Ultrawideband Communications- An Idea Whose Time has Still Yet to Come?

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Ultrawideband Communications—An Idea Whose Time has Still Yet to Come?

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Abstract

This paper presents a critical analysis of ultrawideband (UWB) and considers the turbulent journey it has had from the Federal Communications Commission's bandwidth allocation in 2002 to today. It analyzes the standards, the standoffs, and the stalemate in standardization activities and investigates the past and present research and commercial activities in realizing the UWB dream. In this paper, statistical evidence is presented to depict UWB's changing fortunes and is utilized as an indicator of future prominence. This paper reviews some of the opinions and remarks from commentators and analyzes predictions that were made. Finally, it presents possible ways forward to reignite the high-data-rate UWB standardization pursuit.

Keywords: Ultrawideband (UWB); UWB radar; IEEE 802.15 standards; mobile communication; SHF communication; personal area networks (PANs); wireless sensor networks; microwave communication; UWB technology; high-definition television (HDTV)

1. Introduction

In the first few years after the Federal Communications Commission (FCC) allocated the ultrawideband (UWB) bandwidth [1], UWB was considered to be the future wireless

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solution in medicine [2, 3], homeland security [4, 5], process industry [6], road safety [7], landmine detection [8], and personal area networks (PANs) [9]. In 2004, Yang and Giannakis [10] declared that UWB was "*an idea whose time had come*".

People were focused on investigating all manner of facets of UWB to prepare the way for this new technology, including antenna design [11]; amplifiers [12]; optimal receiver design [13]; filter design [14]; propagation models for single and multiple antennas [15, 16]; wearable fabric antennas [17]; coexistence with other wireless technologies [18, 19]; the effects of humans in the radio environment [20]; wearable wireless technology, including on-body, off-body, and in-body [21–23] communications; pulse generation [24]; and even the terminology [25].

However, few of the promises of this technology have actually been realised; indeed, UWB has not become a household phrase in the same way that Bluetooth and Wi-Fi have. Failure to achieve IEEE standardization and the subsequent abandonment of the technological investment by much of the industry has rendered UWB an unfulfilled promise.

2. Overview of the Technology

UWB is a technology developed to transfer large amounts of data wirelessly over short distances (typically less than 10 m) and operates by transmitting signals over a very wide spectrum of frequencies [26]. The very low power spectral density determined by the FCC UWB spectral mask (see Figure 1) makes it ideal for short-range high-speed communications (e.g., PANs [27], body area networks [28], sensor networks [29], radar positioning [30], and machine-to-machine [31]). UWB benefits include low power, low cost, high data rates, multiple channels, simultaneous networking, the ability to carry information through obstacles that more limited bandwidths cannot, and also potentially lower complexity hardware design [32]. Due to its low transmit power, UWB can use the spectrum currently occupied by existing technologies without causing harmful interference [33].

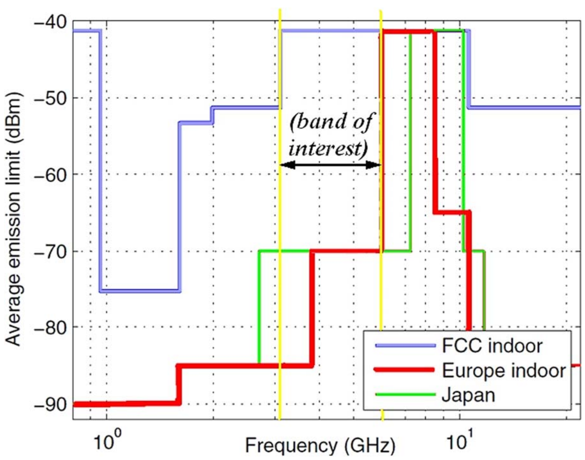

Figure 1. FCC, European, and Japanese UWB masks.

The FCC allocated 7500 MHz of spectrum for unlicensed use of UWB devices in the 3.1- to 10.6-GHz frequency band and defined a radio system to be a UWB system if it has a spectrum that occupies a bandwidth greater than 20% of the central frequency or an absolute bandwidth greater than 500 MHz [1, 34, 35]. Strict power and frequency limitations ensure the protection of other users of this spectral band [32, 36].

