7

High-Speed Wireless Personal Area Networks: An Application of UWB Technologies

H. K. Lau
The Open University of Hong Kong
Hong Kong

1. Introduction

Recently, a large number of wireless networks are being developed and deployed in the market. According to the communication range, wireless networks can be classified into wireless wide area networks (WWANs), wireless metropolitan area networks (WMANs), wireless local area networks (WLANs), wireless personal area networks (WPANs), and wireless body area networks (WBANs). With the advances in wireless technologies, latest generation of WPANs can provide a data rate of hundreds (or even thousands) of Mbps at a distance of less than 10 meters.

Ultra-wideband (UWB) is an emerging technology that offers distinct advantages, e.g. high bandwidth and small communication ranges, for WPAN applications (Park & Rappaport, 2007; Chong et al., 2006; Fontana, 2004; Intel, 2004; Porcino & Hirt, 2003). One of the 'killer' applications of high-speed WPAN is wireless video area network (WVAN) that offers wireless transmission of high-definition videos (several Gbps) within a small communication distance (Singh et al., 2008; Wirelesshd 2009; Whdi 2009).

This chapter provides a comprehensive summary on the latest development and standardization progress of high-speed WPANs. There are seven sections in this chapter. The first section describes the background of WPANs and introduces the IEEE networking standards for WPAN. The second section discusses characteristics of UWB signals and explains why they are particularly suitable for high-speed WPAN applications. The third section discusses technical challenges and standardization issues. The fourth section reports on the latest development of high-speed WPANs. Standards or systems to be discussed in this section include Certified Wireless USB (WUSB), Bluetooth, TransferJet, WirelessHD, Wireless Home Digital Interface (WHDI), Wireless Gigabit (WiGig), and ECMA-387. The fifth section discusses possible research directions of high-speed WPANs. The sixth and the seventh sections are conclusion and references.

1.1 Background

According to the communication range, wireless networks can be classified into WWANs (e.g. GSM and UMTS), WMANs (e.g. IEEE 802.16), WLANs (e.g. IEEE 802.11a/b/g/n), WPANs (e.g. IEEE 802.15 TG1), and WBANs (e.g. IEEE 802.15 TG6). Among these networks, WLANs have received much attention and achieved great success in recently years. The IEEE 802.11a/b/g/n is now the most popular wireless standard for home networking, small office, and even public Internet access. Table 1 summarizes basic characteristics and Fig. 1 shows the range against peak data rate of various wireless networks.

Classification	Communication range	Examples	Current major applications
WWAN	> 10 km	GSM, UMTS	Mobile Internet access
WMAN	<10 km	IEEE 802.16	Broadband Internet access
WLAN	< 100 m	IEEE 802.11a/b/g/n	Internet access, file sharing
WPAN	< 10 m	IEEE 802.15 TG1	File sharing, headset
WBAN	<1 m	IEEE 802.15 TG6	Body senor network

Table 1. Basic characteristics of wireless networks

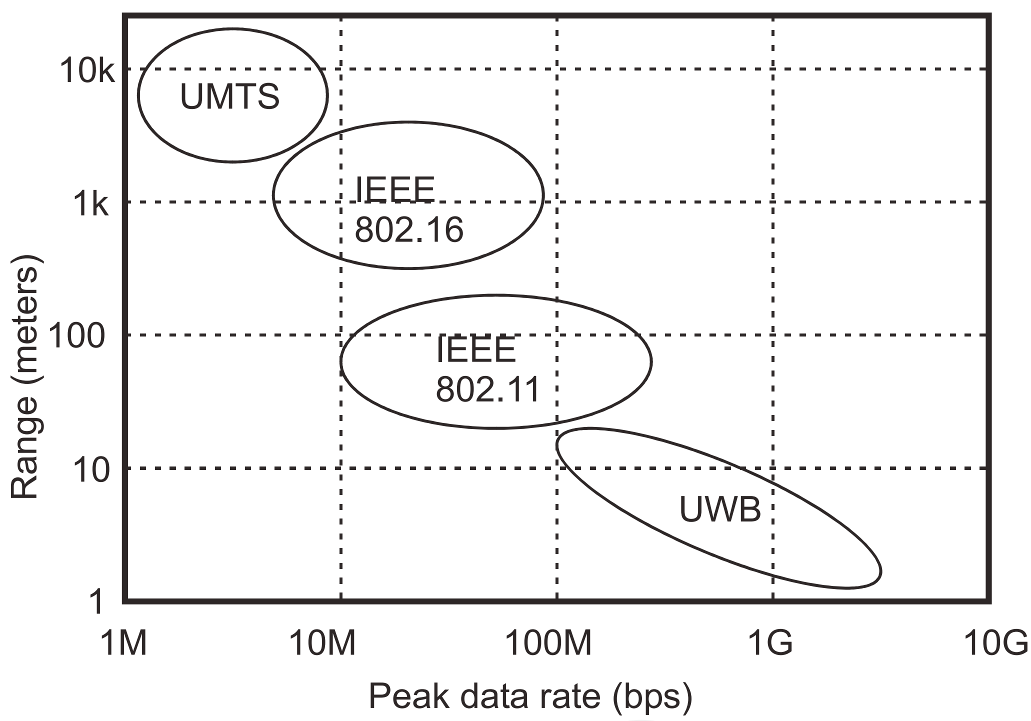


Fig. 1. Communication range against data rate

Recently, high-speed (hundreds of Mbps or several Gbps) WPANs have also received much attention because many innovative ideas and applications (e.g. seamless networking capabilities and HD video streaming) are now becoming a reality and corresponding products are now available in the market. Customer's desires to eliminate cables or complicated connections associated with HDTVs, personal computers or other multimedia systems are not dreams anymore. Obviously, market demands are the major driving force for fast wireless connectivity, especially in WPANs.

1.2 IEEE networking standards for WPAN

Within the IEEE 802 LAN/MAN Standards Committee, the IEEE 802.15 WGs (Working Groups) are responsible for WPAN. The IEEE 802.15.1 (TG1) has derived a WPAN standard based on the Bluetooth v1.1 specifications; while the IEEE 802.15.2 (TG2) has developed a 'Recommended Practices' to facilitate coexistence of WPANs and WLANs. The IEEE

802.15.3 (TG3) and the IEEE 802.15.4 (TG4) are responsible for high and low data rate WPAN, respectively. The IEEE 802.15.5 (TG5) and IEEE 802.15.6 (TG6) focus on mesh networking and WBANs, respectively. The IEEE 802.15.7 (TG7) and IEEE 802.15 IG THZ (IG THZ) are exploring visible light and terahertz communications, respectively. Table 2 summarizes the functions of various TGs in the IEEE 802.15 (IEEE 2011a).

