RFID Tags

Radio Frequency Identification (RFID) is becoming more widely used to facilitate common day-to-day activities due to new developments in processing, wider reading ranges, and larger memory capacities, making it a key contributor to the growth of the radio technology industry. RFID is almost indispensable when it comes to tasks that include automated data capture and identification applications, where a contactless identification is possible through RF signals. Many large corporations are interested in research and development within the field of RFID due to potential growth in areas, such as car identification, which will allow emergency vehicles, for instance, to safely trip traffic signals, production automation, and many other applications. As new materials such as conductive inks are used, printing methods will drive the cost of tags down while enhancing their flexibility and allowing for a wide array of applications. In order for tags to be marketable, better read ranges, processing methods, printable materials, and lower cost materials and processes must be achieved.

RFID History and Basics

RFIDs were invented in 1969 and like many new technologies, the inventors built upon prior knowledge and combined well-known scientific concepts to create something that was versatile and practical. RFID tags, also called smart labels, are simply microchips. They can either be an active tag, requiring a battery, or a passive tag, requiring no battery. Each tag has a scanning antenna, a transceiver with a decoder to interpret data, and a
transponder that is programmed with information. The antenna places an RF signal within a short range. This RF field is responsible for providing a means of communication with the transponder and providing the device with energy if it is passive. The transceiver activates and reads signals from the transponder. It contains a microprocessor responsible for decoding, and performing simple calculations, then sending the information to a computer system for processing. The transponder is commonly referred to as the tag and is the white plastic rectangular object attached to items in stores to prevent shoplifting. It can be programmed with information, such as serial numbers, price, inventory date, which is broadcasted. Transponders are the main reason that RFIDs are versatile because no line-of-sight or direct contact is required with the reader. Another key element lending to the success of RFID is that passive tags contain no battery, leading to tag sizes as small as .3 mm², presented by Hitachi³.

![Image](image.png)

Figure 1. Hitachi’s “mu-chip” is half the size of the smallest chip on the market.

When RFID was first commercially used 30 years ago, it was developed as an electronic article surveillance (EAS) equipment to counter theft. These tags could be made inexpensively by a company called Knogo and functioned based on a 1-bit system, meaning a ‘1’ was detected if a tag was present and a ‘0’ if absent². These systems required the use of microwave or inductive technology. Nowadays, it is not uncommon to see 64-bit, 90-bit, or even 128-bit RFID tags being powered by a radio signal, allowing for much more information to be passed along (about 18 thousand trillion values for 64-
These broadcasts of information can be read by an RFID from a few inches up to a few feet away, depending on the antenna size and power driving the tag. It is possible to have better read ranges by using active tags or a more sensitive RFID receiver, but increased size and cost are an issue. Current passive tags average around 50 cents but prices are decreasing\(^2\). As prices keep going down due to developments in processing and materials, manufacturers may foresee achieving the “holy grail” of 5 cents a tag, meaning it will be cost efficient to place an RFID tag on anything above a dollar.

**Types of RFID Tags**

The two types of RFID tags with read and write capabilities are the inductively coupled and capacitively coupled RFID tags. Inductively coupled RFID tags have been used for years and are the most common ones available. The three parts of the inductively coupled RFID tag are the microprocessor, metal coil, and encapsulating material. The microprocessors are made of silicon and vary in size depending on their purpose. The metal coil is made of either copper or aluminum wire that is wound in a spiral pattern on the transponder and acts as the antenna. The tag transmits signals to the reader with read distances that depend on the coil size. The coils can operate at frequencies of 13.56 MHz which is the industry standard. The encapsulating material is either a glass or polymer material that wraps around the chip and coil\(^4\).

![Figure 2. Inductively coupled RFID tag.](image)
These tags are powered by the magnetic field generated by the reader. The high cost of these tags can be as much as $1 for passive tags and $200 for active tags. This high cost is mainly due to the silicon, coil, and the process needed to wind the coil around the surface of the tag.

