UC Irvine
Recent Work

Title

Ultra Wideband Technology and the Struggle to Adopt a Standard for the Consumer Electronics Industry

Permalink

https://escholarship.org/uc/item/6k91v8sk

Author

Malakooty, Nina

Publication Date

2006-09-01

eScholarship.org Powered by the California Digital Library
University of California

Ultra Wideband Technology and the Struggle to Adopt a Standard for the Consumer Electronics Industry

Nina Malakooty

PCIC
Personal Computing Industry Center
University of California, Irvine

September, 2006

Ultra Wideband Technology and the Struggle to Adopt a Standard for the Consumer Electronics Industry

Nina Malakooty
Personal Computing Industry Center
University of California, Irvine
September, 2006

1: Introduction: Standards Development Organizations

The development of a new technology for the consumer market brings in multiple concerns. Those behind the technology must decide whether to make and sell products themselves or whether to align with other companies so that they may produce similar and complementary products. Neither of these strategies, however, guarantees that the technology will be adopted by consumers. If similar technologies already exist in the marketplace, consumers may be hesitant to adopt the new, especially if companies cannot assure consumers that the technology will not be a fad.

To solicit interest in the marketplace, intellectual property holders often align themselves with a standards development organization (SDO). SDOs can help intellectual property holders refine a standard, solicit the aid of other companies, provide structure to the standard development process, and help ensure compliance with related, pre-existing standards.

The Institute for Electronic and Electric Engineers (IEEE) is an SDO that has helped establish standards such as WiFi and Firewire for the consumer electronics industry. The IEEE standardization process allows groups to receive guidance from IEEE staff, as well as other resources to aid in standards development.

2: Key Players in UWB

One burgeoning technology currently involved with a standards development organization is a wireless technology called ultrawide band, or UWB. For over 40 years, UWB has been used for defense and military applications, such as wall-penetrating imaging. It was not until 2002, however, that the FCC decided to open UWB to public use (*Untangling Ultrawideband* 2004). UWB operates on the same spectrum as GPS systems, cellular phones, WiFi and other technologies, but should not cause disruption due to its extremely low power rate.

Much as a newly deprivatized parcel of land may attract a variety of developers, the newly opened spectrum has caught the eyes of technology developers. Just as one area can be modeled to accommodate tracks for trains, freeways for automobiles and canals for boats, UWB is a plot of spectrum, or "backbone" that could accommodate multiple independent wireless standards. Hence, there has been interest in using UWB to create wireless versions of the existing cable-driven USB and Firewire standards. Next-generation USB devices, which commonly include digital music players and printers, could then have built-in wireless adapters that would allow for

entirely cable-free data transfers. Current USB devices could be outfitted with wireless adapters that would allow cable-free data transfers as well – indeed, plans for such a device are underway.

Considering the impressive potential of UWB-based technologies, it comes as little surprise that the consumer electronics industry wants to harness this wireless protocol. Data transfer rates with UWB could be potentially as high as 1 Gigabit per second (1000 Mbps). At such a speed, UWB would be approximately 20 times faster than the current 802.11g standard often used for wireless local area networks (Hamblen 2004). By comparison, wired connections such as USB 2.0 can only reach speeds up to 480 Mbps, while the fastest available Firewire connection has a top speed of 800 Mbps.

Although UWB speeds may impress, the technology is not a replacement for every existing wireless standard. While a single 802.11b/g Wi-Fi access point can often cover an entire house, and while the proposed WiMax standard could cover city areas, UWB-based applications will likely be limited to a single room. UWB is designed to transmit data at remarkably low power over broad swaths of spectrum, which reduces its transmission distance but works to effectively conserve energy. In the United States, the FCC has mandated that radiation emitted by UWB must be kept below -41.3 dBM/MHz, or approximately $1/200^{th}$ of the power output of one candle (Titus 2006). The low power rate ensures that other electronics operating in these frequencies, such as cordless phones and wireless networks, do not suffer interference. This limits UWB transmission range to approximately 80 feet, although data transfer rates weaken significantly as the distance between UWB-enabled devices increases (Angell 2005).

