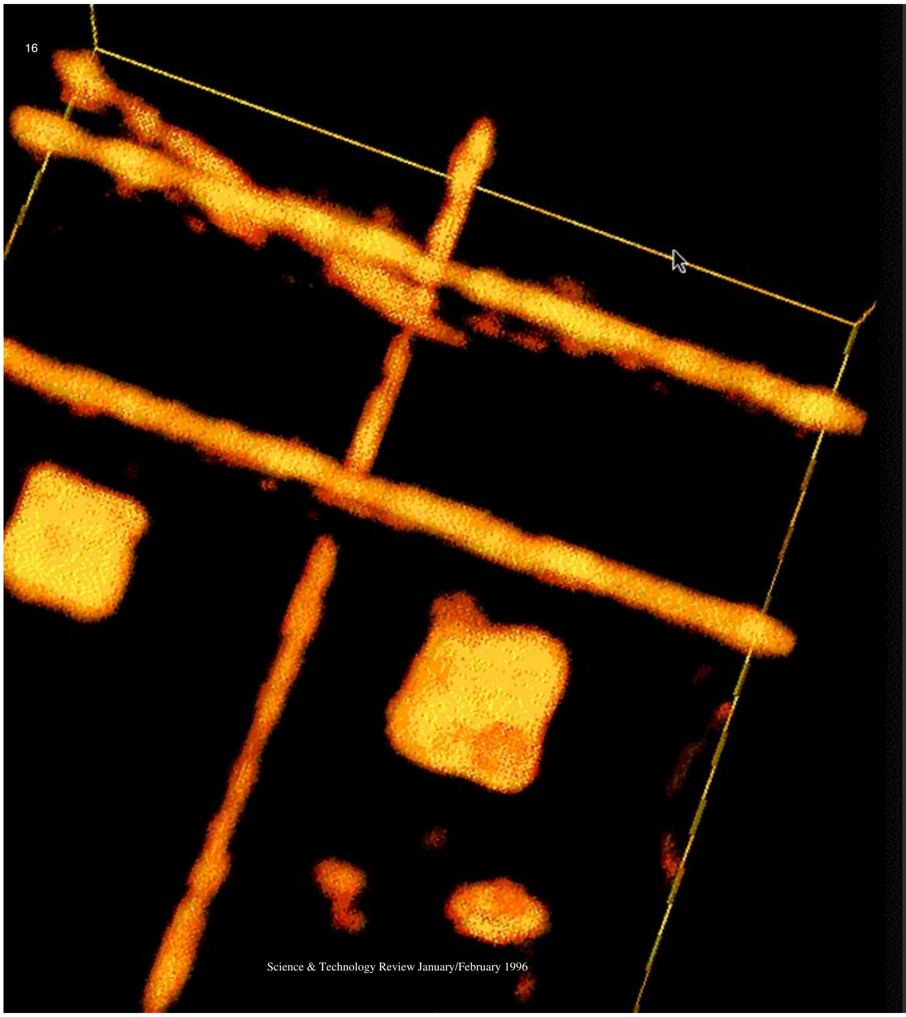


Micropower Impulse Radar

A new pocket-size radar that operates up to several years on AA batteries and costs only a few dollars is stimulating Laboratory research efforts and a variety of industrial products. Its many potential uses include security, rescue operations, and health monitoring.

RADIO detection and ranging (radar) was first developed in the 1920s. Most of us associate radar with combat scenes in movies or an occasional speeding ticket. Conventional radar uses beamed and reflected microwave energy to detect, locate, and track objects over distances of many miles. Almost all types of radar were developed for defense applications, and they continue to be used by the military and a few civilian organizations. Commercial use has been limited primarily because most radar systems are large, and they can be complex and cost $40,000 or more. A dramatic change in radar use is imminent, resulting from work done at LLNL.

We have invented and patented a fundamentally different type of compact, low-power radar system called micropower impulse radar (MIR), which is orders of magnitude less expensive to produce than other conventional radars. Unlike conventional radar, which sends out continuous waves in bursts, MIR uses very short electromagnetic pulses and can detect objects at much shorter range. The new technology has become

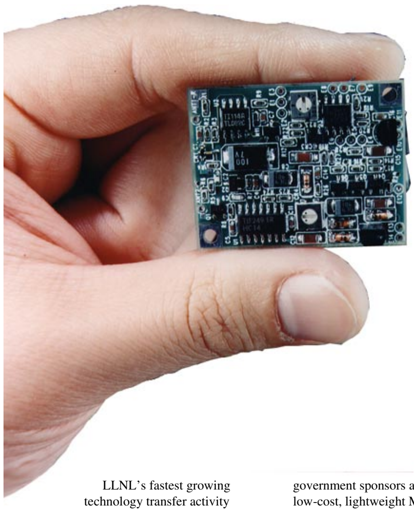


Figure 1. The micropower impulse radar (MIR) proximity sensor board.

