

Shining a Light on Friendly Fire

A new radio technology helps warfighters distinguish between friend and foe

By James A. Moryl

Friendly fire accidents have been a tragic, vexing part of warfare since the beginning of armed conflict. Defined as accidental firing toward one's own forces while attempting to engage enemy forces, the phenomenon is seldom reported unless it results in injuries or deaths, and then only if it occurs during active engagement with the enemy. Even so, incidents of friendly fire have increased in proportion with the increasing combat intensity seen in Afghanistan and the first and second Gulf wars. Today, it accounts for a significant percentage of combat casualties, and it continues to grow. Comparison of a 46-day period during Operation Iraqi Freedom in 2003 with a 41-day stretch of Operation Desert Storm in 1991 revealed

a sixfold increase in friendly fire, from 4.4 to 25 incidents per 100,000 troops, along with a fourfold increase in friendly fire deaths, from 7 to 29. Overall, friendly fire was the second leading cause of U.S. deaths during the combat phase of the Second Gulf War.

Addressing the problem

Analysis of the friendly fire problem indicates that the increase from the First to the Second Gulf Wars may be rooted in two factors: The soldier who shoots first generally is the one who survives, and the intensity of resistance during Operation Iraqi Freedom was considerably greater than it had been in Desert Storm. Taken in that context, those two

factors might explain how even highly trained soldiers might sometimes mistakenly shoot friendly or allied troops located in their weapon's sights.

In the years since the First Gulf War, the U.S. Department of Defense has attempted to address friendly fire with a

Flashlight™ Soldier Combat Identification System consists of two components, a transponder and an interrogator. Currently, the transponder is approximately the size of a smartphone, and the interrogator is like an SLR camera. In future phases of development, the equipment will be further miniaturized, enabling the interrogator to be mounted to a soldier's rifle and aligned with the weapon's sights.

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targeted area, the system would provide a “don't shoot” indication. The concept was extensible to all engagement scenarios, including dismount-dismount, vehicle-dismount and air-dismount, with the potential to provide a single system solution to direct fire combat identification.

In 2004, SwRI initiated an internal research and development project that assessed the technology and improved the technology for focusing the beam. The findings of this project enabled the SwRI team to develop a full proposal to the U.S. Army in 2005 for a combat identification system.

Although the proposal generated significant interest in the

U.S. Department of Defense, it did not result in a project award. The proposed technology was intended to be mounted on tanks, armored personnel carriers and other light vehicles. SwRI learned the more pressing problem in the eyes of the military was that of friendly fire on dismounted warfighters — fire by tanks, vehicles, aircraft and other dismounts.

The engagement scenario of the dismounted warfighter is the most difficult problem to solve because the combat

identification system needs to be miniaturized from a size suitable for mounting on a vehicle to a smartphone-sized device. Further exacerbating the size problem is the need to be battery operated since the combat identification system is hand-carried rather than hardwired into vehicle power. At that time, there was not yet an enabling technology for implementing such a system.

SwRI engineers conceived of enhancements to the fundamental technology proposed to the Army in 2005. During a 12-month effort funded by internal research, SwRI established the feasibility of these ideas and developed a technical approach that enabled scaling the technology to the dismounted warfighter. SwRI efforts resulted in invention disclosures, and in 2009, two patents with joint rights were issued for key technology elements. This novel, single-system solution for direct fire combat identification is called “Flashlight™.”