Task group	**Functions/Descriptions**
TG1	*Bluetooth v1.1 specifications*
TG2	*Coexistence of WPANs and WLANs*
TG3	*High rate WPANs*
TG4	*Low rate WPANs*
TG5	*Mesh networking*
TG6	*Wireless body area networks*
TG7	*Visible light communications*
IG THZ	*Terahertz communications*

Table 2. IEEE 802.15 Working groups

Within the IEEE 802.15.3 (TG3), the IEEE 802.15.3a (TG3a) is responsible for WPAN High Rate Alternative PHY. Unfortunately, due to the deadlock between the two available UWB technologies (namely direct sequence UWB (DS UWB) and multiband orthogonal frequency-division multiplexing UWB (MB-OFDM UWB)), the IEEE 802.15.3a (TG3a) was officially disbanded in 2006. The IEEE 802.15.3b (TG3b) aimed to provide amendment and minor optimizations. The IEEE 802.15.3c (TG3c) has developed a high-speed (> 1Gbps) millimeter-wave (57-64 GHz unlicensed band) based alternative PHY for the IEEE 802.15.3 Information about the IEEE 802.15.3 TG3 is summarized in Table 3 (IEEE 2011a).

Task group 3	**Functions/Descriptions**
Task group 3	*High Rate WPAN*
Task group 3a	*WPAN High Rate Alternative PHY (disbanded in 2006)*
Task group 3b	*MAC Amendment*
Task group 3c	*WPAN Millimeter Wave Alternative PHY*

Table 3. IEEE 802.15 Task Group 3 (TG3)

2. Characteristics and benefit of UWB signals

Before the 90's, UWB technologies were restricted to military applications only. In April 2002, the Federal Communications Commission (FCC) issued the first report and order (RAO) and allowed commercial applications of UWB technologies under strictly power emission limits (FCC 2002). According to FCC, UWB is a radio technology that offers a high bandwidth (> 500 MHz) at very low energy levels over a short communication range (< 10 meters).

2.1 UWB signals

UWB technology is very different from other narrowband and spread spectrum technologies. UWB uses an extremely wide band of spectrum to transmit data. According to the RAO from FCC (FCC 2002), UWB technology is not confined to a specific implementation. Instead, any wireless transmission scheme that occupies a bandwidth of more than 20% of a center frequency, or more than 500 MHz can be considered as UWB. Based on their fractional bandwidth, B_f, signals can be classified as narrowband, spread spectrum (or wideband) or UWB as illustrated in Fig. 2 and Table 4.

Two popular approaches to generate UWB signals are single band UWB (often referred as impulse UWB, direct sequence UWB or DS UWB) and multiband UWB (often referred as multiband orthogonal frequency division multiplexing UWB or MB-OFDM UWB). In single band UWB, the concept of impulse radio is adopted and pulses with very short duration (typically between 10 to 1000 picoseconds) that occupy a very wide bandwidth (hundreds of MHz to several GHz) are transmitted. Multiband UWB, on the other hand, divides the whole available UWB frequency spectrum into a number of smaller and non-overlap bands. MB-OFDM UWB signals are transmitted simultaneously over multiple carriers spaced in those non-overlap bands.

Although both approaches can be used to generate UWB signals, they offer different performance degradations. The effect of multipath (Rayleigh) fading on single band UWB is considered to be insignificant; while multiband UWB may suffer from larger performance degradation due to multipath fading. However in multiband UWB, it is possible to avoid the transmission in certain congested bands (e.g. the 5 GHz band currently used extensively in IEEE 802.11a/n or other cordless telephones).

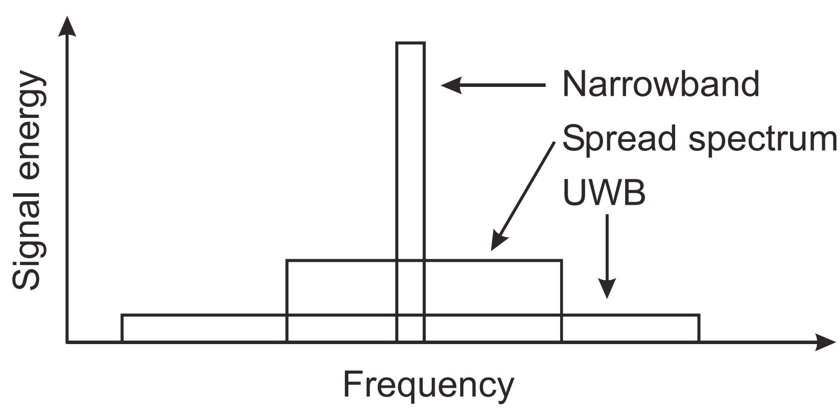


Fig. 2. Spectrum of narrowband, spread spectrum and UWB signals

Signal type	**Fractional bandwidth, B_f**
Narrowband	$B_f < 1\%$
Spread spectrum/wideband	$1\% < B_f < 20\%$
Ultra-wideband	$B_f > 20\%$

Table 4. Fractional bandwidth of narrowband, spread spectrum and UWB signals

2.2 Benefits of UWB technology for WPAN applications

Due to the wide bandwidth and high time resolution characteristics, UWB signals are much more robust to interferences and multipath fading distortion than other narrowband signals. In addition, the large channel capacity and wide bandwidth offer wireless transmission of real-time high quality multimedia files (even uncompressed HD videos in several Gbps). The extremely small transmit power and the very short communication distances result in a large number of other advantages for WPAN applications. Since UWB signals are operating below the noise floor, they provide better security, lower RF health hazards, and lower interference to other systems (which allows the coexistence with current narrowband and wideband systems).

3. Standardization and challenges of UWB WPAN

Although UWB technologies are attractive for WPAN applications, there are standardization and technical issues that need to be addressed.

3.1 Standardization issues

The IEEE 802.15.3a task group is responsible for the WPAN High Rate PHY standardization. The pathway of high-speed WPAN standardization is tough. Due to the deadlock between the two UWB implementations (DS UWB and MB-OFDM UWB), the IEEE 802.15.3a task group was officially disbanded in 2006. Since then, a de-facto standard for high-speed WPAN has emerged in the form of WiMedia Alliance's UWB (Wimedia 2009). However, the WiMedia Alliance announced in March 2009 that all specifications related WiMedia Alliance's UWB will be transferred to the Bluetooth Special Interest Group (SIG), Wireless USB Promoter Group and the USB Implementers Forum. Such a move has big impacts to the specifications and deployment of Wireless USB, Bluetooth and other WPAN systems. Details of Wireless USB and Bluetooth will be discussed later in this chapter.

