Ultra-Wideband Dynamic Pulse Shaping for Communications and Remote Sensing

Improvements in covertness and security for communications links are a constant area of interest in modern industry. The advent of ultra-wideband (UWB) communications has allowed investigation into RF transmission systems using ultra-short time-domain pulses to produce widely spectrally-spread RF bursts. However, state-of-the-art UWB communications systems still rely on traditional pulse-spacing techniques and constant pulse shapes to send data across the channel. This leaves the systems vulnerable to detection and interception.

Recent semiconductor processing advancements have permitted the realization of new ultra-short-pulse-generation hardware using current-steering methods. These new pulse-generation techniques permit ultra-short bursts of pulses to be electronically shaped as they are generated, and their shapes to be altered at high speeds from pulse to pulse.

Project Goals

This capability has two unique applications to data transmission systems. First, by encoding data into the shape of ultra-short bursts, instead of using burst presence/absence or spacing to transfer data, a system's throughput can be greatly increased. Second, since each pulse transmitted has a different shape, it has a different spectral content, even in UWB systems. By combining pulse-to-pulse spectral alteration with transmission schemes pioneered at LLNL, that allow pulses to be sent at untimed, random intervals, the potential for highly covert and secure communications systems can be demonstrated.

This project will test and evaluate this advanced pulse-generation technology, which has the potential to be used in ultra-fast transient digitizers and real-time sampling applications. Such technology can be applied to numerous areas of communications, security, and precision engineering.

Relevance to LLNL Mission

This technology offers numerous advantages over traditional UWB pulse-generation techniques. The existing technologies have limitations, such as ~500-MHz maximum pulse-repetition rates, poor matching

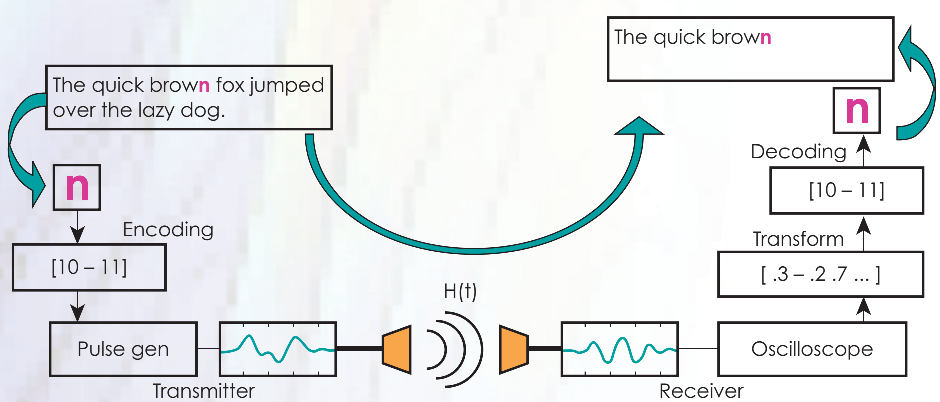
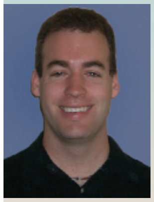


Figure 1. Data flow diagram for the pulse-shape transmission system.



For more information contact
Peter C. Haugen
(925) 422-0749
haugen2@llnl.gov

between multiple units, jitter, and poor temperature stability. This new technology has the potential to be an important addition to current pulse generation and UWB work at LLNL.

FY2005 Accomplishments and Results

The dynamic pulse-shape-generation technique was calibrated for performance against other UWB pulse-generation techniques currently used at LLNL, in terms of time jitter, power output, power consumption, maximum pulse-repetition rate, repeatability, and stability over a wide temperature range. It was then integrated into a demonstration data-coded pulse-shape transmission scheme.

This system was implemented and can be used to transfer data across a free-space link. A series of data bits are encoded into each RF burst using the pulse shaper linked to a PC, and the resulting pulse is amplified and transmitted across the link. On the receiver end, an oscilloscope (with appropriate preamps and filters) is used to capture the RF burst, which is then downloaded to the PC for decoding in an automated process. As expected, the antenna, filters, and amplifiers distort the generated pulse shapes to some extent, so a transfer function must be applied to the received data to recover the original data. This was implemented and the final data flow happens as shown in the data flow diagram (Fig. 1).

The data reconstruction plot (Fig. 2) shows the data flow as it is encoded into RF burst shapes, transmitted, received, and reconstructed. The frequency content plot (Fig. 3) shows how the RF energy spectrum changes as the burst shape changes with the transmitted data. In our testing we have found that, while this pulse-shaping technique does have limitations, it can be readily used to enhance several areas, such as the potential for the creation of reliable, highly covert UWB communication links, and channel-matched transmitters for radar and remote sensing.

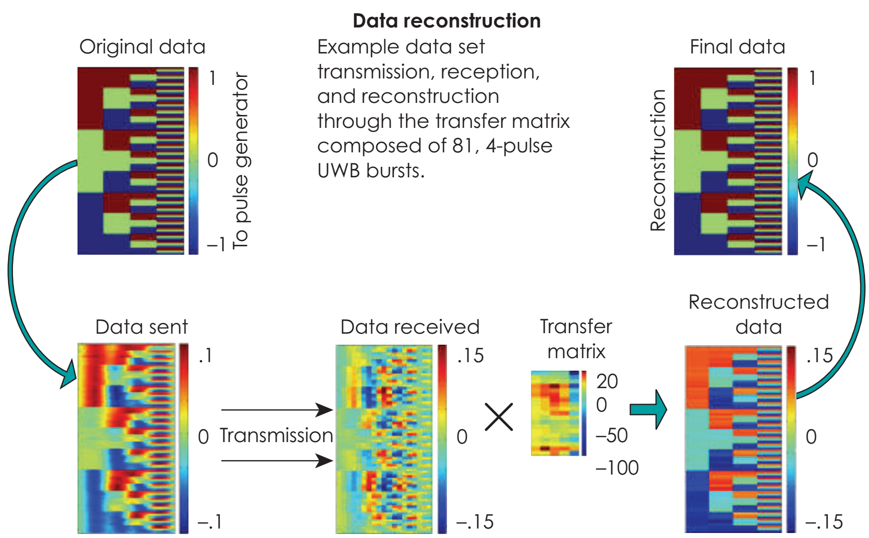


Figure 2. Data reconstruction process of example data set.

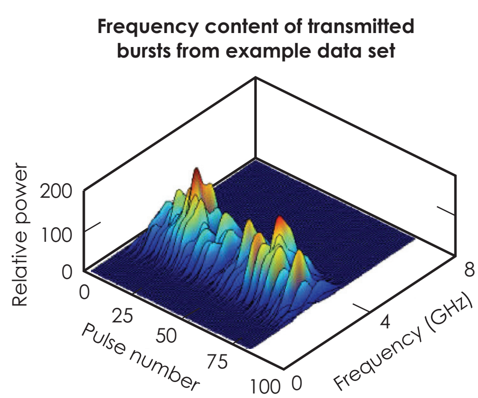


Figure 3. RF spreading spectrum of example data set.