# RFID 2.0

Next-generation UHF systems promise to bring a new level of performance previously thought impossible.

Radio frequency identification technology is about to enter a new phase, with capabilities that, until now, have been thought impossible to achieve. Two companies that are still in stealth mode—RF Controls and Mojix—have given RFID JOURNAL an exclusive look at their ultra-high-frequency systems. Each was developed with expertise from outside the RFID industry—RF Controls' from the U.S. military and Mojix's from NASA. And each takes advantage of the same sophisticated technology—beam-steerable phased-array antennas—though they apply it in different ways to yield distinctly different system characteristics. But both promise a new level of performance by providing a longer read range than previously possible, the ability to verify tags on cases in the middle of a pallet of RF-unfriendly products, and the ability to locate tags more precisely at dock doors, in warehouses and on store shelves. And both promise to lower the cost of deployment.

The ITCS lets users take a zonal approach to tag location, which could be particularly valuable where the location of tagged items is ambiguous and variable, such as in apparel retail stores.

In addition, both systems are compliant with EPCglobal's second-generation UHF air interface protocol standard, and both operate within the regulatory limits for RF energy output established by the U.S. Federal Communications Commission. Neither company was willing to provide photographs of its system. But it's a sure bet that when these two companies go public, you'll be hearing a lot more about them, and they'll create quite a stir in the RFID industry.

## RF Top Gun

RF Controls, based in St. Louis, was started by Graham Bloy and Thomas Ellinwood. Bloy, the company's chief technology officer, holds numerous patents in RF and related fields, and has done research and development in guidance, encryption and tracking systems, as well as in radar and satellite communications. Ellinwood, the company's CEO, was formerly general manager of Omar Tool and Machine, which makes components and systems for military aircraft and aerospace applications. He left Omar to enter the consumer packaged goods industry, where, in 1995, he orchestrated the spin-off of Pillsbury's $100 million Van de Kamp's seafood line and built it into a $500 million business.

Nearly four years ago, one of Bloy's companies was working with Ellinwood on a military project that required RF devices to be located in three-dimensional space. Ellinwood, well aware of the RFID tagging initiatives launched by Wal-Mart through his consumer goods exposure, realized that the RF issues Bloy was trying to address—pinpointing a signal in 3-D space—would have huge implications in the commercial sector.

The ability to accurately locate a tag in 3-D could solve many problems associated with conventional RFID systems, which simply capture the serial number of a tag in a read zone. Such a system would allow a

company to determine, for example, whether a tag was on a product at dock door 2 rather than dock door 1 or 3, or high on a warehouse rack as opposed to low, or entering a facility rather than leaving it. The ability to identify the precise locations of tags in systems with greater read ranges also is important, because simply knowing a tag is present in a large area is not enough to enable a company to make intelligent business decisions about the location or movement of tagged items.

Bloy was unfamiliar with commercial passive RFID tags and asked why anyone would want to track one—let alone in 3-D. "Tom said to me, 'Because there's a lot of money to be made if we can do it,'" Bloy says. "And that caught my interest."

The answer to pinpointing a tag's location in 3-D was to use beam-steerable phased-array antennas, a technology developed by the U.S. military for secure radio-frequency communications and other applications. But applying the military's beam-steerable phased-array antennas approach to RFID to pinpoint a tag's location in a 3-D space wouldn't be easy. These antenna systems, which use a low-powered, focused and electronically steerable beam of RF energy to sweep an area, similar to the way an image is rasterized for display on a computer screen, are extremely expensive—about $250,000 per unit. "That obviously wasn't viable for an RFID system, so the challenge was to bring the cost down dramatically," Bloy says. "With a few smart RF engineers, sophisticated development resources and a lot of hard work over several years, and with millions of dollars invested, we've been able to do that."