The use of the FCC approved UWB band (3.1 to 10.6 GHz) avoids the crowded 2.4 GHz band and reduces interferences from Bluetooth, Wi-Fi, DECT phone,…., etc. Currently, the 3.1 to 10.6 GHz band is relatively free for unlicensed used of UWB. As a result, systems that are operating in this UWB band can provide a much larger bandwidth. Fig. 3 shows the worldwide (updated 1-20-1009) spectrum allocation in the 3.1 to 10.6 GHz band (Wimedia 2009). In addition to IEEE 802.15.3a, the IEEE 802.15.3c is a task group which is responsible for the standardization of WPAN millimeter wave alternative PHY. Brief description on millimeter wave PHY will be given later in this chapter.

Although the standardization of UWB technology faced quite a lot of difficulties (including Intel has stopped the development of UWB, missing of UWB technology in Bluetooth 3.0/4.0, keen competition from other WPANs operating in the 60 GHz unlicensed band, …, etc), UWB has been proved to be an effective technology for short range high speed data transmission between devices.

3.2 Challenges

3.2.1 Pulse shaper design

Since the bandwidth of UWB signals is very large and UWB signals are operated as an overlay system, the coexistence of UWB with other narrowband systems must be carefully investigated. Intensive studies are required on three major aspects – (i) interference from UWB systems to other narrowband systems, (ii) interference from other narrowband systems to UWB systems, and (iii) interference from UWB systems to other UWB systems that are operating in the same frequency band. To address this issue, strictly narrowband interference control and accurate out-of-band filter design are required. The FCC emission limits for both outdoor and indoor operations of UWB are summarized in Table 5 (FCC 2002).

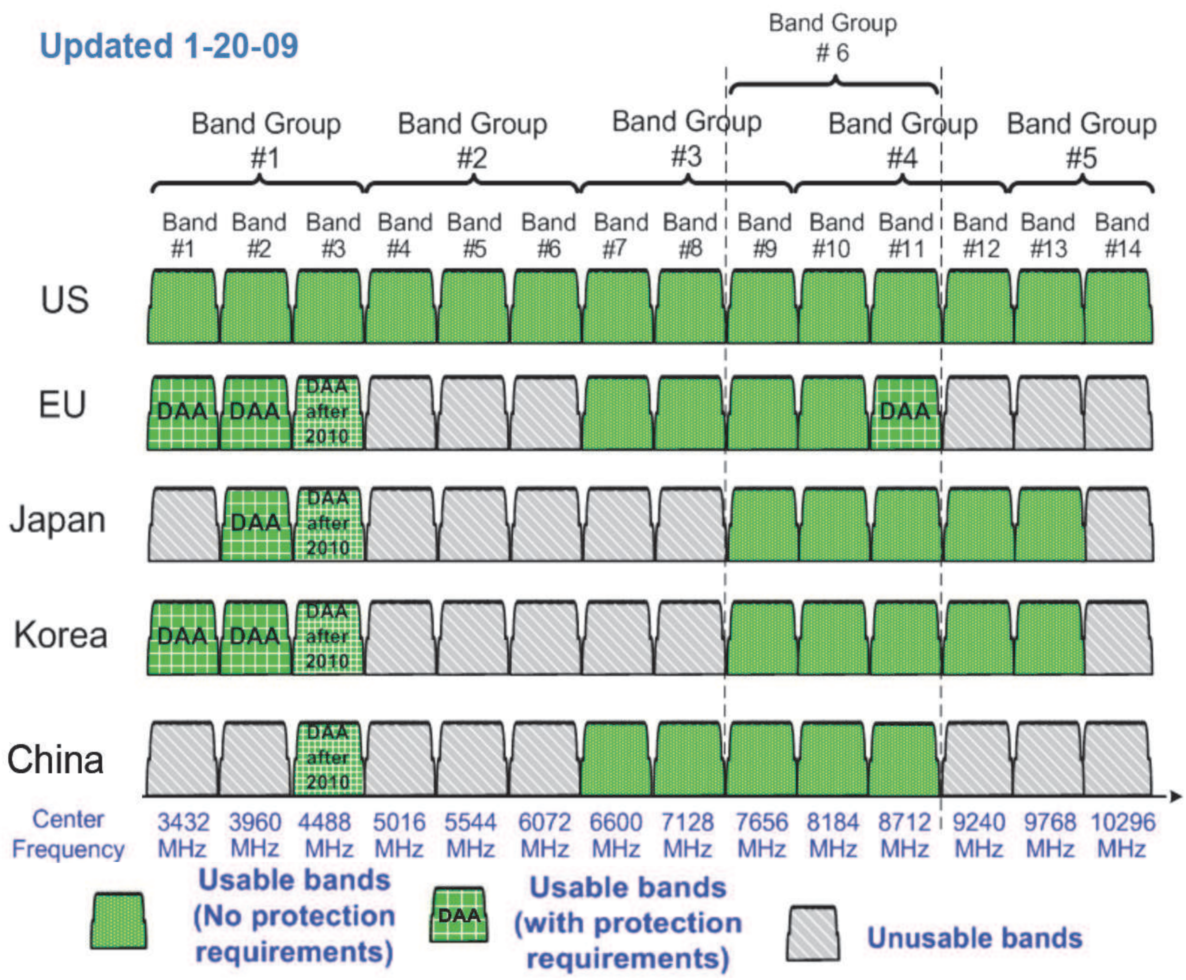


Fig. 3. Spectrum allocation in the 3.1 to 10.6 GHz band (Wimedia 2009)

	Frequency range (MHz)					
	960-1610	1610-1990	1990-3100	3100-10600	Above 10600	1164-1240 1559-1610
Indoor UWB (EIRP)	-75.3 dBm	-53.3 dBm	-51.3 dBm	-41.3 dBm	-51.3 dBm	-85.3 dBm
Outdoor UWB (EIRP)	-75.3 dBm	-63.3 dBm	-61.3 dBm	-41.3 dBm	-61.3 dBm	-85.3 dBm

Table 5. The FCC emission limits for UWB

3.2.2 System design

When MB-OFDM UWB is used (e.g. WiMedia Alliance's UWB), the total transmission power of a UWB signal is distributed over many multipath components. These components are propagating differently and are suffering from different frequency selective fading distortions. To effectively eliminate the effect of multipath fading, accurate channel estimation and synchronization are essential. The choice of modulation techniques for UWB also affects transmission and reception power, data rate and bit error rate performance.

Popular modulation techniques for UWB include pulse position modulation (PPM) and phase shift keying (PSK). Last but not least, effects of multiple access interference (MAI) on system performance must also be investigated.

