Software-Defined Ultra-wideband Radio Communications: A New RF Technology for Emergency Response Applications

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INTRODUCTION

Reliable wireless communication links for local-area (short-range) and regional (long-range) reach capabilities are crucial for emergency response to disasters. Lack of a dependable communication system can result in disruptions in the situational awareness between the local responders in the field and the emergency command and control centers. To date, all wireless communications systems such as cell phones and walkie-talkies use narrowband radio frequency (RF) signaling for data communication. However, the hostile radio propagation environment caused by collapsed structures and rubble in various disaster sites results in significant degradation and attenuation of narrowband RF signals, which ends up in frequent communication breakdowns.

To address the challenges of reliable radio communication in disaster fields, we propose an approach to use ultra-wideband (UWB) or wideband RF waveforms for implementation on Software Defined Radio (SDR) platforms. Ultra-wideband communications has been proven by many research groups to be effective in addressing many of the limitations faced by conventional narrowband radio technologies. In addition, LLNL's radio and wireless team have shown significant success in field deployment of various UWB communications system for harsh environments based on LLNL's patented UWB modulation and equalization techniques. Furthermore, using software defined radio platform for UWB communications offers a great deal of flexibility in operational parameters and helps the radio system to dynamically adapt itself to its environment for optimal performance.

In this position paper, we discuss LLNL's approach for long-range reliable radio communications for emergency responders.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

ULTRA_WIDEBAND TECHNOLOGY AND LLNL'S APPROACH

Ultra-wideband communications is fundamentally different from conventional communication techniques because it employs extremely narrow RF pulses (pico-seconds to nano-seconds) with low duty cycle to communicate between transmitters and receivers. Utilizing short-duration pulses in place of continuous waveforms as the building blocks for communications, directly generates a very wide bandwidth (several Giga-Hertz). A comparison of conventional narrowband and UWB communications is shown in Fig. 1.

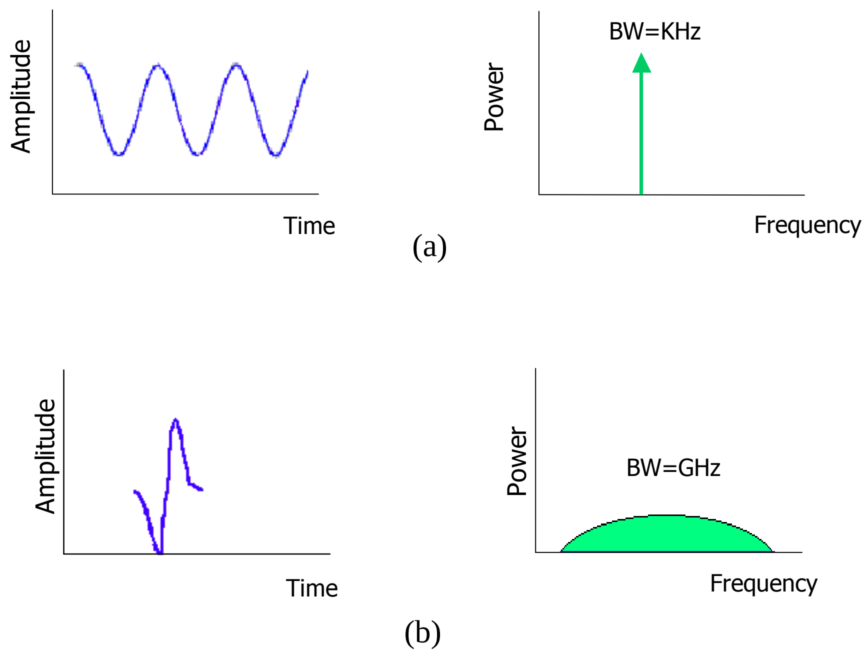

Figure 1. (a) Conventional narrowband communications send long continuous waveforms and generate very narrow frequencies. (b) UWB communications send extremely narrow pulses and generate very wide frequencies.

