Ultra Wide and Communication: Practical Applications and Future Aspects

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Abstract- Wireless communication technology has given us convenient ways to transfer information from one point to other anywhere in the world. The recent popularity of wireless networks results in many additional requirements of the system, especially the need of high data rates, demand for high quality multimedia services and the requirement of the greater bandwidth. The Ultra Wideband (UWB) radio communication is providing a new direction to utilize the radio spectrum for the broader short-range radio communications. Ultra-wideband (UWB) technology is a revolutionary wireless technology used to transmit large amounts of digital data over short distances (up to 230 feet) over a very wide bandwidth (from 1 gigahertz [GHz] up to 10 GHz) and at very low power levels (less than0.5 milli watt). Unlike typical radio frequency broadcasts that use continuous sine waves to transmit data, UWB uses precisely positioned pulses at specific time intervals to transmit the signals across a wide spectrum. Ultra-Wideband (UWB) wireless is a rapidly growing technology that promises to revolutionize low power, short-range wireless applications. UWB has quickly emerged as the leading technology for applications like wireless Universal Serial Bus (USB) and short-range ground penetrating radars. UWB radios differ from conventional narrow-band radios, with a variety of specialized test demands.

This paper discusses the concept behind ultra wide band communication technology, application areas, technological challenges ,spectrum operating zones and future aspects of the technology. The majority of the discussion focuses on the state of the art of ultra wide band technology as it is today i.e. practical applications in present era and in the nearer future.

Keywords – Modulation Technique, Practical Applications, Future Aspects, Challenges infront Of UWB Technology

I. INTRODUCTION

Ultra Wideband was traditionally accepted as pulse radio, but the FCC and ITU-R now define UWB in terms of a transmission from an antenna for which the emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the center frequency. Ultra wideband (also known as UWB or as digital pulse wireless) is a wireless technology for transmitting large amounts of digital data over a wide spectrum of frequency bands with very low power for a short distance.

Ultra-wideband communications is fundamentally different from all other communication techniques due to employing extremely short-time pulses (sub-nanosecond) to communicate between transmitters and receivers. The short duration of UWB pulses instantaneously generates very wide bandwidth (GHz) in frequency domain. UWB is not a new technology. In fact it was first used by Guglielmo Marconi in 1901 for transmitting the Morse code sequences across the Atlantic ocean using spark gap radio transmitters. However, the benefit of a large bandwidth and the capability of implementing multi-user systems provided by electromagnetic pulses were never considered at that time. Narrowband communication systems modulate continuous wave. RF signals with a specific carrier frequency to transmit and receive information. A continuous waveform has a well-defined signal energy in a narrow frequency band (KHz) that makes it vulnerable to intercept and detect. However, UWB systems use carrier less, short duration pulses with very low duty cycle (<0.5%) for transmission and reception of the information. The energy of such signals is spread over a very wide range of frequencies (GHz); therefore, each frequency has very low power which makes UWB signals very difficult to detect and intercept.

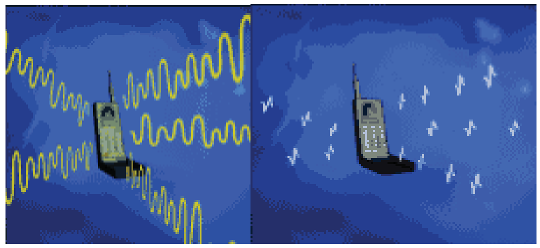

Figure1. Continuous Sine Waves vs. Time Modulated Pulses

II. CONCEPT & HOW IT WORKS

It works on the principle of impulse radio. It is technique of using extremely short duration of pulses(sub-nanosecond) instead of continuous waves without the use of a carrier. The pulse directly generates a very wide instantaneous bandwidth signal. The pulse rate of 106-107 per second results in a very low duty cycle. A signal with ultra-wide bandwidth is generated using electrical short, base-band pulses (100 ps to 1 ns). Data is transmitted using pulse modulation Amplitude, position or phase modulation. The base-band pulses are applied directly to the antenna which is a low cost equipment with minimal RF components. A correlation receiver or RAKE receiver is used to capture the signal.

