Ultra Wideband Technology

1 ABSTRACT

Ultra-Wideband (UWB) is a unique technology recently approved by the FCC for commercial communications. This paper helps to understand UWB, gives a history of UWB development. It reviews the technology, compares it with other wireless technologies. In addition to that it analyzes the FCC and worldwide regulation and standardization process of the UWB market. The paper gives the overview of the targeted markets and compares major vendors and their products.
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4 WHAT IS UWB TECHNOLOGY

4.1 UWB Description

Ultra Wideband technology is a wireless technology to transmit large amounts of digital data as modulated coded impulses over a very wide spectrum of frequency with very low power for a short distance. Pulsed transmission is an alternative to sinusoidal waves traditionally used in wireless communications.

There are several definitions of Ultra Wideband radio:

- Any wireless transmission scheme occupying a bandwidth of more than 1.5 gigahertz (GHz).
- Any signal that occupies more than 500MHz in the 3.1-10.6GHz band and that meets the FCC spectrum mask requirements.
- Any radar (signal) whose fractional bandwidth is greater than 0.25 regardless of the center frequency or the signal time-bandwidth product. Fractional bandwidth is the ratio of the instantaneous bandwidth to the center frequency:

\[
2 \frac{F_H - F_L}{F_H + F_L} \geq 0.25 ,
\]

where \( F_H \) - high frequency, \( F_L \) - lowest frequency

This new technology supports direct transmission of digital information as a baseband signal rather than modulating the information within a sinusoidal carrier. Typical duration of the pulse lasts from a few tens of picoseconds to a few nanoseconds. As the bandwidth is inversely proportional to pulse duration, the spectral extent of these waveforms is very large. Due to low energy density UWB signals cause minimal interference if operated on spectrum already occupied by existing radio services. However, the level of interference of UWB signals is still under research.

UWB uses Complementary Metal Oxide Semiconductor (CMOS) Integrated Circuit (IC) to control the transmission of millions of low-powered, coded pulses at precise intervals every second across a large portion of electromagnetic spectrum. Tens to thousands of these pulses are transmitted at different frequencies for every bit of information passed. Upon receipt of the pulses, a communicating receiver processes them using a bank of matched receivers to recover the transmitted pulses. This process ensures precision timing with few errors, which is critical to the device’s functionality.

There are several implementations of UWB radio. They fall either under Direct Sequence (DS) or Time Hopping (TH) categories. The main difference between them is the duty cycle and the related peak-to-average power ratio.
4.2 Benefits of UWB

UWB technology has many benefits over the existing wireless technologies:

- Very high speed due to high-bandwidth multi-channel performance.
- Extremely easy and cheap transceivers to compare to typical spread spectrum ones due to UWB low power and short burst radio impulse requirements. Both UWB transmitters and receivers consist of integrated CMOS which makes them affordable for consumers.
- UWB systems also consume very little power, around one ten-thousandth of that of cell phones. This makes UWB practical for use in smaller devices, such as cell phones and PDAs.
- Ability to share frequencies with other services without causing harmful interference.
- High flexibility for the adoption of a frequency. UWB systems could be positioned anywhere in the RF spectrum.
- Low power causes less interference than conventional radio networks. Relatively wide spectrum of UWB waves results in less interference from other systems.
- Ability to propagate effectively through materials such as cement and brick.
- Excellent frequency diversity and multipath resolution.
- Exceptional performance in multipath reflective environments, which can be helpful in high precision positioning.
- Low probability of intercept and detection (LPI/D) due to low power densities.
- Reduced fading even in dense high multipath channels (indoor environment).
- Common architecture for communications, radar and positioning systems.

4.3 UWB Challenges

- Potential interference with the existing RF systems especially ones that provide essential military, aviation, fire, police, and rescue services. Recent studies conducted by National Telecommunications and Information Administration (NTIA) shows that UWB systems can potentially interfere with GPS and non-GPS systems if operated under certain frequencies. Most of the concerns remain about the interference of higher-power UWB systems.
- UWB is still an RF wireless technology, and therefore is a subject to the same laws of physics applied to every other RF technology. Thus, there are obvious tradeoffs to be made in signal-to-noise ratio versus bandwidth, range versus peak and average power levels, etc.
- Wide RF Bandwidth Implementation technological challenges.
- Broadband Non-resonant Antennas technological challenges.
- Since a UWB signal is different compare with the conventional RF sinusoidal signal UWB system design represent a major challenge. It is true for transmitters, receivers and antennas.
• Because of the incredible time resolution of UWB signals the channel estimation and multipath combining tasks are extremely challenging.
• Global standardization process.

5 UWB MARKET

Allied Business Intelligence estimates that UWB, to be designated IEEE 802.15.3a, will likely generate $1.39 billion in revenue by 2007.

ABI Research’s report "Ultra Wideband (UWB) Wireless -- An Evaluation of Technology Prospects and Potential Market Applications," predicts that UWB will be the next generation in wireless communications, for diverse applications including wireless LANs and radar. The total global shipments for UWB-enabled electronics and chipsets could reach 45.1 million units by 2007, with resulting revenues of $1.39 billion by the end of that year. Projections include shipments to market segments including such areas as communications, imaging, vehicles, locators and military/government use. Forecasts cover twenty different market segments.