LLNL's fastest growing technology transfer activity primarily because of its low cost and extraordinary range of applications.

Among the scores of uses under investigation for MIR are new security and border-surveillance systems; underground, through-wall, and ocean imaging; fluid-level sensing; automotive safety, including collision-avoidance and intelligent cruise-control systems; "smart" devices such as lights, heaters, and tools that automatically turn on or off; and medical diagnostics.

The technology has potential use in finding earthquake survivors under rubble and in monitoring for sudden-infant-death syndrome. Various government sponsors are interested in low-cost, lightweight MIR sensors in areas of defense, law enforcement, transportation infrastructure, and the environment. Envisioning perhaps hundreds of other uses, Tom McEwan—the electrical engineer who invented MIR—has compared the new technology to the Swiss Army knife.

The Genesis of MIR

MIR, with origins in Lawrence Livermore's Laser Programs Directorate, is now being developed by that directorate's Imaging and Detection Program. The Laboratory is home to the 100-trillion-watt Nova laser. Developed for nuclear fusion research, the ten-beam pulsed Nova laser generates subnanosecond events that must be accurately recorded. In the late 1980s, Laboratory engineers began to develop a new high-speed data acquisition system to capture the data generated by Nova and the next-generation laser system, the National Ignition Facility. The result was a single-shot transient digitizer—a 1993 R&D 100 Award winner described in the April 1994 issue of *Energy and Technology Review*.[1]

The LLNL transient digitizer, which is the world's fastest, functions as a high-speed oscilloscope combined with a digital-readout device. The instrument records many samples from single electrical events (a brief signal called a "transient"), each lasting only 5 nanoseconds (5 billionths of a second). Compared to competitive products, such as the best oscilloscopes, the transient digitizer is much smaller and more robust, consumes less power, and costs far less.

While developing the transient digitizer, project engineer McEwan had an important insight. The sampling circuits developed for it could form the basis of a sensitive receiver for an extremely small, low-power radar system (Figure 1).

MIR Components

The principal MIR components are shown in Figure 2: a transmitter with a pulse generator, a receiver with a pulse detector, timing circuitry, a signal processor, and antennas. The MIR transmitter emits rapid, wideband radar pulses at a nominal rate of 2 million per second. This rate is randomized intentionally by a noise circuit. The components making up the transmitter can send out shortened and sharpened electrical pulses with rise times as short as 50 trillionths of a second (50 picoseconds). The receiver, which uses a pulse-detector circuit, only accepts echoes from objects within a preset distance (round-trip delay time)—from a few centimeters to many tens of meters.

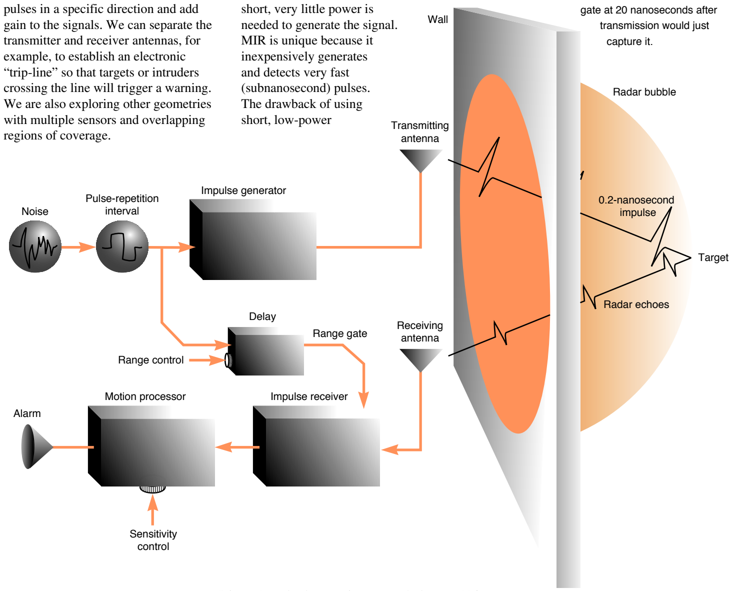
The MIR antenna determines much of the device's operating characteristics. A single-wire monopole antenna only 4 cm long is used for standard MIR motion sensors, but larger antenna systems can provide a longer range, greater directionality, and better penetration of some materials such as water, ice, and mud. Currently, the maximum range in air for these low-power devices is about 50 m. With an omnidirectional antenna, MIR can look for echoes in an invisible radar bubble of adjustable radius surrounding the unit (Figure 2). Directional antennas can aim pulses in a specific direction and add gain to the signals. We can separate the transmitter and receiver antennas, for example, to establish an electronic "trip-line" so that targets or intruders crossing the line will trigger a warning. We are also exploring other geometries with multiple sensors and overlapping regions of coverage.