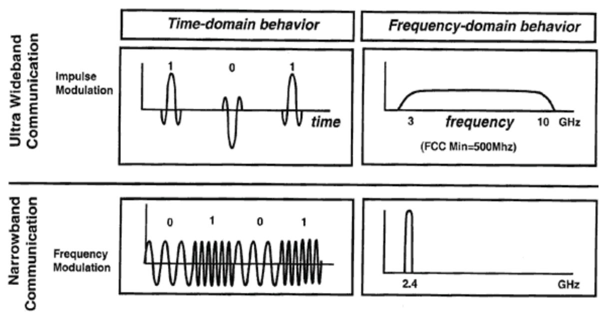

Figure 2. An Approach On Narrowband And UWB Communication

III. MODULATION TECHNIQUES

Some of the common UWB modulation techniques with their advantages and disadvantages are summarized in the following table:

Table1- Modulation techniques of UWB and Their advantages

UWB Modulation	Encoding Method	Advantages	Disadvantages
On Off Keying (OOK)	Presence and absence of a pulse represents digital bits "1" and "0" respectively.	Simple and low power transmitter.	Highly susceptible to noise. UWB synchronization becomes even more challenging if a stream of zeros is transmitted.
Pulse Amplitude Modulation (PAM)	A pulse with higher amplitude represents a data bit "1" and a pulse with lower amplitude represents a data bit "0".	Simple transmitter, since pulses with only one polarity are needed to represent data.	Attenuation in wireless channel can convert them to OOK case.
Pulse Position	Signals are pseudo randomly encoded	Less vulnerable to false detection due to	Requires very strict timing

Modulation (PPM)	**based on the position of the transmitted pulse trains by shifting the pulses in a predefined window in time.**	**noise compared to OOK and PAM pulses.**	**synchronization. Time uncertainties such as drift and jitter cause unreliable detection.**
Bi-Phase Modulation	**Polarity of the pulse changes to represent digital data bits.**	**Less susceptible to distortion since the difference between the two pulse levels is twice the pulse amplitude.**	**More complexity in physical design of the transmitter to generate two polarities.**

V. PRACTICAL APPLICATIONS OF ULTRAWIDEBAND TECHNOLOGY

5.1. Military applications-

Because of the low duty cycle, UWB signals have very low transmission average power, therefore an eavesdropper has to be very close to the transmitter (about 1 meter) to be able to detect the transmitted information. In addition, UWB pulses are time modulated with codes unique to the transmitter/receiver pairs. This time modulation adds more security to UWB transmission, since detecting picoseconds pulses without the prior knowledge of their time of arrival information is next to impossible. A military application could be the detection of biological agents or enemy tracking on the battlefield.

Potential military applications of UWB include-

- *Intra-vehicle wireless network-* Intra-vehicle Wireless Network is attractive for manned and unmanned military vehicles because it eliminates Issues associated with cable weight, space, and costs also substantial cost associated with installing and modifying cabling embedded within the platform.

- *Inter vehicle short range –* limited mobility wireless network- it supports defensive operations, over watch support and surveillance operations.This technique also allows the vehicle crew to operate a variety of vehicle sub-systems from outside of the vehicle and use the significant resources of the vehicle while remaining undercover and concealment. The technology also assist and expedite routine maintenance tasks.

- *Range finding and self location-* Range determination is critical for identifying and tracking of both friendly elements and potential targets.Self location is required in autonomous and semi-autonomous applications, such as, unmanned convoys and unmanned reconnaissance operations.

- *Terrain mapping-* Certain military applications require accurate sensing and mapping of various terrain features from relatively short ranges (5m-20m).Terrain mapping is necessary for certain autonomous and semiautonomous operations such as mine clearing and remote reconnaissance. In military it is required to detect, avoid or neutralize hidden objects for example mines, explosives, etc. and unexpected objects: rubbles, debris, etc.UWB is a good candidate for terrain mapping because of its immunity to hostile detection, hostile jamming and radio frequency interference and its effective penetration capability through different materials. Also it handles fine delay resolution capability.

5.2.”SEE-THROUH-THE-WALL”application by radar imaging-

Unlike narrowband technology, UWB systems can penetrate effectively through different materials. The reason is that the low frequencies covered in the broad range of UWB frequency spectrum have long wavelengths and allow UWB signals to penetrate through different materials including walls. Ultra-wideband is also used in "see-through-the-wall" precision radar-imaging technology precision locating and tracking (using distance measurements between radios), and precision time-of-arrival-based localization approaches. It is efficient, with a spatial capacity of approximately 1013 bit/s/m². UWB radar has been proposed as the active sensor component in an Automatic Target Recognition application, designed to detect humans or objects that have fallen onto subway tracks.

5.3. High data rate applications-

According to Shannon's capacity formula C=B log2(1+SNR); where C the channel capacity (bits per second) increases linearly with bandwidth, B. Therefore, having several GHz of bandwidth available for UWB signals, a data rate of Gbps can be expected. High data rate applications of UWB wireless technology have initially drawn much attention, since many of the applications are suited to the consumer market. Hence, commercial interest in

- *Internet Access and Multimedia Services:* Regardless of the envisioned environment (home, office, hot spot), very high data rates (> 1 Gbit/s) have to be provided – either due to high peak data rates, high numbers of users, or both.