West Technology Research Solutions, which solely focus on the most promising emerging technologies, has an even more optimistic forecast, predicting sales amounting to $2.9 billion by 2007. Given a 4 percent global GDP growth rate, annual shipments for ultra wide band chipsets into the communications segment will exceed 63 million units by 2007. Since the throughput potential of UWB is 1,000 times greater than 802.11b, the technology "has the very real potential" to displace technologies in LANs, PANs, and ultimately in WANs.

The best prospects for wide UWB deployment exist with the consumer electronics industry. UWB chipset shipment growth for video and host device applications is expected to more than double in the years 2005 and 2006, from 1.5 million UWB integrated circuit (IC) shipments in the year 2004 to 3.4 million UWB IC shipments in the year 2005, and to 7.7 million UWB IC shipments in the year 2007.

6 HISTORY OF UWB

The concept of Ultra wideband communication originated in the very early days of radio and has been used for decades. The first radio transmitters by Marconi and Hertz, so called spark gap transmitters, were developed in the early 1900s. In fact they communicated by sending a signal over a very wide bandwidth. Since this use of spectrum did not allow sharing narrow band or tuned communication was used instead. And in 1927 spark gap transmitters were banned completely because of their spectrum usage.

Most of the initial concepts and patents for modern Ultra Wideband technology originated in the late 1960’s by Dr. Gerald F. Ross and K.W. Robbins at the Sperry Research Center, Dr. Henning F. Harmuth at Catholic University of America and Paul
van Etten the USAF’s Rome Air Development Center and in Russia. At that time, the technology was referred to as baseband, carrier-free, impulse, time-domain, nonsinusoidal, orthogonal function and large-relative-bandwidth radio/radar signal. Term Ultra Wideband was applied in 1989, apparently by the Department of Defense.

The Harmuth books and published papers in 1969-1984 described the basic design for UWB receivers and transmitters. At the same time Ross and Robbins (R&R) work in time-domain electromagnetics and numerous patents in 1972-1987 pioneered the use of UWB signals in a number of application areas including communications and radar. Both Harmuth and R&R applied the well known idea of matched filtering to UWB systems. Van Etten developed the main system design and antenna concepts for UWB radar systems. Several critical technical developments such as the invention of the oscilloscope in 1962 by Dr. Barney Oliver have helped in the progress of UWB. In 1974, Morey designed the first UWB ground penetration radar system. In the 1970s it became obvious that the only innovations in the UWB field could come from improvements in particular subsystems but not in the system concept itself. The basic components were known, e.g., pulse train generators, pulse train modulators, switching pulse train generators, detection receivers and wide band antennas. In 1986-1987 Dr. R. Fontana and Dr. Ross developed and implemented a low probability of intercept and detection communication system. In 1987 Time Domain founder Dr. Larry Fullerton patented the invention of the “Pico-timer”, a variable timing chip that synchronizes the transmitter and receiver for time modulated UWB (TM-UWB) transmission. In 1994, T.E. McEwan at Lawrence Livermore National Laboratory invented the Micropower Impulse Radar (MIR), compact and inexpensive UWB device operating at extremely low power.

It is important to mention that in the United States most of the work, particularly in the area of impulse communications, was performed under classified US Government programs. The development of UWB technologies greatly accelerated since 1994 and much of the work have been carried out without classification restrictions. It includes development of UWB handheld transceivers, groundwave communication systems, asymmetric video/command and control UWB transceivers and other technologies/devices.

7 FEDERAL COMMUNICATION COMMISSION

7.1 September 1998, Notice of Inquiry

In September of 1998, the FCC issued a Notice of Inquiry (NOI) to “investigate the possibility of operation of ultra-wideband (UWB) radio systems on an unlicensed basis under Part 15 of FCC Rules.” The responses to NOI highlighted two main obstacles to UWB operation under Part 15 rules. FCC Part 15 applies to unlicensed radio devices and requires that non-licensed operation of low-power transmitter devices can be permitted only if interference to a licensed radio system is mitigated. But UWB operates over a wide bandwidth and therefore can potentially violate other restricted frequency bands, which is prohibited under the existing Part 15. In addition to that, the current emission
measurement requirements also detailed in Part 15 were specifically developed for existing narrowband systems, and probably are not applicable to UWB devices by imposing too many restrictions on them.

7.2 May 2000, Notice of Proposed Rulemaking

On May 11, 2000, the FCC issued a Notice of Proposed Rulemaking (NPRM) “In the matter of revision of Part 15 of Commission’s Rules Regarding Ultra-Wideband Transmission Systems”. This notice proposed that some UWB devices would operate on an unlicensed basis under Part 15 Rules, which could have enormous benefits for public safety, consumers and businesses. UWB devices appear to be able to operate on spectrum already occupied by existing radio services without causing interference. The FCC specifically mentioned that recent advances in UWB technology have resulted in its potential use for a variety of applications such as radar imaging of objects buried under the ground or behind walls and short-range, high-speed data transmissions suitable for broadband access to the Internet. Police, fire, and rescue personnel can also use UWB communications devices to provide covert secure communications.

At the same time the commission expressed the commitment to ensure that safety services, such as Global Positioning System (GPS) are protected from harmful potential interference. Further, this NPRM stated that UWB devices should be exempt from licensing and frequency coordination, allowing the technology to operate under a new UWB section of Part 15 of the FCC Rules. The FCC has proceeded cautiously due to the uncertainty surrounding UWB and whether it will cause interference with other services, such as cellular telephones and GPS. The FCC asked for more testing and analysis in bands below 2 GHz.

