Shrouds of Time

The history of RFID

An AIM Publication

The Association for Automatic Identification
and Data Capture Technologies

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ver. 1.0, published October 1, 2001

Introduction

Many things are hidden in the shrouds of time. The task of tracing history and genealogy is arduous and challenging, but, ultimately, rewarding. Our past can open doors to our future. Whether we realize it or not, RFID (radio frequency identification) is an integral part of our life. RFID increases productivity and convenience. RFID is used for hundreds, if not thousands, of applications such as preventing theft of automobiles, collecting tolls without stopping, managing traffic, gaining entrance to buildings, automating parking, controlling access of vehicles to gated communities, corporate campuses and airports, dispensing goods, providing ski lift access, tracking library books, buying hamburgers, and the growing opportunity to track a wealth of assets in supply chain management.

One can trace the ancestry of RFID back to the beginning of time. Science and religion agree that in the first few moments of creation there was electromagnetic energy. "And God said, 'Let there be light,' and there was light" (Genesis 1). Before light, everything was formless and empty. Before anything else, there was electromagnetic energy.

Scientific thinking summarizes the universe was created in an instant with a Big Bang. Scientists deduce all the four fundamental forces - gravity, electromagnetism, and the strong and weak nuclear forces - were unified. The first form in the universe was electromagnetic energy. During the first few seconds or so of the universe, protons, neutrons and electrons began formation when photons (the quantum element of electromagnetic energy) collided converting energy into mass. The electromagnetic remnant of the Big Bang survives today as a background microwave hiss.

Why is this important, you might wonder? This energy is the source of RFID. It would take more than 14 billion years or so before we came along, discovered how to harness electromagnetic energy in the radio region, and to apply this knowledge to the development of RFID.

The Chinese were probably the first to observe and use magnetic fields in the form of lodestones in the first century BC. Scientific understanding progressed very slowly after that until about the 1600s. From the 1600s to 1800s was an explosion of observational knowledge of electricity, magnetism and optics accompanied by a growing base of mathematically related observations. And, one of the early and well known pioneers of electricity in the 18th Century was Benjamin Franklin.

The 1800s marked the beginning of the fundamental understanding of electromagnetic energy. Michael Faraday, a noted English experimentalist, proposed in 1846 that both light and radio waves are part of electromagnetic energy. In 1864, James Clerk Maxwell, a Scottish physicist, published his theory on electromagnetic fields and concluded that electric and magnetic energy travel in transverse waves that propagate at a speed equal to that of light. Soon after in 1887, Heinrich Rudolf Hertz, German physicist, confirmed Maxwell's electromagnetic theory and produced and studied electromagnetic waves (radio waves), which he showed are long transverse waves that travel at the speed of light and can be reflected, refracted, and polarized like light. Hertz is credited as the first to transmit and receive radio waves, and his demonstrations were followed quickly by Aleksandr Popov in Russia.

In 1896, Guglielmo Marconi demonstrated the successful transmission of radiotelegraphy across the Atlantic, and the world would never be the same. The radio waves of Hertz, Popov and Marconi were made by spark gap which were suited for telegraphy or dots and dashes.

20th Century

In 1906, Ernst F. W. Alexanderson demonstrated the first continuous wave (CW) radio generation and transmission of radio signals. This achievement signals the beginning of modern radio communication, where all aspects of radio waves are controlled.

In the early 20th century, approximately 1922, was considered the birth of radar. The work in radar during World War II was as significant a technical development as the Manhattan Project at Los Alamos Scientific Laboratory, and was critical to the success of the Allies. Radar sends out radio waves for detecting and

locating an object by the reflection of the radio waves. This reflection can determine the position and speed of an object. Radar's significance was quickly understood by the military, so many of the early developments were shrouded in secrecy.

Since RFID is the combination of radio broadcast technology and radar, it is not unexpected that the convergence of these two radio disciplines and the thoughts of RFID occurred on the heels of the development of radar.

Genesis of an Idea

There is an old adage that success has many fathers but failure is an orphan. The development of technology is messy. The potential for an infinite number of things is present, yet the broader human choices determine how technology evolves. There's no clear, text book perfect, or logical progression, and often developments ahead of their time are not recognized until later, if ever. So it was with the development of RFID.

An early, if not the first, work exploring RFID is the landmark paper by Harry Stockman, "*Communication by Means of Reflected Power*", Proceedings of the IRE, pp1196-1204, October 1948. Stockman stated then that "Evidently, considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored."

Thirty years would pass before Harry's vision would begin to reach fruition. Other developments were needed: the transistor, the integrated circuit, the microprocessor, development of communication networks, changes in ways of doing business. No small task. Like many things, timing is everything, and the success of RFID would have to wait a while.

