Ultra-Wideband Technology

1.0 Introduction:
1.1 As the name implies UWB, ultra wide band technology, is a form of transmission that occupies a very wide bandwidth. Typically this will be many Gigahertz, and it is this aspect that enables it to carry data rates of Gigabits per second.
1.2 The fact that UWB transmissions have such a wide bandwidth means that they will cross the boundaries of many of the currently licensed carrier based transmissions. As such one of the fears is that UWB transmission may cause interference. However the very high bandwidth used also allows the power spectral density to be very low, and the power limits on UWB are being strictly limited by the regulatory bodies. In many instances they are lower than the spurious emissions from electronic apparatus that has been certified. In view of this it is anticipated that they will cause no noticeable interference to other carrier based licensed users.
1.3 Ultra-Wideband (UWB) provides an interesting new technology for short-range ultra-high speed communications in the frequency band 3.1 GHz to 10.6 GHz. It supports a bit rate greater than 100 Mbps within a 10-meter radius for wireless personal area communications. The advantages of UWB include low-power transmission, robustness for multi-path fading and low power dissipation. The low power transmission of the UWB is the key characteristic that might allow it to coexist with other wireless networking standards such as 802.11 LAN, 802.16 MAN and WAN.

2.0 How UWB Works:
2.1 Since the capacity of a communications channel in a non-fading environment is expressed as:

\[ C = B \times \log_2 (1+S/N) \]

where

- \( C \) = channel capacity (bit/s)
- \( B \) = channel bandwidth ‘BW’ (Hz)
- \( S \) = signal power (watts)
- \( N \) = noise power (watts)

2.2 According to above equation, the capacity can be increased by either increasing \( B \) or \( S/N \). It is obvious that the capacity can be increased more by increasing \( B \) rather than \( S/N \).

2.3 UWB systems could also suffer from interference from other wireless technologies that exist in the vicinity of operation, but this problem can be mitigated by using adaptive selection of frequency bands in multi band UWB systems.
3.0 UWB wireless systems

3.1 The main types of UWB systems are:
   (i) Imaging systems that include ground penetration radars (GPR), wall and through wall imaging, medical imaging, and surveillance systems;
   (ii) Vehicular radar systems; and
   (iii) Communications and measurements systems.

3.2 These systems operate in the following frequency bands:

3.2.1 Imaging systems operate below 960 MHz or in the 3.1 GHz to 10.6 GHz frequency band. Typical applications are use by rescue organizations, law enforcement, mining companies and construction companies. They are also used to detect the location of objects through a wall and to detect movements of people or objects located behind walls. In medical fields, they are used for health applications and research.

3.2.2 Communications and measurement systems operate in the 3.1 GHz to 10.6 GHz frequency band.

3.2.3 Vehicular radar systems operate in the 22 GHz to 29 GHz frequency band. They are used for near collision avoidance.

4.0 Regulatory Aspects of UWB:

4.1 UWB, ultra wideband technology has been approved for indoor and short range outdoor communication, but with restrictions on the frequencies over which the transmission can spread as well as the power limits. This will enable the UWB ultra wideband transmissions to communicate successfully, but without affecting existing 'narrowband' transmissions.

4.2 To achieve these requirements UWB, ultra wideband transmissions can legally operate in the range 3.1 GHz up to 10.6 GHz, at a limited transmit power of -41dBm/MHz. Additionally the transmissions must occupy a bandwidth of at least 500 MHz, as well as having a bandwidth of at least 20% of the centre frequency. To achieve this last requirement, a transmission with a centre frequency of 6 GHz, for example, must have a bandwidth of at least 1.2 GHz. Consequently, UWB provides dramatic channel capacity at short range that limits interference.
4.3 The fact that very low power density levels are transmitted means that the interference to other services will be reduced to limits that are not noticeable to traditional transmissions. Additionally the lowest frequencies for UWB, ultra wideband have been set above 3 GHz to ensure they do not cut across bands currently used for GPS, cellular and many other services.