Flashlight

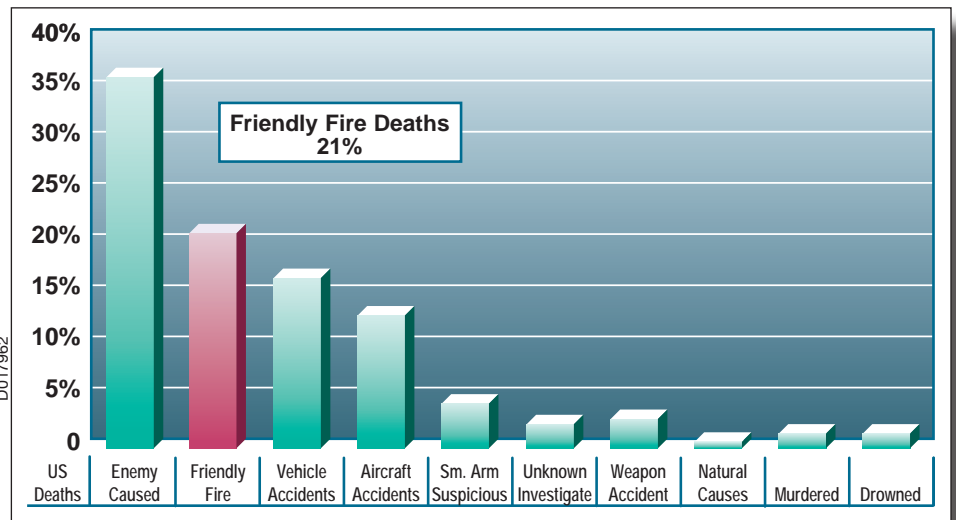
The Flashlight Soldier Combat Identification System is designed for combat identification of dismounts and platforms on the ground and from the air. It is a challenge-and-reply radio-frequency (RF) combat identification system that uses

“system-of-systems” approach. Some of the existing systems address platform-to-platform, others air-to-air, still others air-to-ground; but to date none has been an effective solution for the dismounted soldier.

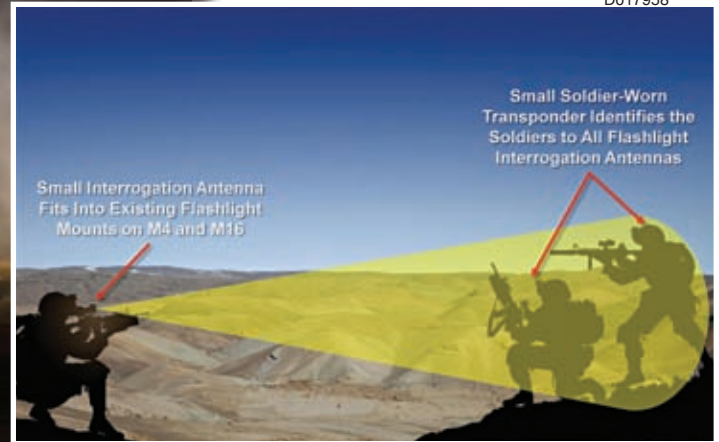
The family of systems approach, if anything, has proven to be a key shortcoming in that there are too many systems trying to address friendly fire, and to date none has gone far enough to offer a comprehensive solution.

Protecting a dismounted soldier with the current system-of-systems approach would require that he or she carry more than a half-dozen systems, along with enough batteries to power each one. Added to the weight of weapons, ammunition and survival gear, such a solution would put the soldier in an untenable position.

As an organization devoted to technology development, Southwest Research Institute (SwRI) in 2003 had become aware of a patented radio frequency technology that showed strong potential to make an impact on the friendly fire problem. The concept was that a warfighter who is deciding whether or not to fire upon an area would use a special radio to send focused radio beams to define the targeted area. If friendly personnel wearing the companion transponder were in the



Friendly fire was the second leading cause of U.S. deaths during the combat phase of the Second Gulf War, accounting for 21 percent of fatalities.



focused beams of microwave energy to confirm friendly forces in an area of regard prior to firing of the weapon — analogous to a flashlight illuminating an area of regard.

Flashlight consists of two components, an interrogator and a transponder, that operate using an interrogation-and-response protocol. The interrogator is intended to be aligned with the sighting system of a weapon so that it defines a zone in the area of regard. Prior to firing, the shooter initiates an interrogation into the area of regard, causing the interrogator to send a spread spectrum query signal in the direction of the line of fire. Transponders in a narrow zone reply with a similar spread spectrum signal, and encrypted user information is sent to the interrogator. Within one second of initiation, the interrogator displays to the shooter if a friendly is in the zone.

