivalent. Unfortunately, reliable circuit models are not available for many UWB antennas. On the other hand, tuning cannot be directly applied to a radiating structure if strong EM coupling between the structure's parts exists; also, it is not clear how the antenna structure can be "cut" to allow the insertion of the tuning ports and physically relevant tuning components. The most common approach to EM-simulation-based design optimization is through repetitive parameter sweeps guided by engineering experience. While this approach is definitely working, it is tedious, time consuming, and it does not guarantee optimal results [39]. An efficient simulation-driven design of UWB antennas was presented in the paper.

Year 2011 and 2012 have been very important as far as various UWB antenna design are concerned. Many researchers proposed various dual band and multi band antennas [40]-[42] for different applications. Design and results are given in Figure 6,7 &8.

Fig. 6 M-shaped patch antenna proposed by [40]

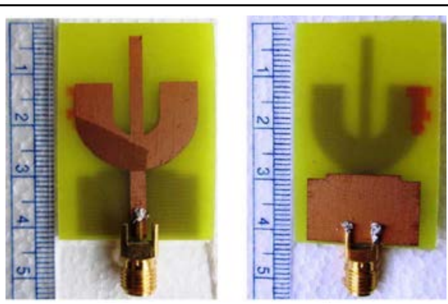

Fig. 7 Dual band Fork-shaped patch antenna proposed by [41]

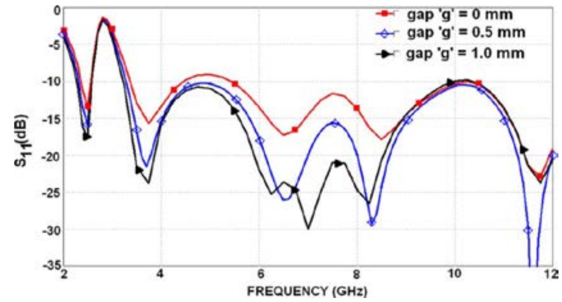

Fig. 8 Return loss for different gap g [41]

A new simple CPW-fed monopole antenna for UWB applications was proposed by Mohsen Koohestani and his mates in the year 2011 [43], a dome-topped, bowl-shaped radiating element and a 50 Ω coplanar feed line for excitation was used in the proposed design as shown in Figure-9:

Fig-9 Coplanar-fed Ultra-Wideband monopole antenna by [43]

A simplified geometry of a human limb was found to be accurate enough for use in input reflection coefficient simulations. The limb tissues were modeled as frequency-dependent materials.

Year 2012 has been the most promising year for design and characterization of UWB antennas for wearable applications. Many authors have tried and proposed a variety of shapes and design for such applications. Md. Shaad Mahmud, Shuvashis Dey [44] proposed compact ultra wide band logo-type textile antenna structure. It was a compact antenna available at that time. Presented antenna was designed with substrate material of permittivity, εr = 3 and thickness 1.6 mm which consist of four letters, AIUB. Hypalon coated Dacron fabric textile material was used as the antenna substrate and woven copper thread was used as the conductive part of the antenna patch. This antenna had two sets of resonance frequencies, first band from 1.2985 GHz to 1.986 GHz and second band from 3.678 GHz to 21.167 GHz. Definitely, the antenna fulfills the UWB band requirement but it doesn't fulfill it completely, since the band has to be confined within 3.1 to 10.6 GHz. So, such a design may create interference with existing standards.

There has been a tremendous increase in interest of researchers to create notch in the characteristics of UWB antenna so that various interference effects may be prevented

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among UWB and existing standards. Many authors worked on this issue and proposed their findings [45]-[53].

Shilpa Jangid and Mithilesh Kumar proposed a Novel UWB Band Notched Rectangular Patch Antenna with Square slot [45]. FR-4 substrate with dielectric constant of 4.4 and thickness of 1.6 mm was used to design the antenna. The proposed antenna had a compact structure with total size of 15×14.5 mm2 as shown in figure-11. The band-notch characteristic in the UWB band to avoid interferences by WLAN (5.15–5.825 GHz) and WiMAX (5.25–5.85 GHz) systems was proposed by the authors. Also, band-notched filtering properties in the 5.15- 5.825 GHz were achieved by rectangular slot on the radiating element.