The consumer electronics industry has specifically eyed UWB to potentially provide wireless connectivity between a computer and display, a computer and digital camera, a television and DVD player, a projector and computer, and numerous other possibilities. Thus, a diverse group of companies have rallied behind the technology. Interest in UWB has sparked the creation of two industry-led interest groups, the MultiBand OFDM Alliance (MBOA) and the UWB Forum. In March 2005, the MBOA joined hands with another UWB interest group, the WiMedia Alliance, and now operates as one with the WiMedia group (Strassberg 2005). Each group is pushing for their own UWB variant to become the recognized standard for the newly accessible technology.

Founded in June 2003 as the MBOA, this coalition has boasted some of the most influential names in consumer electronics. Intel, Sony, Hewlett-Packard, Fujitsu, Sharp, Toshiba and nearly 150 other companies and organizations hold what is now WiMedia Alliance membership (Meade 2004a).

The WiMedia Alliance advocates a multi-band approach in which data hops between different frequencies in a wide swath of spectrum. The group's technique splits the UWB-allowable frequency range into 14 subdivisions, then sends data as "pulses" in a subdivision, switching to other subdivisions as necessary in order to minimize interference and abide by frequency regulations in a particular area (Brown 2004). The WiMedia proposal has been touted as the most feasible for international deployment, due to its ability to easily block out spectra that already may be in use in a particular country.

Locked in a decisive battle with the WiMedia Alliance is the UWB Forum, a group founded by Motorola in late 2004. The group has just over 100 member companies, though unlike the WiMedia Alliance, its members do not include as many prominent consumer electronics companies. The UWB Forum consists mainly of Asian electronic component makers and educational institutions, with the notable exceptions of Motorola, Freescale and Belkin Corporation – although the former two companies have left the group as of April 2006 (*Freescale and Motorola Ditch UWB Forum* 2006). The UWB Forum's technical approach involves transmitting a pseudo-random code at low power, so that the signal appears as background noise, or static. The signal receiver is able to recognize the pseudo-random code, however, so it distinguishes the signal from other background noise (*Untangling Ultrawideband* 2004).

Though most companies align themselves with only one of the competing UWB factions, a selected number have aligned themselves with both the MBOA/WiMedia Alliance and the UWB Forum. In particular, Appairent, PulseLink, Co-Ware, and Furaxa count themselves as members of both groups. Each company has given different reasons for joining both groups; Appairent claims it is radio agnostic, and hence willing to support UWB technology regardless of technical protocol; Co-Ware has made similar statements. PulseLink has championed a possible solution to bring interoperability to the competing standards, and joined both groups to gain access to the technical details of each specification. Furaxa claims it joined both groups because it believes both standards will appear in the marketplace (Meade 2004a).

3: The Road to Standardization

Previous battles in technology standards have demonstrated the handful of ways in which a specification can become known as a "standard." First, standards proponents from each side can align themselves with a major standards development organization, such as the IEEE, and seek official recognition. If the time and cost of sending company representatives to IEEE meetings is a burden, companies could also try their luck by taking products with the standard straight to market. Taking a product to market also lets a company avoid the time and cost of sending representatives to IEEE meetings. If the company has clout or the product appears headed for success, other companies may be compelled to incorporate the standard as well.

In some situations, a technology may become a *de facto* standard in the marketplace. For example, Intel computers running Windows, known as the "Wintel," became a "standard" of sorts after marketplace success. Other examples have included the IBM 360 mainframe, the VHS videocassette standard, Cisco's Internet Operating System, and Adobe's PDF file format. Two or more standards may also exist in the market, which has been the case for GSM and CDMA mobile phone technology and game consoles by Sony, Nintendo and Microsoft.

4: The Stagnated IEEE Process

A dedicated IEEE task group, known as 802.15.3a or TG3a, has been reviewing proposals for a UWB standard since January 2003 (Cox 2004). In July 2003, the competition narrowed to two proposals: one from an Intel-backed group (which later became the MBOA/WiMedia Alliance),

and one from a Motorola-backed group (now known as the UWB Forum). For nearly three years, progress toward an IEEE-recognized standard has been virtually deadlocked.

The task group follows a voting procedure devised in January 2003, in which a proposal must be approved by a 50% majority and later by a 75% majority before it can become the IEEE standard. The process opens with a one-hour presentation and discussion of the proposals. Next, committee members vote on which proposals to keep in contention. Each ballot contains a table listing the proposals, with an option to "consider" or "not consider" each proposal. A voter must mark his or her preference to keep or remove a proposal from contention. If the voter abstains from indicating preference on a particular proposal, his or her entire ballot is invalidated (*TG3a Down Selection Voting Procedure* 2003).