5.0 Two UWB, ultra wideband technologies

5.1 Despite the single named used for the ultra wideband (UWB) transmissions, there are two very different technologies being developed.

- **Carrier free direct sequence ultra wideband technology:** This form of ultra-wideband technology transmits a series of impulses. In view of the very short duration of the pulses, the spectrum of the signal occupies a very wide bandwidth.

- **MBOFDM, Multi-Band OFDM ultra wideband technology:** This form of ultra wideband technology uses a wide band or multiband orthogonal frequency division multiplex (MBOFDM) signal that is effectively a 500 MHz wide OFDM signal. This is 500 MHz signal is then hopped in frequency to enable it to occupy a sufficiently high bandwidth.
5.2 Both these systems have their advantages and disadvantages, each one having its supporters and applications for which it is most suited. The impulse based technology, also called direct sequence ultra wideband (DS-UWB) in view of some of the techniques used is being used for a number of high data rate data transmissions such as short range video transmissions. MBOFDM on the other hand is being adopted for Wireless USB where it performs well.

6.0 DS UWB - Direct sequence ultra wideband technology:

6.1 Ultra wideband UWB is a revolutionary wireless technology that enables data to be transmitted at speed well in excess of 100 Mbps. In view of its capabilities it is likely to become a major presence in the wireless communications industry.

6.2 DS UWB, direct sequence format for ultra wideband is often referred to as an impulse, base band or zero carrier technology. It operates by sending low power Gaussian shaped pulses which are coherently received at the receiver. In view of the fact that the system operates using pulses, the transmissions spread out over a wide bandwidth, typically many hundreds of Megahertz or even several Gigahertz. This means that it will overlay the bands and transmissions used by more traditional channel based transmissions.

6.3 Each of the DS UWB pulses has an extremely short duration. This is typically between 10 and 1000 picoseconds, and as a result it is shorter than the duration of a single bit of the data to be transmitted. The short pulse duration means that multipath effects can usually be ignored, giving rise to a large degree of resilience in ultra wideband UWB transmissions when the signal path is within buildings.

6.4 DS UWB - Energy density & Modulation: In view of the wide bandwidth over which the DS UWB transmissions are spread, the actual energy density is exceedingly low. In fact, many of the transmissions themselves are less that the unintentional or spurious radiation levels from a typical PC. Typically a DS UWB transmitter might transmit less than 75 nanowatts per Megahertz. When integrated over the total bandwidth of the transmission, it means that transmissions may only be around 0.25 milliowatts. This is very small when compared to 802.11 transmissions that may be between 25 and 100 mW, or Bluetooth that may be anywhere between 1 mW and 1 W.
6.5 This very low spectral density means that the DS UWB transmissions do not cause harmful interference to other radio transmissions using traditional carrier based techniques and operating in the existing bands. Even in the bands that are likely to be more sensitive to interference such as the Global Positioning System (GPS), it is possible to reduce the UWB transmission power density levels even further to ensure that there is no noticeable interference. However as GPS and other satellite based navigational systems operate on very low received powers, UWB transmissions should not cover the bands.

6.6 Although DS UWB, direct sequence ultra wideband is a new technology operating using a totally different approach to the traditional carrier based transmissions that are normally used today, UWB with its carrier free technology offers the possibility of very high data rate transmissions using very low power. As such it is a technology that cannot be ignored, and one which will certainly take a significant section of the market.

7.0 **Multiband OFDM UWB:**

7.1 Multi Band OFDM UWB is a form of ultra wideband technology that differs in approach to the impulse, or direct sequence form of ultra wideband.

7.2 MB-OFDM UWB transmits data simultaneously over multiple carriers spaced apart at precise frequencies. Fast Fourier Transform algorithms provide nearly 100 percent efficiency in capturing energy in a multi-path environment, while only slightly increasing transmitter complexity. Beneficial attributes of MB-OFDM include high spectral flexibility and resiliency to RF interference and multi-path effects.