The solution is called the Inventory Tracking and Control System (ITCS). The heart of the system is a sensitive receiver—called a "smart antenna"—that consists of an array antenna, an EPC-compliant reader, a powerful controller and a signal processor. The sensitive receiver allows the ITCS to use less RF energy than conventional RFID systems, which extends the read range well beyond that of a conventional UHF system. It also improves the ability to receive information from the tag through materials, making it easier to read tags on cases at the center of a pallet.

"Most people have been trying to throw more energy at the tag to extend the read range," Bloy says. "The problem is, all that energy [from the reader] is interfering with the signal coming back from the tag. It's like throwing up your high beams in the fog. All you do is blind yourself."

Sophisticated electronics in the back of the smart antenna employ complex multipath ambiguity-resolution algorithms to cancel out reflected signals and spurious "images," which enables the system to locate tags with great precision. For many years, Bloy says, the military has been using similar math equations to improve the accuracy and reliability of targeting information for aircraft, and to resolve false images that could be reflected from the ground or deliberately created to confuse pursuing aircraft.

Using one smart antenna allows the ITCS to locate a tag in two dimensions (which is useful if you want to locate tagged objects on a wall with shelves or a pegboard for item display). When using multiple antennas, the system can triangulate on a tag and identify its location in 3-D, with a precision of 1 foot in three axes.

The ability to locate passive tags in 3-D, at range, is a breakthrough in technology, and its applications are groundbreaking. It allows users to take a zonal approach to tag location; that is, rather than outfitting adjacent dock doors with RFID portals and attempting to filter out reads from neighboring doors, two ITCS smart antennas could cover five to eight dock doors. Users could create zones in software in front of each portal to determine which dock door the tagged items (pallets or cases) were entering or leaving from. This zonal approach could be particularly valuable where the location of tagged items is ambiguous and variable, such as clothes hanging on round metal racks (rounders)

that can be wheeled to different locations within a retail apparel store.

The smart antennas are designed to be suspended from the ceiling or mounted off the ground on a wall, so they don't need to be protected from wayward forklift trucks. Each smart antenna requires an Ethernet connection and power, and RF Controls says it has designed the system to be easy to install and configure.

RF Controls demonstrated a prototype of the ITCS for RFID JOURNAL at an operational warehouse owned by one of Ellinwood's companies. For the demonstration, RF Controls used two large (roughly 2-foot-by-3-foot) smart antennas. But the company says the production models, which it expects to release in the second quarter of 2008, will be smaller and expandable by linking modular antenna units.

The smart antennas were set up about 35 feet apart and 15 feet off the ground. A grid with 5-foot-by-5-foot squares was drawn on the ground to provide a reference indication of the location of tagged objects. Four tagged boxes were placed on the ground. The locations of the boxes were displayed on a computer screen with a proportional grid. When a technician moved a box around, the screen refreshed after a few seconds, and the tags on the boxes were displayed in the new arrangement. Clicking on a tag's serial number caused the tag to blink on the grid, showing how the system could be used to find specific objects.

Technicians then wheeled out a uniform pallet tightly stacked with 96 boxes containing foil packs (which are highly RF-unfriendly) and other materials typically found in packages of food-service items. The screen refreshed and each tag on each case was read and displayed in 3-D. A second technician rotated the visual plane of the software so the tags could be viewed at different angles. Finally, the technicians read an Alien Squiggle tag on an empty box with one bidirectional antenna from 94.7 feet.

RF Controls also demonstrated the ITCS for about 150 people at an event held at the RFID Research Center at the University of Arkansas. Two smart antennas were set up in the center's 1,000-square-foot model retail store area, with 400 to 500 tagged apparel and footwear items. The system was able to read every single item and show its location accurately in 3-D space. To illustrate the system's ability to dynamically monitor tagged items in an area in real time, technicians removed a rounder holding about 50 hanging garments from the store area, and the 50 items were almost immediately removed from inventory data.

"The technology is amazing," says Bill Hardgrave, director of the RFID Research Center. "A zonal monitoring system like that is a game changer. It will not just tell you when items are in the wrong location on the retail floor, but it will also be very useful in the back room of a store, where you need to locate items that have been misplaced."