3.2.3 Wideband RF design

Unobtrusive antennas that can operate effectively under varying propagation conditions are expected in all commercial UWB systems. Due to the nature of UWB signals (very large bandwidth), the design and implementation of wideband RF systems (e.g. antenna and amplifier) are very challenging. Issues related to RF design include impedance matching, radiation patterns, power efficiency, cost and size, …, etc. Recently, the use of multi-input and multi-output (MIMO) in low-cost consumer products (e.g. the IEEE 802.11n Wi-Fi standard) has received much attention. The use of MIMO technology in UWB may further increase the data rate and enhance the interference rejection capability.

3.2.4 Power consumption and battery life

Low power consumption and long battery life are important parameters for all portable and battery-operated devices (especially for consumer products). However, hardware and software complexity play important roles in power consumption. Complex coding and modulation techniques require fast signal processing power, which may increase the power consumption of the devices. In spite of this, UWB-enabled devices can still achieve the lowest power consumption (per Mbps). Table 6 compares the power characteristics of IEEE 802.11g, IEEE 802.11n and WiMedia Alliance's UWB devices (Aiello 2008).

Technology	Range	Throughput	Power
IEEE 802.11g	> 50 m	20 – 30 Mbps	15-20 mW/Mbps
IEEE 802.11n	> 50 m	> 100 Mbps	6-7 mW/Mbps
WiMedia Alliance's UWB	< 10m	> 100 Mbps	1 mW/Mbps

Table 6. Power characteristics of technologies

4. Latest development of high-speed WPANs

This section provides a comprehensive summary on the latest development of high-speed WPANs. Standards or systems reported in this section are (i) Certified Wireless USB (WUSB), (ii) Bluetooth, (iii) TransferJet, (iv) WirelessHD, (v) Wireless Home Digital Interface (WHDI), (vi) Wireless Gigabit Alliance (WiGig), and (vii) ECMA-387.

4.1 Certified Wireless USB (WUSB)

Universal Serial Bus (USB) was originally designed for personal computers, but now has become the most popular de facto standard in connecting peripherals or devices (e.g. digital cameras, scanners, external hard disks, …, etc.). Following the establishment of the Wireless USB Promoter Group in February 2004, the Certified Wireless USB (WUSB) 1.0 specification was released in May 2005. WUSB can be considered as a wireless implementation of USB and is designed to provide high-speed wireless connections between devices that achieving a data rate of 110 Mbps (up to 10 meters) and 480 Mbps (up to 3 meters). WUSB is backward compatible with wired USB. Although the Wireless USB Promoter Group prefers to use the term 'Certified Wireless USB' to distinguish other wireless implementation of USB, Certified

Wireless USB is often referred as Wireless USB or WUSB. Commercial WUSB 1.0 products are available in the market since 2007. Table 7 summarizes the data rate of major USB standards (Wusb 2010).

<table>
<tr><th>USB specifications</th><th>Date of release</th><th>Maximum data rate</th></tr>
<tr><td>USB 1.0</td><td>January 1996</td><td rowspan="2">1.5 Mbps (Low-speed)
12 Mbps (Full-speed)</td></tr>
<tr><td>USB 1.1</td><td>September 1998</td></tr>
<tr><td>USB 2.0 (Hi-Speed USB)</td><td>April 2000</td><td>480 Mbps</td></tr>
<tr><td>USB 3.0 (Super-Speed USB)</td><td>November 2008</td><td>5 Gbps</td></tr>
<tr><td>Wireless USB 1.0</td><td>May 2005</td><td rowspan="2">480 Mbps (up to 2 meters)
110 Mbps (up to 10 meters)</td></tr>
<tr><td>Wireless USB 1.1</td><td>September 2010</td></tr>
</table>

Table 7. Major USB standards

WUSB is based on the WiMedia Alliance's MB-OFDM UWB radio platform, and is designed to operate in the 3.1 to 10.6 GHz frequency range. The WUSB specification 1.1 released in September 2010 has extended the UWB upper band support for frequencies of 6 GHz and above (Wusb 2010).

4.2 Bluetooth

The Bluetooth v1.0 was announced by the Bluetooth Special Interest Group (SIG) in May 1998. Bluetooth is designed to operate in the 2.4 GHz ISM band, rather than the UWB band (3.1 and 10.6 GHz). Both Bluetooth v1.1 and v1.2 were ratified as IEEE 802.15.1-2002 and IEEE 802.15.1-2005, respectively. The Bluetooth v2.1 adopted in 2007 provides a data rate of 2.1 Mbps. Table 8 summarizes the adopted Bluetooth core specifications (Bluetooth 2010).

<table>
<tr><th>Bluetooth specifications</th><th>Date of release</th><th>Data rate</th></tr>
<tr><td>Bluetooth v1.0a</td><td>26 July 1999</td><td rowspan="4">721.2 kbps</td></tr>
<tr><td>Bluetooth v1.0B</td><td>01 December 1999</td></tr>
<tr><td>Bluetooth v1.1 (IEEE 802.15.1-2002)</td><td>22 February 2001</td></tr>
<tr><td>Bluetooth v1.2 (IEEE 802.15.1-2005)</td><td>05 November 2003</td></tr>
<tr><td>Bluetooth v2.0 + EDR</td><td>04 November 2004</td><td rowspan="2">2.1 Mbps</td></tr>
<tr><td>Bluetooth v 2.1 + EDR</td><td>26 July 2007</td></tr>
<tr><td>Bluetooth v3.0 + HS</td><td>21 April 2009</td><td rowspan="2">24 Mbps</td></tr>
<tr><td>Bluetooth v4.0</td><td>30 June 2010</td></tr>
</table>

Table 8. Adopted Bluetooth core specifications

In March 2006, the Bluetooth SIG announced its selection of the WiMedia Alliance's UWB technology for integration with their Bluetooth wireless technology. The most significant improvement in the originally planned Bluetooth v3.0 specification was the adoption of the WiMedia Alliance's MB-OFDM UWB technology that provides a maximum data rate of 480 Mbps. Unfortunately, UWB technology is missing in the final 3.0 specification that was released in April 2009 due to the transfer of WiMedia's technology to other SIGs. The final Bluetooth v3.0 provides a maximum data rate of 24 Mbps through the use of a new High Speed (HS) technology. In June 2010, the Bluetooth SIG also released the Bluetooth v4.0 specification. Two forms of wireless technology systems are adopted in Bluetooth v4.0, namely Basic Rate (BR) and Low Energy (LE). The BR system includes optional Enhanced

Data Rate (EDR) Alternate MAC PHY layer extensions. The BR system provides three different data rates of 721.2 kbps (BR), 2.1 Mbps (EDR) and up to 24 Mbps (High Speed, HS). The HS technology provides better power optimization, better security, enhanced power control and lower latency rate. The LE system is designed for products that require lower power consumption, lower complexity, lower data rates, lower duty cycles and lower cost than BR/EDR. According to the maximum power, Bluetooth devices are divided into three different classes as illustrated in Table 9 (Bluetooth 2010).

