2. UWB TECHNOLOGY AND REGULATORY ISSUES

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The term "ultrawideband" refers to the spectral characteristics of this technology and originates in the work that led up to a Department of Defense (DoD) study [1]. Alternative terms for the same technology include impulse radar, impulse radio, carrierless, carrier-free, time-domain, and others. The fundamental principle is that a short (in time) pulse, also called an impulse, is generated, transmitted, received, and processed. A fundamental principle, true for any radio signal, is the relationship between pulse duration and the bandwidth occupied by that signal.

According to the theoretical Fourier transform, a pulse of duration T seconds (in the time domain) has an occupied bandwidth of 2/T Hertz (in the frequency domain). For example, a pulse on the order of a nanosecond in the time domain occupies about two gigahertz of bandwidth in the frequency domain. An example of time domain signal processing is pulse-position modulation (PPM). Consider the transmission of a train of pulses equally spaced in time. The receiver processing determines whether each received pulse is located where expected or arrives early or late. With PPM, a slightly retarded pulse could represent a "0" and a slightly advanced pulse could represent a "1" when transmitting digital information.

2.1 History of Ultrawideband Technology

One could say that the first wireless[2] system demonstrated by Gugliermo Marconi in 1897 [3], meets the description of UWB radio. Marconi's earliest spark-gap transmitters occupied a large portion of the spectrum, from very low frequencies up through the high-frequency (HF) band and beyond. And, these systems used manual time domain processing. Morse code was sent and received by human operators.

The foundations of modern UWB systems were laid down in work done at the Sperry Research Center in the 1980's by Ross [4]. The emphasis was on the use of UWB as an analytical tool to explore the properties of microwave networks and to determine the intrinsic properties of materials [4,5]. These techniques were then logically extended to support experimental analysis and synthesis of antenna elements [6,7]. These early successes led to the development of an indoor system to measure the impulse response properties of targets or obstacles [8]. This

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[2]The term "radio" did not exist until 1912 [2]. It is a shortened form of "radioconductor" (a contraction of radiation conductor). "Wireless" was the common term before 1912.

approach of using "short-range radar" obviated the need for an expensive anechoic chamber to study radar targets, since unwanted reflections from walls and ceilings could be removed by time-gating techniques.

The use of UWB, with its time domain processing techniques, filled an important need in the early days of computer development. The appearance of high-speed, sub-nanosecond logic circuitry in the late 1960s and early 1970s made higher speed computation possible. However, it was necessary to deliver and distribute large amounts of digital data between the computer central processor and various input and output devices. This problem was solved by using multiplexing of multiple signals on a single transmission line using time-domain processing methods described in a patent by Ross, et al. [9]. This patent could be viewed as a key element in the foundation of UWB communications. It is a small step from this work to developing wireless UWB communications. Further developments during the 1970s led to a more thorough development of principles needed to fully describe and develop the field of time-domain electromagnetics [10, 11, 12].

In the 1980s and 1990s the principles of time domain electromagnetics were applied to wireless communications, in particular to short-range communications in dense multipath environments. Schotz [13] describes this application in detail and explores the advantages and disadvantages. He showed that a large number of such systems could operate in the same space and that such wide bandwidth signals are more immune to the deleterious effects of multipath than are narrow bandwidth signals. A potential application for UWB communications is the accommodation of many users in high-multipath environments, but the challenge is coexistence within the already highly-populated radio spectrum. The advantages may or may not outweigh the disadvantages, and other approaches to wireless operation in dense, high-multipath environments may perform as well as the UWB approach.

The other major application area of UWB technology is sensing, with the likely niche being short-range, high-resolution radar. This area requires much less signal processing and uses much simpler electronics, but has not received as much attention as the more complex communications applications. Ground penetrating radar was one of the first applications [14]. In 1974, Morey [15] patented a radar system that, due to the use of a very wide band of frequencies, was able to penetrate the ground to distances of one to several meters. This patent was later the basis of a commercial success.

2.2. Regulatory Issues

After receiving three requests by UWB developers, the Federal Communication Commission (FCC) issued a Notice of Inquiry (NOI)[3], to gather information on the possible uses of UWB devices. Many comments were received in response to that NOI. The FCC also issued the

[3]OET Docket 98-153, NOI issued Sept 21, 1998.

requested three waivers for a limited number of each of the three low power UWB devices after coordination on the technical limitations required by NTIA to approve the proposals[4]. Information gathered by that NOI led the FCC to release a Notice of Proposed Rule Making (NPRM) in May 2000. The major regulatory issues in that NPRM are centered on the question of how much interference UWB systems might cause to existing radio systems.