The first phase of voting may allow the advancement of up to six proposals. If the original pool contained greater than six proposals, the top six will advance. Any proposal that received at least 20% of votes may also advance. Members continue to cast ballots and whittle down the candidate pool until all but two proposals have been eliminated.

Once only two proposals remain, new elimination criteria go into effect. Now, votes are cast until one of the two proposals receives at least 50% of the votes. The proposal that advances from this step now must face a confirmation vote, in which at least 75% of voters must agree to make it the official IEEE standard (*TG3a Down Selection Voting Procedure* 2003).

If 75% of members fail to ratify the proposal, a structured discussion period begins. First, supporters of the proposal try to sway voters. Proposal opponents may then ask questions; supporters of the proposal address their inquiries.

A second confirmation vote takes place to approve the proposal. Members vote to either make it the IEEE standard or not make it the IEEE standard; at this point, alternative proposals are still cast out. If the proposal still cannot earn the required 75% approval, then the battle between the two final proposals begins anew. Alternatives eliminated in the final round of voting remain eliminated (*TG3a Down Selection Voting Procedure* 2003).

For the TG3a group, this has been the point of impasse: the WiMedia Alliance and the UWB Forum have been behind the two final UWB proposals since March 2003. Members continue to vote between only these last two proposals. Except for one occasion, the WiMedia-backed proposal has always earned a majority of votes, with typically 60% of voters in favor of their proposal (Broockman 2004; Mannion 2004a). However, the proposal has never been able to gain the 75% of votes needed for the confirmation vote. The UWB Forum's proposal, which received just over 50% of votes on one occasion in July 2004 (74-73 people in favor), was also unable to gain the 75% majority to confirm their proposal as the standard (Omatseye 2004; Mannion 2004a).

The lengthy process to get a UWB standard approved by the IEEE may be a result of multiple factors. Some cite the IEEE's voting process as fundamentally flawed, since each person, rather than each company, is permitted to cast a vote. The WiMedia Alliance has alleged that this can result in one side bringing in a high number of "consultants" to cast a vote in their favor

(Broockman 2004). The IEEE informally floated an idea in November 2004 to replace the "one person/one vote" policy in favor of a "one company/one vote" policy, but the idea sparked little interest (Hachman 2004).

Members of the TG3a have been frustrated at the endless voting cycle. The WiMedia Alliance has accused the UWB Forum of hiring a pool of "consultants" in order to pad voting numbers at IEEE meetings. Both sides admit that some task group members may be voting for the proposal supported by their company, rather than backing the most technologically sound proposal. While this practice may come as little surprise, it is cited as yet another reason why proponents cannot agree to one standard.

With the IEEE process at a standstill, both groups pledged to bring their respective UWB standards to market as soon as possible. The discord within the TG3a group ended in January 2006, when the group officially voted to disband (Deffree 2006). At this time, no further IEEE-sanctioned meetings or voting phases will continue.

5: Future and Current Challenges for UWB Technology

The WiMedia Alliance and UWB Forum have continued to take steps to advance their proposals in the marketplace. Despite the different philosophies between the groups, both face similar hurdles ahead. First, gaining international approval to use the appropriate frequencies will be a challenge. To date, only the United States has given approval for UWB use. In the United States, the then-MBOA proposal in particular faced strong FCC scrutiny. In fact, the group did not receive FCC approval for their technology until March 2005, and the first chips based on the standard were not approved until August 2005 (Deffree 2005). The delay was the result of an FCC requirement that UWB systems undergo strict testing. Though the WiMedia specification hops frequencies in order to minimize interference, the FCC ordered frequency hopping turned off during testing, thus allowing the FCC to increase its susceptibility to interference. Further, data transmission would need to take place continuously and gating systems that suppress emissions would need to be turned off. These factors would have made it likely that emissions and interference would appear higher than under actual operating conditions. Although the UWB Forum's proposal was more readily approved by the FCC, UWB's frequency overlap with crucial wireless technologies such as GPS systems and cell phones has caused some concern.

