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 (directly supported), many students in associated projects.

Industrial Partner(s): INHA (just starting)

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, including NSF, DoD, and commercial entities, has been used to build research teams investigating position location algorithms, communication receiver architectures, antenna design, waveform and modulation design and implementation, channel characterization and synchronization schemes, etc. These teams include ten faculty members at three different schools, along with their graduate students. The support of this collaborative MURI project will continue until May 2006.

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 have been developed and provided to the IEEE 802.15 Standards Committee's working group for

UWB channel model development. Information on interference studies 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

Robert Wilson, supported by IMSC, published two conference papers in 2003. Below are their citations and brief descriptions:

In "Comparison of CDMA and Modulation Schemes for UWB Radio in a Multipath Environment" [1], multiple candidate multiple-access and modulation schemes were evaluated using the recently established IEEE standard channel model for UWB radio. It was found that for a single user scenario, bit-flipping outperformed binary pulse position modulation in terms of bit error rate and probability of outage, and that direct sequence multiple access coding provides better multipath resistance than a time hopping code of the same length. A simplified version of the channel model was also used and found to accurately replicate the observed performance measures using the more complex model.

The paper "Template Estimation in Ultra-Wideband Radio" [2] presented a least-squares approach to finding a correlation template in an ultrawideband receiver that only requires knowledge of the transmitted pulse shape. This work results in increased energy capture efficiency when compared to fixed template techniques, while being more resistant to narrowband interference than transmitted reference systems.

Our results for the performance of a variety of UWB modulations in multipath channels have been expanded. Single-path UWB stored reference systems have been compared to UWB transmitted reference systems, based on the 802.15.3 channel models, clearly indicating the trade-off between energy capture efficiency in the SR system and added noise and modulation inefficiency in the TR system. (Support for continuation of this work will be provided by IMSC in 2004.) The motivation for finding simpler, but equivalent, statistical channel models is to enable rapid simulation or, even better, analytical evaluation of candidate systems. Work to date has shown that such model simplifications are possible while maintaining the integrity of performance measures.

Scholtz and Namgoong's cooperative effort (along with MURI collaborator David Pozar from Umass) to design, build, and test a UWB signal synthesizer is progressing. One UWB synthesizer (lab instrument), fabricated in GaAs technology, was brought to USC by Shusaku Shimada of Ando Electric Co., (Yokohama, Japan) for several days of testing. The UltRa Lab then sent one student with Shimada and the instrument to NIST in Boulder for testing by Bob Johnk and his colleagues. Meanwhile at USC, a transmitter with 3 bit digital-to-analog (DAC) has been implemented in 0.25um CMOS and is currently being tested. In addition, a computer search has been initiated for optimal sequences to drive DACs for the purpose of efficiently filling the FCC's UWB emission mask. (Portions of this project supported by the MURI grant.)

The UltRa Lab's website now provides UWB propagation measurement data to the general research community over the Internet.

During the last year, the efforts of this research team have been acknowledged with three major awards:
(1) Jean Marc Cramer, Bob Scholtz, and Moe Win received the **2003 S. A. Schelkunoff Award** for the paper, "An Evaluation of the Ultra-Wideband Propagation Channel," presented by the *IEEE Antennas and Propagation Society* [3].
(2) Eric Homier and Bob Scholtz received the **2003 IWUWBS Best Paper Award** for the coauthored paper, "Hybrid Fixed-Dwell-Time Search Techniques for Rapid Acquisition of UWB Signals", presented by the *International Workshop on Ultra-Wideband Systems* [4].
(3) Mingrui Zhu and Keith Chugg received the **2003 Fred Ellersick Award** for the best unclassified paper at *MilCom 2003* for their paper "Iterative Message-Passing Algorithms for Rapid PN Code Acquisition."
The primary support for (1) was National Science Foundation Grant 9730556. The latter two awards credit support from the UWB MURI grant from the Army Research Office.

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 had several years head start and have a solid database of propagation measurements (that we share with the research community at large). 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. Plan for the Next Year

Future work is planned that will more rigorously show the relationship between the complete and simplified UWB channel models, and ultimately lead to the development of analytical expressions for predicted radio performance.

We are very close to completing a definitive comparison of UWB transmitted-reference and stored-reference systems. We publish this work in the coming year.

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 efficiently filling the FCC's UWB radiation mask. With the cooperation of colleagues, we expect to test some critical circuits on chips.

8. Expected Milestones and Deliverables

There are many milestones related to the larger UWB-associated effort. We expect to document the efforts of the three areas mentioned in Section 7 during the coming year, in addition to demonstrating the implementation of an efficient UWB signal generator.

9. Member Company Benefits

We will provide year-end reports describing activities in the UltRa Lab, invitations to research reviews and workshops related ton UWB efforts. We will also interact with long-term visitors when the situation merits such an arrangement.

10. References

[1] R. Wilson and R. Scholtz, "Comparison of CDMA and Modulation Schemes for UWB Radio in a Multipath Environment," *Globecom 2003*, vol. 2, pp. 754 - 758, Dec 2003.
[2] R. Wilson and R. Scholtz, "Template Estimation in Ultra-Wideband Radio," *Asilomar Conference on Signals, Systems and Computers*, Nov 2003 (Proceedings to appear).
[3] 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.
[4] E. Homier and R. A. Scholtz, "Hybrid Fixed-Dwell-Time Search Techniques for Rapid Acquisition of Ultra-Wideband Signals," *IWUWBS2003*, Oulu, Finland, June 2003.
[5] M. Zhu and K. M. Chugg, " Iterative Message-Passing Algorithms for Rapid PN Code Acquisition," *2003 IEEE Conference on Military Communications (MILCOM),* Boston MA, Nov. 2003.