7.3 February 2002

On February 14, 2002 the Federal Communication Commission adopted a Memorandum Opinion and Order. Again the FCC took a cautious approach in approving limited use of UWB devices and services without a license. The regulations approved by the FCC are based on standards set by the National Telecommunications and Information Administration (NTIA) and are intentionally "conservative" to guard against interference with government operations. Those rules allow only the following:

- Different imaging systems:
  - Medical imaging, similar to X-ray and CAT scans. These devices must be operated in the frequency band 3.1-10.6 GHz. used for a variety of health applications at the direction of or under the supervision of a licensed healthcare practitioner.
  - Through-wall imaging and ground-penetrating radar systems (GPRs) for detecting people or objects in law-enforcement or rescue applications.
These systems must be operated below 960 MHz or in the frequency band 1.99-10.6 GHz.
- Construction applications, including wall imaging systems operating below 960 MHz or in the frequency band 3.1-10.6 GHz.
- Surveillance Systems: Although technically these devices are not imaging systems, for regulatory purposes they will be treated in the same way as through-wall imaging and will be permitted to operate in the frequency band 1.99-10.6 GHz.
  - Vehicular Radar Systems including automotive collision-detection systems and suspension systems that respond to road conditions in the 24 GHz band using directional antennas.
  - Communications and Measurement devices, such as high-speed home or office networking, provided that the devices are designed for indoor use in the frequency range 3.1-10.6 GHz. At the same time outdoor use is restricted to handheld devices engaged only in peer-to-peer operation.

This the FCC decision was a result of a three-year battle between defense and aviation officials on one side and Silicon Valley and consumer electronic groups on the other. Many wireless operators and manufactures of PCS, GSM, and ISM devices vigorously opposed the approval too. The FCC ruling mitigates interference risks by limiting UWB usage to bands outside the 1,559/1,610-MHz frequency occupied by GPS. The FCC said UWB must be used either above 3.1 GHz or below 960 MHz, both of which are well out of the range of the GPS band.

Summary of the FCC Ruling is shown in Table 1.

<table>
<thead>
<tr>
<th>Application</th>
<th>Frequency Band for Operation at Part 15</th>
<th>User Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>3.1 to 10.6 GHz (GPR &lt;960 MHz)</td>
<td>Yes</td>
</tr>
<tr>
<td>Through-wall and Surveillance</td>
<td>1.99 to 10.6 GHz</td>
<td>Yes</td>
</tr>
<tr>
<td>Communications (indoor &amp;</td>
<td>3.1 to 10.6 GHz</td>
<td>No</td>
</tr>
<tr>
<td>Vehicular</td>
<td>24 to 29 GHz</td>
<td>No</td>
</tr>
</tbody>
</table>

*Table 1: Summary of FCC Ruling.*

Indoor and outdoor communications devices have different out-of-band emission limits.
To address a possibility for interference among UWB devices and other systems in September of 2002 the FCC issued an “Inquiry on Unlicensed UltraWideband Transmission Systems”. This document was seeking inputs that would enable a careful evaluation of the technology and its benefits. Responses from industry, government agencies and other interested entitled helped the FCC define standards and operating requirements to regulate UWB use.

8 REGULATORY APPROVAL IN OTHER COUNTRIES

Unfortunately UWB technology has not been regulatory approved in any other country. However there is significant interest in many countries and steps are being taken to explore a number of foreign markets and regulatory processes.

International Telecommunication Union (ITU) has begun studying UWB under task group 1/8. It seems to be adopting the similar to FCC approach towards UWB. Europe is also getting active in the field of UWB via standardization through European Telecommunication Standard Institute (ETSI) and regulation overseen by Conference European of Post and Telecommunications (CEPT)

Figure 1: FCC and ETSI comparison.

Figure 1 shows the difference between new FCC and proposed ETSI spectral usage rules.

Currently European regulation bodies are conducting the following studies:

- ETSI TG31A - Generic UWB
- ETSI TG31B - Ultra Wide Band Automotive Radar
- CEPT SE24 - UWB compatibility
- ITU 5.340 – Prohibited emission
- ETSI EN 302 065 for communications and measurements in 3.1 to 10.6 GHz
• ETSI EN 302 066 for Radio Location Services in 100MHz to 6 GHz
• ETSI EN 301 091 for 24 GHz Automotive Radar

The list of major European companies contributing in UWB include such companies as Siemens, Philips, STMicroelectronic, IMST GmbH, University of Roma, University of Oulu, CEA, etc.

Substantial progress in regulating UWB has been made in Japan. A consortium of more than 40 companies from the commercial, government and academia sectors is involved in this process. The list of Japanese companies involved in UWB development include Sony, Sharp, Fujitsu and others.

9 OTHER STANDARDS

9.1 Institute of Electrical and Electronics Engineers Inc. (IEEE)

The IEEE and ETSI standards bodies are in the process of defining a standard for Ultra Wideband physical layer systems.

The indoor wireless standards can be categorized into three standards groups.

• IEEE 802.11 - responsible for Wireless Local Area Networks (WLAN) standards
• IEEE 802.15 – responsible for Wireless Personal Area Networks (WPAN)
• IEEE 802.16 – responsible for Wireless Metropolitan Area Networks (“last mile” access networks).

UWB falls under 802.15 WPAN Working Group, which was founded in March 1999.

Currently there are four IEEE 802.15 standardization projects in the development and correspondingly four 802.15 groups working on these projects. Figure 2 shows all four WPAN groups.
9.1.1 Task Group 1
Task Group 1 (TG1) is working on WPAN standard based on Bluetooth™ technology. It will operate in 2.4 GHz Industrial, Scientific and Medical (ISM) band with the data rate about 1Mb/s. The IEEE Standard 802.15.1™-2002 was approved as a new standard on 15 April 2002.

