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UCRL-TR-229163

UTag: Long-range Ultra-wideband Passive Radio Frequency Tags

Farid Dowla

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Disclaimer

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UCRL-XX-XXXX

2007 R&D Awards Entry Form

UTag: Long-range Ultra-wideband Passive Radio Frequency Tags

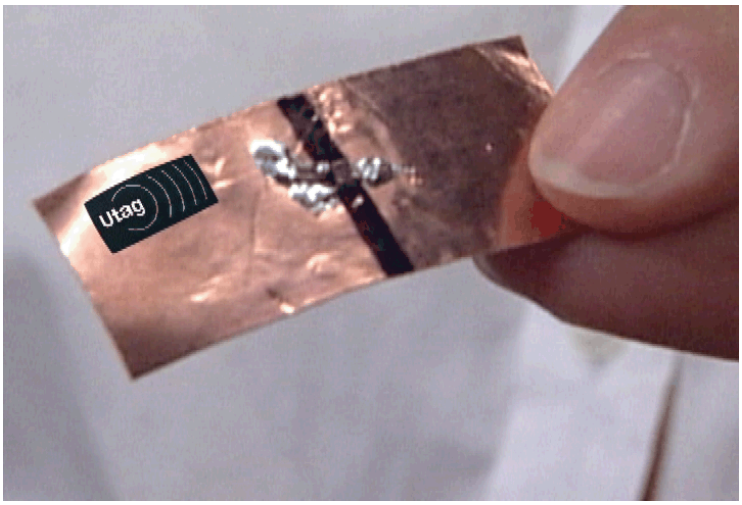

Figure 1: UWB passive tags are small, have an infinite lifetime, and can operate in harsh propagation environments.

Long-range, ultra-wideband (UWB), passive radio frequency (RF) tags are key components in Radio Frequency IDentification (RFID) system that will revolutionize inventory control and tracking applications. Unlike conventional, battery-operated (active) RFID tags, LLNL's small UWB tags, called "UTag", operate at long range (up to 20 meters) in harsh, cluttered environments. Because they are battery-less (that is, passive), they have practically infinite lifetimes without human intervention, and they are lower in cost to manufacture and maintain than active RFID tags. These robust, energy-efficient passive tags are remotely powered by UWB radio signals, which are much more difficult to detect, intercept, and jam than conventional narrowband frequencies. The features of long range, battery-less, and low cost give UTag significant advantage over other existing RFID tags.

DISCLAIMER

Long-Range Ultra-wideband Passive RF Tags

1. Submitting Organization

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AFFIRMATION: I affirm that all information submitted as a part of, or supplemental to, this entry is a fair and accurate representation of this product.

Submitter's signature: _____

2. Joint Entry: No

3. Product Name: Long-range Ultra-wideband Passive Radio Frequency Tags, "UTag".

4. Brief Description: Long-range, ultra-wideband, passive RF tags will revolutionize RFID inventory and tracking applications because they can be interrogated at long

distances in harsh propagation environments, resist interception and jamming, and have almost infinite life spans without requiring batteries. A video of the UTag system in operation is included on the compact disc accompanying this submission.

5. When was this product first marketed or available for order?

These long-range, ultra-wideband, passive RF tags have been available for commercial applications since January 2006.

6. Inventors or Principal Developers:

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7. Product Price: The product price for these long-range, UWB, passive RF tags will be less than $1 each when they are mass-produced. The licensee will decide the final price.

8. Do you hold any patents or patents pending on this product?

We have applied for the following patents:

- "Method for Detecting Multiple UWB Passive Tags in an RFID System."
- "Method for Remote Powering."
- "Ultra-wideband Backscatter Communications."

9. Describe your product's primary function as clearly as possible.

Radio Frequency IDentification (RFID) is an automatic identification technology that uses radio signals to identify and track objects. Although many types of short-range RFID systems are available for inventory management and tracking of high-value items, most fall short in critical areas: range of operation (commercially available passive short range RFID operate over very short ranges), power consumption (active tags require batteries), cost, size, and security. Our innovative RFID system consists of passive RF tags and a reader that employs coded radar pulsing to overcome these deficiencies, and uses ultra wideband frequencies to communicate (Figure 2).

