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UWB Technology: Applications and Challenges

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Abstract

Ultra-wideband (UWB) technology had gained significant interest amongst researchers in the last decade due to several advantages with prime focus given on the design of UWB antennas, UWB antennas with multiband integrated and band-notch characteristics. However, by the end of the last decade, the UWB technology lost its significance as applications enabled with UWB technology did not appear in the market. In this paper, we will discuss the various applications which can be designed using UWB technology. Also, an overlook of the challenges in the development of UWB technology has been presented.

Keywords *– UWB, integrated, band-notch*

1.INTRODUCTION

Ultra-wideband (UWB) systems refer to systems having very large bandwidth (usually, larger than 500 MHz or has a 10 dB bandwidth ≥ 20% of its center frequency) [1], [2]. UWB has been viewed in many forms until recently it gained momentum and became popular amongst researchers when worldwide regulatory bodies including FCC (Federal Communication Commission) allotted a free to use, an unlicensed frequency of 3.1 to 10.6 GHz with 7.5 GHz bandwidth for UWB applications in the year 2002. With 7.5 GHz bandwidth, researchers saw potential advantages such as[3]:

- Higher bandwidth
- High datarates
- Higher channel capacity and efficiency
- Low powerconsumption
- Higher obstacle penetrationcapabilities
- Better time resolution
- Low implementationcost
- Resistance to interferences due to low signal to powerdensity
- Coverttransmission
- Enhanced channel capacity,and
- Ability to coexist with existing narrowbandsystems.

The first experimentation on UWB antenna was reported in 1893 by Hertz [2], meaning, the entire existing wireless communication system is based on UWB technology. Hertz in his experiment used spark gaps and arc discharges between carbon electrodes to generate wideband pulse waveforms which we transmitted as electromagnetic waves. However, with progression in the technology, the need for communication systems shifted to narrowband sinusoidal waveforms thereby neglecting the advantages of UWB technology. The greatest advantage of UWB technology is evident from the famous Shannon channel capacity formula[2]:

$$C_c = B_W log\left(1 + \frac{P_s}{B_W N_0}\right)$$

Where

C_C is the capacity of the communicationchannel (in bps),

$B_W$is the bandwidth of the communication channel (in Hz),

$P_s$is the power of transmitting signal (in W) and

$N_0$is the noise spectral density (in W/Hz).

Two important observations can be drawn from Shannon's formula [3]:

1. For a given noise spectral density, N_0, the power of the transmitting signal can be traded off (decreased) with the channel bandwidth B_W(if more bandwidth is available), while maintaining the channelcapacity.
2. Contrarily, for a given signal power P_s, the channel capacity CC can be increased with an increase in bandwidth B_W.

The tradeoff amidsignal power and bandwidth of communication channelinspired the development of spread spectrum and UWB wideband communication systems. Also, with minuscule noise spectral density of UWB (-41.3dBm/MHz), which is practically below the noise level of most other technologies, UWB technology can be useful for more than one purposes[4]:

1. Short-range communication systems that offer very high data rates (of up to 480 Mbps and higher), with very low energy per transmittedbit;
2. Long-range communication systems that offer much lower data rates with extremely long batterylife.

The second approach was pursued and successfully standardized in IEEE 80.15.4a

2. UWB Antennas and Applications

After the FCC allocated the7.5 GHz bandwidth for UWB applications in 2002, researchers focused on developing wide range of applications ranging from high data rate Wireless Personal Area Networks (WPANs) to low data rate monitoring and control networks. The FCC has categorized the commercial applications of UWB as follows:

1. Imagingsystems:

The imaging system applications of UWB include ground-penetrating radars (GPR), medical imaging applications, and surveillance. An antenna for GPR (undersurface radar) operating over 500 MHz to 3 GHz is presented in [5]. A wall through detection and human tracking system using multiple UWB antennas that deploys short range communication system is presented in [6]. A 2D full-wave simulator that utilizes the FDTD method was used to design the UWB imaging system. The synthetic data from the simulator was delivered to signal processing algorithms for processing and image development. Medical imaging application for breast cancer detection based on UWB technology was proposed in [7] which deploys a compact UWB antenna array that conducts a 3D scan through so-called digital beamforming in the space-time domain. The system used for imaging consists of a transmitter module that transmits low-power short-range microwave pulses into the human body and detects the differentiated scattering due to the change in dielectric constant between the infectious and healthy tissue. Fig 1 shows the high gain broadband 4 elements tapered slot array (TSA) antenna developed for breast cancerdetection.

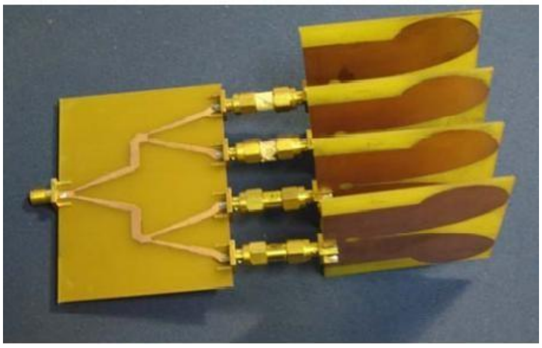

Fig. 1 High gain broadband 4 elements tapered slot array (TSA) antenna developed for breast cancerdetection.