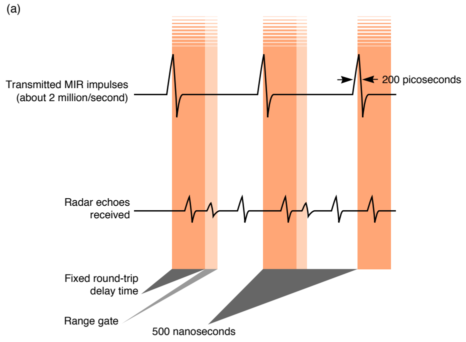
Behind MIR Technology

Impulse Radar

Conventional radar sends out short bursts of single-frequency (narrow-band) electromagnetic energy in the microwave frequency range. Other radars step through multiple (wide-band) frequencies to obtain more information about a scene. An impulse, or ultrawide-band, radar such as MIR sends individual pulses that contain energy over a very wide band of frequencies. The shorter the pulse, the wider the band, thereby generating even greater information about reflected objects. Because the pulse is so short, very little power is needed to generate the signal. MIR is unique because it inexpensively generates and detects very fast (subnanosecond) pulses. The drawback of using short, low-power

Figure 2. In an MIR motion sensor, a transmitting antenna radiates a pulse that is about 0.2 nanoseconds long. Reflections from targets return a complex series of echoes to the receiving antenna. The return signal is sampled at one range-gate time by an impulse receiver containing a voltage sampler along with an averaging circuit and amplifier. The detector listens at the appropriate time for an echo. For an object about 3 m from the MIR, the sampled gate at 20 nanoseconds after transmission would just capture it.





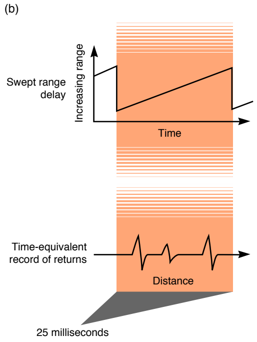


Figure 3. (a) Following an impulse transmitted by MIR, a range gate opens briefly after a fixed delay time to sample the received radar echoes. (b) To obtain a more complete record of returns for more sophisticated applications, we sweep the range delay over various delay times to obtain target information at different distances. We have effectively slowed down the radar signal by about a factor of 1 million to get an "equivalent-time" record of radar returns that can be correlated to object distances. (Pulses pictured here are not to scale.)

pulses is that less energy can be measured on the radar returns. We solved this problem by transmitting many pulses rapidly and averaging all returns.

The advantages of producing and detecting very brief radar impulses are considerable:

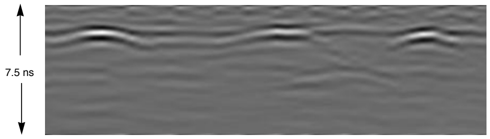
- The target echoes return much information. With short pulses, the system operates across a wide band of frequencies, giving high resolution and accuracy. The system is also less susceptible to interference from other radars.
- Battery current is drawn only during the short time the system is pulsed, so power requirements are extremely low (microamperes). One type of MIR unit operates for several years on two AA batteries.
- The microwave power associated with pulsed transmission is exceedingly low (averaging tens of microwatts) and is medically safe. MIR emits less than one-thousandth the power of a cellular telephone.

Range-Gated Radar

Transmitted energy from any radar is diffracted and scattered by objects in the field of view, such as cars, trees, or people. Larger and more conductive objects generally produce larger returns. Because the wavelength of MIR signals in air is currently about 15 cm, we can easily detect objects of that size or larger at distances of about 15 cm or greater. Distorted, low-amplitude reflections of the transmitted pulse are picked up by the receiving antenna in the time it takes for light to travel from the MIR to the object and back again.

The operating principle of MIR motion sensors is based on the relatively straightforward principle of range gating. In looking for the return signals, MIR samples only those signals occurring in a narrow time window after each transmitted pulse, called a range gate. If we choose a delay time after each transmitted pulse corresponding to a range in space, then we can open the receiver "gate" after that delay and close it an instant later. In this way, we avoid receiving unwanted signals.

(a) Unprocessed data



(b) Reconstructed image

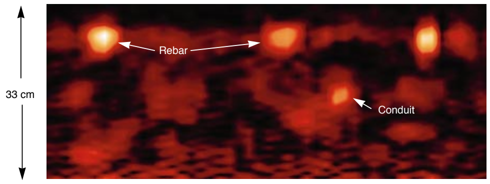


Figure 4. (a) Unprocessed radar information we obtained along a concrete floor in the Nova facility. (b) After applying a specialized image-reconstruction algorithm to the unprocessed MIR data, buried rebar and conduit shown in a cross section become clear.