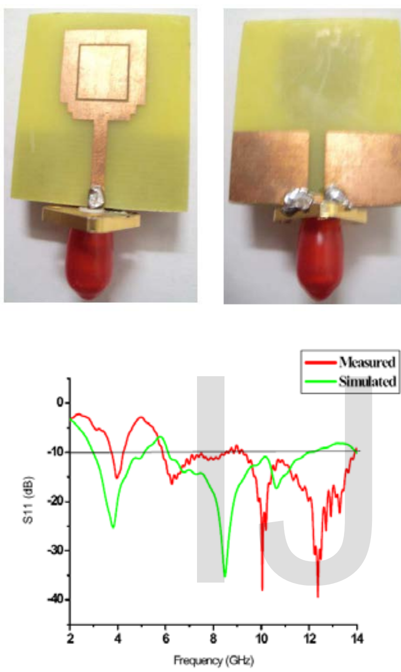

Fig. 10 Antenna and its return loss characteristics proposed by [45]

May be due to manufacturing or otherwise the proposed structure is not showing proper characteristics throughout the UWB band as shown in figure-10.

Some authors have presented reconfigurable antennas for wearable application [52], [54]. In [54], the radiating element was created by stitching the conductive thread instead of the copper metallization. The ground plane was created by using a Liquid Crystal Polymer (LCP) material (εr=2.9). The substrate of the designed antenna was made from jeans fabric (εr=1.7) while the radiating element was made from stainless steel coated conductive thread. By changing the shaped ground, the direction of the radiation pattern was reconfigured. Some has proposed multiple band, multi polarized structures [55], [56], multiple sector structures [57].

Recently, various authors have concentrated on changing the feed network for UWB antenna structures [58]-[63].

In January 2013, Chan Hwang See with his fellow researchers proposed Ultra-Wideband Modified Planar Inverted-F Antenna [64]. A miniaturized modified planar inverted-F antenna (PIFA) with experimental results was presented. It consists of a planar rectangular monopole top-loaded with a rectangular patch attached to two rectangular plates, one shorted to the ground and the other suspended, both placed at the optimum distance on each side of the planar monopole. The fabricated antenna prototype had a measured impedance bandwidth of 125%, covering 3 to 13GHz for reflection coefficient better than 10 dB. The radiator size was 20×10×7.5 mm3, making it electrically small over most of the band and suitable for incorporation in mobile devices.

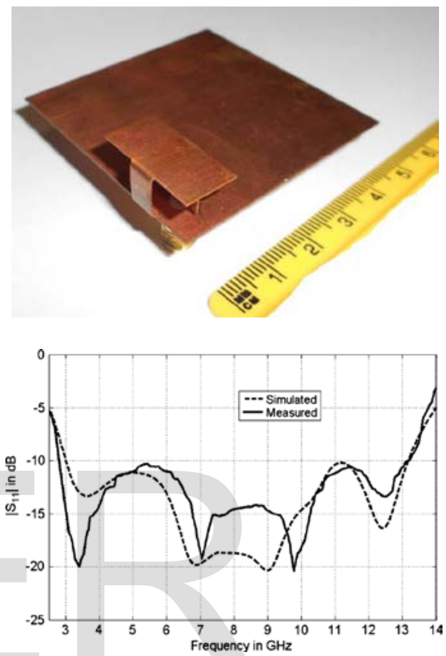

Fig-11 Proposed antenna with return loss characteristics by [64]

In the proposed model different impedance bandwidth enhancing techniques were combined together to enable coverage of the entire FCC UWB frequency band. All of the antennas presented before were very sensitive to variation of ground plane size in the lower part of the usable operating band and this is due to significant contribution of the ground plane resonance over these bands. This creates problems as the ground plane behavior will be heavily influenced by a human hand holding a mobile terminal. So, in the presented design dependability of ground on antenna characteristics by combining top-loading, off-centre rectangular plate feeding and a shorting wall techniques of impedance matching. This was the unique feature in this paper.

A unique Hybrid UHF/UWB Antenna for Passive Indoor Identification and Localization Systems has been proposed by Catarina C. Cruz and his fellows [65] for simultaneous identification and centimetre-resolution localization of multiple targets in indoor environments. A new planar antenna for hybrid passive tag systems was proposed, which operates both in the UHF-RFID band and in the FCC UWB band. The co-designed UHF and UWB antenna elements were printed back-to-back on each side of a common substrate (RT

Duroid 5880 εr = 2.2 & loss tangent = 0.0009) as shown in figure-13 with appropriate topology for future integration with a single UHF-UWB RFID chip.