7.3 Although a wide band of frequencies could be used from a theoretical viewpoint, certain practical considerations limit the frequencies that are normally used for MB-OFDM UWB. Based on existing CMOS technology geometries, use of the spectrum from 3.1GHz to 4.8GHz is considered optimal for initial deployments. Limiting the upper bound simplifies the design of the radio and analogue front end circuitry as well as reducing interference with other services. Additionally the frequency band from 3.1 GHz to 4.8 GHz is sufficient for three sub-bands of 500 MHz when using MB OFDM UWB.

7.4 **Development of ultra wide band technology:** Just as many wireless technologies seem to be moving into high volume production and becoming established a new technology has hit the scene and is
threatening to turn the industry upside down. Known as Ultra Wide Band (UWB) this new technology has much to offer both in the performance and data rates as well as the wide number of application in which it can be used. Currently ultra wideband (UWB) technology has been proposed for or is being used in applications from radar and sensing applications right through to high band width communications. Furthermore ultra wide band, UWB can be used in both commercial and military applications.

7.5 Unlike most other wireless technologies in use today, ultra wideband (UWB) employs a totally different method of transmission. Rather than using a specified frequency with a carrier, the technique that is used by traditional transmissions, UWB uses what may be termed "time domain" electromagnetics. In other words UWB uses pulses that spread out over a wide bandwidth, rather than transmissions that are confined within a given channel.

7.6 It is the fact that UWB uses a different approach to wireless or radio transmissions is part of the reason UWB development may appear to be slow. With wireless transmissions using traditional techniques filling the airwaves, care has to be taken when establishing UWB, that interference does not result, and that whatever legislation is introduced, does not have to be changed later.

8.0 Applications for ultra wide band technology:

8.1 There is a wide number of applications that UWB technology can be used for. They range from data and voice communications through to radar and tagging. With the growing number of way in which wireless technology can be used, the list is likely to grow.

8.2 Although much of the hype about ultra wideband UWB has been associated with commercial applications, the technology is equally suited to military applications. One of the advantages is that with the pulses being spread over a wide spectrum they can be difficult to detect. This makes them ideal for covert communications.

Commercial:
- High speed LAN / WAN (>20 Mbps)
- Avoidance radar
- Altimeter (aviation)
- Tags for intelligent transport systems
- Intrusion detection
- Geolocation
Military:
- Radar
- Covert communications
- Intrusion detection
- Precision geo-location
- Data links

8.3 With the growing level of wireless communications, ultra wide band UWB offers significant advantages in many areas. One of the main attractions for WAN / LAN applications is the very high data rates that can be supported. With computer technology requiring ever increasing amounts of data to be transported, it is likely that standards such as 802.11 and others may not be able to support the data speeds required in some applications. It is in overcoming this problem where UWB may well become a major technology of the future.

9.0 Spectrum Provision in India:
The National Frequency Allocation Plan 2011 (NFAP-2011) has the following provision for UWB:
“Use of Ultra Wide Band (UWB) equipment may be considered in the frequency band 6.0 – 7.25 GHz with maximum EIRP density of -41 dBm/MHz in any 1 MHz bandwidth with maximum 500 MHz on non exclusive and non protection basis.”

10.0 Conclusion:
10.1 UWB provides an interesting new technology for short-range ultra-high speed communications. It supports a bit rate greater than 100 Mbps within a 10-meter radius for wireless personal area communications. The advantages of UWB include low-power transmission, robustness for multi-path fading and low power dissipation. The low power transmission of the UWB is the key characteristic that might allow it to coexist with other wireless technologies. However, there are still challenges to surmount before this technology performs up to its full potential.

10.2 UWB, ultra wideband technology is still in its infancy. Despite this it is being recognised as a technology with a huge capability and as such it is being adopted in many new areas. Many silicon manufacturers have already developed solutions which are being demonstrated, and more are being developed. Accordingly this new technology shows a significant degree of promise and should be a major force in the wireless industry in years to come. Which flavour of UWB, ultra wideband technology is the more widely used, and the areas in which they are adopted remains to be seen.