QR Hits a Homerun:

Landmine-Detection Systems Based on Quadrupole Resonance Technology Show Progress

This study explains how quadrupole resonance technology in mine-detection systems improves with use and drastically reduces false alarms and deminer fatigue.

by Dr. Peter Turner and Caroleen L. Williams
[GE Security]

For the past 10 years, Quantum Magnetics, Inc. (a California corporation and wholly owned subsidiary of General Electric Security, Inc., hereinafter referred to as GE Security) has been developing landmine detection technology specific to identifying landmine explosives. Although the company also develops other technologies for bomb, drug and concealed-weapons detection, it continues to keep its core objective on course: discovering the explosives used in buried landmines quickly, with few false alarms. By targeting the specific molecules contained in explosives such as ammonium nitrate, PETN, RDX, tetryl, and TNT, the company's scientists believe its sensors will soon be instrumental in removing not only mines in battlefields but also the estimated 60 to 110 million abandoned landmines throughout the world.

Quadrupole resonance is the only chemically specific technology that detects the presence of bulk explosives. Funded by U.S. agencies and organizations such as the Federal Aviation Administration, the Transportation Security Administration, the Defense Advanced Research Projects Agency, the U.S. Army, and the Office of Naval Research and in cooperation with the Naval Research Laboratory, GE Security's Magnetics Center of Excellence pioneered the use of QR explosives detection technology for landmine detection and aviation security. The U.S. Department of Defense sought to clear lanes through minefields quickly in battlefield conditions. The same technology can be applied for humanitarian and commercial demining situations, where each and every mine must be found and removed to make the land safe for the general population.

Detection Technologies

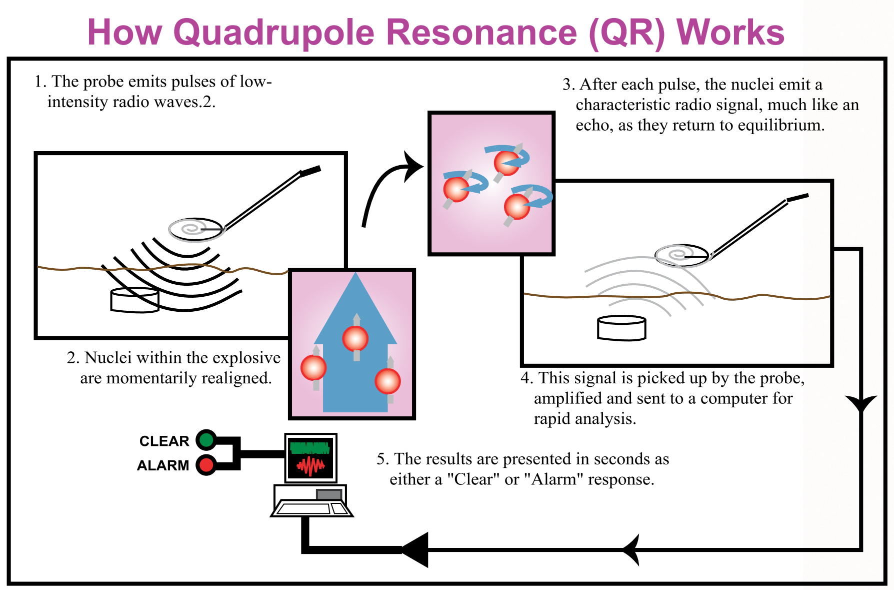
Current detection technologies are clutter-limited, as deminers now endure between 100 and 1,000 false alarms for every mine found. Deminers must investigate each alarm, however, and many false alarms lead to "alarm fatigue," which prompts careless and dangerous mine-removal techniques. It is no mystery, for example, why during the first three years of demining work in Bosnia, there were 93 victims among deminers while only 15 square kilometers (6 square miles) were cleared.[1]