Power class	Maximum power	Communication range
1	100 mw (20 dBm)	~ 100 meters
2	2.5 mW (4 dBm)	~ 10 meters
3	1 mW (0 dBm)	~ 1 meter

Table 9. Power classes of Bluetooth devices

4.3 TransferJet

TransferJet is a close-proximity technology developed by Sony and was first presented at the 2008 Consumer Electronics show in Las Vegas (Transferjet 2008). The TransferJet technology is very different from other WPAN technologies that employ electro-magnetic radiation field (e.g. WiMedia Alliance’s UWB). TransferJet, on the other hand, is designed to work with longitudinal electric induction fields (Transferjet 2010). It is operating in the UWB band and can achieve a data rate of 560 Mbps (up to 3 cm) with a transmission power of under -70 dBm/MHz. Based on channel conditions, TransferJet is able to determine and adopt the most appropriate data rate for transmission by itself. Sony has also developed a new antenna element for TransferJet called ‘TransferJet Coupler’ that consists of a coupling electrode, a resonant stub, and ground. Since TransferJet is designed to operate in the near field, which is a non-polarized field, devices are not required to be precisely oriented to initialize communications (Transferjet 2008). Data transfer can be initialized simply by touching the transmitting device to the receiving device.

There are a number of advantages of very short communication distance (within few centimeters) in TransferJet. Firstly, the very short communication distance virtually eliminates the effects of multipath fading and shadowing that commonly exist in other WPANs. It also reduces the interference to other systems and the chance for unauthorized access to TransferJet enabled devices. In addition, the small power requirement can significantly prolong the battery life.

The TransferJet Consortium was established in July 2008 by a group of international companies. The main duties of the consortium include the development of the specification and compliance testing process, management of the certification program and promotion of the TransferJet technology. As of April 2010, there are 18 Consortium members, including Sony, Panasonic, Sharp, and Toshiba. Table 10 summarizes key specifications of TransferJet (Transferjet 2010).

Based on the TransferJet specification, the Technical Committee 50 (TC50) of European Computer Manufacturers Association (Ecma) International has completed the First Edition of its standard titled “Close Proximity Electric Induction Wireless Communications” and is expected to be formally approved by the Ecma General Assembly in June 2011 (Transferjet 2011).

Items	Details
Carrier Center Frequency	4.48 GHz
Transmission Power	At or below -70 dBm/MHz (average)
Transmission Rate	560 Mbps (max) / 375 Mbps (effective throughput)
Communication Distance	A few centimeters (3 cm nominal)
Topology	One-to-one, Point-to-point
Antenna Element	Electric induction field coupler
Modulation	$\pi/2$ shift BPSK + DSSS
FEC	½ Convolutional code + Reed Solomon code

Table 10. TransferJet specifications

4.4 WirelessHD

The WirelessHD specification is one of the industrial standards which are specially designed for wireless transmission of HD videos. A relatively new terminology – wireless video area network (WVAN) – is now commonly used for this special type of WPAN application. The WirelessHD specification v1.0 that provides a data rate of about 4 Gbps was finalized in January 2008 and was the first de facto standard for 60 GHz millimeter wave frequency band applications based on the IEEE 802.15.3c specification (Wirelesshd 2009).

In May 2010, the WirelessHD Consortium released the v1.1 specification that further boosts the data rate to 10 - 28 Gbps and support HD resolution four times beyond that of 1080p. It also defines common 3D formats and resolutions for WirelessHD-enabled devices. Commercial WirelessHD-enabled products, including notebook PCs and TVs, are now available in the market. Table 11 shows the applications supported by WirelessHD v1.1 (Wirelesshd 2010).

Application	Data rate	Target latency
Uncompressed QHD 2560×1440p, 60 Hz, 36 bit color	8.0 Gbps	2 ms
Uncompressed 720p frame sequential 3D A/V 1280×1440p, 60 Hz, 36 bit color	4.0 Gbps	2 ms
Uncompressed 1080p, 120 Hz, 30 bit color	7.5 Gbps	2 ms
Uncompressed 1080p A/V	3.0 Gbps	2 ms
Uncompressed 1080i A/V	1.5 Gbps	2 ms
Uncompressed 720p A/V	1.4Gbps	2 ms
Uncompressed 480p A/V	0.5Gbps	2 ms
Uncompressed 7.1 surround sound audio	40 Mbps	2 ms
Compressed 1080p A/V	20-40 Mbps	2 ms
Uncompressed 5.1 surround sound audio	20 Mbps	2 ms
Compressed 5.1 surround sound audio	1.5 Mbps	2 ms
File transfer	>1.0 Gbps	N/A

Table 11. Applications supported by WirelessHD v1.1 (Wirelesshd 2010)

According to WirelessHD v1.1, the WVAN consists of one *Coordinator* and zero or more *Stations*. The *Coordinator* can be a device that is sink for audio or video data (e.g. a display). A *Station* is a device that has media that it can source and/or sink or has data to exchange. An example of WVAN under WirelessHD is illustrated in Fig. 4 (Wirelesshd 2010).

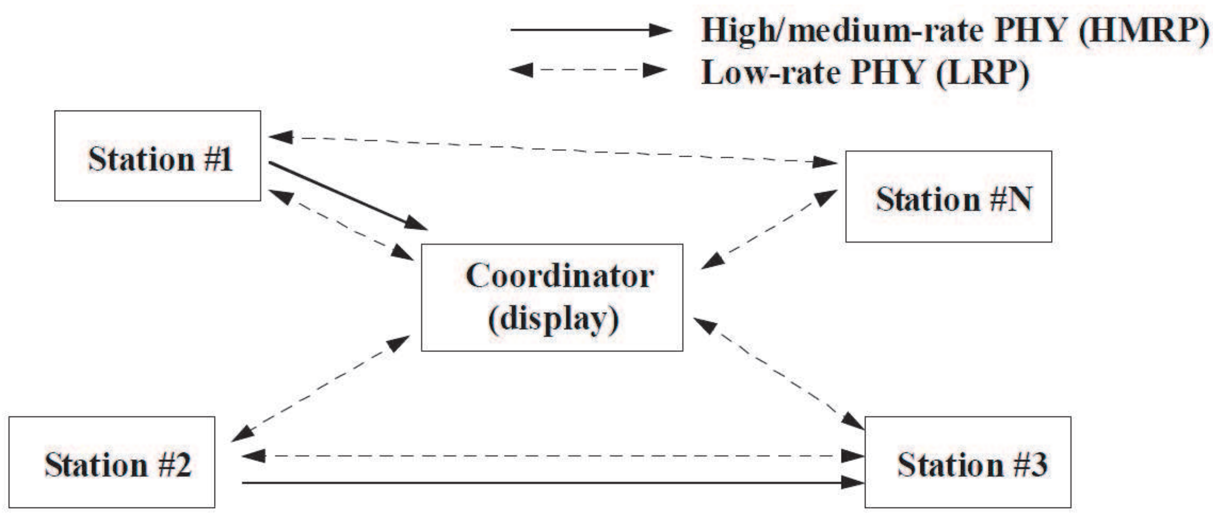


Fig. 4. An example of WirelessHD WVAN (Wirelesshd 2010)