A lot has happened in the 53 years since Harry Stockman's work. The 1950s were an era of exploration of RFID techniques following technical developments in radio and radar in the 1930s and 1940s. Several technologies related to RFID were being explored such as the long-range transponder systems of "identification, friend or foe" (IFF) for aircraft. Developments of the 1950s include such works as F. L. Vernon's, "*Application of the microwave homodyne*", and D.B. Harris', "*Radio transmission systems with modulatable passive responder*". The wheels of RFID development were turning.

The 1960's through the 1980s: RFID Becomes Reality

The 1960s were the prelude to the RFID explosion of the 1970s. R. F. Harrington studied the electromagnetic theory related to RFID in his papers "*Field measurements using active scatterers*" and "Th*eory of loaded scatterers"* in 1963-1964. Inventors were busy with RFID related inventions such as Robert Richardson's "*Remotely activated radio frequency powered devices*" in 1963, Otto Rittenback's "*Communication by radar beams*" in 1969, J. H. Vogelman's "*Passive data transmission techniques utilizing radar beams*" in 1968 and J. P. Vinding's "*Interrogator-responder identification system*" in 1967.

Commercial activities were beginning in the 1960s. Sensormatic and Checkpoint were founded in the late 1960s. These companies, with others such as Knogo, developed electronic article surveillance (EAS) equipment to counter theft. These types of systems are often use '1-bit' tags – only the presence or absence of a tag could be detected, but the tags could be made inexpensively and provided effective anti-theft measures. These types of systems used either microwave or inductive technology. EAS is arguably the first and most widespread commercial use of RFID.

In the 1970s developers, inventors, companies, academic institutions, and government laboratories were actively working on RFID, and notable advances were being realized at research laboratories and academic institutions such as Los Alamos Scientific Laboratory, Northwestern University, and the Microwave Institute Foundation in Sweden among others. An early and important development was the Los Alamos work that was presented by Alfred Koelle, Steven Depp and Robert Freyman "*Short-range radio-telemetry for electronic identification using modulated backscatter*" in 1975.

Large companies were also developing RFID technology, such as Raytheon's "*Raytag*" in 1973. RCA and Fairchild were active in their pursuits with Richard Klensch of RCA developing an "*Electronic identification system*" in 1975 and F. Sterzer of RCA developing an "*Electronic license plate for motor vehicles*" in 1977. Thomas Meyers and Ashley Leigh of Fairchild also developed a "*Passive encoding microwave transponder*" in 1978.

The Port Authority of New York and New Jersey were also testing systems built by General Electric, Westinghouse, Philips and Glenayre. Results were favorable, but the first commercially successful transportation application of RFID, electronic toll collection, was not yet ready for prime time.

The 1970's were characterized primarily by developmental work. Intended applications were for animal tracking, vehicle tracking, and factory automation. Examples of animal tagging efforts were the microwave systems at Los Alamos and the inductive systems in Europe. Interest in animal tagging was high in Europe. Alfa Laval, Nedap, and others were developing RFID systems.

Transportation efforts included work at Los Alamos and by the International Bridge Turnpike and Tunnel Association (IBTTA) and the United States Federal Highway Administration. The latter two sponsored a conference in 1973 which concluded there was no national interest in developing a standard for electronic vehicle identification. This is an important decision since it would permit a variety of systems to develop, which was good, because RFID technology was in its infancy.

About this time new companies began to surface, such as Identronix, a spin-off from the Los Alamos Scientific Laboratory, and others of the Los Alamos team, myself being one of them, founded Amtech (later acquired by Intermec and recently sold to TransCore) in the 80s. By now, the number of companies, individuals and institutions working on RFID began to multiply. A positive sign. The potential for RFID was becoming obvious.

The 1980s became the decade for full implementation of RFID technology, though interests developed somewhat differently in various parts of the world. The greatest interests in the United States were for transportation, personnel access, and to a lesser extent, for animals. In Europe, the greatest interests were for short-range systems for animals, industrial and business applications, though toll roads in Italy, France, Spain, Portugal, and Norway were equipped with RFID.

In the Americas, the Association of American Railroads and the Container Handling Cooperative Program were active with RFID initiatives. Tests of RFID for collecting tolls had been going on for many years, and the first commercial application began in Europe in 1987 in Norway and was followed quickly in the United States by the Dallas North Turnpike in 1989. Also during this time, the Port Authority of New York and New Jersey began commercial operation of RFID for buses going through the Lincoln Tunnel. RFID was finding a home with electronic toll collection, and new players were arriving daily.