Figure 1 displays the equivalent isotropic radiated power levels (in dBm) with respect to frequency for a number of different UWB regulations from around the world. The FCC spectral graph for 15.519 is for the USA. In Europe, the European Commission's Radio Spectrum Committee approved the operation of UWB in late 2006. ETSI and Ofcom developed the standards for UWB for U.K. deployment. In the other areas of the world, countries are developing their own UWB regulations. For example, in August 2006, Japan approved their own UWB spectral mask.

Due to short pulse lengths, UWB transmissions are robust to multipath fading when using an appropriate receiver and are thus ideal for cluttered indoor environments [28]. The large bandwidth of UWB waveforms significantly increases the ability of the receiver to resolve the different reflections in the channel, as the system bandwidth is greater than the coherence bandwidth of the channel. UWB transmission rates are restricted by the root-mean-square delay spreading, leading to intersymbol interference [37], and also by large- and small-scale signal power variations [38].

3. Interest Waning

UWB radio has, for a number of years, been considered as a solution to an ever-increasing thirst for bandwidth and data rates [39]. UWB boasts low energy levels for short-range communications, shared spectrum with narrowband users, and large data rates and has shown promise as a solution technology for off-body computing [1].

However, an examination of technical catalogues and manufacturer's websites reveals a dearth of UWB or even UWB-enabled commercial devices. Indeed, a Google Shopping search returns mostly academic books on the topic, not consumer products. It is recognized that UWB conferences continue to attract academics from around the globe. At the time of writing, 15 841 results are returned for a "UWB" keyword search, and 19 905 results are returned for an "Ultra wideband" keyword search from published work from journals and conferences on IEEE Xplore dating from 2002 (when the UWB spectrum allocation was announced) until the present. If these are analyzed by year, it is clear to see that the number of published articles with UWB in the title increased year on year from 2002 to 2008, then fluctuated for a few years, and the actual number of papers being published has been on the decline since a final peak in 2010 (see Figure 2). A further study for other central UWB keywords

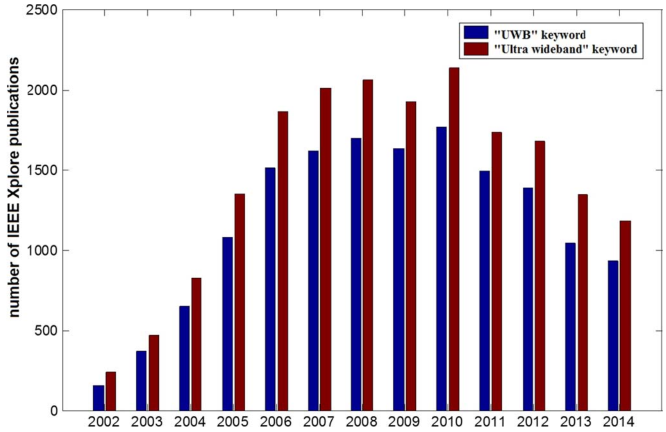

Figure 2. Returned results by year for keyword searches from IEEE Xplore.

such as UWB radar, sensors, and localization highlights the number of papers being published each year (IEEE Xplore) in these topics reveals a generally later interest and a much slower decline than for UWB communication applications, although the total number of papers published under these keywords is considerably less.

Based on these data, it appears that UWB publications will continue to decline in number, with the obvious conclusion that interest in UWB within the academic community is also in steady decline; indeed, all the data strongly suggest that UWB as a commercial technology has had its chance and has failed. Whether this is true or not is a matter for debate, but to understand where UWB appears to be heading, it is necessary to understand its journey to date.

4. History of the SIGs IEEE Standardization, and the In-Fighting

After the FCC released the spectrum allocation for UWB in 2002, the IEEE set about developing an international technical standard for UWB as the physical-layer technology. Of key focus were two standards, namely, IEEE 802.15.3a for short-range (10 m/33 ft) high-rate wireless PANs (WPANs) and IEEE 802.15.4a for short-range low-rate WPANs.

A task group (TG3a) was set up for IEEE802.15.3a standardization, and two key industrial organizations emerged to establish IEEE standards for UWB. The first, the UWB Forum, promoted UWB wireless computer networking products using direct-sequencing UWB (DS-UWB) that utilizes the direct-sequence pulse design developed by Xtreme Spectrum (who were bought over by Freescale Semiconductor) and the fabless semiconductor company DecaWave.