The High and Medium Rate PHY (HRP and MRP) are highly directional and are mainly used for unicast connections (several Gbps). The MRP supports multiple video resolutions with more than one data rates. The Low Rate PHY (LRP) are bidirectional links and can be used for both unicast and broadcast connections (several Mbps). Similar to MRP, the LRP also supports more than one data rates. In a single stream using OFDM modulation with beamform mode, the HRP can achieve a data rate of greater than 7 Gbps. When combined with spatial multiplexing, the HRP may further boost the data rate to greater than 28 Gbps. The transmit masks of HRP and LRP are shown in Figs. 5 and 6, respectively.

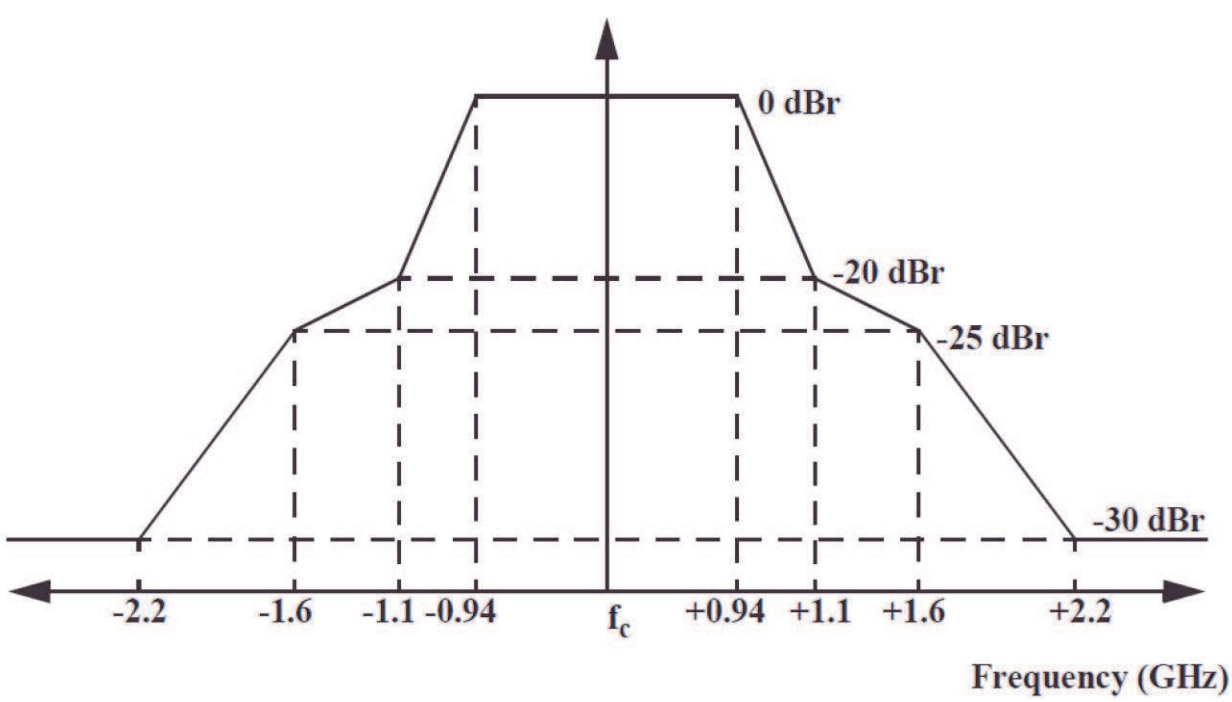


Fig. 5. The HRP transmit mask (Wirelesshd 2010).

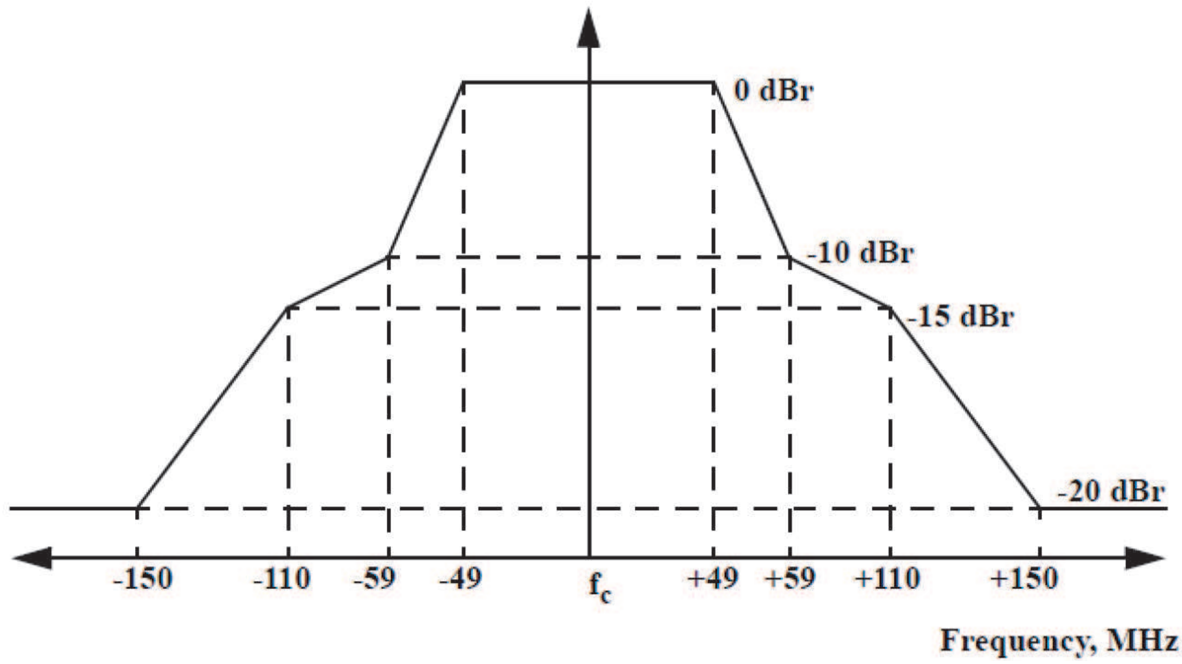


Fig. 6. The LRP transmit mask (Wirelesshd 2010)

Currently, the 57-64 GHz band is allocated in North America and South Korea, the 59-66 GHz band is allocated in Japan and the 57-66 GHz band is allocated in the European Union. The current regulations in the 60 GHz band allow very high effective isotropic radiated power (EIRP) of greater than 10 W for reliable high bandwidth transmission. The use of the 60 GHz band seems to be a good solution to support bandwidth-hungry applications (e.g. uncompressed HD video transmission).

