Space-Time Secure Communications for Hostile Environments

Communicating in a complex environment is a difficult problem in situations like a hostile urban setting populated with a multitude of buildings and vehicles, or a maze of tunnels and caves. This project uses multichannel time-reversal (T/R) processing techniques to communicate in a highly reverberative environment.

For our final year, we focused our attention on 1) wideband acoustic communications using a time reference modulation technique; and 2) multichannel communications in a tunnel (or cave or pipe) with many obstructions, multipath returns, severe background noise, disturbances, long (~180 ft) propagation paths with disruptions (bends). For this environment, we showed that multichannel T/R receivers can be extended to the wideband designs while demonstrating their performance in both the "canonical" stairwell of our previous work as well as a tunnel-like structure.

Acoustic information signals are transmitted with an eight-element host or base station array to two client receivers with a significant loss in signal levels due to the hostile environment. In this project, the results of the new wideband T/R processor and modulation scheme demonstrate the overall performance of both high (24-bit) and low (1-bit) bit level analog-to-digital (A/D) converter designs. We validated these results by performing proof-of-principle acoustic communications experiments in air, showing that T/R receivers are capable of extracting the transmitted coded sequence from noisy microphone array measurements with zero-bit error.

The multichannel communications problems we solve using wave propagation physics are shown in Fig. 1, where we see that the host or base array transmits its coded information along different and unique paths to each client receiver.

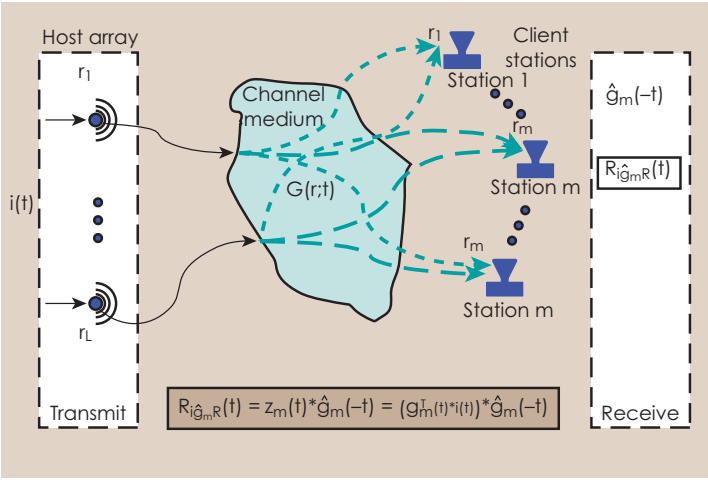

Figure 1. Basic communications environment, including the host T/R, hostile medium, the corresponding unique sets of Green's functions, and T/R pairs from host array to client receiver stations.

Project Goals

Successful implementation and demonstration of T/R receiver performance will lead to the next generation advance for military and defense applications, as well as potential commercialization. Ultimately, our success will provide improved communications in noisy, distorted environments, with a potential breakthrough technology for both military and civilian (commercial) applications. This proposal is aimed at developing a core competency in wireless

For more information contact
James Candy
(925) 422-8675
candy1@llnl.gov

communication networks, and falls within the advanced sensor and instrumentation competency area.

Relevance to LLNL Mission

Both the maintenance of communications in a strong multipath environment, and the protection of the communication against intercept, are important to LLNL. Thus, there is a strong need for reliable channels in corrupting environments, with the additional feature that they be secure. Secure communications can be derived from T/R principles that will lead to novel applications, ranging from military applications (such as battlefield communications, urban warfare, tunnel complexes, and pipes) to the hostile urban environment. The T/R receiver technology also promotes protection of communication channels against intercept, and thus supports LLNL's national security mission as well as homeland defense applications.

FY2005 Accomplishments and Results

Our FY2005 accomplishments included:

1. development of multichannel theory for T/R communications;
2. implementation of new wideband T/R modulation scheme;
3. performance of controlled acoustic experiments in various environments;
4. demonstration of T/R performance;
5. investigation of experimental design for EM hardware; and
6. initiation of hardware design for FPGA technology.

The experimental set-up in the tunnel-like structure is shown in Fig. 2, with all of its bends, pipes, blind corners and multitude of reflectors, creating an extremely hostile acoustic communication environment for T/R receiver performance analysis.

We have obtained results for one-receiver performance in this environment, for both a 24-bit and a 1-bit receiver design. We have noted a degradation going from 24- to 1-bit A/D conversion.

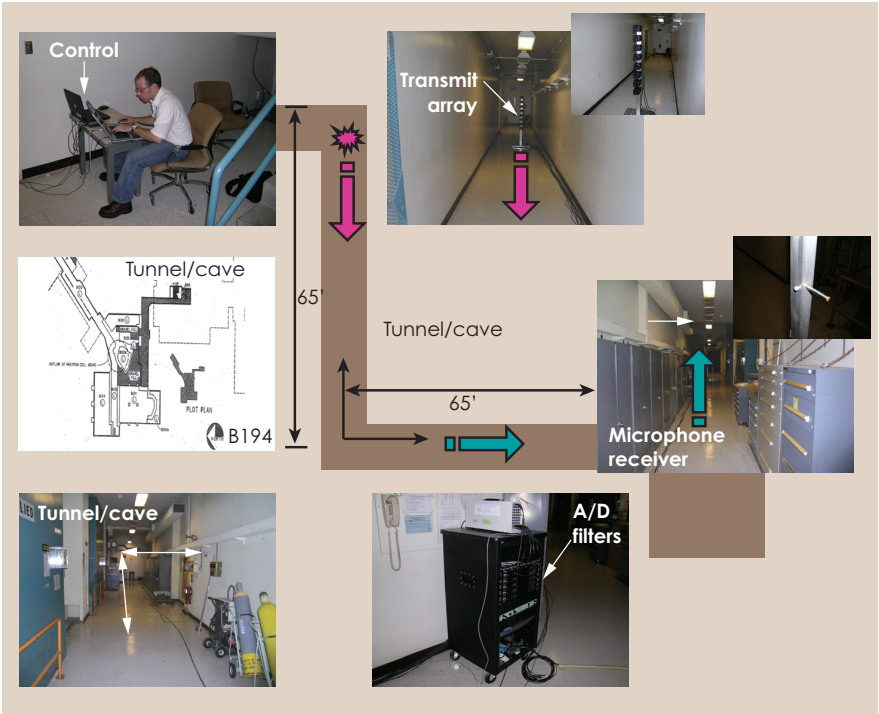

Figure 2. The experimental and environment set-up in a tunnel-like structure, with bends, pipes, blind corners and multitude of reflectors. Note that a schematic map demonstrates the tunnel communications path, with the client receiver approximately 180 ft away.

Related References

1. Candy, J., A. Poggio, D. Chambers, B. Guidry, C. Robbins, and C. Kent, "Multichannel Time Reversal Processing for Acoustic Communications in a Highly Reverberant Environment," *Journal of the Acoustical Society of America*, **118**, 4, pp. 2339-2354, 2005.
2. Candy, J., A. Meyer, A. Poggio, and B. Guidry, "Time Reversal Processing for an Acoustics Communications Experiment in a Highly Reverberant Environment," *Journal of the Acoustical Society of America*, **115**, pp. 1621-1631, 2004.
3. Chambers, D. H., J. V. Candy, S. K. Lehman, J. S. Kallman, A. J. Poggio, and A. Meyer, "Time Reversal and the Spatial-Temporal Matched Filter," *Journal of the Acoustical Society of America*, **116**, pp. 1348-1350, 2004.