The second type of tag, the capacitively coupled RFID tag, was created in response to the high price of inductive RFID tags. These tags do away with the metal coil and use less silicon to perform the same function as previous tags. The three parts of the capacitive tag are the microprocessor, conductive ink, and paper. The microprocessor is made of silicon or polymer and can be as small as a few square millimeters. The special ink is a conductive carbon ink that acts as the antenna and can be printed onto a paper substrate by conventional printing methods. The paper substrate allows for low cost and disposability of the tag, as well as easy integration on conventional product labels. The price of the capacitive tag will be much lower than inductive tags due to the replacement of the metal coil by conductive carbon ink, the use of paper substrates, and roll-to-roll printing methods.

![Figure 3. Capacitively coupled RFID tag in a roll.](image)

In addition to low cost, the tags are more flexible than inductive tags. The tags can bent and crumpled and can still relay information to the reader. Another difference is that instead of being powered by a magnetic field, the tags are powered by an electric field.
from the reader. The disadvantage of these tags is their very limited range. Most capacitive tags have ranges of less than 1 cm. If the tag covered a larger area, the range would improve, but the system would not be ideal for retailers. Some companies have boosted this read range but at the expense of increasing cost. Much research is being done to improve the read range to a few feet but the costs come out to as much as bar code technology.

**Processing Methods and Materials**

For traditional inductive RFID tags, the device is made by depositing a layer of copper and using photolithography to etch away metal to achieve a desired thickness. This process is expensive, time-consuming, and creates chemical waste that is expensive to get rid of and harmful to the environment. Rather than etching, printing antennas would be less wasteful and less harmful to the environment while also lowering costs of RFID tags by half. A printed antenna could potentially be attached to a microchip and turned into a complete transponder that is ten times faster than typical transponders made from metal. The only way printable antennas will be a practical alternative is if the conductive inks being used can function in existing industrial presses, such as roll-to-roll, inkjet, screen, and thermal processes. The reason is because it would require too much capital for present industrial printing companies to enter the market on a large scale.

Cabot-PEDs, a printable electronic device branch of Cabot Corp., develops these conductive inks using metallic nanoparticles that weld together to form a conductive ink when heated\(^6\). Other alternative inks are not as conductive. DuPont’s ink uses thin silver flakes which require a glue to bind together, and thus are not welded together. This glue
acts as an insulator between flakes and reduces conductivity as a result. In addition, the flakes are too large to be used in traditional inkjet printers. Another key factor to consider is the temperature threshold of the materials used in the tags. Flexible materials such as paper and polymer substrates will be damaged if brought to temperatures above 150 °C, which means printing processes must also stay below this limit. Cabot-PEDs is also developing a way to print transistors, so that the microprocessor can be printed, as well. In order to do so, the silicon is replaced by a printable, recyclable, semi-conducting polymer. However, before such a polymer can be employed, degradation and poor conductivity issues must be overcome. Also, an even bigger issue will be calibrating present printing equipment to be able to produce intricate lines required to print integrated circuits.

Currently, it is only possible to print antennas onto substrates while conventional photolithography is still required for building the integrated circuits. If it becomes possible to print the entire transponder, the antenna and circuit, costs of production and manufacturing times would plummet significantly as RFID tags could be printed directly onto packaging and products. A disadvantage of using conductive inks is that printed antennas have lower conductivities than metal ones, especially at high frequency, such as 13.56 MHz. There are a number of ways to improve the conductivity of printed antennas. If a screen-printing process were used, antennas could be printed at an elevated thickness, which would increase their conductivity. Increasing the thickness requires more ink, which means higher cost. Another method is through electroplating, which involves immersing the object in an electroless chemical solution and using a current to deposit a
coating. However, this process slows the manufacturing process and requires a large investment in equipment and materials.

In February 2006, scientists at Philips Research were the first to achieve a functional 13.56 MHz flexible RFID tag on plastic using a pentacene-based chip instead of a silicon one and a printable ink antenna. The integrated circuit still required photolithography to create. The move to a processor made of semi-conductive and conductive polymers was to eliminate a separate step to connect the chip to the antenna, which is time consuming with silicon based tags. The read range is extremely short, however, being only a few millimeters. Another company, PolyIC, claimed it was the first to create a high frequency plastic RFID tag in October 2005, with a polymer based chip made of polythiophene. Philips agreed with their claim but stated that PolyIC’s tag can only transmit a single, constant string of data, whereas their tag can transfer variable data. The next obstacle for Philips is determining the best chemicals, materials and processes to use and finding a way to mass produce the tags.