9.1.2 Task Group 2
The Coexistence Task Group 2 (TG2) for WPANs is developing Recommended Practices to facilitate coexistence of WPANs (802.15) and WLANs (802.11).

9.1.3 Task Group 3
Task Group 3 (TG3) for WPANs is responsible for a high-rate (20Mbit/s or greater) WPAN standards. Besides a high data rate, the new standard will provide for low power, low cost solutions addressing the needs of portable consumer digital imaging and multimedia applications. This group has already developed a standard to deliver data rates from 20 Mbps to 55 Mbps over short range (less than 10 meters) WPANs.

9.1.4 Task Group 4
Task Group 4 (TG4) is creating a low data rate, low power WPAN standard.
9.1.5 Task Group 3a

Task Group 3a is responsible for identifying an alternative to 801.15.3 physical layer for high data rate WPAN systems that could support data rates between 110 Mbps and 480Mbps. The 802.15.3a standard has a goal that exceeds anything that Bluetooth can currently deliver: a combination of low power requirements, high transfer rates, and simplicity. UWB high data rate, potential for coexistence, fine multipath resolution, tremendous capacity potential and February 2002 FCC approval makes it an extremely attractive candidate for high data rate WPAN systems.

9.1.6 Intel vs. Motorola

More than 30 proposals have been submitted to Task Group 3a to develop a new standard for high-speed personal networking. It came down to a real war between rival proposals from the Alliance led by Intel, Texas Instruments and other 40 companies from one side and Motorola Ultra-Wideband Operation (formerly known as XtremeSpectrum) on the other one.

Intel coalition technology uses Multi-band orthogonal frequency-division multiplexing (MB-OFDM) to achieve performance 600 Mbps over five meters and 188 Mbps over ten meters. In contest Motorola direct-sequence code-division multiple-access (DS-CDMA) technology uses a single band approach to reach 100 megabits per second with the currently available and 500 Mbps with next version of its XtremeSpectrum chips.

Each camp cites benefits with respect to time-to-market, signal detection and regeneration, scalability, interference, integration potential, complexity, range, cost and power consumption. But the technical pros and cons will play out in the context of other factors, such as industry support, the direction international regulatory bodies may take-starting with the ITU-licensing and Federal Communications Commission compliance.

The last issue is especially crucial for MB-OFDM, which must settle the much-debated question of whether the frequency-hopping scheme can comply with FCC regulations and still meet the 802.15.3a performance requirements.

Unfortunately the task group was unable to come to an agreement on which of the competing standards should be ratified. Both July and September 2003 IEEE meetings ended in the deadlock.

In the 2003 meetings, MB-OFDM proposal received about 60% votes, but failed to gain the 75% required for adoption and necessary to exclude competing proposals. In a reversal of past votes most recent July 2004 IEEE meeting Motorola DS technology won the vote but again was not able to exceed the 75% threshold. As a result, many observers believe the standards battle will be settled in the marketplace as vendors release products with the competing standards hoping to win sufficient acceptance to set a de facto standard. Motorola has the advantage of having an existing and recently FCC approved chip, which has already been adopted by companies like Samsung. This summer the FCC
approved Freescale Semiconductor's (former Motorola XtremeSpectrum) XS110 chipset for commercial multimedia use.

But the Intel/Texas Instrument alliance has support from a larger number of consumer electronic players including Sony, Panasonic, Philips, etc. However, the lack of standards could hold up the market and reduce UWB’s potential to threat Bluetooth in the near term. Some companies could be reluctant to adopt a not standard technology. While the FCC tries not to interfere in this fight, European based ITU favors Motorola technology. Of course the world can accumulate one IEEE and one ITU standards. But since the compatibility between them is doubtful this dispute can split the market.

10 UWB APPLICATIONS

2002 FCC R&O authorizes 5 classes of UWB applications (devices)

- Imaging Systems
  1. Ground penetrating radars, wall imaging, medical imaging
  2. Thru-wall Imaging & Surveillance Systems
- Communication and Measurement Systems
  3. Indoor Systems
  4. Outdoor Hand-held Systems
- Vehicular Radar Systems
  5. Collision avoidance, improved airbag activation, suspension systems, etc.

10.1 Radar Applications

10.1.1 Classification

Major radar applications are:

- Collision/Obstacle Avoidance
- Precision Altimetry
- Intrusion Detection (“see through wall”)
- Ground Penetrating Radar

10.1.2 Description

UWB radar systems have been in the commercial world since the 1970s. They have been successfully used in ground-, wall- and foliage-penetration, position-location, collision warning for avoidance, fluid level detection, intruder detection and vehicle radar measurements. Future applications include: distance and air-bag proximity measurements and backup warning, road and runway inspection, breathing and heart monitoring, RFID, and camera auto-focus.
Radar applications use the concept of the signal penetrating nearby surfaces but reflecting surfaces that are farther away. It allows objects to be detected behind walls or other coverings.

Transmitting very fast impulses is attractive because the accuracy to which the target range can be measured (range resolution) is proportional to the radar's bandwidth. Thus ultra-wideband radars can resolve targets of small physical size. Consequently several small targets located close together, which would appear as one target when observed at lower range resolution, can be separated using UWB radar. In the case of composite targets like land mines the use of high range resolution allows information to be gathered from which the size and nature of the mine may be determined. The UWB technology has been used for ground penetrating radar (GPR) applications.