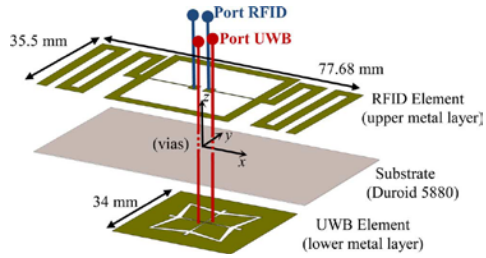

Fig-12: Hybrid RFID-UWB antenna proposed by [65]

The UHF element based on a meandered line plus loop and the UWB based on modified version of the Crossed Exponential Tapered Slot antenna (XETS) proposed in [66], [67] was used in the design proposed. The hybrid antenna presented in the paper is appropriate for potential systems that combine identification and centimeter-class indoor localization using passive and therefore very low cost technology. This type of solution does not exist in current commercial systems and encourages the emergence of new applications. But these hybrid chips do not yet exist commercially, so it can be proposed to adopt such hybrid systems for future work and research.

Recently, it has been demonstrated by various authors that fractal geometries based on space filling and self-similarity attributes can be useful to improve the performance of antenna [68]. Also, fractal-based antennas can effectively couple energy to free space [69]–[71]. In addition, different feeding methodologies can be applied on fractal antennas without degrading their performance like microstrip lines [72] and coplanar waveguide (CPW) [73]. CPW transmission-line feed method these days is becoming popular because of lower loss, low radiation leakage and more convenience with shunt and series connection on the same side of substrate avoiding via holes [74]. Latest design and analysis of UWB CPW-Fed Fractal Patch Antenna With Band-Notched Function Employing Folded T-Shaped Element has been presented in [75].

5 CONCLUSION

Generations of the UWB antennas for wearable application development have been presented. Recent advancements have been characterized by the failure of successive generations of antenna designers to benefit from the lessons of earlier pioneers. It is necessary to be familiar with the history of the antenna art for any serious antenna designer who aims to implement novel designs rather than recreate the antennas of previous generations. The paper presents recent trend in UWB technology especially for wearable applications.

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REFERENCES

[1] Hertz, H., Electrical Waves, London, Macmillan and Co., 1893

[2] J. G. Santas, A. Alomainy, and Y. Hao. "Textile Antennas for On-Body Communications: Techniques and Properties." Antennas and Propagation, EuCAP 2007. The Second European Conference, (978-0-86341-842-6), pp. 1-4, 2007

[3] First Report and Order, Revision of Part 15 of the Commission's Rules Regarding Ultra-wideband Transmission Systems FCC, FCC02-48, 2002.

[4] Kumar, M., A. Basu, and S. K. Koul, "Electromagnetic short pulse generation techniques," 2010 International Symposium on Electromagnetic Theory (EMTS 2010), 332{335, Berlin, Germany, Aug. 16-19, 2010.

[5] G.Brzezina, Q. Ye, L.Roy, "Development of a Practical Ultra-Wideband Antenna with Planar Circuit Integration Possibilities" in IEEE Antenna and Propogation Soc. Int. Symp. 2005, 3-8 July 2005, pp. 504- 507.

[6] Mohammad HadiBadjian, Chandan Kumar Chakrabarty, Goh Chin Hock, and Sanjay Devkumar, "An Impulse UWB Patch Antenna with Integrated Bandpass Filter" in IEEE 2008 6th National Conference on Telecommunication Technologies and IEEE 2008 2nd Malaysia Conference on Photonics, 26-27 August 2008, Putrajaya, Malaysia.

[7] Salonen, P. and H. Hurme, "A Novel Fabric WLAN Antenna for Wearable Applications" 2003 IEEE Antenna & Propagation Society Int. Symp. Columbus, OH, Vol. 2, 2003, pp. 700-703.