![Image](image_url)

**Figure 4.** Philips’ plastic RFID tag as thin as paper and no larger than a postage stamp.

**Market**

RFID tags can be used in any situation where a barcode or optically read technology is being employed. The tag does not have to be on the surface of the object, meaning it is
not subject to wear, multiple items can be read at once rather than one at a time, and the read time is less than 100 ms. However, bar codes and other scanning technologies are still very prevalent on the market.

The patent for bar codes was issued in 1952 and it took twenty years before it was approved for use\textsuperscript{1}. When it first came out on the market only 15,000 suppliers used barcodes. By 1984, that number rocketed to 75,000 suppliers. The reason for this drastic increase was mainly due to Wal-Mart. When Wal-Mart wanted a better way to manage its inventory, it turned to the bar code. As a result, any supplier that wanted to keep in business with Wal-Mart was required to use bar codes. It will not be long before bar codes are replaced, however. Besides the inconvenience of waiting in lines to scan each bar code one at a time, the major drawback of bar codes is that they are a read-only technology, meaning they cannot send out information. In the future, it might be possible to see RFID tags on everything with a variable price depending on the time of day, and of course, there will not be any lines to wait in, as shoppers can walk straight out of the store and have their

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debit card charged automatically. Thus, by using RFID tags, data stored on these labels can be changed, updated, and locked, a huge advantage over bar codes. The only issue is driving down costs.

Wal-Mart is already taking action in using RFID tags, requiring that its top 100 suppliers have RFID tags attached to their products and have scanners. This has led other companies, such as Target, CVS, Lowe’s, and Home Depot, to jump on board. With the potential for RFID tags to streamline and improve inventory management, the cost savings can be tremendous. For Wal-Mart, the world’s biggest retailer, with sales of over $200 billion a year, 10 percent of overall sales goes to costs of storing, transporting, and maintaining goods. Six to seven percent of those costs could be saved annually with RFID tags, amounting to about $1.5 billion saved. However, at this point, suppliers do not have any real incentive, as tag costs are too high. To be practical for use, the price will have to come down to 5 cents. Current suppliers using RFID tags are enduring the brunt of the tag cost, while retailers reap the benefits. Many manufacturers are optimistic that as volumes increase, prices will drop.

As for other industries, RFID tags are already being widely used. RFID tags are used in tracking pets, EZPass, or ExxonMobil’s SpeedPass, all for convenience. In terms of security, some airlines are tagging customers’ bags in order to reduce baggage loss and enable easy routing of bags. Seaport operators have agreed to use RFIDs to track the thousands of containers that arrive each day at US ports because currently only a small percentage is being inspected. Michelin is also considering implanting RFID tags into their tires that will contain information about the owner’s vehicle. This will help car
manufacturers while also countering car theft, but at the same time it may not be good for those who do not want their car to be broadcasting their current location.

**Some Issues to Consider**

Some may think that all the convenience that RFID tags have to offer is at the expense of privacy. Imagine if read ranges were improved to large distances by higher gain antennas. People could be tracked if they bought clothing or groceries and brought them home. This also allows anyone with a reader to determine the contents of bags and purses. RFID tags are difficult to remove and some are printed right on the product, hindering anonymity. Even worse, what if RFID tags were implanted into babies upon birth, so that one day, all humans could be traced by anyone with access to tracking information. These issues must be considered before RFID tags are used everywhere.

**Conclusion**

RFID tags have come a long way from their induction in the ‘60s. They are clearly a means of convenience when it comes to maintaining goods and inventory and are no longer just for countering theft. It will not be long before bar codes become extinct. RFID tags will undoubtedly be a huge business for the radio technology industry in coming years as more suppliers pick up on the trend. Presently, the only major obstacle for RFID tags is cost, but as volumes increase, and new materials and processes are introduced, cost will not be a factor. Already, flexible RFID tags on plastic are showing promising characteristics that will allow for printable tags in roll-to-roll processes, cutting manufacturing times and cost. Wal-Mart may be one of the biggest supporters in getting
RFID tags into the market. The only question remaining is whether or not all the convenience is worth sacrificing privacy.

References


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