The frequency diversity in spectral domain makes UWB pulses resistant to jamming and interference, makes them less sensitive to multipath effects compared to narrowband signals, and provides better signal penetration capabilities. In addition to inherent advantages of UWB signaling for reliable communications, LLNL's analog equalization-modulation technique, called multipulse modulation, offers considerable advantages over conventional modulation techniques (i.e., ASK, FSK) in terms of channel estimation, relaxed synchronization requirements, and exploiting multipath reflections for high processing gain and improved signal-to-noise ratio.

The proposed multipulse modulation in its basic form consists of the transmission of a pair of pulses or doublets separated in time with a delay known to the receiver. The receiver demodulates the received data by correlating the received signal with a delayed replica of itself. This method takes advantage of the fact that the two signals being correlated have experienced the same channel distortion with respect to multipath phenomenon and therefore, there is always high correlation between them that result in reliable communications in dense multipath environments.

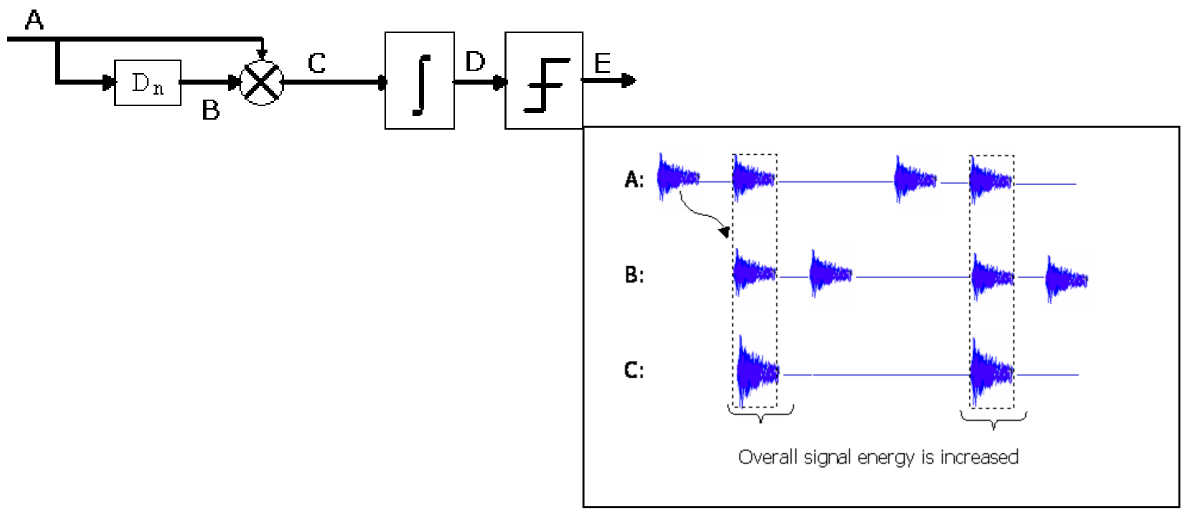

Figure 2: (Left) Block diagram of a multipulse receiver (similar to Fig.2). Dn is the delay between the transmitted pulses. (Right) Signal representation of multipulse receiver in multipath channels. Due to passing through the same channel, the signal energy for correlation is stronger.

Although the above method has been proven to be successful by LLNL team in many field experiments, there is a need for adding flexibility to the system by implementing this technique in SDR platform where the operational parameters such as operational frequency, transmit power, pulse shape, delay between the pulses, etc. can be changed and optimized on-the-fly to adapt the UWB communications system to its operation environment in emergency situations.

In summary, SDR offers the flexibility between bandwidth and range, the ability to adapt to the environmental parameters and employ optimal wide-band pulse characteristics for channel equalization and robustness, and finally the capability to easily adapt to current communication infrastructures, such as personal computers. We have been developing these advanced techniques in our laboratory for both short- and longer range RF communication. Preliminary tests in the field have also shown great potential for SDR-based wideband wireless communications.

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