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The Technology of On-Metal RFID

September 2009

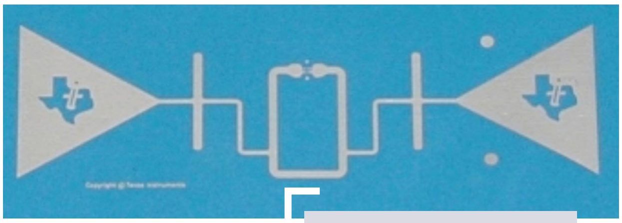
Omni-id passive UHF RFID tags

- Omni-ID™ Max Pro
- Omni-ID™ Max HD
- Omni-ID™ Ultra

What is RFID?

Radio Frequency Identification, or RFID, is a method of communicating using radio waves. Just as radio signals can travel through the walls of your home to your radio, radio waves can communicate between an RFID tag and an RFID reader without requiring line-of-sight visibility.

RFID systems are used to send an identification signal from a tag to a reader. RFID tags have two parts: a silicon chip, which stores a small amount of data, and an antenna, which receives and transmits radio frequency (RF) signals. When an RFID tag receives a signal from an RFID reader, it returns a modified version of the reader's radio waves, communicating the data it has stored. In basic systems, the information stored on the chip is a unique identification number. Hence, Radio Frequency Identification, or RFID.



A Texas Instruments UHF RFID Tag.

This simple but clever technology was first developed as an offshoot of transponder and covert listening device technology used during World War II. The first patent for RFID technology was issued in 1973. Early RFID tags were large, complex devices made of metal-coiled antennas and glass. Over the ensuing 35 years, many improvements were made to RFID technology. The miniaturization of silicon chips, the increase in their data storage capacity, and the ability to manufacture very inexpensive printed, etched, or stamped antennas have all contributed to much smaller, more portable, and far less expensive RFID tags.

Active and Passive RFID

Today's RFID tags can be categorized as active, semi-active, semi-passive, or passive. This categorization refers to the energy source for the tag. In addition to their chip and antenna, active, semi-active, and semi-passive tags contain a power source—typically a battery—to facilitate communication over long distances or to communicate longer or more resource-intensive data payloads. Passive tags do not have their own power source. Instead, they harvest energy from the incoming reader signal and then reflect back a modified version of that signal to communicate their data. The tag's signal is roughly analogous to a signal that one could create by using a mirror to reflect flashes of light.

Active RFID

With both a power source and a transmitter, an active tag has a longer read range and the capability to transmit larger data streams. While they are significantly more expensive than a passive tag, the longer range—typically 100 meters or more—makes them useful for applications such as tracking heavy equipment and containers in shipyards and rail depots.

Active RFID tags are available in two basic types: transponders and beacons. Transponders, the type of RFID used in toll-collection systems, are relatively smart. They remain dormant until a specific frequency is detected that "wakes up" the tag and causes it to broadcast its unique ID and associated data. This allows the tag to conserve battery power. In some applications, transponder tags can perform simple interactions and are capable of secure communications. They can also store and transmit a much larger amount of information than other tag types—making it possible for them to be used without the need to query a back-end database.

Beacons are relatively simple. They broadcast their ID and optionally, some additional data, at a fixed interval. For example, a sensor beacon may broadcast the temperature in a frozen food container. A remote receiver, detecting a rise in temperature, could generate an alert, preventing food spoilage in the case of a breakdown. RFID beacons are also used in location applications. Unlike GPS, RFID can track objects indoors.

Active tags are typically priced from $10 to $100 each, depending on processing power, battery life, robustness, and range capabilities. Many beacon implementations operate in the 433 MHz range, while the more complex transponders use the public bands of 2.4 GHz and 5.8 GHz

Passive RFID

Passive RFID tags use a completely different technology than active tags. They have neither a power source nor a transmitter. While that may seem to be inconsistent with their prime purpose, the lack of those two elements makes possible the manufacturing and delivery of the tags for less than 25 cents each. Passive tags get power from the electromagnetic signal sent by the RFID reader. This signal is then altered by the tag's microchip and is reflected back to the reader, which interprets the signal.

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Passive tags operate in one of two modes: near field or far field. Near field is within one wavelength of the RFID reader, usually less than one-half meter, and far field is outside of one full wavelength. Low Frequency and High Frequency tags typically use near-field inductive coupling, a process in which the magnetic field couples the tag's antenna coil to the reader's antenna, allowing each antenna to induce electric currents in the other. The tag draws energy from this induced current to power the chip. The chip then transmits data by changing the impedance, an electrical property, of the antenna coil, which in turn is recognized by the reader and converted to data. To couple the magnetic field requires proximity of the tag to the reader, so this technique works for shorter range applications.

