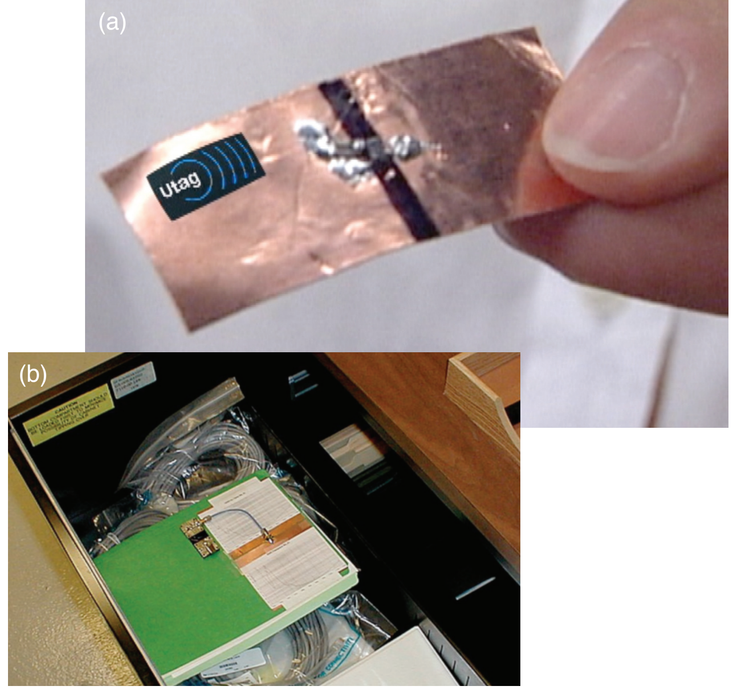
Wireless That Works



(a) Utags are small, lightweight radio-frequency identification devices that use ultrawideband signals to monitor cargo containers. (b) In tests, Utags were attached to documents and placed inside metal cabinets. Results showed the metal did not interfere with the transmitted signals.

EVEN though cell phones and other wireless communication technologies are in widespread use, reception is notoriously poor in certain places such as underground or in tunnels and dense urban landscapes. Livermore engineer Faranak Nekoogar calls these hard-to-reach areas “harsh propagation environments.” Nekoogar, who works in the Laboratory’s Engineering Directorate, leads an effort to develop wireless communication technologies that will work where conventional devices are limited or fail altogether.

“Radio-frequency communications use narrowband signals, which are inherently limited,” says Nekoogar. “In harsh propagation environments, the signals attenuate as they are reflected by metal, concrete, and other objects.” When radio signals bounce from structure to structure, the repeated reflections, called multipath phenomena, can cause signals to fade or be canceled. To overcome these limitations and improve transmissions, the Livermore team is using ultrawideband (UWB) electromagnetic pulses, which can penetrate concrete buildings and metallic obstructions.

Low-Power, Long-Range Transmissions

Traditional narrowband wireless technologies transmit strong, continuous-wave signals, which are easily detected, intercepted, and jammed. Narrowband electronics also require extensive circuitry to filter and extract information from the signal. In addition, licensing the required bandwidth can be expensive. Livermore’s UWB technology sends extremely short electromagnetic pulses across a wide band of frequencies. High-speed digital receivers record the pulses reflected by nearby objects. (See *S&TR*, September 2004, pp. 12–19.)

UWB pulses last only a few trillionths of a second, so interfering with a transmission is difficult. The pulse power is spread over a broad frequency range, resulting in extremely low power levels at any given frequency. Best of all, devices can be designed so that UWB signals will not affect other wireless technologies such as flight radios, ground-based beacons, the Global Positioning System, and cell phones. Also, the technology uses the entire radio spectrum, so there is no cost for licensing a particular frequency.

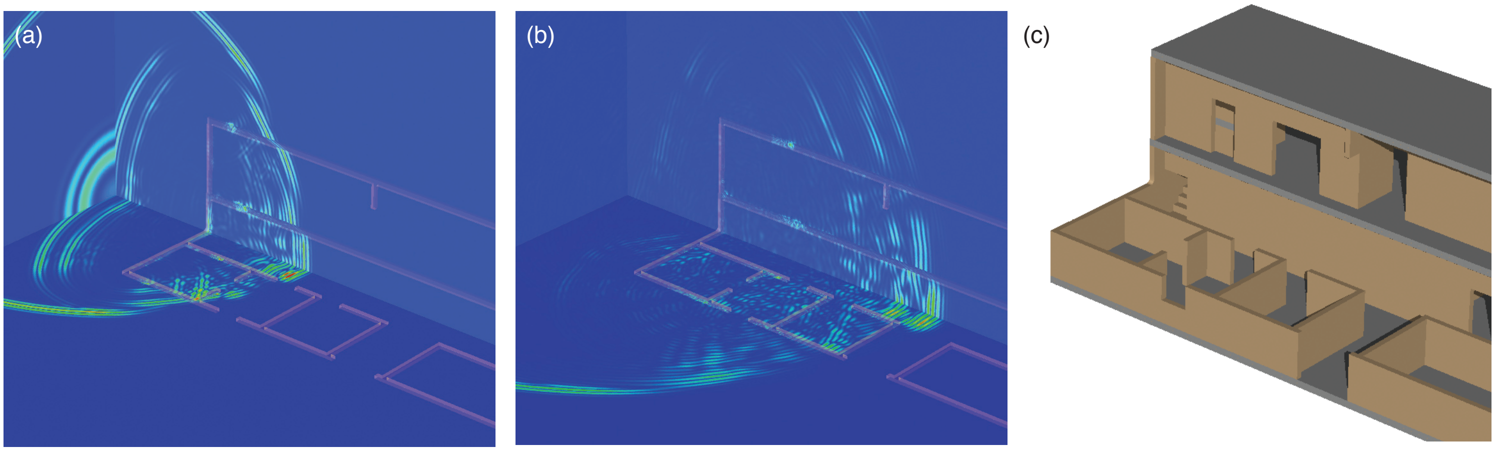
The range of a UWB transmitter and receiver pair is affected by the transmitted power and the frequency bandwidth used. Because the Federal Communications Commission mandates a frequency between 3.1 and 10.6 gigahertz for commercial UWB systems, they are typically used for short-range applications, within about 10 meters. However, the bandwidth at that range is so high that UWB systems can process gigabytes of data per second, allowing them to simultaneously transmit high-resolution voice, video, and data recordings in real time.