UWB also faces competition from other high-speed wireless standards, particularly from the next-generation wireless local area network (WLAN) standard 802.11n. An 802.11n proposal received preliminary approval at a January 2006 IEEE meeting, meaning that after additional confirmation and possible modifications, it will become the official IEEE standard. Although these final steps may take up to a year, device makers can opt to market products based on the pre-802.11n standard. Chip companies Broadcom and Marvell have begun to produce chips based on the preliminary specification (Hachman 2006). Once the 802.11n standard becomes official, device makers can make firmware upgrades available to account for any changes in the 802.11n specification. As an addition to the well-established 802.11b/g Wi-Fi standards, it is almost certain to see use in home and office settings as the newer, faster form of Wi-Fi. Although UWB will be more energy efficient than 802.11n and therefore ideal for portable devices, both technologies will operate at similar speeds (Brown 2004). The 802.11n standard

will have a significantly broader range, estimated to be 300 feet versus UWB's 80 feet, and the ability to operate through walls and other major obstacles (Angell 2005).

While it is nearly certain that the WiMedia Alliance and the UWB Forum will contend with 802.11n technology, competition from yet another technology may surface as well. A third UWB standard has emerged from PulseLink, a company which has been part of both the WiMedia Alliance and the UWB Forum (Mannion 2004b). Throughout 2004, PulseLink worked to coax both UWB groups into accepting a Common Signaling Mode (CSM), which would specify a common physical layer that would allow devices from both groups to interoperate. The UWB Forum supported the idea, while the then-MBOA refused to change their proposal to allow a Common Signaling Mode (Meade 2004b). At a July 2004 IEEE meeting, a CSM nearly had a chance when a vote was administered to consider employing a common physical layer across both standards. However, the vote resulted in a 50-50 split, and the idea was subsequently discarded (Mannion 2004). With PulseLink's dream of producing a dual-mode chip dashed, the company briefly appeared to step out of the limelight. However, the company has since taken surprising steps in the UWB race, and is now pushing its own variant of UWB called C-Wave (*PulseLink Announces First WLAN UWB Evaluation Kit* 2005). The group demonstrated a working prototype of their UWB technology at the Consumer Electronics Show in January 2006. Although both the UWB Forum and the WiMedia Alliance have greater lead times on their technology, PulseLink's C-Wave technology could enter the market as yet a third UWB platform. The April 2006 departure of UWB Forum founders Motorola and Freescale could allow PulseLink to assume control of the group and impress their standard upon members.

Despite the likely competition from future and current wireless technologies, UWB could easily be incorporated to work with existing standards. Since Bluetooth and UWB have similar data transfer ranges, concern initially rose over whether UWB would eclipse the technology, particularly since it could potentially perform the same tasks at dramatically increased speeds. Typically used to wirelessly link computers to peripherals such as keyboards and headsets, Bluetooth operates at approximately $1/100^{th}$ of potential UWB speeds. Perhaps recognizing the potential downfall of their technology, the group responsible for developing and popularizing Bluetooth decided to link themselves to UWB proponents. Known as the Bluetooth Special Interest Group, the coalition is now working with the WiMedia Alliance to develop a high-speed version of Bluetooth (*Bluetooth Transmission Speed Set to Increase* 2006).

The first UWB-based products were previously slated to be on the market by the end of 2005, but neither the WiMedia Alliance nor the UWB Forum met this target. Instead, both groups announced they would eye initial product releases in 2006, pushing for widespread adoption through 2007. The UWB Forum recently began to fulfill their promise, announcing the first UWB product for the consumer marketplace in January 2006. Belkin Corporation's four-port USB hub and dongle will allow instant wireless connectivity between a computer and devices such as printers, scanners and external hard drives. Transfer speeds are expected to be comparable to traditional wired USB connections, although Belkin has not offered specific numbers. According to the company, no software will be required to use the wireless USB hub. The hub will go on sale in July 2006 for an estimated $129.99 (*Belkin CableFree USB Hub Enables Instant Wireless Connectivity* 2006). Belkin worked with then-UWB Forum member and Motorola spin-off Freescale Semiconductor to develop the product. However, three months

after the announcement of the Belkin device, Motorola and Freescale left the UWB Forum to independently continue work on the CableFree USB initiative. Although the wireless USB hub is slated to be shipped in September 2006, it is unclear whether the sudden departures of Motorola and Freescale have affected relations with Belkin Corp., who apparently remains part of the UWB Forum.