Ultra High Frequency tags usually operate in the far field and are not inductively coupled, though they still draw their operating power from the energy transmitted by the reader. To communicate, they use multiple techniques to alter the incoming signal from the reader. The reader's antenna picks up the altered signal and uses the information derived from the wave's altered state, or backscatter, to convert it to data.

Because there is no internal power source, passive tags are inexpensive to make and have an extremely long lifetime—often decades, depending on the materials used and environmental conditions. For these reasons, they are very attractive for applications that require large numbers of tags, such as retail, supply chain, anti-counterfeiting, and asset identification and tracking.

Why Frequency Matters

Radio Frequency refers to the range of electromagnetic radiation from 30 kHz to 3000 MHz. Within that range, certain more specific frequencies are commonly used for RFID, and standards have been built around them.

Reviewing the chart above, some of the differences between RF types become clear. Low Frequency wavelengths can be a kilometer long, so passive tags operating in near field (within one wavelength) can still have a very useful read range. Even HF tags using near-field technology can operate at a meter or a bit more. Yet LF and HF RFID do not transfer data as quickly or reach as far as do higher frequencies, and they are more expensive to produce. To achieve faster transfer rates and longer reads, far-field UHF is the preferred technology.

There are other advantages to using UHF tags besides just longer read ranges and higher data rates. Higher frequencies have a shorter wavelength, which means they can operate with smaller antennas. So using higher frequency allows one to make smaller tags, which can be important when the goal is a small-footprint, unobtrusive tag. Problems arise, however, because higher frequency wavelengths are not as good at penetrating materials. As the frequency increases, the waves are more likely to reflect or be absorbed rather than pass through some materials.

Reflection occurs with materials that conduct electricity, particularly metals. These materials alter the electromagnetic field that the RFID tag and reader rely on to communicate signals and can make tags unreadable. On the other hand, water tends to absorb radio waves, making it difficult for tags to collect enough energy to operate.

> **"With more and higher-value high technology equipment in use, tracking and managing metal equipment is a priority"**

Passive UHF RFID has been very effective in many applications. Because it needs relatively no power to receive a signal and send backscatter, the tag can be very efficient from extraordinary distances. Tags in this range can be so small and inexpensive that they are disposable—perfect for use in tracking things like retail items that pass through the supply chain and then are discarded. The downfall of passive UHF has been the inability to establish reliable read rates in environments that contain materials like metals and liquid. Because UHF has so many advantages, industry experts have worked hard to find ways to make passive UHF tags work in these environments. The next section of this paper will discuss in more detail some of the advances that have been made in this area.

Band – Radio Frequency	Range	Commonly used RFID frequency	Wavelength
Very low frequency and below – almost sound	< 3000 Hz		>10 km
Low frequency (LF)	30-300kHz	125 – 134.2 kHz and 140-148.5 kHz	1—10 km
High Frequency (HF)	3-30 MHz	13.56 MHz	10 – 100 m
Ultra High Frequency (UHF)	300-3000 MHz	866-960 MHz	10 – 100 cm
Microwave	> 3000 MHz		< 10 cm

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Standards

Before leaving our section on frequency, we must mention frequency standards in geographic regions. As with conventional radio, frequencies for RFID are subject to government regulation, and the approved frequencies can be different in different geographies: For example, approved frequencies for UHF are centered on 866 MHz in Europe, 915 MHz in the United States, and 953 MHz in Japan. Tags and readers are typically manufactured to work best at a specific frequency and will have a different performance if moved to a different geography and used at a different operating frequency. There are also geographic differences limiting the amount of power the RFID reader can use to activate and read a tag. Since the radiated power has a direct effect on the read ranges of an RFID system, a tag may have different performance characteristics based on where it is used.

On-Metal Technology

There are many applications where passive UHF RFID tags can be extremely useful—only if they can deliver reliable read rates on metal or water. Manufacturing and industrial environments are full of metal equipment. IT Data centers could use RFID for inventory control of expensive electronic assets. Supply chains that use metal carts, tracking of metal tools, and warehouses with metal racks could all benefit. Even applications that typically use active RFID tags, such as shipping container tracking, could reduce costs by moving to passive RFID tags.

One solution used in the past has been to reduce the effects of interference by adding a “spacer” made from high air-content material such as foam. Spacers are typically 5 mm thick or more, and they separate the RFID tag from the interfering material with enough distance to mitigate the disruption of the electromagnetic field. Using spacers improves performance to some degree, but creates other problems. Adding spacers greatly complicates tag production, programming, and printing. These issues would be manageable if the spacers truly solved the problem, but tags using spacers still have performance limitations.