Mines are metal-cased, plastic-cased or occasionally wood-cased; all contain a small metal firing pin. Since WWII, metal detectors have been used for mine detection more often than other devices, but such detectors can cause more problems than they solve. Metal-cased mines are typically much larger than clutter items such as cartridge cases and shell fragments, so they are relatively easy to detect and discriminate from the surrounding clutter. To detect only the small metal firing pin in an otherwise all-plastic or all-wood mine, however, the metal detector must be set to a very high sensitivity. Consequently, such detectors also find every other piece of metallic clutter littering a battlefield and are unable to distinguish between the two. A technology capable of distinguishing real landmines from clutter would be welcome to deminers, soldiers and citizens alike.

About Quadrupole Resonance

QR is a low-cost variant of MRI technology commonly used as a diagnostic tool in hospitals. Low-intensity radio waves at frequencies in and just above the AM radio band are used to probe certain molecular properties of items adjacent to the detection coil (see Figure 1). The probe emits pulses of low-intensity radio waves at a frequency unique to the target atomic species and its molecular environment. The radio waves momentarily disturb the alignment of the targeted nuclei. As the nuclei relax to their equilibrium condition, they emit their own—albeit much weaker—signal, which is picked up and sent to a computer for rapid analysis. The signal emitted by each type of explosive is unique and readily distinguishable from those of harmless materials. Over 10,000 compounds have been investigated and no two have produced identical responses.[2]

Figure 1: A schematic illustration of the QR method of detection. Only specific nuclei within the target compound responds to the initial radio pulses. Graphic courtesy of GE Security.



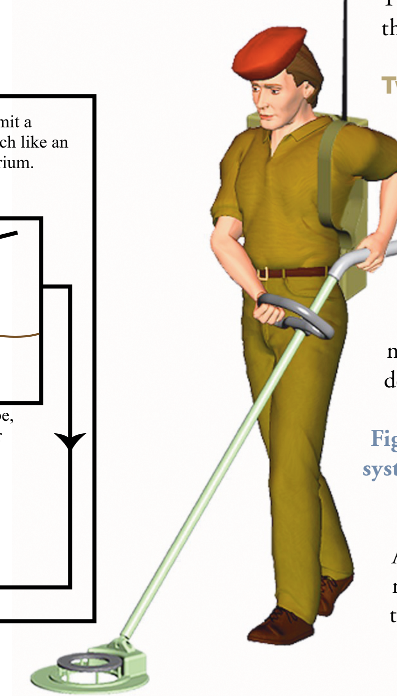
Technology incorporated within the QR system also responds to the presence of large metal objects, so the QR system can detect both anti-tank and anti-personnel mines, either metal- or plastic-cased, with an exceptionally high probability of detection—all while maintaining a very low false alarm rate. Since QR is chemically specific, the presence of other substances will not adversely affect results.

A significant advantage of QR detection is that it is signal-to-noise-ratio-limited, not clutter-limited, so QR is the only technology capable of resolving its own false alarms. For example, the longer the QR probe remains at a site, the greater the signal accumulated at that site, while the random and fluctuating electronic noise that occasionally masks the QR signal is averaged to a consistent and uniform value.

Reducing clutter alarms by even as little as 70 to 80 percent doubles the productivity of every deminer and substantially reduces the fatigue element they suffer when coping with the hundreds of false alarms. Moreover, as the QR detection probe "interrogates" a given area, results are presented as a simple red light/green light display to indicate either the presence—or the absence—of a landmine. QR systems require no calibration or special maintenance and are ruggedly designed to withstand many hours of uninterrupted use. Importantly, the technology is safe for the user, as it does not use ionizing radiation, radioactive sources or strong magnetic fields.

Test Results

The Center has already demonstrated the potential of its QR technology in a series of military-sponsored blind tests at Camp Pendleton (Calif.), Fort Leonard Wood (Mo.), Yuma Proving Grounds (Ariz.) and a specially earmarked area set aside for such tests near Tuzla, Bosnia. The last test results reportedly represented the first-ever QR detection of TNT landmines in the field. Subsequent developmental programs at the Center have substantially increased TNT sensitivity to the point where it now detects TNT-filled anti-tank landmines and all but the very smallest anti-personnel landmines.