6: A Final Examination of the Failed UWB Standardization

With the first UWB product now announced and headed for the marketplace, the efforts invested into the IEEE standards process may seem futile. However, without IEEE involvement, other companies may have been hesitant to put work into a technology that could be a "fad," particularly since the capabilities of UWB were initially understood to have some overlap with the existing Bluetooth and 802.11b/g standards. The IEEE process can sometimes serve to spark interest in a technology, although that can be unnecessary if many large-scale consumer electronics companies are already aligned with the technology, as occurred in this situation. The near-unanimous vote that disbanded the 802.15.3a group reflects the frustration of the two battling UWB groups.

To some extent, the IEEE voting schematic may be partially responsible for the lack of an approved UWB standard. Though both the then-MBOA and the UWB Forum succeeded in winning the initial vote, the high margin needed to win final confirmation eluded both groups. The ability to have multiple affiliates from the same organization cast a vote may have played a role as well. However, an informal poll by the IEEE showed that members had little interest in developing a one-vote-per-corporation rule. This apparently demonstrates that members feel it is acceptable if larger companies can send multiple representatives, thus potentially contributing more votes for their side. While the results of the IEEE poll may seem counterintuitive for such a seemingly democratic standards organization, it is worthwhile to note that many of the corporations who can afford to send members to vote at IEEE meetings are large corporations themselves, often with a strong opinion as to which side should emerge victorious in a standards battle. Issues such as intellectual property and the potential of paying high royalties in product development can easily lead to a distinct preference for a particular standard.

Only one year ago, it appeared that the battle for UWB dominance would be waged between only two groups, the WiMedia Alliance and the UWB Forum. However, with the recent UWB Forum departure of Motorola and Freescale, and with PulseLink wielding a new standard in a group that could now become their own, the future of UWB may be more malleable than expected. Further, instead of developing an entirely new wireless standard based on UWB, the WiMedia Alliance and the Freescale-Motorola duo have stepped back to join hands with existing standards Bluetooth and USB, respectively, at least for the immediate future. Compatibility with existing products is key for encouraging faster adoption by consumers. Instead of tackling the industry with proprietary new wireless standards, proponents are approaching conservatively to first move popular standards to the UWB backbone. If the WiMedia Alliance proposal or the UWB Forum proposal had gained enough votes during IEEE proceedings, then an 802.15.3a standard would be in existence today. Even a merger of the two proposals could have led to the ratification of an 802.15.3a specification. Despite the failed IEEE process, however, it seems that the WiMedia Alliance and the Freescale-Motorola duo could have at least limited success in

the marketplace, if their respective links with Bluetooth and USB prove fruitful. However, if the WiMedia Alliance attempts their own wireless USB or Freescale and Motorola try to develop their own high-speed Bluetooth, devices from the two groups will not be able to communicate with their rival's version of the same standard. Since PulseLink did not have success convincing both sides to adopt a Common Signaling Mode, the method of transmission and reception differs between the groups' protocols.

Fortunately for consumers, the WiMedia Alliance and Freescale / Motorola have not yet chosen to overlap the other's territory in such a manner. Incidentally, with the Bluetooth Special Interest Group backing the WiMedia Alliance, it would be unlikely Freescale / Motorola would attempt to create their own version of UWB-based Bluetooth. However, since Freescale and Motorola do not appear to have the official backing of USB proponents, the WiMedia Alliance could swoop down upon the USB territory and gain official backing with the aid of their high-profile companies. Unfortunately for the UWB Forum, key figures in the USB arena have already started to build a separate wireless USB based on the WiMedia Alliance platform. The USB Implementers Forum, which created the wired USB 2.0 specification currently in broad use throughout consumer electronics, is building a wireless USB variant called "Certified Wireless USB," or "CWUSB." Due to system limitations, however, CWUSB may not be suitable for use in personal computers, and may be relegated to medical devices instead (Titus 2006). In this great technological land grab, it remains to be seen whether each UWB variant will cohabit harmoniously or seize additional territory.

References

Angell, M. (2005, October 27). Ultrawideband Challenges Wi-Fi in Fight for Wireless Consumers. *Investor's Business Daily.* Retrieved October 2005, from the LexisNexis database at http://www.lexisnexis.com.

Belkin CableFree USB Hub Enables Instant Wireless Connectivity of USB Devices. (2006, January). Retrieved from the Belkin Corporation web site at http://www.belkin.com/pressroom/releases/uploads/01_03_06CableFreeUSB.html.

Bluetooth Transmission Speed Set to Increase. (2006, March 26). *The Wall Street Journal.* Retrieved May 2006, from the Factiva Database at http://global.factiva.com.