The MIR receiver has a very fast sampler that measures only one delay time or range gate per transmitted pulse, as shown in Figure 3a. In fact, we use circuitry that is similar to the transmit impulse generator for this range-gated measurement, another unique feature of our device. Only those return pulses within the small range gate—corresponding to a fixed distance from device to target—are measured. The gate width (the sampling time) is always fixed based on the length of the pulse; but the delay time (the range) is adjustable, as is the detection sensitivity. Averaging thousands of pulses improves the signal-to-noise ratio for a single measurement; i.e., noise is reduced, which increases sensitivity. A selected threshold on the averaged signal senses any motion and can trigger a switch, such as an alarm.

Randomized Pulse Repetition

As mentioned earlier, a noise source is intentionally added to the timing circuitry so that the amount of time between pulses varies randomly around 2 MHz. There are three reasons for randomizing the pulse repetition rate and averaging thousands of samples at those random times. First, interference from radio and TV station harmonics can trigger false alarms; but with randomizing, interference is effectively averaged to zero. Second, multiple MIR units can be activated in one vicinity without interfering with each other if the operation of each unit is randomly coded and unique. Each unit creates a pattern recognizable only by the originating MIR. Third, randomizing spreads the sensor's emission spectrum so the MIR signals resemble background noise, which is difficult for other sensors to detect. Emissions from an MIR sensor are virtually undetectable with a conventional radio-frequency receiver and antenna only 3 m away. In other words, randomizing makes the MIR stealthy.

Equivalent-Time Sampling

More sophisticated MIR sensors, such as our MIR Rangefinder, cycle through many range gates. As shown in Figure 3b, the delay time is swept, or varied, slowly with each received pulse (about 40 sweeps per second) to effectively fill in the detection bubble with a continuous trace of radar information. In essence, we are taking samples at different times, thus different distances, away from the device. The result is an "equivalent-time" record of all return pulses that can be correlated to object distance. The equivalent-time echo pattern exactly matches the original "real-time" pattern, except that it occurs on a time scale slowed by 10^6. We can easily display the equivalent-time echo pattern on an oscilloscope or read the data into a computer. We are applying this sampling technique to many short-range applications, such as lightweight altimeters or reservoir-level measurement, as well as all MIR imaging applications.

Forming Images

With equivalent-time sampling, we can form images by moving the Rangefinder in front of a target area or by using a stationary array of Rangefinders. Figure 4a shows unprocessed radar information we obtained along a concrete floor in the Nova facility. Each vertical trace is a return signal from a different position

Table 1. Some commercial applications of MIR.

Commercial Sector	Application of MIR
Automotive	Parking assistance; backup warning; precollision detection; cruise control; airbag deployment; electronic dipstick for all fluid levels
Security	Home intrusion and motion sensor; keyless locks, automatic doors; child monitoring; vehicle theft alarm; radar trip wire; perimeter surveillance
Appliances	Stud finder; laser tape measure; wireless thermostat; automatic dispenser; automatic tool shutoff; toys, games, and virtual reality
Manufacturing	Fluid-level, proximity, and harsh-environment sensing; robotic sensor; industrial automation

along the floor. When many individual vertical views into the floor are stacked side-by-side, resembling slices of bread making up a loaf, we can reconstruct a cross section of the floor. As expected, features are obscured by the clutter inherent in all radar measurements. To resolve the locations of buried objects, such as rebar and conduit shown in Figure 4b, we apply a specialized image-reconstruction algorithm using diffraction tomography.[2]

Many such slices stacked together form a full 3-D view of the subfloor or other concrete structure (Figure 5). This unique combination of the MIR sensors and imaging software is spurring new, low-cost nondestructive inspection methods.

Summary of Features

As MIR technology has evolved, a unique combination of features resulted. Although certain specifications—signal strength, operating range, and directionality—can vary depending on the type of system and its intended purpose, the following features are common to most units:

- Low cost, using off-the-shelf components.
- Very small size (circuit board is about $4\ \text{cm}^2$).
- Excellent signal penetration through most low-conductivity materials, so it is able to "see through" walls, concrete, and other barriers, including human tissue.
- A sharply defined and adjustable range of operation, which reduces false alarms.
- Long battery life, typically several years, because of micropower operation.
- Simultaneous operation of many units without interference.
- Randomized emissions, making the sensor difficult to detect.

Current MIR prototype units at LLNL are made with low-cost, discrete components. In the planning stages are single chips—application-specific integrated circuits (ASICs)—that will replace most of the discrete parts and result in even lower cost and smaller size.

One limitation is that the penetration of MIR signals through a material decreases as that material's electrical conductivity increases. Thus, the technology cannot see through thick metal, such as a ship's hull, or sea water, but it still can penetrate substances with moderate electrical conductivity, such as the human body.