Another workaround has been to create tags that are tuned to work specifically on metal. These tags also use a spacer, but with careful design, they can be somewhat smaller and work well with thinner spacers. By taking into account the reflections expected from the metal, tags and readers can be optimized so that the metal interference contributes to the RF field in a constructive way, so performance can be quite good. This is not easy to do, technically, but has been done successfully. One downside of this approach is that the tags tend to work well only over a fairly narrow frequency range—so production yields (and hence tag cost) can be affected by the tight manufacturing tolerances required.

Development of the Plasmonic Structure

In the late 1990s, a team of scientists and engineers at QinetiQ, an international defense and security technology company, spent time exploring problems that required breakthrough technology to solve— including the problem of liquid and metal interference with passive UHF RFID technology. They used the practice of biomimetics—the application of designs and processes found in nature—to help them develop innovative, out-of-the-box solutions. The team studied how the wing structure of the Blue Morpho butterfly reflects light to produce its iridescent color. Taking this concept for reflected light and applying it to UHF radio waves, the team developed a plasmonic structure—a structure that impacts the oscillations within an electromagnetic field—to generate the same kind of reflection within an RFID tag.

When the plasmonic structure is in place, and an RFID reader sends a signal to the tag, the plasmonic structure captures and holds the oncoming waves without interference from nearby liquids and metals. The captured waves then oscillate within the plasmonic structure, building up a region of highly concentrated energy. This energy activates the microchip, which then transmits its identification information to the reader.

Because the high energy field isolates the RFID tag from the structure on which it is placed, RFID tags using this technology can be read regardless of the material they are on. This turns out to be a very useful property in RFID tracking. For example, in data centers, some equipment is metal, and others look like metal but are actually metallic plastic. A tag that works on both eliminates the need to evaluate each piece of equipment in order to select an appropriate tag. A wooden pallet is not a problem when dry, but when it gets wet, it acts as a liquid—so a tag that works both on and off liquid is a requirement. Pallets or boxes stored on metal warehouse racks need to work equally well on and off the racks.

The Blue Morpho butterfly’s iridescent blue markings inspired the technology behind new passive UHF RFID developments

The plasmonic structure has other properties that are sometimes surprising and non-intuitive. For example, it has properties that allow the tag to be built with a smaller footprint than is typically used in UHF tags. The plasmonic structure also creates a stronger signal than other workarounds used for on-metal application. As a result, tags tuned specifically for on-metal performance exhibit longer read ranges than other on-metal tags of similar size. Another benefit of this type of tag is that the structure inherently produces a frequency response that has two peaks rather than the single peak found in conventional tags. That facilitates the development of broadband on-metal tags—tags that work across the different frequencies used in different regions of the world. Broadband, or “global” tags, are fairly common in label form for use where metals are not present, but most on-metal RFID tags are not capable of operating across a broad frequency spectrum. Tags using the plasmonic structure are able to offer this broadband capability.

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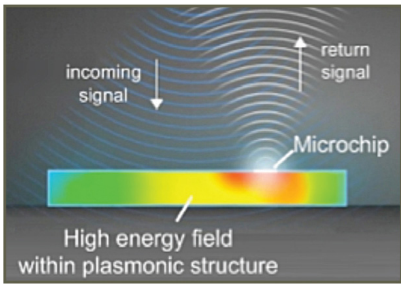
Omni-id passive UHF RFID tags

In 2007, after the development and testing of this breakthrough technology, QinetiQ worked with Cody Gate Ventures LLP and Qinetic Ventures LP to spin off an independent company, Omni-ID, to offer the technology commercially. Since that time, Omni-ID has implemented RFID systems worldwide using this technology. It is currently the only company selling RFID tags based on QinetiQ's breakthrough research.



Omni-ID's tags have proven very successful in the short history of the company. The tags have been used in industrial settings, such as tool tracking for Holt Cat, a heavy equipment and engine company that implemented a successful passive RFID system in an environment with metal tools and equipment, metal walls and doors, and metal shavings on the floor. They have been used for supply chain RFID tagging in major retail warehouses—an area that had a lot of buzz around RFID but ran into many problems because of the many different types of materials on the warehouse shelves. Omni-ID tags

have enabled successful use of RFID in the warehouse environment. The tags have been used in IT data centers, a metal-rich environment, for better and more efficient control of assets. Omni-ID tags were chosen by IBM to use as part of their Data Center Resource Management solution.