The other organization, the WiMedia Alliance (which at one stage had around 350 member companies), sponsored a form of multiband orthogonal frequency-division multiplexing (MB-OFDM) architecture endorsed by Texas Instruments. The UWB Forum claimed that the synchronization scheme of MB-OFDM was unnecessarily complicated; Wimedia Alliance argued that its strength was in being less susceptible to interference from neighboring UWB systems. Indeed, both proposals offered mutually exclusive communication architectures and therefore had major interoperability issues with each other [40]. By the end of 2004, the proceedings had ground to a halt.

The TG3a task group members could not agree on which technology to take forward to develop as the IEEE standard. They voted numerous times to elect a technology scheme, but each time, no group could attain the required 75% threshold approval rating. This continued for some time, and despite genuine attempts to find a mutually beneficial solution, no agreement could be found; at this stage, the originally elected Task Group Chair (Bob Heile) resigned.

By the beginning of 2006, the UWB technology development had effectively stalled due to the standardization issues as industry was hesitant to invest in either of the uncertain technology proposals [41]. With permanent stalemate between the two industry alliances, the original December 2002 project authorization request was officially withdrawn in January 2006 [42]. Key UWB Forum members, including Motorola and Freescale Semiconductor, left the group, and the IEEE 802.15.3a Task Group was thus disbanded by the IEEE Standards Association. To this date, IEEE 802.15.3a WPAN High Rate is listed under "projects in hibernation" on the IEEE 802.15 projects website. The WiMedia Alliance proceeded to transfer the UWB specifications work on future high-speed and power-optimized implementations to the Bluetooth Special Interest Group (SIG), Wireless USB Promoter Group, and the USB Implementers Forum. They then formally terminated all activity in 2010.

5. Current Standardization Position

Despite the failure of the IEEE802.15.3a standardization, UWB technology had more success in its WPAN Low Rate Alternative PHY (4a) version. IEEE 802.15.4a provided higher precision ranging and location capability (greater than 1 m accuracy), longer ranges, and lower power consumption. IEEE 802.15.4a offers very low power and low data rates using DS-UWB and has been commercialized for asset tracking, sensor networks, and ranging.

IEEE 802.15.3a continues to be suspended due to the failure to agree on the operating technology. However, one of the competing proposals, i.e., MB-OFDM, has since enjoyed limited commercial success in the form of wireless USB, which boasts 480-Mb/s data rates and a 3.5-m (10-ft) range. The original vision of UWB was of high-rate data transfer, including wireless high-definition television (HDTV), etc. However, the high-data-rate (HDR) mantle has been passed to other technologies such as WiGig at 60 GHz [43, 44]. Thus, UWB technology is left with low-power low data rate for USB, radar, ranging, imaging, etc., which could be considered an insult to its true ability.

Nevertheless, UWB remains distinct in terms of its interference-resistant characteristics. As commercial and residential environments continue to be engulfed in wireless technology, UWB may hold a key to the ever-cluttered sub-1-GHz band and the industrial, scientific, and medical (ISM) bands at 2.5 and 5.2 GHz; indeed, it may be a requisite to ensure successful use of multiple wireless devices.

6. Industrial Ventures and What Happened to Them

UWB had a number of industries investing in its technology, but as 802.15.3a standardization was never achieved, many therefore never materialized as commercial products. This, in turn, has had an impact on the investing companies. Intel removed backing for UWB, fabless semiconductor company WiQuest shut down in November 2008, and UWB semiconductor developers T-Zero Technologies folded in February 2009. Cambridge Silicon Radio (CSR) and Samsung no longer offer UWB chips, and both Freescale and SkyCross no longer manufacture UWB components. Wisair (who produced UWB chipsets for laptop-to-HDTV wireless technology), Radiospire, and Staccato have all gone out of business. UWB has left a trail of broken companies and failed ventures in its wake.

7. Current Commercial Position and Research Trends

There are, however, a few companies still offering UWB technology, with current products revolving around radar, locating systems, and wireless USB. Time Domain Corporation are still producing UWB research equipment, radar, and other ranging equipment, whereas Zebra Technologies, DecaWave, and Ubisense are offering UWB real-time location systems. Alereon are offering UWB chipsets, and Wireless2000 are selling patient-monitoring devices that utilize UWB technology. NDS Surgical Imaging are marketing UWB hubs for surgical informatics systems, and there are also a few companies offering wireless USB that exploits UWB technology, such as American consumer electronics manufacturer Belkin.

