



## Hammering Out IEDs—Detecting Explosives with Biologically Inspired Research

The peculiar anatomical feature from which the hammerhead shark derives its name—a flattened cephalofoil with the eyes spaced wide on either end—was first thought by biologists to provide the animal an advantage in sight. However, further research determined that the shark’s head provides more the benefits of a metal detector than a pair of binoculars. Sharks (as well as several dozen other species of electro-receptive fish) have sensory pores called ampullae of Lorenzini that allow them to detect the electrical discharges from the muscles of their prey. By spacing these pores along the width of its head, the hammerhead increases the range of its electroreceptory powers: the sharks are able to pick up a charge as small as a half-billionth of a volt. The far-off twitch of a tuna’s tail is enough to tip the shark off to its next meal.

Now imagine providing a soldier with the same ability to locate and identify targets through changes in the electric field. By shooting out a burst of electromagnetic energy and “listening” to the perturbations in the received electric field, he could map the interiors of distant buildings, spy snipers nestled under cover, or safely spot roadside explosives before moving into their deadly range.

MITRE’s “Biologically Inspired Sensing” project is currently exploring that last use of electroreceptory prowess. Improvised explosive devices (IEDs) are a lethal and difficult-to-discover threat to our soldiers—responsible in Iraq for 63 percent of U.S. deaths. Researchers hope to perfect the ability to detect the materials used in IEDs through a technique called dielectric spectroscopy.

### How Did the Worm Cross the Road?

Dielectric spectroscopy involves analyzing the way an electrical charge builds up and migrates through different materials. Different materials have different dielectric signatures. Run an electric field through a car abandoned by an Iraqi road and you could determine whether it contained an IED or just sand and scorpions.

The idea to harness dielectric spectroscopy to detect explosive materials first germinated in lead researcher Nick Donnangelo’s imagination years ago. “I have long marveled at the ability of even simple animals to find food, avoid predators, and locate others of their same species. When I was a child, I noticed how after a rain on a summer afternoon the washed-up earthworms would often attempt to cross the road perpendicularly, by the shortest route possible. I remember wondering how they could do that without even any eyes.”

As is often the case with researchers, that early fascination nudged Donnangelo along as he pursued his studies and initial career. He found himself an expert at what he calls “unconventional sensing,” the attempt to squeeze the maximum amount of information out of an event in order to infer the technical capability of the system. This expertise served Donnangelo well in the intelligence work he undertook early in his career. He came to MITRE to continue plumbing the potential of unconventional sensing to serve the public good.

### Residue and Radioactivity

Donnangelo wanted to study further an observation he had made in earlier studies: that the dielectric properties of materials emit a signature response when subjected to low-frequency electric fields. He believed this phenomenon could help overcome the current deficiencies in explosives detection.

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The hammerhead shark is a species of electro-receptive fish that can detect the electrical discharges from the muscles of their prey. They can detect a charge as small as a half-billionth volt. It’s possible this phenomena may be used to detect IEDs.

Soldiers may one day map interiors of faraway buildings and spot distant roadside IEDs.

Dielectric spectroscopy relies on relatively simple, inexpensive, low-power electronics.

Currently there are three methods primarily used in screening for explosive materials. The first is known as “The Electronic Dog Nose.” This method draws air through a polymer mesh. The mesh has tiny gaps in the shape of the molecules found in the vapors and residue of explosive materials. Should one of those molecules fill a corresponding gap in the mesh, the electrical properties of the mesh change, alerting to the presence of explosive vapors or residue in the air being tested.

The second method involves swabbing suspicious material. The swab is then run through a mobility spectrometer to test for traces of explosives.

The disadvantage to these methods is that they rely on residue and vapors. Explosive material encased in an air-tight container would pass through these systems undetected. Conversely, testing for explosives in an environment, such as a war zone, saturated with explosive residue would result in a slew of false positives.

The third method does not rely on “sniffing out” explosives. Instead, it scans suspicious objects with ionizing radiation and analyzes the resulting material signature. The obvious drawback to this method is its use of radioactivity.

### Advantages and Disadvantages

Dielectric spectroscopy has several advantages over these methods. Most important, it doesn’t require the presence of residue or vapors. Like the ionizing radiation method, it simply scans the tested material and reads its signature. But rather than requiring radioactive sources or a 150,000-volt mobility spectrometer, dielectric spectroscopy relies on relatively simple, inexpensive, low-power electronics.

Not that detecting explosive materials through dielectric spectroscopy doesn’t come with its own hurdles. For instance, because it is a capacitive measurement, dielectric spectroscopy is employable only at relatively close ranges. And the signatures it elicits from materials can be difficult to catalogue. Scan an object with an infrared spectrograph and the resulting graph would be very easy to read, replete with soaring peaks and crashing valleys. Dielectric spectroscopy, however, with its use of low-frequency electric fields, draws out much smoother signatures, making it harder to catalogue distinctions between materials. And even small changes in the moisture content, temperature, and position of the material being scanned can lead to variations in the material’s signature that make exact classification even trickier.

But it’s not necessary for dielectric spectroscopy to be uniformly superior to other scanning systems. “This system doesn’t have to be the be-all, end-all,” says Donnangelo. “In fact, I don’t think any system is.” He considers one of the primary advantages of dielectric spectroscopy is that it not only works where other systems fail (such as with air-tight containers), but that the ambiguities in dielectric spectroscopy are uncorrelated to conventional sensing modalities. “Ideally, if you’re trying to determine what something is, and you have a number of different measurements that you’re throwing at it, you want the sensitivities for those different measurements to be orthogonal—in other words, independent of each other.”

### The First Steps

For Donnangelo’s team, the first two goals were to begin building a database of material signatures and to conduct a successful demonstration of the technology.

Building the database is a slow, painstaking process. “We need to catalogue a wide range of signatures under a wide range of environmental situations—different temperatures, moisture levels, purity levels, material properties—and see how distinguishable from each other they are,” explains Donnangelo. He and his team continue to piece together a comprehensive database of materials both innocent and incendiary, the latter supplied by a relationship with the Fairfax County [Va.] Bomb Squad.

—by Christopher Lockheart

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