4.5 Wireless Home Digital Interface (WHDI)

Similar to WirelessHD, the Wireless Home Digital Interface (WHDI) is an industrial WVAN standard that offers video transmission (up to 3 Gbps) in the 5 GHz unlicensed band (Whdi 2009). The WHDI v1.0 was released in December 2009 and the communication distance is beyond 30 meters, through walls, and latency is less than one millisecond. Both HDCP revision 2.0 and digital content protection are supported by WHDI.

A multi-input multi-output (MIMO) 20 MHz/40MHz bandwidth channel over the 5 GHz band and the joint source-channel coding (JSCC) approach are used in WHDI (Whdi 2009). There are three major elements in WHDI's JSCC approach. Firstly, video processing and representation are prioritized according to their importance. Secondly, unequal error protection (UEP) is used to protect data with different importance levels. Thirdly, adaptive signal constellation is adopted. According to the report from WHDI, the use of JSCC improves the protection of important components and achieves a better utilization of the available channel capacity (Whdi 2009). Following the WHDI 3D specification update in June 2010, the WHDI v2.0 specification is targeted for release in the second quarter of 2011. Key features in WHDI v2.0 specification include (Whdi 2009):

- Full 3D support (HDMI 1.4a 3D modes, 1080p 60Hz × 2 3D format)
- Support four times the resolution of 1080p (4,096 × 2,160)
- Support WHDI-Wi-Fi integration and same channel co-existence
- Support mobile device integration through reduced power consumption and footprint

Beside WHDI, the IEEE 802.11ac is formed recently for standardization of high throughput WLAN near the 6 GHz band (IEEE 2011b).

4.6 Wireless Gigabit (WiGig) Alliance

The Wireless Gigabit (WiGig) Alliance was formed in May 2009 and aims to establish a unified specification for high-speed (several Gbps) wireless technologies in the 60 GHz band. The WiGig specification is based on the existing IEEE 802.11 standard and was contributed to the IEEE 802.11ad draft standard (Wigig 2011). In May 2010, WiGig Alliance and Wi-Fi Alliance established a cooperation agreement to share technology specifications for the development of certification programs.
Under the WiGig v1.0 specification, WiGig devices with tri-band (2.4 GHz, 5 GHz and 60 GHz) radios are able to seamlessly integrate into existing 2.4 GHz and 5 GHz Wi-Fi networks (e.g. IEEE 802.11a/b/g/n). In addition to uncompressed video transmission, multi Gbps data transfer (e.g. wireless docking station and file transfers between computers/devices) are supported by WiGig. The following key elements are included in the v1.0 specification (Wigig 2011):

- Supports data transmission rates up to 7 Gbps
- Backward compatible with the IEEE 802.11 standard
- Protocol adaptation layers to support specific system interfaces
- Support for beam-forming
- Support for advanced security and power management

4.7 ECMA-387

Ecma International is a standards organization for information and communication systems. Ecma's Technical Committee 48 (TC48) is responsible for the development of standards and technical reports for high rate wireless communications. The ECMA-387 is a standard that specifies the High Rate PHY, MAC, and HDMI (PAL) for the 60 GHz band. The first edition of ECMA-387 has been published by the ISO and IEC as ISO/IEC 13156 in October 2009. Under ECMA-387 2nd edition (revision 2), there are two types of devices, namely Type A and Type B devices (Ecma 2010). Type A devices are equipped with high gain trainable antennas that enable video streaming and other high data rate (0.4 Gbps to 6.4 Gbps) applications within 10 meters communication range under LOS or NLOS environments. Type A devices also support UEP, open-loop and closed-loop antenna training protocols, and transmit switch diversity protocols. Type B devices, on the other hand, are low cost and low power implementation offer a basic data rate of 0.8 Gbps (which can be extended to 3.2 Gbps) within 1-3 meters communication range under LOS environments.

5. Possible research directions

There is a strong customer desire to have a small, portable, cheap, secured and easy to use device that provides wireless transmission of bandwidth-hungry signals. Commercial millimeter-wave transmission technology is a new wireless communications concept that aims to provide multi Gbps transmission in the 60 GHz unlicensed band. In addition to WirelessHD, WiGig, and ECMA-387 that are highlighted in previous section, the IEEE 802.15.3c and the IEEE 802.11ad groups are formed recently to define standardized modifications to the IEEE 802.11 that enable 60 GHz operation (IEEE 2011c).

Apart from commercial millimeter-wave transmission technology, UWB-over-fiber has received much attention recently. The communication range of UWB signal can be significantly increased by connecting the antenna to a fiber, i.e. UWB-over-fiber (Pan & Yan 2010; Guillory et al. 2010).
Other researches (e.g. medical imaging, radar imaging, vehicular radar systems, wireless sensor networks, UWB-based WBANs) are carried out in the areas of high-speed WPANs or UWB technologies. For example the NDSsi ZeroWire technology is a UWB-based medical grade wireless video system that delivers real-time full HD surgical video at a maximum data rate of 480 Mbps within 10 meters (Ayar 2010). Besides imaging applications, UWB technologies are widely used in wireless sensors networks (WSN) and wireless body area networks (Xia et al., 2011). Since UWB technologies can also provide accurate ranging capability and excellent time resolution, other emerging applications are through-wall surveillance radar and vehicular radar systems.

6. Conclusion

Wireless networking products are enjoying great success and high-speed WPANs are undergoing rapid development. Innovative applications like short-range streaming of high-definition video are now possible. This chapter provides a comprehensive summary on the latest development and standardization progress of high-speed WPANs. Although the IEEE 802.15.3a task group was disbanded in 2006, research and development activities on UWB-based WPANs are still carried on. However, approval from regulatory organizations plays an important role in the success of WPANs. The complex mix of standards and technologies introduces barriers in the standardization of high-speed WPANs. When UWB was first introduced, the proposed data rates were attractive (hundreds of Mbps). However, since some regional regulators had posted restrictions on use of UWB in the 3.1 to 10 GHz band, products took a long time to become available in the market. When commercial UWB products are available (e.g. WUSB in mid 2007), their data rates were no longer significantly higher than other completing technologies, like IEEE 802.11n. Obviously, market demands are the major driving force for fast wireless connectivity. High-speed wireless networking would be an important direction of research in telecommunications.