In November 2008, RFID Wizards conducted an independent evaluation and benchmarking study of passive RFID Durable asset tags, comparing tags from Omni-ID, Confidex, SimplyRFID, Intermec, and Avery Dennison. Tags were tested on metal, on plastic near metal, on water, and in water. The only tags that consistently had strong read rates in all environments were the Omni-ID tags.[1]

Second-Generation Omni-ID RFID Tags

In the fall of 2009, Omni-ID launched its second generation technology RFID tags. This generation of technology was developed around two objectives: Address some of the requests customers were bringing to Omni-ID, and take advantage of more of the unique properties of the plasmonic structure. With these goals in mind, the new line of Omni-ID products includes the following new technologies:

- **Global Broadband Standard and Operability**—One of the unique features of the plasmonic structure is its ability to give a broadband signal even on metal. Omni-ID now offers tags with an effective read range between 860 and 960 MHz, therefore operating at the standard frequencies in Europe (866 MHz), the United States (915 MHz), and Japan (953 MHz).

1 Durable Asset Tag Product Evaluation & Benchmarking, November 26, 2008, by Louis Sirico, IndustryWizards.com

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- **New Plasmonic Structure**—Omni-ID has refined and improved the construction of its plasmonic structure, both improving the durability of the tag and making the manufacturing process more scalable and repeatable for higher quality and lower cost.
- **New Coupling Structure**—Omni-ID uses a coupler and chip attach as opposed to a typical tag structure with a chip attached to antennae. This coupling structure takes better advantage of the plasmonic structure core technology, improving reliability and stability and giving the tag a longer life span.

> **"This generation of technology was developed around taking advantage of more of the unique properties of the plasmonic structure."**

- **Migration from Higgs 2 chip to Higgs 3 chip**—Moving to the next generation chip technology adds functionality to the tags. This is a single-chip UHF RFID Tag IC, conforming to EPCglobal Class 1 Gen 2 specifications. The Higgs 2 chip operates at extremely low power levels and offers flexible memory architecture that provides for optimum allocation of EPC and User memory. Incorporating these new technologies, Omni-ID's new products include:

Omni-ID™ Max Pro – The Max Pro was developed to offer additional read range on metal and greater toughness and resistance to harsh indoor and outdoor environmental conditions. Optimization for on-metal performance instead of balanced performance extends the read range of this tag, and it has a more durable design and a larger surface area for external abel applications.

Omni-ID™ Max HD – The Max HD offers even greater durability, including a polycarbonate case option, and broadband performance for use of a single tag globally. This tag can function in higher temperatures and extreme weather conditions and works equally well on, off, and near metals.

Omni-ID™ Ultra – The Ultra is the first passive UHF RFID tag with a read range on metal of 100 feet. By optimizing the plasmonic structure's properties, the technology has enabled a read range in a passive RFID tag that is typically seen in active tags. With the lower cost and longer lifetimes of passive tags, it remains to be seen whether passive RFID tags will begin to take the place of active tags for some applications.

For more information about Omni-ID's current and upcoming product lines, visit the Omni-ID website at www.omni-id.com.

Omni-ID is the leading supplier of passive, low-profile UHF RFID solutions. Through our patented technology, Omni-ID "cracked the code" to overcome the problems traditionally associated with RFID, enabling a broad range of new applications that improve accuracy and efficiency in asset tracking, supply chain management and work-in-process.

Our family of versatile RFID tags works reliably in the harshest environments, including on, off, and near metal and liquids and excels in solving tracking and identification challenges with unprecedented accuracy.

With offices in the USA, UK, Asia and India backed up by a purpose-built manufacturing facility in China, our mission is to drive the widespread adoption of RFID and wider IoT technologies as the optimal tracking and identification devices.

Omni-ID's global presense:

USA Office:
333 West Commercial Street
Suite 333–1500
East Rochester
New York 14445

Tel: +1 585 299 5990

UK Office:
The Enterprise Centre
Coxbridge Business Park
Alton Road
Farnham, Surrey
GU10 5EH United Kingdom

Tel: +44 (0) 1252 748 020

Asia Office:
Omni-ID Technology Trading
(ShangHai) Co. LTD
1308 Room Unit B
Sunyoung Center 28 XuanHua Rd
ShangHai 205002

Tel: +86 21 5240 0359

India Office:
Omni-ID India Private Limited
1007, Mayuresh Square
Plot No. 17, Sector 15, CBD Belapur
Navi Mumbai, Maharashtra 400614,
India

Tel: +91 (0) 22 2757 7969

Visit www.omni-id.com to learn more or email sales@omni-id.com for all product or technology inquiries and we will be pleased to get in touch.

omni-id.com