[8] Hertleer, C.; Tronquo, A.; Rogier, H.; Vallozzi, L.; Van Langenhove, L., "Aperture-Coupled Patch Antenna for Integration Into Wearable Textile Systems," Antennas and Wireless Propagation Letters, Volume 6, Page(s):392 – 395, 2007

[9] Ramesh Garg, Prakash Bhartia, Inder Bahl, Apisak Ittipiboon, "Microstrip antenna design handbook", Artech House, 2001.

[10] Hoagland, H.; Morrow, B.; "Using rainwear as switching jackets: a reasonable solution for electric arc exposure" , Industry Applications, IEEE Transactions on, Volume 36, Issue 5, Page(s):1241 – 1246, Sept.-Oct. 2000

[11] D. Thompson, O. Tantot, H. Jallageas, G. Ponchak, M. Tentzeris and J. Papapolymerou, "Characterization of Liquid Crystal Polymer (LCP) Material and Transmission Lines on LCP Substrates From 30-110 GHz," IEEE Transactions on Microwave Theory and Techniques, Vol. 52, No.4, pp. 1343-1352, April 2004.

[12] Symeon Nikolaou, Manos M. Tentzeris, John Papapolymerou, "Study of a Conformal UWB Elliptical Monopole Antenna on Flexible Organic Substrate Mounted on Cylindrical Surfaces", The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07), 2007.

[13] M. Swaminathan, Bavisi, A., Yun, W., Sundaram, V., Govind, V. and Monajemi, P., "Design and fabrication of integrated RF modules in LCP Substrates", Industrial Electronics Society (IECON), November 2005.

[14] Nevin Altunyurt, Madhavan Swaminathan, Venkatesh Sundaram, George White, "Conformal Antennas on Liquid Crystalline Polymer Substrates for Consumer Applications", Proceedings of Asia-Pacific Microwave Conference, Dec. 2007.

[15] T. Peter and R.Nilavalan, "Study on the Performance Deterioration of Flexible UWB Antennas", Loughborough Antennas & Propagation Conference, 16-17 November 2009, Loughborough, UK

[16] E. Antonino-Daviu, M. Cabedo-Fabres, M. Ferrando-Bataller, and A.Valero-Nogueira, "Wideband double-fed planar monopole antennas," Electronics Letters, 2003, 39, pp. 1635–1636.

[17] M.J. Ammann, and Z.N. Chen, "Wideband monopole antennas for multi-band wireless systems", IEEE Antennas Propag. Mag., 2003, 45, pp. 146–150.

[18] W. Wang, S.S. Zhong, and Chen, S.B. "A novel wideband coplanar fed monopole antenna," Microw. Opt. Technol. Lett., 2004, 43, pp. 50-52.

[19] M.J. Ammann, and Z.N. Chen, "An asymmetrical feed arrangement for improved impedance bandwidth of planar monopole antennas" Microw. Opt. Technol. Lett., 2004, 40, pp. 156–158.

[20] M. John, and M.J. Ammann, "Optimisation of impedance bandwidth for the printed rectangular monopole antenna," Microw. Opt. Technol. Lett., 2005, pp.153–154

[21] C. Zhang, and A.E. Fathy, "Development of an ultra-wide band elliptical disc planar monopole antenna with improved omni directional performance using a modified ground", IEEE Int Antennas Propag Symp Dig, Alburqueque, NM, 2006, pp.1689–1692.

[22] C.-Y.Huang, and W.-C Hsia, "Planar elliptical antenna for ultrawideband communications," Electronics Letters, 2005, 41, pp.296–297.

[23] X. L. Bao, and M. J. Ammann, "Investigation on UWB printed monopole antenna with rectangular slitted ground plane," Microw. Opt. Technol. Lett., 2007, 49, pp.1585–1587.

[24] H. Kobayashi, T. Sasamori, T. Tobana, and K. Abe, "A Study on Miniaturization of Printed Disc Monopole Antenna for UWB Applications Using Notched Ground Plane," IEICE Trans. Commun., 2007, 90, pp.2239–2240.

[25] Invited paper on "UWB Antennas for Communication Systems" by Grzegorz Adamiuk, Thomas Zwick and Werner Wiesbeck, Proceedings of the IEEE | Vol. 100, No. 7, July 2012

[26] P. Salonen, J. Rantanen, , "A Dual Band and Wide-Band Antenna on Flexible Substrate for Smart Clothing", 27th Annual Conference of the IEEE, Vol.1, 2001.