MIR as a Sensor Technology

MIR technology opens up many possible low-cost sensor systems for motion detection or proximity, distance measurement, microwave image formation, or even communications. For example, in some cases it has advantages over many kinds of conventional proximity and motion sensors, such as passive infrared (heat sensors), active beam-interruption infrared, ultrasound, seismic, and microwave Doppler devices. Many of these sensors are adversely affected by temperature, weather, and other environmental conditions, making them prone to false alarms. Passive infrared sensors can be triggered by light and heat, and their detection range is not well defined. Even a thin sheet of paper blocks both infrared and ultrasound signals. Similarly, ultrasound motion and Doppler microwave sensors interfere with one another when several units are co-located. Without range gates, these sensors can trigger as easily on distant objects as on nearby insects. They can also have limited material penetration, detectable emissions, and expensive components. MIR technology provides an attractive alternative to these devices.

We are following two paths in developing and applying MIR technology. For well-developed products, we encourage commercial applications, and we are licensing the technology to qualified manufacturers in the U.S. using a procedure that ensures fairness of opportunity. For ideas that require more research and systems development, we are continuing to explore electronics, antennas, signal processing, and imaging concepts as we develop programs that will apply MIR technology to support Laboratory missions and address problems of national interest.

Commercially Ready MIR

Table 1 lists some of the commercial applications of MIR. One key factor in virtually all commercial markets for MIR is cost. Most of our sensor units can be manufactured at a fraction of the cost of existing technology—indeed, they are typically hundreds of times less expensive. In many cases, there simply is no practical alternative technology on the market that is as robust, accurate, and inexpensive.

Security Systems

Home security systems now on the market can cost thousands of dollars, require regular maintenance, and be disrupted by interference from a neighbor's system. At a projected cost of $20, an MIR sensor (Figure 6), powered by AA batteries, operates without frequency channels or wiring and is simple to install. Motion sensors can be adjusted for sensitivity and range so that a pet, for example, would not trigger an alarm and could roam freely anywhere below a ceiling-mounted MIR sensor. Installations of MIR sensors already exist in the DOE nuclear weapons

MIR Recognition and Awards

- Thirty U.S. patent applications.
- Twelve industry licensees and many more expected.
- *Popular Science,* cover story March 1995 and Best of What's New Award 1994.
- *New Scientist,* cover story August 1995.
- *Electronic Design News,* 100 Hottest Products of 1994.
- Intellectual Property Owners, Distinguished Inventor of 1994.
- Federal Laboratory Consortium Award for Excellence in Technology Transfer 1995.

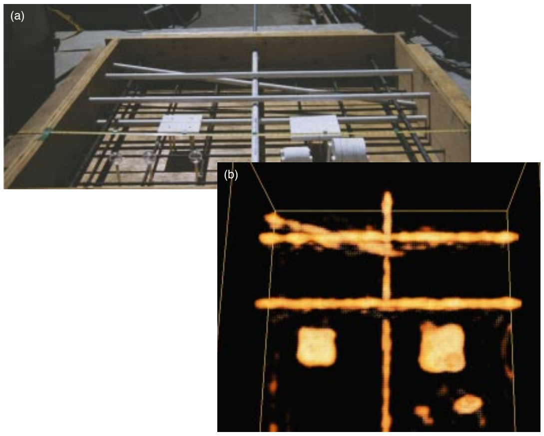
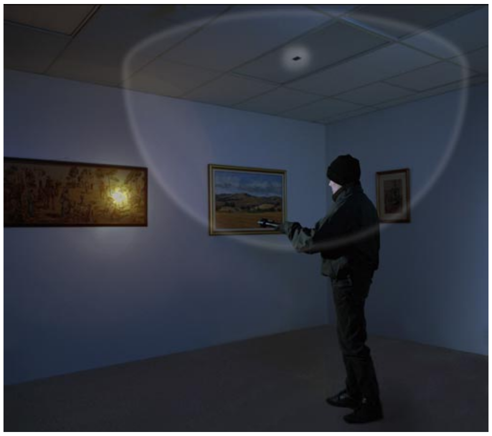


Figure 5. Imaging steel in concrete with MIR. (a) The internal elements of a concrete slab before pouring. (b) Reconstructed 3-D MIR image of the elements embedded in the finished, 30-cm-thick concrete slab.

Figure 6. An MIR concealable intrusion sensor detects intruders at ranges up to 6 m. Units can be mounted on the ceiling, located behind objects, or hidden in shelves, closets, or drawers. The system detects motion by repeatedly monitoring the echo pattern to see if it changes. A change signifies that an intruder has penetrated the invisible radar bubble.



complex, DoD Special Forces, U.S. Border Patrol, and the intelligence community. At Livermore, an MIR security system is now being installed in the lobby of the Nova building.