- *Wireless peripheral interfaces*: A growing number of devices (laptop, mobile phone, PDA, headset, etc.) are employed by users to organize themselves in their daily life. The required data exchange is expected to happen as conveniently as possible or even automatically. Standardized wireless interconnection is highly desirable to replace cables and proprietary plugs. It has to be emphasized, however, that wireless solutions in this context will be attractive mainly for battery-powered devices without the need for an external power supply.

- *Location based services:* To supply the user with the information he/she currently needs, at any place and any time (e.g. location aware services in museums or at exhibitions), the users' position has to be accurately measured. UWB techniques may be used to accommodate positioning techniques and data transmission in a single system for indoor and outdoor operation.

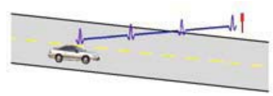

Figure 3. Location based services

5.4. Home Networking and Home Electronics-

One of the most promising commercial application areas for UWB technology is wireless connectivity of different home electronic systems. It is thought that many electronics manufacturers are investigating UWB as the wireless means to connect together devices such as televisions, DVD players, camcorders, and audio systems, which would remove some of the wiring clutter in the living room. This is particularly important when we consider the bit rate needed for high-definition television (HDTV) that is in excess of 30Mbps over a distance of at least a few meters.

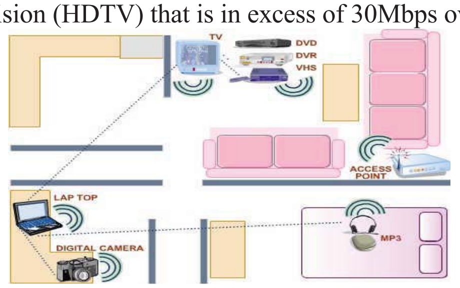

Figure 4. A wireless home networking system

5.5. Wireless Body Area Networks (WBAN)-

WBANs are another example of how our life could be influenced by UWB. Probably the most promising application in this context is medical body area networks. Due to the proposed energy efficient operation of UWB, battery driven handheld equipment is feasible, making it perfectly suitable for medical supervision. Moreover, UWB signals are inherently robust against jamming, offering a high degree of reliability, which will be necessary to provide accurate patient health information and reliable transmission of data in a highly obstructed radio environment.

5.6. Low Data Rate (LDR) Applications-

The use of very short pulses in impulse radio transmission, and careful signal and architecture design, facilitate the design of very simple transmitters, permitting extreme low energy consumption and thus long-life battery-operated devices, which are mainly used in low data rate networks with low duty cycles. The inherent noise-like behavior of UWB systems makes robust security systems highly feasible. They are not only difficult to detect, but also excel in jamming resistance. These characteristics are essential, not only for traditional security alarm systems, but also for Wireless Body Area Networks (WBANs), which are envisaged for medical supervision. Today's indoor solutions use either infrared or ultrasonic approaches. The former requires line-of-sight-propagation which can not be guaranteed, and the latter has the disadvantage of propagating with limited penetration. Simple UWB radio technology may fill this gap between demand and physical constraints, and is currently under development . For industrial needs, e.g. in the automotive field, distance measuring systems are yet another example for the deployment of UWB systems as logistics will also profit from highly precise location determination.

V. FUTURE ASPECTS OF ULTRAWIDEBAND TECHNOLOGY

5.1 UWB as Telimedicine Technology-

The possibility to process and transmit a large amount of data and transfer vital information using UWB wireless body area networks would enable tale-medicine to be the solution for future medical treatment of certain conditions. In addition, the ability to have controlled power levels would provide flawless connectivity between body-distributed networks. UWB also offers good penetrating properties that could be applied to imaging in medical applications; with the UWB body sensors this application could be easily reconfigured to adapt to the specific tasks and would enable high data rate connectivity to external processing networks (e.g. servers and large workstations).

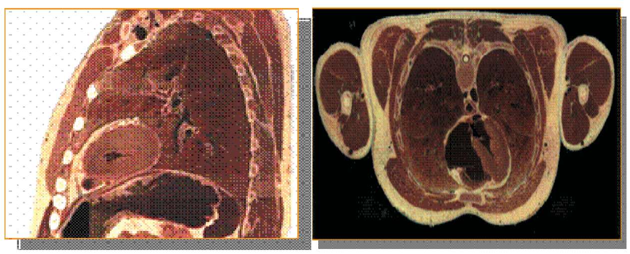

Figure 5. The heart imaging using UWB biomedical sensor .