The Vivaldi antenna demonstrated in [8] (as shown in Fig.2) consists of a tapered slot antenna with exponential tapering that offers broad bandwidth, minimal antenna size, and mismatch is used for the design of impulse radar applications. The Vivaldi antenna is usually fed using a micro-strip feed line and typically offers 15:1 bandwidth.

Fig. 2 Vivaldi antenna configuration for impulse radar applications

Another 4 × 4 hemispherical UWB antenna array (shown in Fig. 3) for breast cancer detection is demonstrated in [9].

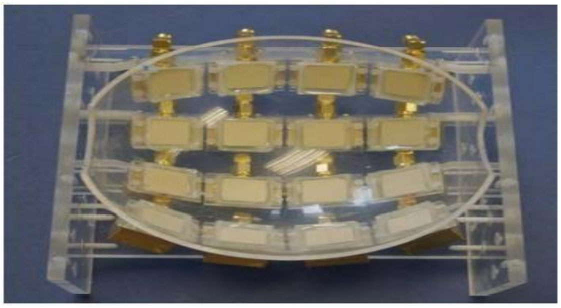

Fig. 3 A 4 × 4 hemispherical UWB antenna array for breast cancer detection

2. Vehicular radarsystems:

Operating at 24 GHz frequency band, these systems are entirely dedicated to terrestrial vehicles.

3. Communication and measurementsystems:

These include applications that require

- High data rate,
- Short-range,
- Wireless communication, and networking such as high-speed file transfers, wireless printing, and
- High definition (HD) audio/video streaming services and
- Other consumer electronics (CE), personal computing (PC)applications.

A wireless USB dongle that uses the Multiband-Orthogonal Frequency Division Multiplexing (MB-OFDM) mechanism was deployed in UWB communication systems. A compact U-shaped ring monopole band notch UWB antenna having dimensions of 20 × 14.5 mm^{2}was deployed as Wireless USB dongles is presented in [10] (as shown in Fig. 4). A small wireless UWB dongle antenna was developed at the Institute for Infocomm Research, Singapore, as shown in Fig. 5 [11] that has a triangle monopole with an extended impedance matching network with a slot cut in the radiating patch for loading.

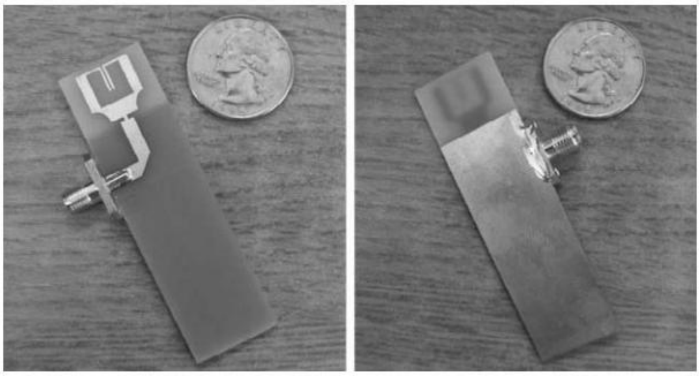

Fig. 4 A UWB antenna for wireless USB dongle with band-notch characteristics

Fig. 5 Tiny wireless USB dongle

4. EMmeasurements

UWB antennas have been widely used for the EM measurement applications ranging from measurement of antenna characteristics, EMI testing to EM spectrum monitoring where wideband signals are to be detected and measured. Hence, Ultra- wideband or broadband antennas such as double ridge horn antennas can be used. A dicone antenna with broadband characteristics is used for monitoring the electromagnetic spectrum.

In a development, a UWB technology based Autonomous Interference Monitoring System (AIMS) (Fig. 6), was deployed by Ofcom (Office of Communication, UK) for monitoring theelectromagnetic spectrum [12]. The AIMS system uses two compact UWB antennas that operate from 100 MHz to 10.6 GHz with omnidirectional radiationcharacteristics.

Fig.6 Autonomous Interference Monitoring System

In a development reported in [13], a receiving antenna was used for detecting and measuringtheelectromagnetic interferences from the camera, display, and other units inside a mobile handset is shown in Fig 7.

Fig. 7. Detecting antenna with EMC testing unit developed at Queen Mary, University of London

3. Challenges

With rapid research on UWB antennas to mitigate various limitations such as interference with narrowband systems researchers developed UWB antennas with single, dual, triple, quad, and even pentaband-notch characteristics are presented in various pieces of literature. Also, to make UWB antenna coexist with existing narrowband technologies such as Bluetooth, GSM, GPS, Wi-Fi, Wi-MAX, WLAN researchers developed multiband integrated UWB antennas. However, over the last decade, researchers have focused on the design of UWB antennas only and less attention has been paid to the development of applications that can be commercialized in the consumer market. One of the main reasons that keep researchers away from the development of UWB products is the lack of knowledge of the UWB TCP/IP model that makes actual data transfer happening. In Literature [4], a detailed discussion on various modulation schemes that can be used for the design UWB application is presented. A broad discussion on the Physical layer, Media Access Control Sublayer, and Protocol Adaptation Layer for UWB technology has been also presented which will be a good kick-starter for young researchers and innovators who are looking forward to the development of UWBapplications.

Declaration

No funding is received for this work. There are no conflicts of interest for this work and is completely transparent for data and material availability. No custom software is used for carrying out this work.

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