Several companies are developing UWB systems that employ radar principles. UWB radars are being developed for new types of imaging systems that would enable police, fire rescue personnel to locate persons hidden behind wall or under debris in situations involving such events as hostage rescues, collapsed buildings, or avalanches. Imaging devices also could be used to improve the safety of persons in the construction and home repair industries by allowing individuals to locate steel reinforcement bars in concrete, or wall studs, electrical wiring and pipes hidden inside walls. Some products of various companies are listed below:

**10.1.3 Time Domain RadarVision family of products.**

![Figure 3: TimeDomain RadarVision 1000](image)

RadarVision 1000 is a radar imaging product developed by Time Domain. It is powered by the PulseON chipset. Its numerous capabilities can be use for

- Through wall sensing to literally detect motion and provide vital, potentially life-saving information to security and public safety personnel
- Underground imaging to reveal both the location and potentially the soil conditions near surface objects
- Proximity sensing to reduce collisions and to sense the position of passengers to enable the precise timing and deployment of an air bag
- Disaster recovery to locate victims buried under debris or avalanches.

Main Time Domain RadarVision features are:
• Hand-held
• Lightweight
• Rugged
• Easy to operate
• Detect motion
• Intuitive graphical display
• Display compatible with night-vision equipment
• Rechargeable battery
• UWB technology
• Ultra-low transmit power

The TimeDomain RadarVision family of products includes:

• RadarVision 2 - the Second Generation Through Wall Motion Detection Radar For Enhanced Tactical Entry (for US use only). It has Increased range to 20m.
• RadarVision 2i - the Second Generation Through Wall Motion Detection Radar For Enhanced Tactical Entry (for worldwide use only)
• SoldierVision - Through Wall Motion Detection Radar For Military Operation in Urban Terrain (for US Military use only)

Video clips demonstrating TimeDomain RadarVision through wall capabilities can be watched online on www.radarvision.com.

10.1.4 UWB Radar Terrain Mapping Sensor

Figure 4: UWB radar sensor

This product is developed by Intelligent Automation, Inc in partnership with Time Domain for U.S. Army Robert Morris Acquisition Center and uses TM UWB technology. The goal of this product is to develop a sensor that is able to sense the ground profile in front of a mine-breaching vehicle, Grizzly (an M1 tank body). The problem is particularly difficult because the sensor must be able to look in front of the vehicle at an
angle of approximately 45 degrees and the accuracy requirement +/-1 inch. Synthetic aperture radar techniques are used where the synthetic aperture is in the direction of the vehicle.

TimeDomain UWB based Intelligent Automation applications are:

- Distributed Positioning Instrumentation using TM-UWB Transmission (Naval Air Warfare Training System Division): The goal is to develop a system for measuring the azimuth and elevation angles of a weapon to support STRICOM's Advanced Tactical Engagement Simulator project.
- TM-UWB Multi-channel Data System (NASA / Lyndon B. Johnson Space Center): The goal is to develop a wireless communication system with the capability to transmit high data rates and the ability to track the motion of an astronaut.
- Alternative Communications for Non-line-of-Sight Applications (U.S. Army Aviation and Missile Command): In this work, IAI is a subcontractor to TDC. The purpose of the project is to achieve a high bandwidth over the horizon capability using a swarm of micro air vehicles, each of which will carry a TM-UWB radio

### 10.1.5 Multispectral Solutions radars

Multispectral Solutions, Inc. is a pioneer and an established industry leader in the development of ultra wideband systems for communications, radar and precision positioning applications. Multispectral Solutions developed and implemented a family of different UWB based radars.

- UWB altimeter and obstacle avoidance radar
- UWB collision avoidance backup sensor with an extremely low false alarm rate and high dual tunnel detector
- UWB intrusion detector that is a through-the-wall sensor, which can detect 0-200 feet through wall
- UWB collision avoidance radar that is designed for micro air vehicle applications.

Figure 5 and Figure 6 show two examples of MultiSpectral Solutions UWB Communications and Radar Applications.
10.1.6 Ultrasound Mimicking Radar (UMR)

McEwan Technologies has developed a 24GHz Ultrasound Mimicking Radar (UMR) that acts like an ultrasonic rangefinder without the drawbacks of acoustics and active-reflector Doppler radar. Applications include RFID, automotive backup and collision warning,
precision radar range finding for fluid level sensing and robotics, precision radiolocation, wideband communications and time-resolved holographic imaging.

![Figure 7: UMR vs. Ultrasound radars comparison](image)

McEwan Technologies website shows 24 GHz microRADAR (Ultrasound Mimicking Radar) comparison to 40 kHz Ultrasound video clip

### 10.1.7 Micropower Impulse Radar (MIR)

![Figure 8: MIR Circuit board.](image)

MIR technology is under development at Lawrence Livermore National Laboratory, at University of California. The technology uses the concepts of UWB technology to develop short-range sensors e.g., MIR sets for detecting motions of nearby objects within approximately 1 m range. The MIR sets transmit a short burst of several electromagnetic waves with a 2-GHz nominal frequency.
This technology presents a new paradigm in radar technology. It is expected to outperform conventional radar and sensor equipment. Both the radar transmitter and receiver are contained in the two square inch package. Eventually the micro-radar can shrink to the size of a silicon microchip.