[27] T. Peter, R. Nilavalan "Study on the Performance Deterioration of Flexible UWB Antennas" Antennas & Propagation Conference 16-17 November 2009, Loughborough, UK pp 669-672.

[28] B.Sanz-Izquierdo, F. Huang, J.C.Batchelor "Wearable Dual Band Button Antennas", Loughborough Antennas & Propagation Conference (LAPC), Loughborough April 2006, pp. 33-35.

[29] B.Sanz-Izquierdo, M.I.Sobhy, J.C.Batchelor "UWB Wearable Button Antenna", European Conference on Antennas and Propagation EuCAP06, Nice, France, p. 131, 2006 November

[30] Bo Tian, Mingchun Deng, Zhengjie Li "Time Domain Optimization of UWB Antenna by Means of Genetic Algorithm IEEE letter 2008 pp 883-886

[31] David Lamensdorf and Leon Susman , "Baseband-pulse-antenna techniques", IEEE Antennas and Propagation Magazine, Vol.36, No.1. p. 20-30, February 1994.

[32] Jeff Foerster, Evan Green, Srinivasa Somayazulu, and David Leeper, "Ultra-wideband technology for short- or Medium-rang wireless communications", Intel Technology Journal Q2, p. 1-11, 2001.

[33] Jeong Soo Lee and Cam Nguyen, "Novel low-cost ultra-wideband, ultra-short-pulse transmitter with MESFET impulse-shaping circuitry for reduced distortion and improved pulse repetition rate", IEEE Microwave and Wireless Components Letters, Vol. 11, No. 5, p. 208- 210, May 2001.

[34] Robert J. Fontana, "Recent system applications of short-pulse ultrawideband (UWB) technology", IEEE Transactions on Microwave Theory and Techniques, Vol.52, No.9, September 2004, p.2087-2104.

[35] Shinho Kim and Yuanxun Ethan Wang, "UWB pulse generation techniques with switched resonators", 2006 IEEE International Conference on Ultra Wideband, Waltham, USA, September 2006,p. 91-95.

[36] Qammer H. Abbasi, Akram Alomainy, Yang Hao "Recent Development of Ultra Wideband Body-Centric Wireless Communications" Proceedings of 2010 IEEE International Conference on Ultra-Wideband (ICUWB2010)

[37] Md. Hasanuzzaman Sagor, Qammer H. Abbasi, Akram Alomainy and Yang Ha "Compact and Conformal Ultra Wideband Antenna for Wearable Applications" 5th European Conference on Antennas and Propagation (EUCAP) pp 2095-2098

[38] Mai A. R. Osman, M. K. A. Rahim, M. Azfar. A, K. Kamardin, F. Zubir, and N. A. Samsuri "Design and Analysis UWB Wearable Textile Antenna" 5th European Conference on Antennas and Propagation (EUCAP) pp 530-533

[39] Stanislav Ogurtsov and Slawomir Koziel "Optimization of UWB Planar Antennas Using Adaptive Design Specifications" 5th European Conference on Antennas and Propagation (EUCAP) pp 2091-2094

[40] S.H Karamchandani, S. Shubham, H.D Mustafa, S.N Merchant U.B Desai "Dual Band M-shaped UWB Patch Antenna for Wireless Body Area Networks" International Conference on ICS 2011.

[41] Sanjeev Kumar Mishra, Rajiv Kumar Gupta, Avinash Vaidya, and Jayanta Mukherjee, "A Compact Dual Band Fork-Shaped Monopole Antenna for Bluetooth and UWB Applications" IEEE Antennas And Wireless Propagation Letters, Vol. 10, 2011 pp 627-630

[42] B.Sanz-Izquierdo, F. Huang, J.C.Batchelor "Wearable Dual Band Button Antennas", Loughborough Antennas & Propagation Conference (LAPC), Loughborough April 2006, pp. 33-35.

[43] Mohsen Koohestani, Nuno Pires, Anja K. Skrivervik, and Ant´onio A. Moreira "Influence of the Human Body on a New Coplanar-fed Ultra-Wideband Antenna" 6th European Conference on Antennas and Propagation (EUCAP) 2011 pp 316-319

[44] Md. Shaad Mahmud, Shuvashis Dey "Design, Performance and Implementation of UWB Wearable Logo Textile Antenna" IEEE conference 2012.