Automotive Sensors

MIR motion sensors placed on the side of vehicles can alert drivers about other cars in blind spots, warn when another vehicle is too close, and activate side air bags. A sensor placed on the rear bumper, for example, provides parking assistance or warns when a curb is very close. In one test, a sensor unit installed in a car's taillight section functioned perfectly even when we smeared mud over the taillight or placed 30 cm of ice in front of the sensor unit. One licensee is expected to equip cars with MIR proximity sensors by the 1997 or 1998 model year. Other automotive uses include security systems, traffic flow sensors, distance and speed indicators, and dipsticks (described below).

Tools to Manufacturing

Do-it-yourself tools based on MIR can locate wooden or steel studs in a wall, steel within concrete (Figure 5), plumbing lines, or electrical wiring. We envision electronic tape measures, automatic thermostats, automatic dispensers, games, and toys that incorporate the new MIR technology. In manufacturing, we are exploring robotic sensors, harsh-environment sensors, and industrial automation equipment based on MIR.

One application in particular, the "electronic dipstick," has the potential to revolutionize the way fluid levels are measured in virtually every industry. The electronic dipstick, a low-cost, solid-state sensor that has no moving parts, is impervious to wetting, corrosion, sludge, and condensation. The device shown in Figure 7 launches a signal along a single metal wire, rather than through air, and measures the transit time of reflected electromagnetic pulses from the top of the dipstick down to a liquid surface. Our tests show that the electronic dipstick can resolve fluid-level changes smaller than a millimeter and is accurate to within 0.1% of its maximum length. The dipstick can detect all fluid levels in a car, measure oil levels in supertankers, and remotely monitor water levels in reservoirs, among many other uses.

Projects in the Works

Some of our ongoing projects include specialized motion sensors, short-range altimeters, radar ocean imaging, highway and bridge-deck inspection, and hand-held wall surveying. In defense and law enforcement, we are exploring MIR in scenarios such as border control and surveillance systems, mine and ordnance imaging, the imaging of individuals behind walls, and proximity fuses. We also envision potential uses in environmental and medical research.

Many of these applications of national interest are government-sponsored, involving signal processing, computations, and communications expertise along with hardware development, and we draw on Laboratory experts in all those fields. Following are a few areas in which we have already made substantial progress.

Border Surveillance

Border and perimeter surveillance pose serious technical problems for the nation and many industries and agencies, including drug enforcement, land management, and military security. Among many other issues, visible devices such as antennas or cameras are often targets for vandalism or attack. The Laboratory is working with the U.S. Border Patrol to demonstrate an automated, covert surveillance system for international borders as well as for military sites and police boundaries.

By combining an array of concealable MIR units with advanced, low-cost computation and communication technologies, we plan to deploy an automated surveillance method. We can monitor a localized area or establish an unattended, electronic trip-line that would cover a few kilometers and eventually extend across perhaps hundreds of kilometers. MIR modules placed up to 100 m apart would measure human movement—discriminating between people and other sources of motion—and rapidly communicate an intrusion down the chain of modules to the nearest base station. We now have sensor units in place at the Border Patrol station in El Centro, California, at an International Atomic Energy Agency facility, and at Sandia National Laboratories, Albuquerque.

Detecting Mines

Landmine detection is a serious military and humanitarian problem. One thousand people are killed or maimed every week worldwide by mines left from previous wars. MIR can detect both plastic and metallic land mines buried in most soils. Our technology is attractive because its small size and low cost allow either hand-held or vehicle-mounted arrays and because images formed by an array aid in discriminating mines from ground clutter.[3,4] Currently, a laptop computer can reconstruct an image in less than 10 seconds, but much higher speeds are feasible. Field tests at the Nevada Test Site show conclusively that the MIR sensor readily detects buried mines through 2-D imaging, but full 3-D imaging (Figure 8) may be necessary to more reliably discriminate between a mine and other buried features, like rocks of similar size and shape. A linear array of MIR modules mounted on the front of a remote-controlled vehicle, or on a boom extending beyond the vehicle, can detect antitank and antipersonnel mines. Even in areas of rough terrain or dense foliage, portable mine-detection systems operating in the look-ahead mode are feasible with current technology.

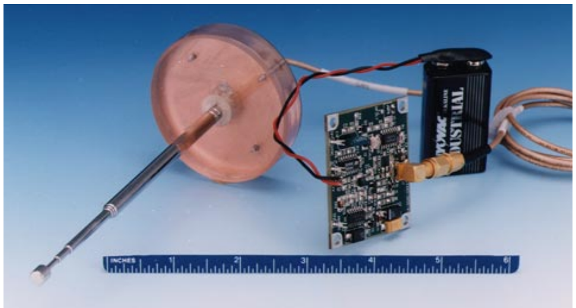


Figure 7. The electronic dipstick is a metal wire connected by cable to an MIR electronic circuit. As a highly accurate fluid-level sensor with no moving parts, this device has myriad applications in manufacturing and is significantly lower in cost than laboratory equipment performing the same task.