The ITCS also was able to read—from a distance of 30 or 40 feet—every tag on cases of candles stacked tightly on a pallet. The RFID Research Center had been unable to achieve this with any standard UHF system using a portal configuration. "We didn't do robust testing to see the penetration capabilities of the technology," Hardgrave says, "but reading all those candles was not something we'd seen before."

RF Controls will test the system in real-world environments with several major retailers and other companies this spring and summer. The company is not disclosing product pricing at this time.

## From Deep Space to Warehouse Space

Around the same time that Ellinwood and Bloy set up RF Controls, Ramin Sadr, a Ph.D. in electrical engineering and computer science, formed a company called Mojix. Sadr has more than 25 years of experience in the telecommunications industry as an entrepreneur, researcher and executive. He founded Telecom Multimedia Systems, a company that specialized in developing integrated digital signal processing software, hardware and systems. Prior to that, he was with the California Institute of Technology, home of NASA's Jet Propulsion Laboratory, where he led research for NASA in the areas of digital signal processing and deep-space

telecommunication systems. He has received 15 NASA awards for his contributions to the U.S. space program.

Sadr assembled a team of scientists and engineers to apply technical breakthroughs in deep-space telecommunications to a passive RFID system, to create a product that could do things not possible with conventional UHF RFID systems. The Mojix system—called Space Time Array Reader (STAR)—can read passive UHF tags at distances of hundreds of feet away, verify tags on cases in the middle of pallets of RF-unfriendly materials, identify tags in 3-D space, and provide new levels of security for tagged shipments, Sadr says.

To do all this, Mojix combines advanced signal processing techniques and a new approach to delivering energy to the tag. For years, NASA has used steerable phased-array antennas to detect faint signals from deep-space probes communicating back to Earth; the antennas narrowly focus on signals being transmitted from deep space and cancel unwanted signals. Mojix has applied the same basic approach, which enables its system to pick up faint signals emitted from passive tags that are much farther away than conventional RFID systems could detect.

The system can cover hundreds of thousands of square feet in a 3-D space without having direct line of sight to the tags. But covering a large area is not enough: Companies don't simply want to know a case of product is in a warehouse or back room, they want to know where it is so someone can retrieve it. STAR can identify the locations of tags in 3-D with great precision, making it a potentially game-changing technology for deployments in large facilities.

In addition, Mojix has developed an innovative way to solve the problem of being unable to read tags on cases in the middle of pallets of RF-unfriendly materials, such as water and metal. Its approach, which we can't describe in full at this time but will cover in future articles online, also allows companies to verify the authenticity of tags. This means companies can use the system for electronic proof of delivery (because it can verify that all tags are present even when they can't all be read), and for anticounterfeiting, security and privacy (because the system can verify that the tags are legitimate, placed on the goods by a retail partner).

STAR has been installed in field trials with a number of large consumer packaged goods and retail companies to prove the technology works. Mojix invited a group of analysts to view a demonstration at a large U.S. distribution center in late December.

STAR can cover hundreds of thousands of square feet in a 3-D space—and identify the location of tags with great precision—without having direct line of sight to the tags.

"The technology's range was impressive," says Michael Liard, research director for RFID and contactless technologies at ABI Research. "One STAR antenna array could potentially support a very large area—perhaps an entire warehouse, depending on the size—which could potentially lower the total cost of ownership and overall investment."

Mojix will launch its system at RFID Journal LIVE! in April and demonstrate STAR's capabilities in the exhibit hall. At that time we will publish more details on how the system works and comments from customers that have been using it.

The systems and new capabilities demonstrated by RF Controls and Mojix will not solve every business problem. Portal, mobile and handheld readers will continue to have a role to play in many RFID applications. But clearly, the ability of these two systems to cover a much larger area than conventional RFID systems can, to locate tags in 3-D, and to identify all the cases on a pallet of RF-unfriendly products represents a significant leap forward for passive UHF systems. —*Mark Roberti*