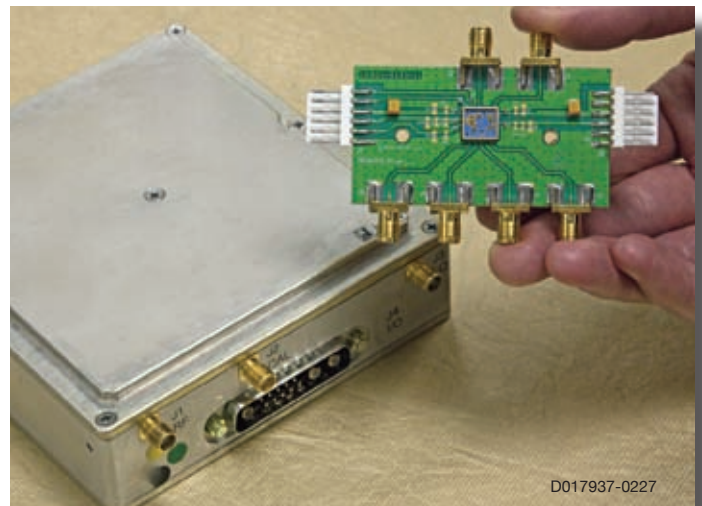
Operation in a constantly changing outdoor environment poses a number of technical challenges to the design team. The microwave signals are affected by objects in the vicinity of the system components, which obscure line of sight and cause reflections that result in multiple copies of the signals being seen by the transponder. Fading of the signals, diffraction and penetrating common battlefield obscurants such as haze, dust

and smoke add to the difficulties. A key technical challenge is reducing the size, weight and power consumption so the system is of a suitable size and battery life to be carried by an individual soldier. These technical challenges are substantial and impose significant risk to developing the Flashlight technology.

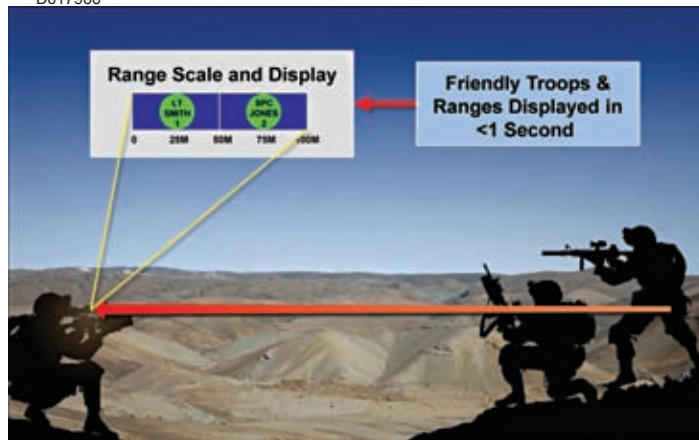
Flashlight is being developed in a series of technology “spirals,” each of which executes under a separate externally funded program phase. Each spiral of development builds upon the successes and lessons learned from the previous spiral to divide and conquer the technical challenges and the development risk. During the first phase, SwRI engineers advanced the technology for beam focusing that was developed under internal funding. The goal of the first phase was to demonstrate that focused beams of RF energy were able to define a zone of interest; this is the fundamental capability of the Flashlight system. To demonstrate this, the SwRI team developed a number of custom, microwave frequency, specialized radio sets in fewer than 10 months. These stand-alone radios

included microwave frequency analog circuitry, signal processing hardware and software, control hardware and software, a user interface, and the key to the Flashlight concept, a novel antenna that uses a Luneberg lens to focus the radio beams. The first phase successfully demonstrated that Flashlight technology is able to define a zone of interest using radio waves and detect the presence of a corresponding radio in that area.