Inspecting the Infrastructure

More than 40% of the 578,000 highway bridges in the U.S. have structural deficiencies or are obsolete. Corrosion of steel reinforcing bars (rebar), hidden by concrete and asphalt layers, leads to fracturing and delamination, which can result in failure. Visualizing the details of many structures such as bridge decks has required destructive techniques, such as coring.

We are developing MIR devices to nondestructively image bridges and roadbeds, evaluate civil structures, inspect power poles, and locate buried pipes. We received funding from the Federal Highway Administration to build a vehicle for highway and bridge deck inspection. In that project, we have designed a prototype vehicle-mounted inspection system (Figure 9) that acquires data at speeds approaching the normal flow of traffic. Speed is important because a large portion of inspection costs arise from traffic controls. We envision three modes of inspection: a quick mode at the highest vehicle speeds for preliminary assessments, a limited-depth mode for higher-resolution data, and a detailed mode at slower speed to inspect the entire deck thickness (up to 40 cm). Deployment of the full system is scheduled for fall 1996.

Depth of 4 cm

Depth of 5 cm

Depth of 6 cm

Figure 8. A typical plastic antitank mine is shown (top) before burial at the Nevada Test Site. MIR technology was used (bottom) to image the mine at three depths, or horizontal "slices."

Medical Applications

Our radar's average emission level is about a microwatt—about 3 orders of magnitude lower than most international standards for continuous human exposure to microwaves. Thus, MIR is a medically harmless diagnostic tool. In addition, the sensors we are testing remotely measure human vital signs much like the medical tricorder envisioned in Star Trek, without interfering with computers, digital watches, FM radio, or television.

Our MIR heart monitor (Figure 10a) measures muscle contractions (responses of the heart) rather than the electrical impulses (stimuli) measured with an electrocardiogram (EKG). Figure 10b shows the output waveform of a prototype heart monitor compared to that obtained from a standard EKG. The MIR output is complex and rich in detailed information, and we are actively working with physicians to understand its significance.

As a medical monitor, a very small MIR unit built into a single chip could substitute for a stethoscope. The U.S. Army is interested in a portable device that could be worn inside clothing so that a soldier's vital signs can be relayed from the field to a medical command post.

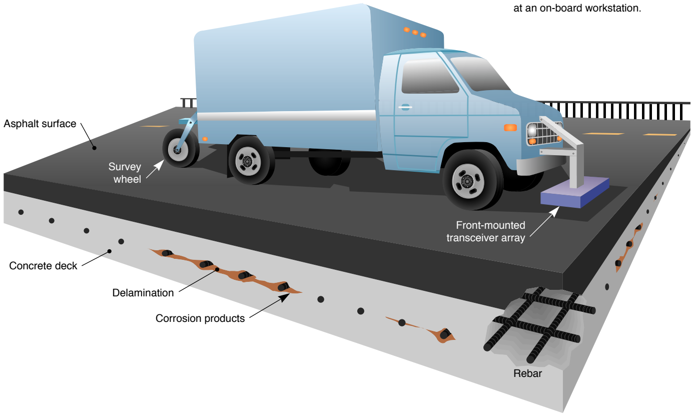
An MIR-based breathing monitor (Figure 11) does not have to make contact with a person's body, and it can operate through a mattress, wall, or other barriers. The detection of breathing motion can be a valuable asset in hospitals and homes, could guard against sudden-infant-death syndrome, and might be used by people with breathing disorders such as sleep apnea, in which the affected individual occasionally stops breathing.

We are exploring the use of MIR for additional medical devices, including speech-sensing devices and a polygraph sensor. Devices for the blind could warn of obstacles and variations in terrain and help to train individuals in using canes. We are initiating clinical studies to optimize medical radars for heart, respiration, and speech applications. The potential payoffs are enormous not only in financial terms but also in benefits to society.

Rescue Operations

Cameras, dogs, and acoustic equipment tuned to signs of life currently help rescuers to find survivors buried after an earthquake, avalanche, or other disaster. Soon, wall- and rubble-penetrating portable MIR devices could assist in search-and-rescue operations. We have tested units that detect respiration and heartbeats at a range of about 3 m. In the midst of wreckage too unstable to support rescuers, miniature radar devices could be tossed into the debris from a safe distance and signal personnel when physiological signs are detected. We are working with the U.S. Army Corps of Engineers Earthquake Preparedness Center (San Francisco) and with the NASA Disaster Response Team (Ames) to develop such devices.

