Micropower Impulse Radar (MIR) Technology Overview

The Micropower Impulse Radar (MIR) is a fundamentally different type of radar that was invented and patented by Lawrence Livermore National Laboratory (LLNL). It is a pulsed radar like other ultra-wideband radars, but it emits much shorter pulses than most and, because it is built out of a small number of common electronic components, it is compact and inexpensive.

The genesis of these radars starts with LLNL's 100-trillion-watt Nova laser, the world's highest power laser system, which was developed for nuclear fusion research. The pulsed laser generates high-speed (sub-nanosecond) events that must be recorded. In answer to this need, special fast electronic circuitry was developed for driving a 33 gigasample-per-second transient digitizer that records such events. Thomas McEwan, the LLNL engineer who designed this high-speed data acquisition system, then had an important insight: these new circuit concepts could be augmented by additional electronics into extremely small, low-power radar systems.

Soon after McEwan's breakthrough in 1993, it became evident that such radars had the possibility of impacting an extremely wide range of applications. Since then, nearly 30 patents have been filed, hundreds of commercial applications have been identified, and MIR technology has become LLNL's biggest technology transfer activity.

Licenses with industry have been signed in the areas of automobile back-up systems and in hand-held tools for finding studs and other objects behind walls. Many other diverse applications are under investigation, including fluid level sensing (electronic dipsticks), heart monitoring for medical applications, security systems, detection of breathing through walls or rubble (e.g., finding survivors of earthquakes), monitoring of infants for the possible prevention of Sudden Infant Death Syndrome (SIDS), underground and through-wall imaging, and many others.

McEwan and his team continue to innovate and develop new ideas for the MIR technology including new electronics, antennas, signal processing, and imaging concepts. LLNL is following the dual paths of licensing the technology to qualified manufacturers and developing programs that use the technology in support of the laboratory mission.

One unique feature of the MIR is the **pulse generation circuitry**, which, while small and inexpensive, had never before been considered in radar applications. Each pulse is less than a billionth of a second and each MIR emits about two million of these pulses per second. Actual pulse repetition rates are coded with random noise to reduce the possibility of interference from other radars, while each is "tuned" to itself. The same pulse is used for transmitting to send via the transmit as for sampling the received signal. Three direct advantages of the short pulse-width are:

1. With pulses so short, the MIR operates across a wider band of frequencies than a conventional radar, giving high resolution and accuracy, but also making it less susceptible to interference from other radars.
2. Since current is only drawn during this short pulse time and the pulses are infrequent, there are extremely low power requirements. One type of MIR unit can operate for years on a single AA battery.
3. The microwaves emitted by the pulse are at exceedingly low, and therefore medically safe,

levels (microwatts). Indeed, the MIR emits less than one-millionth the energy of a cellular telephone!

Probably the main unique feature of this radar is the **cost**. The current version uses off-the-shelf electronic components so that a standard MIR board can be assembled with less than $20 of parts. Future development plans include reducing the MIR components to multi-chip modules or ASIC's as the demand increases and it becomes economically feasible.

As with conventional radars, the **antenna configuration** on the MIR determines much of its operating characteristics. Several antenna systems have been designed to match the ultra-wide frequency characteristics of the MIR sensor. For the standard MIR motion sensor with a center frequency of about 2 GHz, we use a small 1.5-inch antenna. However, the MIR is also flexible enough that it can operate at a relatively lower center frequency, using larger antenna systems, giving it longer range and better capability for penetrating water, ice, and mud.

What makes the MIR so useful for **security applications** is its range gating capability. Imagine that each radio pulse is a large wave traveling across a lake. The wave bounces off an island and comes back to you. The amount of time it takes the wave to return depends on the distance to the island. By setting the radar's "gate," or echo acceptance range, to open only at the right time to receive echoes from a certain distance, it can ignore all other echoes. Range gating can therefore be used to set up an invisible security bubble around the radar. In a burglar alarm, for instance, the range might be set at 20 feet. The radar then detects only objects that modulate the reflected signal at this distance. It detects motion by repeatedly checking the echo pattern to see whether it changes over time; a change means the bubble has been penetrated by a moving object. This eliminates triggering on stationary background objects or "clutter."

The current MIR motion sensor can be fully concealed behind walls or inside drawers while detecting intruders at ranges up to 20 feet. Its sharply-bounded detection range is easily adjusted for any situation. In addition, the MIR can project a set or sweep of range shells to generate a filled volume of sensitivity. It does not respond to objects outside the current range gate, and it attempts to avoid false triggering on near objects such as insects. However, the range-gating mechanism may be susceptible to triggering on large-object movement in the near-field (inside the range bubble) because radar phenomena like multiple scattering will modulate the range-gate return.

Averaging of many thousands of pulses is done on the MIR to reduce the effects of noise and to increase sensitivity. A single received pulse in the nanosecond time scale may be contaminated with various forms of outside interference, but if the returns of many pulses at the same range gate are combined, the result is much more representative of the actual return. The number of averages per range gate is adjustable (nominally it is about 10,000 samples) and is one of the tradeoffs in the MIR design.

The exact pulse emission and detection times are randomized for three reasons.

1. Continuous wave (CW) interference, such as from radio and TV station harmonics, may cause beat frequencies with the received echoes that can trigger false alarms. When the 10,000 samples of MIR return echoes are averaged at randomly-dithered times, random samples of CW interference are effectively averaged to zero.
2. Random operation also means that multiple MIR units can be collocated without interfering with each other. Channel allocations are not needed and a nearly unlimited number of sensors can be in the same vicinity even though they occupy the same wideband spectrum.
3. Randomizing also spreads the sensor's emission spectrum to the point that it resembles random thermal noise, making it difficult to distinguish from background noise. That is, this randomizing makes the MIR very stealthy.

Imaging and Detection

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