The second phase was more ambitious than the first. With the concept proven to be feasible, it also had to operate under real-world conditions. Multipath, signal fading, obscurants to line-of-sight and polarization of the electromagnetic field are some of the challenges for wireless systems. To address each of these and other challenges during the second program phase, a sophisticated mathematical model of the system was conceived. The model enabled antenna patterns and signal processing for communications and for zone resolution to be developed, simulated and refined prior to the start of hardware and software development. Simulations



A key technical challenge is reducing the size, weight, and power consumption so that the system is of a suitable size and battery life to be carried by an individual soldier. The size of the electronics has been reduced in spirals of technology development. Significant size reduction was achieved in the radio frequency circuitry by using low-temperature co-fired ceramic substrates onto which bare, microwave-integrated circuit dies are wire-bonded.



included perturbations to the communication channel so candidate technical approaches for working in a real environment could be tested.

Once confidence was gained in the models, hardware and software development began. A team of up to 12 engineers worked in parallel to create the antennas, microwave circuitry, signal processing and control circuitry, signal processing firmware, and protocol and control software. As hardware and software elements were developed and tested, data collected during testing replaced that element of the computer model, enabling an incremental build and test that verified operation of the new circuits and embedded software. The result was the successful demonstration of interrogators and transponders suitable for engineering testing in outdoor environments in fewer than 12 months.

Although not at the final small size in the second phase, the interrogators and transponders were hand-carried, battery operated and fully self-contained radios at microwave frequencies. These radios communicated using short bursts of direct sequence spread spectrum communication waveforms to help mitigate multipath beams and to provide reduced signal interception and detection characteristics over traditional narrow band signals. The short duration of the combat identification

bursts of communication made synchronization to the signal challenging, especially when equipment size and power consumption needed to be minimized. A novel technique for rapid code synchronization for direct sequence spread spectrum signals with long spreading codes was conceived and put into practice during the second program phase, and an invention disclosure was filed.

Successful development of these full-featured combat identification radios led to important demonstrations to congressional and military officials in the summer of 2009. The technical successes enabled the third and current phase of the program

in which the radios are being drastically reduced in size, weight and power consumption compared to the units developed in the second phase.

Traditional printed circuit board techniques would not enable the desired size reduction, so the SwRI team looked toward the consumer electronics industry for inspiration. With

the help of an external consultant from the cellular communication industry, SwRI engineers conducted a trade study to select technology that would meet the size, weight and power consumption goals while fitting within the available, and limited, funding and schedule. Technologies from cell phones, WiFi

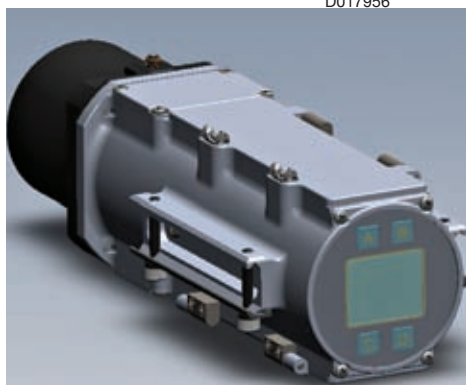
Prior to firing a weapon, the soldier initiates a radio frequency interrogation into the area of regard, causing the interrogator to send a discreet query signal in the direction of the line of fire (left figure). Transponders in a narrow zone reply with a similar signal, and encrypted user information is sent to the interrogator (center figure). Within one second of initiation, the interrogator displays to the shooter if friendly troops are in the zone (right figure).

and WiMAX were examined, and the approach selected for microwave circuit miniaturization involved developing sophisticated ceramic substrates onto which bare microwave integrated circuit dies are mounted. For the digital circuits, chip-scale packages were selected, and high-density printed circuit boards with blind and buried vias were designed. Still a work in progress, the interrogator hardware is now approximately the size of a digital SLR camera, and the interrogator is approximately the size of a Blackberry®.

Future and implementation

At present, the SwRI team is halfway through the prototype development phase. By September 2011 the team plans to enter military testing to show the utility of the Flashlight concept as part of a Department of Defense analysis of alternatives for dismounted soldier combat identification. Flashlight was one of four technologies selected from among 14 that were originally submitted. By summer 2011, two finalists are expected to be selected for future development, and the SwRI team is working to be one of them.

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The interrogator is intended to be the size of a small flashlight that is mounted to a soldier's rifle. Mechanical concepts of this embodiment include antennas, electronics, batteries and a user interface in a small yet rugged package.