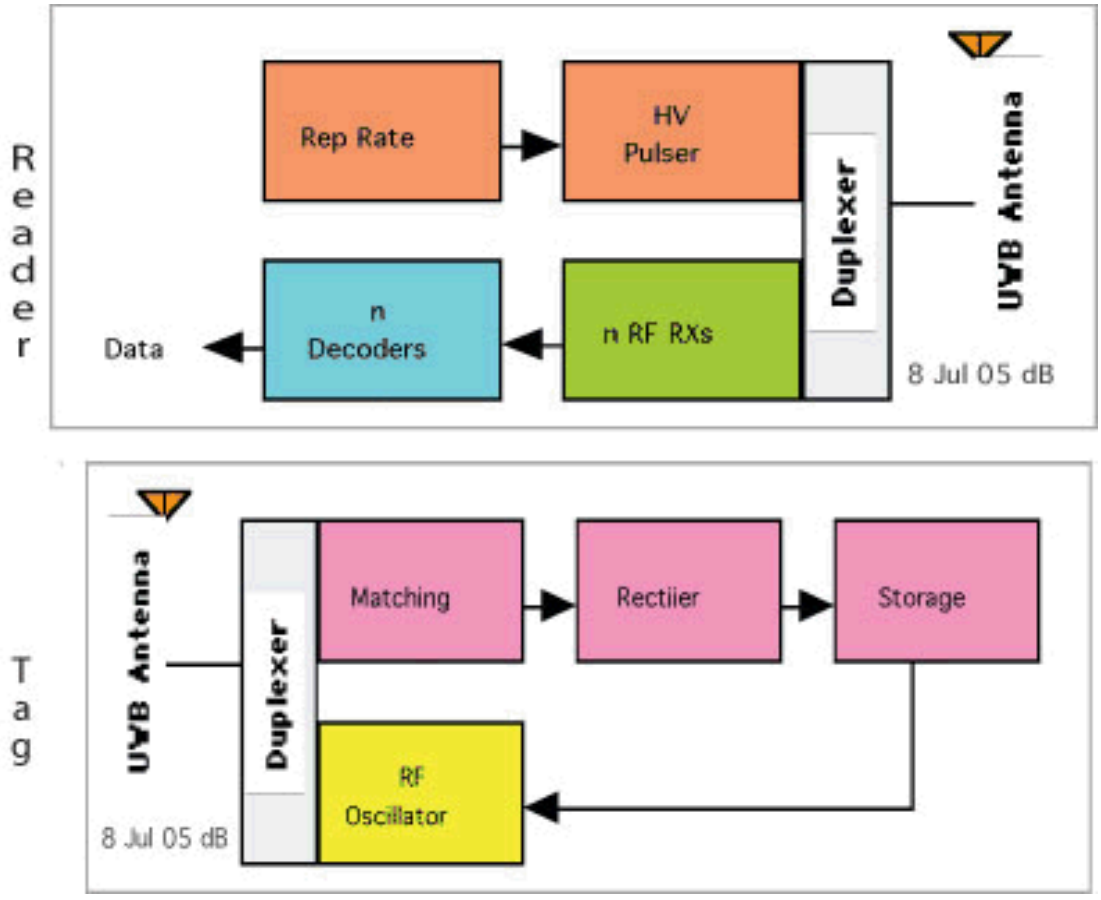


Figure 2. Schematic diagram of our UWB RF system

In our RFID system, passive RF tags can be attached to a valuable item, such as a computer hard drive, or to a sensitive medium, such as a computer disk containing product specifications, prototype drawings, or personnel records. A code pulsed radar simultaneously interrogates an unlimited number of such tags even in cluttered or metallic environments (warehouses, retail stores, corporate offices, military installations) at long range. Remote powering, multi-tag detection, and radar-based interrogation are the key novel concepts in our innovative RFID system.

How does it do it?

Background

Conventional RFID systems—like those used by automated toll systems—consist of a reader that is both a transmitter and a receiver, and target tags. The reader communicates with the tags using narrowband radio signals. The tags store a serial number and perhaps other data and are attached to an antenna that transmits identification information to the reader. Most commercially available tags require an energy source, such as batteries, which are expensive, have a limited lifetime, and must be changed out periodically. The narrowband signals that carry the identification data cannot penetrate some materials, including walls, dirt, or metal; most have short ranges (less than 2 meters); and they cannot operate in cluttered environments, such as warehouse full of metal shelving. Moreover, other commercially available RFID systems that use narrowband frequencies are vulnerable to interception and detection, making them unsuitable for most military and high security applications.

Ultra-wideband Technology

Ultra-wideband technology traces its roots to experiments by Guglielmo Marconi in the late 1800s. UWB is a wireless communication technology that transmits data in

extremely short (50- to 100-picosecond) pulses across a wide range of the electromagnetic spectrum. The Federal Communications Commission (FCC) defines a radio system as an UWB system if the fractional bandwidth of the signal is greater than 20 percent or greater than 500 MHz, respectively. UWB systems can carry large data bursts (hundreds of gigabits per second) because data are carried simultaneously across a wide range of frequencies.