Private industry has focused its research on developing short-range, high-data-rate communication systems, but UWB technologies offer more than improved communications. The low power levels and wideband features make the signals ideal for secure, covert transmissions in combat settings or for surveillance systems. Livermore engineer Peter Haugen is leading several research efforts that focus on optimizing UWB communication technology for long-range applications. Laboratory engineers are also designing UWB technologies to address national security needs. For example, they have developed intrusion sensors, rapidly deployable perimeter networks, and noncontact triage and sensing devices.

Improving Port Security

Each year, more than 18 million cargo containers enter U.S. ports from overseas. Security officials are concerned that one of them will contain a threat material or have had its contents tampered with. To address those concerns, Nekoogar’s team developed a small, lightweight UWB radio-frequency identification tag, called Utag.

Utags work without batteries and can be placed inside metal containers to identify the container, keep a record of its contents, and detect intrusions. Security personnel can use the tags to monitor a container’s contents from up to 20 meters away, a distance 20 times greater than the passive narrowband tags currently available. According to engineers Greg Dallum and Dave Benzel, the team plans to extend the receiving range to 100 meters in the near future. Utags can also be connected to radiation monitoring hardware, which will transmit results to a computer aboard ship or to a handheld reader.



(a, b) Large-scale simulations modeled ultrawideband radar propagating through a building. (c) The resulting data were used to determine the building's internal structure.

Because Utags have geolocation capability, they can be used to track objects or individuals. Once a Utag is attached to a target, receivers can remotely query the tag and process the returned signal into images. By viewing the images in sequence, researchers can estimate where the target is moving. The inexpensive, tamper-resistant Utags could help combat units track soldiers, supplies, and munitions. The devices could also be adapted to monitor hazardous or dangerous materials, search for lost children or pets, and secure assets such as jewelry.

VisiBuilding Sees through Walls

Another application for the Livermore technology supports the VisiBuilding Program directed by Ed Baranoski in the Department of Defense's Defense Advanced Research Projects Agency. VisiBuilding combines radar, signal processing, statistical analysis, and deconvolution algorithms to map a building's floor plans and track insurgents—all from outside the structure.

For this project, Livermore engineers in collaboration with SRI International and Signetron, Inc., developed a model-based methodology that uses noncontact UWB imaging to reconstruct building interiors and determine what lies behind the walls. Led by Laboratory engineer Farid Dowla, the team's first goal was to ensure that the concept would work as expected. Using Livermore's massively parallel supercomputers, the team simulated UWB wave propagation inside various structures. The simulations took into account how the signals would be received and determined the optimal locations for receivers.

With these results, the team developed algorithms to translate the simulated signals into physical models that predict a building's contents. The full system—including modeling algorithms, system planning knowledge, and hardware—will be developed in the project's next phase. (See *S&TR*, November 2007, pp. 4–10.)

Secure Communication at Sea

Livermore's engineers envision many ways to apply UWB communication technology to problems of national importance and are continuing to examine potential innovations. Most recently, a team led by project manager Kique Romero conducted large-scale field exercises to demonstrate a UWB wireless communication system that works aboard ships. The small, highly metallic corridors on ships create virtually unlimited paths for signal reflections. In the demonstration tests, the Livermore prototype transmitted voice and video data from a ship's top deck down to the engine room, even as normal activity continued with hatches opening and closing.

The Laboratory has licensed many UWB applications, and several inventions have received R&D 100 awards, including the noninvasive pneumothorax detector. (See *S&TR*, October 2007, pp. 4–5.) Livermore innovations include locating buried plastic and metallic land mines, inspecting bridges, imaging roadbeds, and detecting motion inside protected areas. (See *S&TR*, January/February 1996, pp. 16–29.)

"As we investigate the broader realm of wideband and UWB systems, we are just beginning to dream of possibilities," says Romero. "Thanks to recent advances both in industry and at Livermore, we are generating innovative solutions that were not even possible a few years ago."

—Karen Rath

Key Words: radio-frequency identification tag, ultrawideband (UWB) radar, Utag, VisiBuilding project, wireless communication technology.

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