Two Configurations for Detection

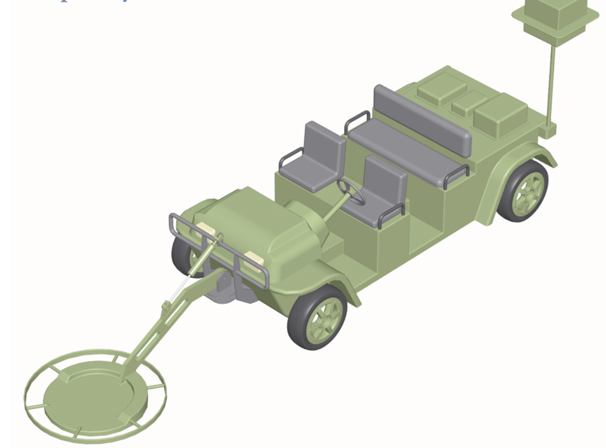
Supported by the Office of Naval Research, the Magnetics Center of Excellence is currently working on a man-carried backpack QR/metal detection/ground penetrating radar system for use by the U.S. Marine Corps. Once this work is completed, the handheld detector will be capable of scanning all variations of terrain encountered by deminers, either military or civilian.

Figure 2: Backpack-mounted landmine system. Graphic by Walter Freeman

A separate project sponsored by the U.S. Army focuses on incorporating QR technology into a vehicle-mounted configuration for use in detecting anti-tank mines in route-clearance operations (see Figure 3). A prototype confirmation sensor, designed to validate or clear alarms produced by other primary sensor technologies, has been tested during night and day intervals.

Results of these tests demonstrated QR technology was practical during the night when higher radio frequency interference conditions are prevalent—previous QR systems were unable to operate in areas subject to high radio interference. The performance of this latter prototype has been further improved and the system is now undergoing engineering development to reduce the size, weight and power consumption of the detector while meeting stringent field-reliability requirements.

Figure 3: Vehicle-mounted landmine-detection system. Graphic by Walter Freeman



QR Technology Today

When work is completed on both the handheld and vehicle-mounted QR-based systems, today's false alarm rates are expected to be reduced by 60 to 95 percent. Other important milestones have been met as well. For example, four years ago, the electronics needed to perform the handheld QR measurements occupied two racks of electronics weighing well over 200 pounds and consuming 2 kilowatts of electric power. Today, the handheld detection system can be comfortably carried and used by one person, and it operates for many hours at a time without recharging—a substantial improvement over earlier models. Moreover, the earlier vehicle-mounted route-clearance prototype required over 1,000 pounds of control electronics and a 500-pound, 10-kilowatt diesel generator to power it. The current prototype weighs less than 200 pounds and is complete with its own portable battery power supply; it is also much more sensitive and can be adapted for use on many different types of vehicles.

Conclusion

Obviously, important progress has been made, but the Center continues to work on a fast track to further improve landmine detection technology as it recognizes the need for safe, reliable landmine-detection systems as soon as possible—for both military and humanitarian uses. It is expected the handheld demonstration units will be ready within a year, and it is possible the vehicle-mounted systems will be available soon thereafter. This is a goal the Center's scientists are determined to meet.

See "References and Endnotes," page 108

Peter Turner holds a doctorate in gravity wave physics from the University of Western Australia. He joined GE Security in 2001. He is now principal investigator for the Communications-Electronics Command-sponsored QR Scanning Sensor Program, developing advanced technology for landmine-detection applications.

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Endnotes

1. Rant, J.J. Institute J. Stefan. Ljubljana, Slovenia. Private communication, October 1999.
2. Japanese Association of International Chemical Information (JAICI). NQR Database. Japan, 1999.