The combination of broad spectrum, low power requirements, and extremely short pulses causes much less interference with other devices using conventional narrowband wireless systems. At the same time, UWB devices are more resistant to jamming and interference from other devices.

Unique Characteristics of Passive UWB Tags

Our passive RF tags, the key components in our innovative RFID system, consist of a device similar to a capacitor that receives and stores energy from a wireless UWB signal, a UWB antenna, a micro controller, and a backscatter switch (Figure 3).

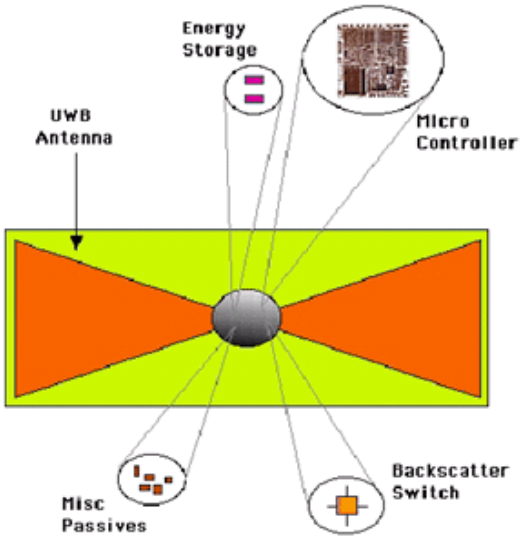


Figure 3. Long-range UWB, passive RF tags consist of simple, low-cost components.

A code pulsed radar sends a UWB signal that provides the necessary energy to activate the tag. The same pulse powered radar also interrogates the tag to obtain the tag's unique serial identification code.

Our passive RF tags have the following innovative characteristics that take advantage of UWB technology:

Battery-less Remote Charging. Conventional methods for remote powering use continuous wave (CW) radio frequency bursts or a magnetic field. These charging methods limit the range of commercially available tags. To lengthen their range, conventional tags must have an energy source, such as a battery; but batteries have a limited lifetime, and are expensive and large in size.

By using UWB pulses, our RFID system provides increased energy efficiency and greater communications range. Unlike high-power narrowband tags, our system utilizes a short-duration, high-peak amplitude UWB pulsing transmitter to remotely power the tags. The receiver uses an efficient, energy-scavenging, UWB-matched circuit to receive the sub-nanosecond UWB pulses to the tags. The pulses reflect off nearby objects and are detected by the passive UWB tags. Just a few microwatts of remote power is adequate to power up the tags because low duty cycle UWB pulses contain much higher peak power than CW signals. The large instantaneous power in UWB pulses overcomes the diode drop associated with the rectifying diode, resulting in increased efficiency of energy extraction and, therefore, powering out to greater distances. Figure 4 demonstrates the advantage remote powering with UWB or CW signals.

The peak power minus the diode drop in UWB signaling is still sufficient enough to power up an electronic signal at a far distance; but in CW powering, far distances diminish the signal strength. In addition, the frequency diversity of UWB signals mitigate multipath fading, which is common to narrowband or CW techniques.

Digital Backscattering. Another advantage of our RFID system is the use of digital backscattering to interrogate a UWB RF tag (that is, detect tag information). The interrogator unit consists of a UWB transmitter, a receiver, and an antenna that detects energy reflected from one or more remote tags. When a tag's power capacitor circuit charges up remotely ("wakes up"), its logic circuit drives the tag backscattering antenna into unique sequence of switching transitions (a series of OPEN/CLOSE impedance

states), generating a unique code. In other words, once the tag is powered up, it transmits its unique tag address or code by way of its backscattering antenna.