Future research studies in the medical domain to correlate UWB include:

- ultrasound heart M-Mode tracings.
- external phonocardiogram and apex cardiogram tracings.
- external ballistic cardiogram tracings.
- invasive pressure pulse recordings.
- electrocardiogram recordings.
- better understanding and modeling of RF pulse propagation in the living tissues.

5.2 UWB as Radio free Technology-

UWB Technology envisions a future in which all devices are connected by smart radios. The vision is called Radio free, and it embodies the concept of a smart radio that can reprogram and reconfigure itself based on available spectrum, the desired application, and the device at hand. Configurations would include an 802.11 radio for communicating with a WLAN hotspot, a Bluetooth Technology radio for communication with a cell phone, or a UWB radio for participation in a WPAN. To promote this vision, it is involved in all areas of the RF space. In wireless wide area networks WWAN), it could be the case of Wi-MAX. Now, with support of UWB technology for the WPAN space, the concept of Radio Free technology is one step closer to reality.

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5.3 UWB Impulse Radar And Biomedical Sensor-

An UWB radar can be used to measure cardiac volume; respiration movement detection and diagnostic (e.g. prevention of Sudden Infant Death Syndrome –SIDS–, and Obstructive Sleep Apnea Syndrome –OSAS–);internal blood pressure that can be indirectly derived from a measurement of arterial pulsation; pregnancy monitoring; in general almost any object of adequate size can be monitored (e.g. vocal cords; vessels; bowels; lung; chest; bladder; fetus; etc.). From all the applications listed before this proposal focuses specially in the Heart Rate Variability (HRV). The HRV, as an indicator for the cardiovascular autonomous nerve system, codifies the activity of the peripheral and central parasympathetic and sympathetic nervous system. For example, through the usage of brain imaging methods it has been confirmed that the high frequency power component contained in the HRV signal, reflects activities seen in some areas of the brain critical to the allocation of resources during stress, such as the medial pre-frontal cortex.

5.4 UWB In MICRO AIR VEHICLE –

The term "micro air vehicle" or MAV refers to a new class of aircraft whose target dimensions are less than 15 cm (6 in) in any one dimension. In the future, even insect size vehicles are envisioned. The military application for MAVs is primarily in the area of reconnaissance, and the projection is for tiny "spy planes" that a soldier can carry in a backpack, launch and use to scout ahead for enemy troops. Dr. Jim McMichael, first DARPA Program Manager for MAV development ,envisioned an urban setting for many MAV scenarios :-
“In urban operations, MAVs, acting in small cooperative groups, will enable reconnaissance and surveillance of inner city areas, and may serve as communication relays. They may also enables observations through windows, and sensor placement on vertical and elevated surfaces. Their application to building interiors is the most demanding envisioned. The capability to navigate complex shaped passage ways ,avoid obstacles and relay information will require yet another level of technology….Constricted corridors of complex geometry, multiple obstacles -–and some of them moving – must all be reckoned with if the MAV is to become useful to the war fighter."

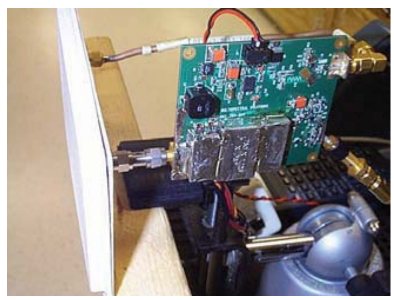

Figure 6. C-band MAVCS Prototype

VI. CHALLENGES INFRONT OF THE UWB TECHNOLOGY

There are many challenges involved in using nanosecond duration pulses for communications. Some of the main difficulties of UWB communications are discussed in the following table.

Table- 2 challenges and problems with UWB communication

Challenge	**Problem**
Pulse shape distortion	**Low performance using conventional pulse detection technique (i.e., classical matched filter receivers)**
Channel estimation	**Difficulty in predicting the template signals**
High frequency synchronization	**Very fast ADCs required**
Multiple access interference	**Detecting the desired user's information is more challenging than in narrowband communication**
Low transmission power	**Information can only travel to short distances**

IV. CONCLUSION

The majority of the discussion so far has focused on the state of the art of UWB technology as it is today and near future. However, future UWB developments and drivers that may shape future evolutions of this technology are:

• Integral part of 4G communications networks;

• Very high data rate requirements driven by the development of 3D imaging technology and applications;

• Digital implementation solutions; and

Super-high density wireless sensor networks.

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