7. References

Aiello, R (2008). Using WiMedia UWB technology to enable future-generation WPANs. EE Times, Visited in July 2011, Available from: http://www.eetimes.com/design/microwave-rf-design/4012949/Using-WiMedia-UWB-technology-to-enable-future-generation-WPANs

Ayar, E. (2010). UWB Wireless Video Transmission Technology in Medical Applications. August 2010, Visited in July 2011, Available from: http://www.ndssi.com/products/surgical/visualization/zerowire/index.php

Bluetooth (2010). Adopted Bluetooth Core Specifications. Visited in July 2011, Available from: https://www.bluetooth.org/Technical/Specifications/adopted.htm

Chong, C.; F. Watanabe F.; & Inamura H. (2006). Potential of UWB Technology for the Next Generation Wireless Communications. *Proceedings of 2006 IEEE Ninth International Symposium on Spread Spectrum Techniques and Applications*, Brazil, August 2006, pp. 422-9.

Ecma (2010). Standard ECMA-387 High Rate 60 GHz PHY, MAC and HDMI PAL: 2nd edition. December 2010, Visited in July 2011, Available from: http://www.ecma-international.org/publications/standards/Ecma-387.htm

FCC (2002). First Report and Order: Revision of Part 15 of the Commissions Rules Regarding Ultra-Wideband Transmission Systems. Visited in July 2011, Available from: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-02-48A1.pdf

Fontana, R. (2004). Recent System Applications of Short-pulse Ultra-wideband (UWB) Technology. *IEEE Transactions on Microwave Theory and Techniques*. Vol. 52, Issue 9, September 2004, pp. 2087-2104.

Guillory, J. et al. (2010). Radio-Over-Fiber Architectures. *IEEE Vehicular Technology Magazine*. Vol 5, Issue 3, September 2010, pp 30-38

IEEE (2011a). Current status of IEEE 802.15 Working Group for WPAN. Visited in July 2011, Available from: http://ieee802.org/15/index.html

IEEE (2011b). Status of Project IEEE 802.11ac. Visited in July 2011, Available from: http://www.ieee802.org/11/Reports/tgac_update.htm

IEEE (2011c). Status of Project IEEE 802.11ad. Visited in July 2011, Available from: http://www.ieee802.org/11/Reports/tgad_update.htm

Intel (2004). Ultra-wideband (UWB) Technology: Enabling high-speed wireless personal area networks. Visited in July 2011, Available from: http://www.intel.com/technology/comms/uwb

Pan, S & Yao, J. (2010). Performance Evaluation of UWB Signal Transmission over Optical Fiber. *IEEE Jounral on Selected Areas in Communications*. Vol 28, Issue 6, August 2010, pp. 889-900

Park, C. & Rappaport, T. (2007). Short-Range Wireless Communications for Next-Generation Networks: UWB, 60 GHz Millimeter-Wave WPAN, and ZigBee. *IEEE Wireless Communications*, Vol. 14, Issue 4, August 2007, pp 70-78.

Porcino, D & Hirt, W (2003). Ultra-Wideband Radio Technology: Potential and Challenges Ahead. *IEEE Communications Magazine*, Vol. 41, Issue 7, July 2003, pp.66-74

Singh, H, et. al., (2008). A 60 GHz Wireless Network for Enabling Uncompressed Video Communication. *IEEE Communications Magazine*. Vol. 46, Issue 12, December 2008, pp. 71-78.

Transferjet (2008). Sony Develops New Close Proximity Wireless Transfer Technology "TransferJet". Visited in July 2011, Available from: http://www.sony.net/SonyInfo/News/Press/200801/08-002E/index.html

Transferjet (2010). TransferJet Overview: Concept and Technology Rev 1.1. February 2010. Visited in July 2011, Available from: http://www.transferjet.org/tj/transferjet_overview.pdf

Transferjet (2011). Ecma completes the First Edition of the TC50 specifications based on TransferJet. February 2011, Visited in July 2011, Available from http://www.transferjet.org/news/index.html

Whdi (2009). WHDI Technology. Visited in July 2011, Available from: http://www.whdi.org/

Wigig (2011). WiGig: Defining the Future of Multi-Gigabit Wireless Communications. July 2010, Visited in July 2011, Available from: http://wirelessgigabitalliance.org/specifications/

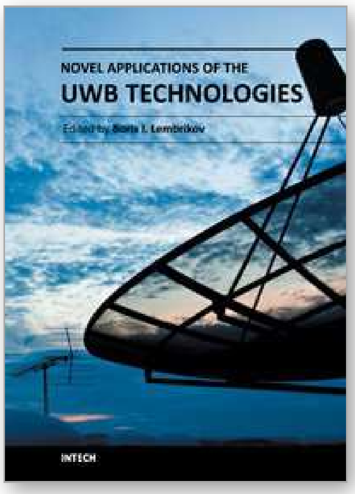
Wimedia (2009). Worldwide Regulatory Status. Visited in July 2011, Available from: http://www.wimedia.org/

Wirelesshd (2009). WirelessHD Next Generation Standard Now Available. Visited in July 2011, Available from: http://www.wirelesshd.org/category/news/

Wirelesshd (2010). WirelessHD Specification Version 1.1 Overview. May 2010, Visited in July 2011, Available from: http://www.wirelesshd.org/pdfs/WirelessHD-Specification-Overview-v1.1May2010.pdf

Wusb (2010). Wireless Universal Serial Bus Specification, Revision 1.1. Visited in July 2011, Available from: http://www.usb.org/developers/wusb/wusb1_1_20100910.zip

Xia, L; Redfield, S; & Chiang, P (2011). Experimental Characterization of a UWB Channel for Body Area Networks. EURASIP Journal on Wireless Communications and Networking. Vol 2011, Article ID 703239. Visited in July 2011, Available from: http://www.hindawi.com/journals/wcn/2011/703239/



Novel Applications of the UWB Technologies
Edited by Dr. Boris Lembrikov

ISBN 978-953-307-324-8
Hard cover, 440 pages
Publisher InTech
Published online 01, August, 2011
Published in print edition August, 2011

Ultra wideband (UWB) communication systems are characterized by high data rates, low cost, multipath immunity, and low power transmission. In 2002, the Federal Communication Commission (FCC) legalized low power UWB emission between 3.1 GHz and 10.6 GHz for indoor communication devices stimulating rapid development of UWB technologies and applications. The proposed book Novel Applications of the UWB Technologies consists of 5 parts and 20 chapters concerning the general problems of UWB communication systems, and novel UWB applications in personal area networks (PANs), medicine, radars and localization systems. The book will be interesting for engineers and researchers occupied in the field of UWB technology.