Current research trends in UWB communications revolve around design and optimization of the various RF circuit building blocks such as antennas [45], filters [46], oscillators [47], baluns [48], etc. There are also some research activities focused on realizing futuristic personal and body area networks for various applications such as medical body area networks [49], bespoke learning environments [50], etc. A further key trend in UWB is the focus on implementing radar sensor network technologies such as indoor localization and personnel tracking [51, 52], intruder movement [53], through-wall and under-rubble radar [54, 55], and mobile robot navigation [56], to name a few. UWB excels in these applications due to its large bandwidth and high accuracy at low signal-to-noise ratios.

These current research trends indicate that the research community continues to see the potential of UWB, although popular opinion has waned. It also highlights a greater current prominence of radar, sensor, and localization application focus.

8. Future of the Allocation, Technology, and Applications

In 2009, Network World wrote *"I'm in no way writing off UWB at this point. I expect we will see progress here over the next couple of years. But the degree of success that we can expect from UWB may be much more constrained than many, myself included, previously thought"* [57]. To date, that statement remains correct. Abbasi et al. [58] also recognized that *"while on-body systems adopting Zigbee and ISM standards remain popular in the commercial world, UWB body-centric wireless communications will be a main focus in the research community."* Again, this is still true in 2014, although the research focus has diminished year on year (see Figure 2).

Digikey corporation remarked "*It has been a long fall for UWB—from the solution for all things wireless to the solution for one limited application*" [59]. One of those 'limited applications' is that of cable replacement, such as wireless USB, which is a short-range high-bandwidth wireless radio communication protocol created by the Wireless USB Promoter Group (sometimes referred to as Certified Wireless USB to differentiate it from the competing UWB standard). As aforementioned, Wireless USB has data rates of 480 Mb/s at 3 m (9.8 ft) and 110 Mb/s at 10 m (33 ft).

Many researchers and industries have now shifted focus from 3–10 GHz UWB to the two 60-GHz unlicensed band technologies, namely, Wireless Gigabit Alliance (WiGig) (802.11ad) and WirelessHD (IEEE 802.15.3c-2009).

9. Summary

No one imagined the implementation of HDR UWB would fail as it was (and still is) such a promising technology. There have been many commentators dispensing hindsight on why HDR UWB did not succeed. John Santhoff, founder and CTO of Pulse-LINK, sums it up aptly: "*The fact is UWB didn't fail. What failed was a specific implementation of UWB known as WiMedia. When people think of UWB they think of UWB from Intel known as WiMedia. The term UWB has more to do with a unique spectrum allocation than a specific implementation*" [60].

However, while the standardization of IEEE 802.15.3a remains "in hibernation," so too hibernates the hope that the implementation of HDR UWB with its entire original promise and merit is just around the corner. However, [61] recognizes that we need UWB to solve the growing burden on the spectrum gridlock, and when one considers UWB's potential in a world demanding even higher data rates and ever more robust wearable communications, it seems unacceptable to let UWB remain a victim of a power struggle between two industrial factions, a struggle in which everyone lost.

10. The Way Forward

If HDR UWB is to ever been realized, there are two options. First, the IEEE standards association could drive standardization through. This is unlikely as the protocol requires technical consultation, typically through task groups, and of course to follow this path may lead to an almost identical scenario that derailed UWB standardization originally.

The second approach is where a number of companies create a collaborative group (much like the Continua Alliance group have done to address Bluetooth interoperability [62]) to invest in the technology without prior standardization and create UWB devices that have no interoperability issues. However, UWB now has greater competition as 60-GHz low-power Bluetooth, etc., can challenge it. While IEEE 802.15.4a (low-data-rate UWB) is in existence, the FCC will not withdraw the 3- to 10-GHz frequency allocation, thus keeping the spectrum allocation available for a revived HDR UWB. In addition, UWB is attractive in its interference-resistant characteristics, and as the home continues to be filled with an increasing number of RF devices that increasingly interfere with each other, then UWB may yet become successful in the home out of necessity.

So is UWB a technology whose time is still to come? If the majority of industry cannot agree on a structured approach, then the diluted version UWB we see in IEEE 802.15.4a is as good as it is likely to get, and a great opportunity to develop an HDR wireless solution will have been squandered. However, if the industries can begin to develop a coherent methodology and work in collaboration for the greater good, we may yet see a rebirth of this technology of great promise. Time will tell.

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