The FCC and NTIA jointly manage the radio spectrum in the United States. Part 15 of Volume 47 of the Code of Federal Regulations (47 CFR- Part 15) contains the FCC rules for authorizing non-licensed operation of low power radio devices that typically radiate signals in bands licensed for other types of devices. The current Part 15 rules define three classes of radiators: Incidental Radiators (which do not deliberately generate the RF signals they emit and are not regulated; e.g., an electric drill), Unintentional Radiators (which need to generate RF signals, but do not intend to radiate them, e.g., a computer), and Intentional Radiators (which deliberately radiate low-level radio signals, e.g., a garage door opener). The NPRM proposes that UWB devices be operated under a new section of the Part 15 rules, with approximately the same numerical limits for new UWB devices as for the existing intentional radiators.

Major regulatory issues include a determination of what numeric limits should apply to UWB emissions and what techniques should be used to measure those emissions. The NPRM proposes numerical limits and measurement techniques identical to those described in current Part 15 rules for Intentional Radiators, with the addition of a maximum total absolute peak limit or a possible peak limit measured in a 50-MHz bandwidth.

Important related questions include whether these limits should be lower in specific restricted frequency bands used by the Federal Government for particularly critical applications, including the Global Positioning System (GPS). These critical frequency bands have already been identified in the existing Part 15 rules, and Intentional Radiators are prohibited from deliberately radiating signals in any of these identified critical bands. Since UWB systems will typically radiate energy in frequency bands managed by NTIA, as well as frequency bands managed by the FCC, the two agencies must concur on the new rules.

2.3 References

[1] "Assessment of Ultra-Wideband (UWB) Technology," July 13, 1990. DTIC No. ADB146160. The Executive Summary of this report is published in the *IEEE Aerospace and Electronics Systems Magazine*, Nov. 1990. pp 45-49.

[2] W.F. Snyder and C.L. Bragaw, "Achievement in Radio," NBS Sp. Pub. 555, Oct. 1986.

[3] W.L. Weeks, *Antenna Engineering*, McGraw-Hill, 1968.

[4] Three waivers granted by Chief of OET, June 25, 1999, after coordination with NTIA.

[4] G.F. Ross, “The transient analysis of certain TEM mode four-post networks,” IEEE Trans. on Microwave Theory and Tech., Vol. MTT-14, p. 528, Nov. 1986.

[5] A.M. Nicholson and G.F. Ross, “The measurement of the intrinsic properties of materials by time-domain techniques,”IEEE Trans. on Instrum. and Meas., Vol. IM-9, pp. 377-382, Nov. 1970.

[6] G.F. Ross, “A new wideband antenna receiving element,” 1967 NREM Conference Symposium Record, Boston, MA, Nov. 1967.

[7] P. Fenster and G.F. Ross, “Members of the class of TEM-mode wire antennas with TLIR” presented at the IEEE International 1968 PGAP Symp., Boston, MA, Sept. 1968.

[8] A.M. Nicholson and G.F. Ross, “A new radar concept for short-range application.” Proceedings of IEEE first Int. Radar Conf., pp. 146-151, Washington, D.C. Apr. 1975.

[9] G.F. Ross, L. Susman, and E. Eves, “Time-domain multiplexer-demultiplexer for digital transmission of GHz data,” U.S. Patent No. 3,763,318, Oct. 1973.

[10] G.F. Ross, “A time-domain electromagnetics bibliography,” Sperry Research Center, Report SCC-RR-75-1, Mar. 1975.

[11] C.L. Bennett and G.F. Ross, “Time-domain electromagnetics and its applications,” Proceedings of IEEE, Vol. 66, No. 3, Mar. 1978.

[12] E.K. Miller (Ed), *Time domain measurements in electromagnetics*, Van Nostrand Reinhold, 1986.

[13] R.A. Scholtz, “Impulse Radio,” IEEE PIMRC 97, Helsinki, Finland, 1997.

[14] D.L. Moffat and R.J. Puskar, “A subsurface electromagnetic pulse radar,” Geophysics, Vol. 41, pp. 506-518, 1976.

[15] R.N. Morey, “Geophysical survey system employing electromagnetic impulses,” U.S. Patent No. 3,806,795, Apr. 1974.