Figure 9. Vehicle-mounted radar imaging for bridge-deck inspection. Arrays of MIR modules mounted on the front and rear allow the vehicle to cover a 2-m-wide swath with each pass. Radar images are reconstructed and processed at an on-board workstation.



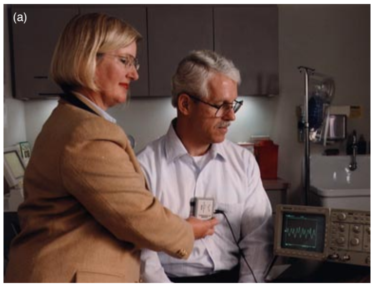
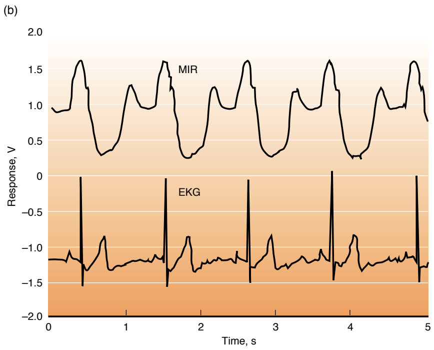


Figure 10. (a) An MIR cardiac monitor.
(b) Its output (upper trace) is distinctly different from that obtained by a conventional EKG (lower trace). We are working with physicians to correlate the radar signals with physiological functions.



Looking to the Future

We continue to develop MIR for a variety of applications, and we are exploring ways to increase its performance in difficult situations. Even though the new radar technology performs very well, we still need to address issues such as reduced clutter, enhanced resolution and contrast, electromagnetic attenuation by different media, multiple scattering, shadowing, dispersion, real-time operation, and full 3-D imaging speed.

For some applications, we want to extend MIR from the centimeter-wave region into the higher-frequency, millimeter-wave region. Higher-frequency MIR will provide better resolution and give greater signal directionality with divergence of only a few degrees. Higher frequency will also mean that MIR could detect smaller objects of 2 cm or smaller diameter, such as concealed weapons or bullets, and even tiny asteroids approaching a spacecraft. MIR using millimeter waves could replace ultrasound motion sensors, such as those used for automatic door openers.

The current maximum range for MIR is about 100 m using high-gain antennas. Our intent is to extend the range to about half a kilometer. Longer range will require an improved signal-to-noise ratio. We are looking at higher-power systems and improved antenna designs to extend the range and at better signal and image processing to reduce noise.

Key Words: electronic dipstick; micropower impulse radar (MIR); radar heart monitor; ultrawide-band radar, radar imaging, microwave sensors.

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For licensing and MIR partnering information contact (510) 422-6935 (mir@llnl.gov). Also see our homepage (http://www-lasers.llnl.gov/ lasers/idp/mir/mir.html).

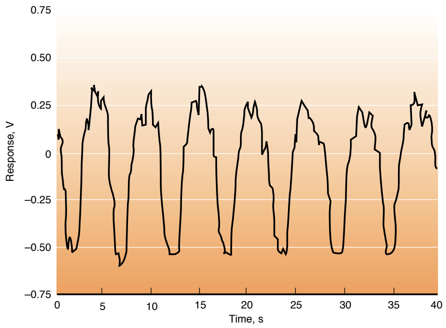
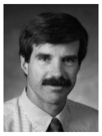


Figure 11. An MIR breathing monitor detects the respiratory cycle through a 10-cm-thick chair back. The higher-frequency waveforms are cardiac activity.

About the Researchers



STEPHEN AZEVEDO, currently the Program Group Leader of the Microradar Project in the Laser Programs Directorate, has a background in digital signal and image processing. Concentrating in electrical engineering, he received a B.S. (1977) from the University of California at Berkeley; an M.S. (1978) from Carnegie-Mellon University; and a Ph.D. (1991) from the University of California at Davis. Azevedo joined LLNL in 1979 and since has been a principal investigator in computed tomography research and radar remote sensing; he also has done work in signal processing, modal analysis, x-ray inspection, nondestructive evaluation, and imaging. He is the author or coauthor of over 40 publications on these subjects.

THOMAS E. McEWAN has been a member of the Laser Programs Directorate in the Imaging and Detection Program since joining the Laboratory in 1990. His accomplishments here include inventing the micropower impulse radar (MIR) and developing the world's fastest solid-state transient digitizer and a palm-size impulse generator. He received his B.S. (1970) and M.S. (1971) degrees from the University of Illinois (Chicago Campus) in electrical engineering. From 1970 to 1985, he was a design engineer at Nanofast Inc. From 1986 to 1989, McEwan led the design of high-speed microelectronics at Northrop Corporation, where he supported programs in radar jamming, electronic countermeasures, and computer-chip development. In addition to the MIR recognitions listed on p. 23, he has six patents in wideband electronics.