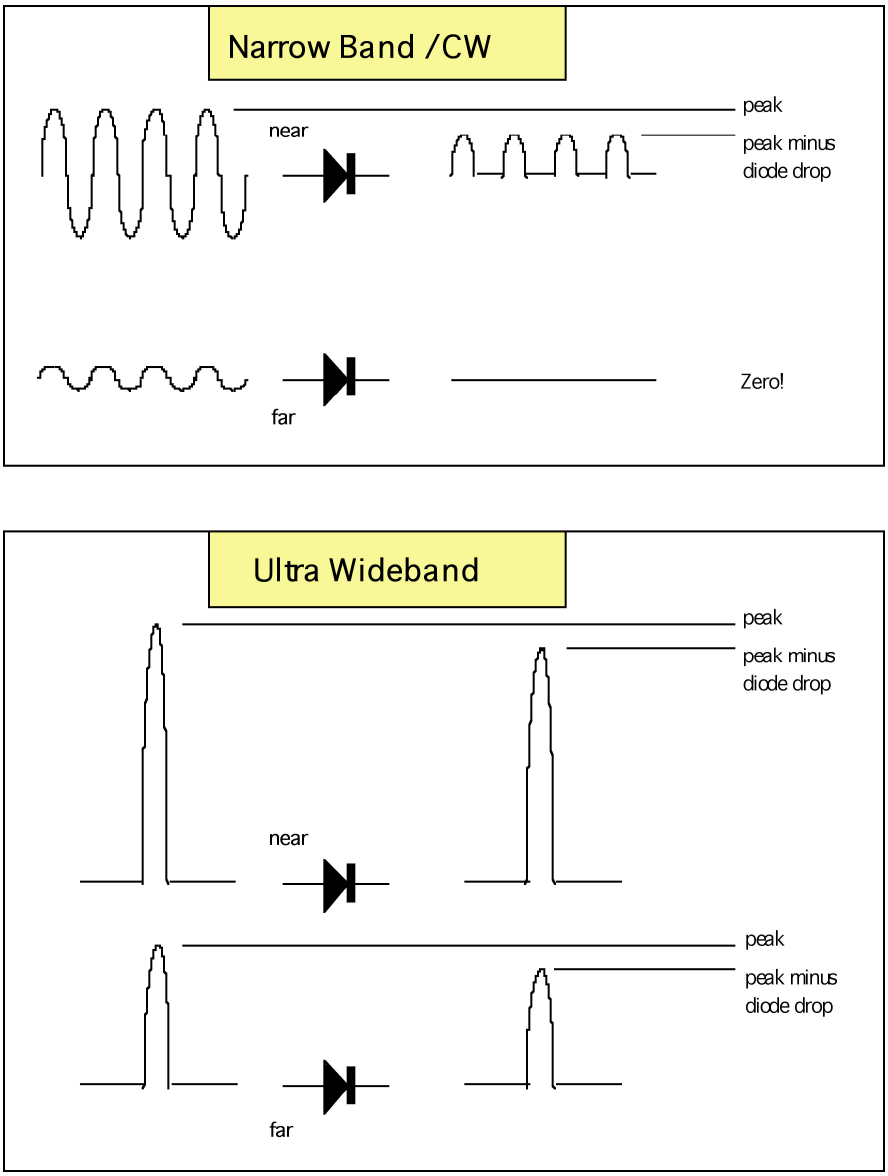


Figure 4. Comparison of CW and UWB remote powering of an electronic device.

The tag behaves as a "digital backscatterer," with the backscattering pattern defined by the switching timing code. The codes can be orthogonal codes, just as in code division

multiple access (CDMA) technology, providing an additional advantage. The interrogator unit receives and demodulates the backscattered pulse from the tag.

A UWB RF tag needs only a couple of microwatts of power from a transmitter/receiver to active its digital backscattering behavior, thus the power available in the UWB tags (unlike other commercially available backscattering tags) is not the limiting factor to meet long-range tag interrogation capabilities.

Immune to Signal Blockage. UWB RF tags perform in harsh, cluttered environments. Our UWB tags activate and transmit in environments where a GPS system might fail. UWB frequencies penetrate most low-conductivity materials; thus, UWB tags perform through walls; glass; buried in dirt; inside concrete buildings and in warehouses vaults, airplanes, and ships; and outside in landscapes full of rocks, trees, people, and buildings. Line of sight is not needed.

Low Complexity. Low Cost. Our UWB tags have few components, making them easy and inexpensive (less than $1) to manufacture by conventional electronic manufacturing methods. UWB frequencies are available worldwide, making them ideal for global applications. Their lower cost and small size (about that of a quarter) make their use with lower value items or small pieces of equipment feasible.

Undetectable. UWB pulses reside below the noise floor of a typical narrowband receiver, becoming undetectable from background noise. Only the intended receiver is able to detect the UWB pulses.

Multi-tag Interrogation. In inventory and tracking systems involving multiple UWB RF passive tags—such as tags attached to equipment in a warehouse, low frequency UWB signals from a transmitter power all tags simultaneously. Once the tags are all awake, the UWB radar sends specific "interrogating codes" to the tags. The unique interrogating code triggers the appropriate tag to respond with its unique "response code," using the backscattering technique explained above.

A serial number generator inside each tag produces a specific "tag code," and the tag antenna switches based on the specific serial number from open to short and vice versa. In other words, individual tags listen for their specific interrogating code, and they only respond after being called. Using this method, multiple tags can be read without any interference from other tags communicating with the reader. In addition, no high power synchronization technique is required to separate each tag's information from another's.