[45] Shilpa Jangid, Mithilesh Kumar "A Novel UWB Band Notched Rectangular Patch Antenna with Square slot" Fourth International Conference on Computational Intelligence and Communication Networks 2012.

[46] Jae-Min Lee, Ki-Baek Kim, Hong-Kyun Ryu, and Jong-Myung Woo "A Compact Ultrawideband MIMO Antenna With WLAN Band-Rejected Operation for Mobile Devices" IEEE Antennas And Wireless Propagation Letters, Vol. 11, 2012 pp 990-993

[47] M. Mehranpour, J. Nourinia, Ch. Ghobadi, and M. Ojaroudi Dual Band-Notched Square Monopole Antenna for Ultrawideband Applications IEEE Antennas And Wireless Propagation Letters, Vol. 11, 2012 pp 172-175.

[48] M. Moosazadeh, A.M. Abbosh, Z. Esmati "Design of compact planar ultrawideband antenna with dual-notched bands using slotted square patch and pi-shaped conductor-backed plane" IET Microw. Antennas Propag., 2012, Vol. 6, Iss. 3, pp. 290–294.

[49] Hu Shuai-jiang, WANG Guang-ming, ZHENG Long "Design of a compact Double - sided printed Bandnotched planar Antenna for UWB Applications" 2012

[50] Elham Erfani, Javad Nourinia, Changiz Ghobadi, Mahmoud Niroo-Jazi, and Tayeb A. Denidni "Design and Implementation of an Integrated UWB/Reconfigurable-Slot Antenna for Cognitive Radio Applications" IEEE Antennas And Wireless Propagation Letters, Vol. 11, 2012 pp 77-80

[51] Shilpa Jangid, Mithilesh Kumar "Compact Planar UWB Patch Antenna with Integrated Bandpass Filter & Band Notched characteristics" 2012 International Conference on Communication Systems and Network Technologies.

[52] Nasser Ojaroudi, Mohammad Ojaroudi, Noradin Ghadimi "Dual band-notched small monopole antenna with novel W-shaped conductor backed-plane and novel T-shaped slot for UWB applications" IET Microw. Antennas Propag., 2013, Vol. 7, Iss. 1, pp. 8–14

[53] Mohammad Ojaroudi, Nasser Ojaroudi, and Noradin Ghadimi "Dual Band-Notched Small Monopole Antenna With Novel Coupled Inverted U-Ring Strip and Novel Fork-Shaped Slit for UWB Applications" IEEE Antennas And Wireless Propagation Letters, Vol. 12, 2013 pp 182-185

[54] Shobana sree.R, Radha S, P.H.Rao "Pattern reconfigurable Ultra Wideband Thin Antenna" ICCCNT'12 26th to 28th July 2012, Coimbatore, India

[55] Adel Elsherbini, and Kamal Sarabandi "Dual-Polarized Coupled Sectorial Loop Antennas for UWB Applications" IEEE Antennas And Wireless Propagation Letters, Vol. 10, 2011 pp 75-78

[56] E. Antonino-Daviu, M. Cabedo-Fabres, M. Ferrando-Bataller, and A.Valero-Nogueira, "Wideband double-fed planar monopole antennas," Electronics Letters, 2003, 39, pp. 1635–1636.

[57] Sai Ho Yeung, Kim Fung Man, and Wing Shing Chan "Multiple Circular-Sector Structures for Wideband Planar Monopole Antenna Designs Covering 146% Fractional Bandwidth" IEEE Antennas and Propagation Magazine, Vol. 54, No. 1, February 2012 pp 76-94

[58] M. Naser-Moghadasi, R. A. Sadeghzadeh, T. Sedghi, T. Aribi, and B. S. Virdee, "UWB CPW-Fed Fractal Patch Antenna With Band-Notched Function Employing Folded T-Shaped Element" IEEE Antennas And Wireless Propagation Letters, Vol. 12, 2013 pp 504-507.