Common features of MIR technology are:

- Low cost, using off-the-shelf components
- Very small size (circuit board is about 4 cm2)
- Excellent signal penetration through most low-conductivity materials, so it is able to see through walls, concrete, and other barriers, including human tissue
- A sharply defined and adjustable range of operation, which reduces false alarms
- Long battery life, typically several years, because of micro-power operation
- Simultaneous operation of many units without interference
- Randomized emissions, making the sensor difficult to detect

Commercial applications using MIR include:

- Automotive: parking assistance; backup warning; pre-collision detection; cruise control; airbag deployment; electronic dipstick for all fluid levels
- Security: home intrusion and motion sensor; keyless locks, automatic doors; child monitoring: vehicle theft alarm; radar trip wire; perimeter surveillance
- Appliances: stud finder; laser tape measure; wireless thermostat; automatic dispenser; automatic tool shutoff; toys, games, and virtual reality
- Manufacturing: fluid-level, proximity, and harsh-environment sensing; robotic sensor; industrial automation

10.2 Tracking Applications

Knowing position location is very important to many military and commercial applications. UWB devices can be used to measure both distance and position. UWB positioning systems could provide real time indoor and outdoor precision tracking for many applications. Some potential uses include locator beacons for emergency services and mobile inventory, personnel and asset tracking for increased safety and security, and precision navigation capabilities for vehicles and industrial and agricultural equipment. The current Global Positioning System has a lot of limitations like inability to work inside buildings or under cloud cover.

10.2.1 Time Tag
It is a Time Domain product and its uses proprietary BroadSpec antenna, which is approximately the same size as a standard business card and can operate from at least 5.5GHz to 1.0GHz with about a +1dBi gain. Time Tag has the capabilities to track items to within an inch of its location. It can be used as a tracking mobile with highly accurate 3-D asset tracking, as an indoor tracking and communication system, in precision navigation devices, in precision location devices and in ranging instruments.

**10.2.2 Localizer**

Æther Wire & Location Inc has developed integrated ultra-wideband transceivers, called Localizers used for highly accurate, precise position location and low data-rate communication. Localizers determine location by sharing range information within a network of units distributed in the environment. The range between pairs of Localizers is determined by transmitting ultra-wideband coded sequences of signals. Using precise timing techniques the Localizers are able to establish these ranges to an accuracy of about a centimeter.

The advantages of CMOS based UWB Localizer technology are:
• Accurate position
• Low cost, low power units
• The network approach allows units to be far apart without requiring the power to directly reach that distance
• Small size of the localizer is 2.0” x 3.6”

The small size, low power consumption, range, accuracy, encryption and anti-jam features of the Localizer make it an ideal platform for a variety of applications:

• **IFF:** Localizers are an ideal means of providing individual soldiers with Identification Friend or Foe (IFF) capability. In addition, the ability to group sets of Localizers into "families" associated with a squad, fighting vehicle or team makes it harder for enemy units to infiltrate using captured Localizers. Furthermore, Localizers can be integrated with other sensors for monitoring the soldier's state (e.g. blood pressure, heart rate, body temperature, etc.), and can signal distress if any of these factors go outside of safe limits. Localizers would also enhance C3I for the unit commanders and the theater commander.

• **Logistics Control:** Localizers act as bar code identification tags that not only can be read from a mile away, but can give the precise location of the logistics item. Future smaller and inexpensive Localizers can be placed on individual weapons and even individual munitions items. These could also be linked with the C3I system to give commanders real-time information on logistics usage and proximity to battlefield units.

• **Ground Surveillance:** Localizers combined with micro-sensors (e.g. gas sensors, vibration sensors, etc.) can be the heart of a field-scatterable sensor array to identify the size and composition of an enemy ground force getting such data as number of vehicles, weight of vehicles, etc.. The precise knowledge of time and location within a network of Localizers allows a synthetic phased array antenna to be formed; one of its uses could be to uplink sensor information to satellites. The transmission could be non-sinusoidal, or small satellite transceivers could be combined with Localizers for sinusoidal transmission.

• **Mine Clearing:** Localizers combined with microsensors and small autonomous ground vehicles (AGVs) could be used as a mine clearing force. Small, inexpensive, robotic vehicles, combined with Localizers to ensure full geographic coverage, could clear an area of mines and unexpended munitions. The low cost of the Localizers and the robots would make any loss of units in the mesh inconsequential in terms of systems operating cost.

• **Smart Minefields:** Field-scatterable minefields have the advantage of rapidly mining a large area. They have the disadvantage of being difficult to clear once
hostilities have ended. Combining mines with Localizers would allow a friendly force to easily locate the small, non-metallic scatterable mines, and effectively clear the minefield.

In Consumer/Commercial area Localizers can be used for such applications as:

- Personal Location – safety devices, child locators, item locators etc.
- Inventory Control – act as bar cod identification tags, could be read from a kilometer away, but can give precise location.
- Smart Highways – part of intelligent vehicle highway system (IVHS)
- Machine Control - automate construction operations
- Smart Homes - combining Localizers with home appliances

Æther Wire presented the concept of Localizers on "ONR Workshop on UWB Communications" held in May 2000.

**10.2.3 Multispectral Solutions UWB High Resolution Geolocation System and UWB tags**

Multispectral Solutions (MSSI) develops UWB precision geolocation system to determine precision location in urban terrain and within building structures. This geolocation system was originally developed for the precision location of a warfighter in a complex, urban environment.