10A. List your competitors by manufacturer, brand and model number.

To date, there is no known direct competition for long-range passive UWB tags. MultiSpectral Solutions, Inc., has a UWB tag, model MSSI PAL650, available. Parco Wireless PT-EA-0710-001 and Alien ALL-9334 are commercially available, active tags. The passive tags commercially available are based on narrowband technology and have very limited ranges, from inches to a few meters.

10B. Supply a matrix or table showing how the key features of your product compare to existing products or technologies, include both numerical and descriptive comparisons.

	Radio Frequency Tags			
Features	**UTag**	**MSSI PAL650**	**Parco Wireless PT-EA-0710-001**	**Alien ALL-9334**
UWB Technology	Yes	Yes	No	No
Passive	Yes	No	No	Yes
Long Range	Yes	Yes	Yes	No
Operable in harsh environments/metallic	Yes	No	No	No
Geolocation capability	Yes	No	No	No
Small, low-cost	Yes	No	No	Yes
Resistance to jamming/tempering	Yes	Yes	No	No

10C. Describe how your product improves upon competitive product technologies.

Using UWB signals to remotely power our passive RF tags offers several advantages, including resistance to jamming and high tolerance to multipath phenomenon created by harsh metallic environments. Our tags can be used to do an inventory of a large room cluttered with objects instantaneously. Until now, this instantaneous inventorying capability was available only with commercial active (battery-powered) tags, but the lifetime of active tags is limited by battery life. Active tags are also generally more expensive than passive tags and are larger in size, making them unsuitable for unsuitable for tracking small pieces of lower value equipment or products. Furthermore, our UWB tags offer a geo-location capability that is generally not available in any other commercial passive tag.

11A. Describe the principle applications of this product.

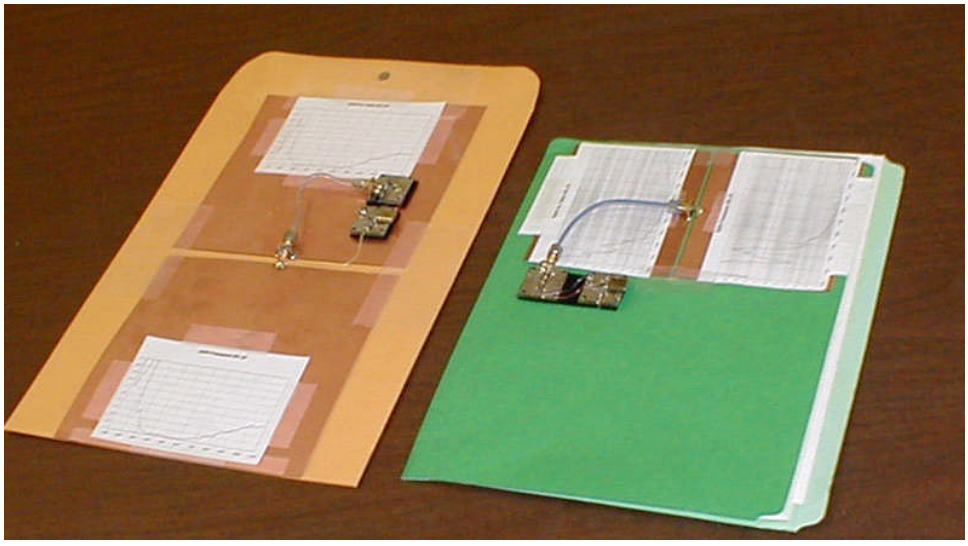
The tags can be used to inventory valuable items in harsh environments, such as constricted and cluttered corridors of warehouses with lots of metallic shelves and containing metal or metallic packaging. Another major application area is in applications that require very long lifetimes for the tags, such as ordnance components.

11B. List all other applications for which your product can now be used.

Unexploded explosive ordnance (UXO) detection. The U.S. Navy is interested in unexploded explosive ordnance (UXO) detection with this technology.

Cargo containers. High-valued commercial items or items stored in harsh environments, such as containers in cargo ships, would benefit from this invention.

Classified Documents.



12. Summary

Long-range remote powering is an important invention that further enhances the uses of RFID systems. Worldwide, the demand for RFID systems is growing among, including electronics and consumer goods manufacturers, as well as aerospace, defense, and pharmaceutical companies. Passive tags, because they are low in cost and energy efficient and have long lifetimes, improve asset tracking throughout a supply chain. This technology could be utilized in medical applications, including sensors emplaced inside the body. This technology would provide a way to easily communicate with micro-sensors without the need for batteries.

ORGANIZATION DATA

13. Contact person to handle all arrangements on exhibits, banquet, and publicity.

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