Ultrawideband Wireless Systems

1. Research Team

Project Leader:	Prof. Robert Scholtz, *Electrical Engineering*
Other Faculty:	Prof. Keith Chugg, *Electrical Engineering* Prof. Urbashi Mitra, *Electrical Engineering,* Prof. Won Namgoong, *Electrical Engineering*
Graduate Students:	Robert Wilson
Undergraduate Students:	Phil Hirz
Industrial Partner(s):	NTT DoKoMo, Time Domain Corporation

2. Statement of Project Goals

The long-term goal of this project is to perform basic research in support of the design and deployment of ultrawideband (UWB) wireless systems that are compliant with recently published FCC regulations for UWB emissions [1].

3. Project Role in Support of IMSC Strategic Plan

UWB radio is constrained by regulation to be a short-range and/or low data rate link. We expect this technology to be of interest in a variety of home networking applications, including wireless audio and multimedia transmission.

4. Discussion of Methodology Used

There are several challenges to the eventual deployment of UWB radios, more than can be handled in one small project. Support from a variety of sources has been used to build research teams investigating position location algorithms [2], communication receiver architectures, antenna design, waveform and modulation design and implementation, channel characterization and synchronization schemes [3], etc. These teams include ten faculty members at three different schools, along with their graduate students.

5. Short Description of Achievements in Previous Years

The UltRa Lab was founded as an integral part of the formation of the IMSC. This Lab now provides the high-quality instrumentation necessary to perform UWB radio measurements, both within and outside RF anechoic environments. Research in the past several years has been theoretical in nature, tied to the propagation measurements made with UltRa Lab equipment, and has given solid estimates of UWB radio systems and subsystems capabilities. Statistical models [4] have been developed and provided to the IEEE 802.15 Standards Committee's working group

for UWB channel model development. Information on interference studies [5,6] has been provided to the FCC as part of the annual reports required for our UWB Experimental license.

5a. Detail of Accomplishments During the Past Year

In April 2002 the FCC published regulations that control UWB emissions. Because of the potential for interference with other narrowband radio systems, these regulations are quite stringent, requiring that even in the best of circumstances the radios operate at extremely low levels. The effort of the UltRa Lab, now backed by the support of a joint research project with faculty from the University of Massachusetts and the University of California at Berkeley, has been to determine the hardware options for implementing low-power short-range UWB radios.

Our support over the last year from IMSC has been in the form of support for a research assistant who has been used to put UWB modulation selection on a firm basis. This problem is of interest for two reasons: (1) nothing in the FCC regulations constrains UWB modulation to be of a specific form, and the IEEE Standard has not yet been defined. (2) The effects of multipath propagation on UWB modulation selection and receiver design are not yet well understood. Our analysis of the trade-offs between time-hopping and direct sequence modulations is nearly complete and documentation of the results is in progress.

It is noteworthy that during the Summer of 2002, the research assistant working on this project performed propagation measurements of waves propagating through materials in the frequency range from approximately 2 to 6 Ghz. This was done directly as a summer employee of Magis Networks, firm in San Diego developing OFDM radio chips, a technology that will undoubtedly be competing with UWB radio in the future. The work was performed in the UltRa Lab's Paul G. Allen Wireless Test Facility (an RF anechoic chamber).

During this year with the assistance of the Intel Corporation, we were able to make a database of UWB propagation measurements available over the web (See http://ultra.usc.edu/New_Site/).

6. Other Relevant Work Being Conducted and How this Project is Different

With the FCC's approval of UWB regulations, many universities and companies have jumped into the realm of UWB research. Our advantage has been that we have several years head start and have a solid database of propagation measurements. The work that we have done has been more universally accepted because of our reliance on actual propagation measurements (rather than models developed for narrowband applications) as the starting point for design studies [7].

7. Plan for the Next Year

We expect to complete the exploration of modulation performance in multipath early in the next year. The complementary work, namely UWB pulse generation, is a major challenge from our point-of-view. If this is not done correctly, extremely inefficient radios can be the result, and this inefficiency is exacerbated by the extremely low power levels at which UWB radios are required to operate. Our objective, along with our collaborators, is to build a UWB pulse generator that is efficient in its design with respect to FCC regulations. Papers on this topic are

missing key points regarding how the regulatory measurement is made, what the effect of the transmitting antenna is, how the waveform driving the antenna is generated, and how efficient power transfer from UWB waveform generator to antenna is achieved across the ultrawide bandwidth. Discussions with Pico-Second Pulse Labs and Agilent have indicated that they do not have this technology yet. We have begun a theoretical study to explore the design of efficient UWB pulse generators.

8. Expected Milestones and Deliverables

Within the next year, we expect to be able to define the relationship between the UWB signal generator's design parameters, the radiating antenna, and the generator's quality with regard to filling the FCC's UWB radiation mask. With the cooperation of colleagues, we expect to test some critical circuits on chips. This is the direction in which we expect the immediate research supported by IMSC to go.

There are many milestones related to the larger associated effort, but the above is the one most closely related to IMSC goals and interests.

9. Member Company Benefits

In return for the support that we had earlier in this year from NTT DoKoMo and Time Domain, we provided reports of our research to assist these companies in evaluating and guiding their efforts in the UWB radio development area.

10. References

[1] ---, "First Report & Order," ET Docket 98-153 (Revision of Par 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems), Federal Communications Commission, adopted February 14, 2002, released April 22,2002.
[2] Joon-Yong Lee and Robert A. Scholtz, "Ranging in a Dense Multipath Environment Using an UWB Radio Link," *IEEE Journal on Selected Areas in Communications,* vol. 20, no. 9, pp. 1677-1683, December 2002.
[3] E. A. Homier and R. A. Scholtz, "Rapid Acquisition of Ultra-Wideband Signals in the Dense Multipath Channel," *2002 IEEE Conference on Ultra Wideband Systems and Technologies*, Baltimore MD, May 2002.
[4] Jean-Marc Cramer, R. A. Scholtz, and Moe Z. Win, "Evaluation of an Ultra-Wideband Propagation Channel*," IEEE Transactions on Antennas and Propagation*, vol. 50, no. 5, pp. 561-570, May 2002.
[5] R. Weaver, E. Homier, J. Lee, P. Hilmes, A. Taha, R. Wilson, and R. A. Scholtz, "UWB Radio Deployment Challenges," *PIMRC 2000*, London, UK, September 18-21, 2000.
[6] R. D. Wilson, R. D. Weaver, M.-H. Chung and R. A. Scholtz, "Ultra-Wideband Interference Effects on an Amateur Radio Receiver," *2002 IEEE Conference on Ultra Wideband Systems and Technologies*, Baltimore MD, May 2002.
[7] Moe Z. Win and R. A. Scholtz, "Characterization of Ultra-Wide Bandwidth Wireless Indoor Communications: A Communication-Theoretic View," *IEEE Journal on Selected Areas in Communications,* vol. 20, no. 9, pp. 1613-1627, December 2002.