The System utilizes a set of untethered, fixed position "Beacons" and an untethered mobile "Ranger". Three-dimensional positioning information is obtained by determining the round-trip time-of-flight from the UWB Ranger to each Beacon transponder. The system utilizes a 2.5 nanosecond (27% fractional bandwidth) burst waveform, and a unique tunnel diode receiver which is sensitive to the received pulse leading edge. Its range is up to two kilometers for outdoors and up to 300 feet indoors (5-25dB /wall attenuation). The system achieves centimeter-level range resolution.
Multispectral UWB geolocation system is self-synchronizing and does not require the existence of a clock distribution system and associated cabling. Unlike GPS the system is capable of providing operation under conditions in which satellite coverage is unavailable or is blocked by obstructions or shielding. It can be used in wartime operation, in buildings, urban environments, under heavy canopy, next to large obstructions such as vertical mine walls, etc.

10.2.4 Multispectral Solutions UWB tags

UWB tags were developed for Intelligent Transportation System (ITS) applications. It includes vehicle-to-vehicle and vehicle-to-roadside communications, as well as unique applications such as the detection of problem (like suspended license) drivers. The information exchanged includes both images and data. The range of UWB tags is 800
feet in high multi-path environment and 2000 or more feet for line-of-sight paths. The system operates on 115.2 kb/s packet burst mode.

10.3 Communications Applications

Most of the WPAN applications require transmission of very high data rates over short distances. Table 2 shows estimated transmission speed requirements for different applications.

<table>
<thead>
<tr>
<th>Application</th>
<th>Min Data Rate</th>
<th>Max Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.323 / T.120 Video Conferencing</td>
<td>188+ Mbps</td>
<td>1.4+ Gbps</td>
</tr>
<tr>
<td>Home Theater</td>
<td>43 Mbps</td>
<td>56.8 Mbps</td>
</tr>
<tr>
<td>Interactive Application (e.g. gaming)</td>
<td>76.8+ Mbps</td>
<td>unknown</td>
</tr>
<tr>
<td>Content Downloading (e.g. photos, MP3, CD, movies)</td>
<td>90+ Mbps</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Table 2: Estimated transmission speed.

UWB devices can be used for variety of communications applications involving the transmission of very high data rates over short distances without suffering the effects of multi-path interference. UWB communication devices can be used for wireless services such as phone, cable, and computer networking throughout a building or home. UWB communication devices can also be utilized by police, fire, and rescuer personnel as covert secure communication devices.

UWB WPAN applications include:

- Desktop and Laptop PCs
  - High res. printers, scanners, storage devices, etc
  - Connectivity to mobile and CE devices

- Mobile Devices
  - Multimedia files, MP3, games, video
  - Personal connectivity

- CE Devices
  - Cameras, DVD, PVR, HDTV
  - Personal connectivity

10.3.1 Variety of Multispectral UWB Communication Radars
Multispectral UWB communication radars include a whole array of different devices.

10.3.1.1 High-speed Ultra Wideband Radios

![UWB Radio](image13)

**Figure 13: UWB Radio.**

High-speed ultra-wide band radios with a range of up to 5 miles line-of-sight for outdoors with omni (vertical polarization) antennas have the following features:
- LPI/D command & control uplink and video downlink for UAVs and ground robots
  - C&C uplink 115.2 kb/s
  - Video downlink 1-25 Mb/s compressed
- Full duplex TDMA packet burst
- 400 MHz instantaneous bandwidth

10.3.1.2 Ultra-wideband ground wave radios

![UWB Ground Wave Radio](image14)

**Figure 14: UWB Ground Wave Radio.**

Half duplex Non-LOS radio uses surface/ground wave radio propagation with a range of more than ten miles depending upon terrain with omni antennas. The radios’ performance also depends on ground permittivity and conductivity.
10.3.1.3 Ultra Wideband Handheld Radios

Full duplex, packet burst, LPI/D digital voice/data radio operates in 1-2 km range low with low profile omni antennas and achieves multiple miles with higher gain antennas.

10.3.2 Multispectral Solutions Communication Projects

On September 27, 2004 Multispectral Solutions Inc. announced receiving a $24.5 million contract from the Naval Air Systems Command for the production of UWB-based aircraft wireless intercommunications systems (AWICS).

10.3.3 Pulse Link UWB Wireless Line Prototype

In October 2003 Pulse~LINK Inc demonstrated an UWB wireless transceiver prototype, showing an unprecedented 125 Megabit data rate transmission at 20 meters compliant with the FCC power and spectrum regulations. Real time, two-way, full motion video, sound and Internet browsing over a transmission range exceeding 50 meters was also demonstrated. This prototype challenges the widely held belief that UWB is only capable of achieving a ten-meter transmission range under the current FCC rules. Pulse~LINK is the only UWB company demonstrated a WLAN (up to 100 meter) vs. WPAN (up to 10 meter) transmission. Recently Pulse-Link combined its efforts with Fujitsu Microelectronics on a proprietary 400Mbps UWB implementation, which is going to operate over 100 meter distances.

11 UWB CHIPSETS

11.1 Motorola XtremeSpectrum™ Chipset
In 2002 XtremeSpectrum, now Freescale Semiconductor, Inc., a wholly-owned subsidiary of Motorola, became the first company to deliver a UWB wireless chipset complying with the FCC rules for unlicensed usage.

XSI100 Trinity chipset provides full wireless connectivity implementing bi-phase modulated ultra-wideband. It is implemented using a modified compact flash form factor reference design. The reference design incorporates a patented omni-directional antenna design that is printed on standard printed circuit board material and can be manufactured in extremely high volumes. This antenna is a critical component for meeting the FCC's spectral mask as well as in delivering the performance capability of the complete system solution.