Broockman, E. (2004, September 30). MBOA SIG Standard Sprints Ahead of Stalled IEEE Process. *UWB Insider.* Retrieved November 2005, from http://www.uwbinsider.com/viewpoints/2_3_MBOA_SIG_IEEE.html.

Brown, E. (2004, September 2). Ultrawideband Takes on Wi-Fi. *Technology Review*. Retrieved November 2005, from http://www.technologyreview.com/articles/04/09/wo_brown090204.asp?p=1.

Cox, J. (2004, February 23). USB Could Go Wireless in 2005. *Techworld.* Retrieved November 2005, from http://www.techworld.com/mobility/news/index.cfm?newsid=1073&page=1&pagepos=2.

Deffree, S. (2005, March 14). FCC Opens Up UWB. *Electronic News*. Retrieved January 2006, from http://www.reed-electronics.com/electronicnews/toc/03%2F06%2F2005.

Deffree, S. (2006, January 30). No Standard for UWB. *Electronics News*. Retrieved March 2006, from the Factiva Database at http://global.factiva.com.

Freescale and Motorola Ditch UWB Forum. (2006, April 10). *Computer Business Review Online*. Retrieved May 2006, from http://www.cbronline.com/article_news.asp?guid=BFDF6A0A-883D-42A4-829C-52A0850F56AE&z=rc_PCsandWorkstations.

Hachman, M. (2004, November 19). Could IEEE Voting Changes Break Tech Stalemate? *ExtremeTech.com.* Retrieved October 2005, from the Factiva database at http://global.factiva.com.

Hachman, M. (2006, January 20). 802.11n Proposal for Next-Gen Wi-Fi Approved. *PCMag.com*. Retrieved January 2006, from http://www.pcmag.com/print_article2/0,1217,a=169649,00.asp.

Hamblen, M. (2004, August 2). Ultrawideband: A Better Bluetooth. *Computerworld.* Retrieved November 2005, from the Expanded Academic Database at http://infotrac.galegroup.com.

Mannion, P. (2003, December 15). Multiband UWB Camp Lifts Royalties. *Electronic Engineering Times.* Retrieved November 2005, from the Expanded Academic Database at http://infotrac.galegroup.com.

Mannion, P. (2004a, July 15). Both Sides Surprised by Outcome of UWB Vote. *CommsDesign.* Retrieved October 2005, from http://www.commsdesign.com/showArticle.jhtml?articleID=23900998.

Mannion, P. (2004b, April 28). UWB Developer Raises $30 Million; Joins Both Standards Camps. *Silicon Strategies.* Retrieved November 2005, from http://www.siliconstrategies.com/article/showArticle.jhtml?articleId=19202142.

Meade, P. (2004a, June 3). A Funny Thing Happened on the Way to the UWB Forum. *UWB Insider.* Retrieved November 2005, from http://www.uwbinsider.com/industry/1_10_mboa_uwb_forum.html.

Meade, P. (2004b, June 3). The Not-So-Common Signaling Mode? UWB Insider. Retrieved December 2005, from http://www.uwbinsider.com/technology/1_10_common_signaling_mode.html.

Omatseye, S. (2004, July 19). DS-UWB Squeaks Out Win in Standards Fight. *RCR Wireless News*. Retrieved November 2005, from the Expanded Academic database at http://infotrac.galegroup.com.

PulseLink Announces First WLAN UWB Evaluation Kit; New CWave UWB Technology Unveiled. (2005, February 14). Retrieved January 2006 from the PulseLink web site at http://www.pulselink.net/pr-feb-14-2005.html.

Strassberg, D. (2005, September 29). *Testing UWB: Don't Try This at Home.* EDN. Retrieved November 2005, from the LexisNexis Academic Database at http://www.lexisnexis.com.

TG3a Down Selection Voting Procedure. (2003, January). Retrieved November 2005 from the IEEE website, at http://grouper.ieee.org/groups/802/15/pub/2003/Jan03/03041r7P802-15_TG3a-Down-Selection-Voting-Procedure.doc.

Titus, J. (2006, May 1). *USB Snips the Wire.* ECN. Retrieved May 2006, from the Factiva Database at http://global.factiva.com.

Untangling Ultrawideband. (2004, September 16). *The Economist.* Retrieved October 2005, from http://www.economist.com/science/tq/displayStory.cfm?story_id=3171534.