[59] Anil Kr Gautam, Swati Yadav, and Binod Kr Kanaujia, "A CPW-Fed Compact UWB Microstrip Antenna" IEEE Antennas And Wireless Propagation Letters, Vol. 12, 2013 151-155

[60] Mohd Ezwan Jalil , Mohammad Kamal A. Rahim, Muhammad Azfar Abdullah, Osman Ayop "Compact CPW-fed Ultra-Wideband (UWB) Antenna Using Denim Textile Material" Proceedings of ISAP2012, Nagoya, Japan pp 30-33

[61] Mohsen Koohestani, Nuno Pires, Anja K. Skrivervik, and Ant´onio A. Moreira "Influence of the Human Body on a New Coplanar-fed Ultra-Wideband Antenna" 6th European Conference on Antennas and Propagation (EUCAP) 2011 pp 316-319

[62] Mohammad Reza Ghaderi, Member, IEEE, and Farzad Mohajeri "A Compact Hexagonal Wide-Slot Antenna With Microstrip-Fed Monopole for UWB Application" IEEE Antennas And Wireless Propagation Letters, Vol. 10, 2011 pp 632-635.

[63] M. Naser-Moghadasi, R. A. Sadeghzadeh, M. Katouli, and B. S. Virdee, "CPW-fed compact slot antenna for WLAN operation in a laptop computer," Microw. Opt. Technol. Lett., vol. 52, pp. 870–873, 2010.

[64] Chan Hwang See, Hmeda I. Hraga, Raed A. Abd-Alhameed, Neil J. McEwan, Jim M. Noras, and Peter S. Excell "A Low-Profile Ultra-Wideband Modified Planar Inverted-F Antenna" IEEE Transactions On Antennas And Propagation, Vol. 61, No. 1, January 2013 pp 100-108

[65] Catarina C. Cruz, Jorge R. Costa, and Carlos A. Fernandes, "Hybrid UHF/UWB Antenna for Passive Indoor Identification and Localization Systems" IEEE Transactions On Antennas And Propagation, Vol. 61, No. 1, January 2013 pp 354-361

[66] J. R. Costa, C. R. Medeiros, and C. A. Fernandes, "Performance of a crossed exponentially tapered slot antenna for UWB systems," IEEE Trans. Antennas Propag., vol. 57, no. 5, pp. 1345–1352, May 2009.

[67] C. R. Medeiros, J. R. Costa, and C. A. Fernandes, "Compact tapered slot UWB antenna with WLAN band rejection," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 661–664, 2009.

[68] M. Naser-Moghadasi, R. A. Sadeghzadeh, T. Aribi, T. Sedghi, and B. S. Virdee, "UWB monopole microstrip antenna using fractal tree unitcells," Microw. Opt. Technol. Lett., vol. 50, no. 10, pp. 936–939, Oct. 2012.

[69] M. N. Jahromi, A. Falahati, and R. M. Edwards, "Bandwidth and impedance-matching enhancement of fractal monopole antennas using compact grounded coplanar waveguide," IEEE Trans. Antennas Propag., vol. 59, no. 7, pp. 2480–2487, Jul. 2011.

[70] B. Ozbakis and A. Kustepeli, "The resonant behavior of the Fibonacci fractal tree antennas," Microw. Opt. Technol. Lett., vol. 50, no. 4, pp. 1046–1050, Oct. 2008.

[71] H. Oraizi and S. Hedayati, "Miniaturized UWB monopole microstrip antenna design by the combination of Giusepe Peano and Sierpinski carpet fractals," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 172–175, 2011.

[72] M. Naser-Moghadasi, H. Rousta, R. A. Sadeghzadeh, and B. S. Virdee, "Compact UWB planar monopole antenna," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 1382–1385, 2009.

[73] M. Naser-Moghadasi, R. A. Sadeghzadeh, M. Katouli, and B. S. Virdee, "CPW-fed compact slot antenna for WLAN operation in a laptop computer," Microw. Opt. Technol. Lett., vol. 52, pp. 870–873, 2010.

[74] C. Deng, Y. J. Xie, and P. Li, "CPW-fed planar printed monopole antenna with impedance bandwidth enhanced," IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 1394–1397, 2009.

[75] M. Naser-Moghadasi, R. A. Sadeghzadeh, T. Sedghi, T. Aribi, and B. S. Virdee "UWB CPW-Fed Fractal Patch Antenna With Band-Notched Function Employing Folded T-Shaped Element" IEEE Antennas And Wireless Propagation Letters, Vol. 12, 2013 pp 504-507.

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