Trinity XSI100 delivers up to 100 Mbps data transfer rate supporting applications like streaming video, streaming audio, and high-rate data transfer at very low levels of power consumption. In addition to high data rates the chipset supports peer-to-peer as well as ad hoc networking for truly mobile wireless connectivity, consumes low power and cheap.

Trinity key features are:
- Data rates of 25, 50, 75 and 100 Mbps
- Support for IEEE 802.15.3 streaming media protocol
- Enables wire-like High Definition video applications
- 200 mW ~ 3.3v power consumption for battery powered products
- Co-exists with 802.11b/a/g, Bluetooth, GPS, and all US-based wireless systems
- Built using low-cost 0.18 µm CMOS and SiGe technology
- 10 meter Range

The chipset supports next applications:
- Multiple wireless MPEG-2 or MPEG-2HD video streams
- Wireless Fast Ethernet, USB2, and 1394
- Home residential gateways/set-top boxes supporting secure digital video distribution to multiple displays/televisions
Streaming digital video/audio for digital cameras, MP3 players, and PDAs
Client device location tracking for wireless LAN (802.11) products

Standard Trinity XSI100 chipset consists of a single-chip Medium Access, baseband processor, RF Transceiver chips and Trinity UWB antenna.

Recently Freescale revealed that its planned UWB product families will be engineered to deliver 220 Mbps, 480 Mbps and 1 Gbps data transfer rates.

11.2 Time Domain UWB Chipset

Time Domain has the intellectual rights to Time Modulated-Ultra Wideband (TM-UWBTM) technology. TM-UWB is the underlying architecture behind PulsON® chipset. Time Domain PulsON 200 chipset is used in a few of non-FCC (military, etc.) products using the UWB technology.

“Pico-timer” is a variable timing chip that synchronizes the transmitter and receiver that makes UWB transmission possible. The company claims that the PulseON® is a “revolutionary technology that fuses communications, radar and tracking capabilities into single chipset, and can both enable entirely new wireless applications and products and provide improvement to already existing applications.”

PulsON 200 Chipset consists of:

- 2 timer chips (each chip includes 2 independent timer circuits)
- 2 correlator chips (each chip includes 2 correlator pairs)
- 1 digital baseband chip

PulsON 200 Chipset is the heart of Time Domain PulsON 200 UWB Evaluation Kit (EVK), which allows product developers to examine the performance, capabilities and properties of ultra wideband technology. Time Domain UWB chipsets are manufactured by IBM.
In August 2003 Time Domain spun off its communication group to develop chips for high-data-rate communications. Chips from the new venture, Alereon Inc., will be designed to meet IEEE’s 802.15.3a standard when those specs are finalized.

### 11.3 Wisair UBLinkTM Chipset

The UBLink chipset is a high bit rate, low cost and modular UWB-based communication system developed by Wisair Ltd. Its design goal is to provide short-range, in-home/in-building wireless connectivity solutions as multi-streaming of high quality video, fast upload/download of content or broadband multi-media. The UBLink chipset provides high-speed communication interface for the customers’ applications. The chipset roadmap includes support for different types of interfaces such as USB 2.0 and IEEE 1394. The company provides its customers a family of FCC compliant chipsets with a full reference design.

UBLink Single Chip Solution will include both PHY and MAC chips on one silicon die.

Key Features of the chipset are:

- Consists of two chips: MAC/PHY mixed signal and PHY RF chips
- Bit Rates 55 -480Mbps (Future versions support for 1Gbps)
- Bit rate scalability
- Range of 10m to 30m dependent on the selected bit rate
- Power Consumption of ~200mW (dependent on the selected bit rate)
- Future conformance to 803.15.3a standard
- Co-existence with other wireless systems and services in typical environments and conditions of use
- Low power consumption for active mode and power-save for standby mode Auto configuration
- Power supply from standard interface

### 11.4 Other companies
Among the companies developing UWB chipsets are:

- Pulse~LINK is developing proprietary techniques to seamlessly integrate its UWB-wireless and UWB-wired communications on the same chipset platform.
- Multispectral Solutions develops efficient low cost chipset.
- Intel develops a working prototype with 100Mbps data rate, 0.5W power working over 3m distance.
- Texas Instruments Inc. and STMicroelectronics are developing a standard cdma2000 1xEV-DV (1xEvolution for Data and Voice) chipset.
- Alereon Inc., Time Domain spin-off develops Single Digital CMOS Baseband and MAC chip for increased power savings.
- Royal Philips Electronics and General Atomics are jointly developing wireless communication chipsets for very high bit rate networks, up to 480 Megabits per second (Mbps).
- Staccato Communications is teaming up with San Jose, Calif.-based WISME to develop a single-chip UWB system.
- In 2003 Royal Philips Electronics and General Atomics announced they would work together to jointly develop UWB wireless communication chipsets and support the standardization process.

The list of companies taking an active part in UWB development includes such heavyweight as Intel, Motorola, Sony, Texas Instruments, Fujitsu, Panasonic, Siemens, Philips, General Atomics, STMicroelectronic and others.

12 CONCLUSION

With transfer speeds as high as 480 Mbps, UWB has little effective competition, UWB technology has already demonstrated great potential in different areas including communications, radar and geopositioning applications. Ultra-Wideband communications ideally suited for many commercial and military applications.

13 WEB LINKS

17. http://www.sss-mag.com/
25. http://www.theregister.co.uk/