The 1990's

The 1990's were a significant decade for RFID since it saw the wide scale deployment of electronic toll collection in the United States. Important deployments included several innovations in electronic tolling. The world's first open highway electronic tolling system opened in Oklahoma in 1991, where vehicles could pass toll collection points at highway speeds, unimpeded by a toll plaza or barriers and with video cameras for enforcement. The world's first combined toll collection and traffic management system was installed in the Houston area by the Harris County Toll Road Authority in 1992. Also a first was the system installed on the Kansas turnpike using a system based on the Title 21 standard with readers that could also operate with the tags of their neighbor to the south, Oklahoma. The Georgia 400 would follow, upgrading their equipment with readers that could communicate with the new Title 21 tags as well as the existing tags. In fact, these two installations were the first to implement a multi-protocol capability in electronic toll collection applications.

In the Northeastern United States, seven regional toll agencies formed the E-Z Pass Interagency Group (IAG) in 1990 to develop a regionally compatible electronic toll collection system. This system is the model for using a single tag and single billing account per vehicle to access highways of several toll authorities.

Interest was also keen for RFID applications in Europe during the 1990s. Both Microwave and inductive technologies were finding use for toll collection, access control and a wide variety of other applications in commerce.

A new effort underway was the development of the Texas Instruments (TI) TIRIS system, used in many automobiles for control of the starting of the vehicle engine. The Tiris system (and others such as from Mikron - now a part of Philips) developed new applications for dispensing fuel, gaming chips, ski passes, vehicle access, and many other applications.

Additional companies in Europe were becoming active in the RFID race as well with developments including Microdesign, CGA, Alcatel, Bosch and the Philips spin-offs of Combitech, Baumer and Tagmaster. A pan-European standard was needed for tolling applications in Europe, and many of these companies (and others) were at work on the CEN standard for electronic tolling.

Tolling and rail applications were also appearing in many countries including Australia, China, Hong Kong, Philippines, Argentina, Brazil, Mexico, Canada, Japan, Malaysia, Singapore, Thailand, South Korea, South Africa, and Europe.

With the success of electronic toll collection, other advancements followed such as the first multiple use of tags across different business segments. Now, a single tag (with dual or single billing accounts) could be used for electronic toll collection, parking lot access and fare collection, gated community access, and campus access. In the Dallas - Ft. Worth metroplex, a world's first was achieved when a single TollTag® on a vehicle could be used to pay tolls on the North Dallas Tollway, for access and parking payment at the Dallas/Ft. Worth International Airport (one of the world's busiest airports), the nearby Love Field, and several downtown parking garages, as well as access to gated communities and business campuses.

Research and development didn't slow down during the 1990s since new technological developments would expand the functionality of RFID. For the first time, useful microwave Schottky diodes were fabricated on a regular CMOS integrated circuit. This development permitted the construction of microwave RFID tags that contained only a single integrated circuit, a capability previously limited to inductively-coupled RFID transponders. Companies active in this pursuit were IBM (the technology later acquired by Intermec) Micron, and Single Chip Systems (SCS).

With the growing interest of RFID into the item management work and the opportunity for RFID to work along side bar code, it becomes difficult in the later part of this decade to count the number of companies who enter the marketplace. Many have come and gone, many are still here, many have merged, and there are many new players ... it seems almost daily!

Back to the future: The 21st Century

Exciting times await those of us committed to the pursuit of advancements in RFID. Its impact is lauded regularly in mainstream media, with the use of RFID slated to become even more ubiquitous. The growing interest in telematics and mobile commerce will bring RFID even closer to the consumer. Recently, the Federal Communications Commission (FCC) allocated spectrum in the 5.9 GHz band for a vast expansion of intelligent transportation systems with many new applications and services proposed. But, the equipment required to accommodate these new applications and services will necessitate more RFID advancements.

As we create our future, and it is bright, let us remember, "Nothing great was ever achieved without enthusiasm" (Ralph Waldo Emerson). We have a great many developments to look forward to, history continues to teach us that.

The Decades of RFID

Decade	Event
1940 - 1950	Radar refined and used, major World War II development effort. RFID invented in 1948.
1950 - 1960	Early explorations of RFID technology, laboratory experiments.
1960 - 1970	Development of the theory of RFID. Start of applications field trials.
1970 - 1980	Explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980 - 1990	Commercial applications of RFID enter mainstream.
1990 - 2000	Emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.

Some Helpful Background on Research Resources

Some US Patents of interest (Note: a search of the US Patent Office alone will reveal over 350 patents related to RFID and its use)

Patent Number	Title
3,713,148	Transponder apparatus and system
3,745,569	Remotely powered transponder
3,852,755	Remotely powered transponder having a dipole antenna array
4,001,822	Electronic license plate for motor vehicles
4,068,232	Passive encoding microwave transponder
4,096,477	Identification system using coded passive transponders
4,114,151	Passive transponder apparatus for use in an interrogator-responder system
4,123,754	Electronic detection and identification system
4,242,663	Electronic identification system
4,345,146	Apparatus and method for an electronic identification, actuation and recording system
4,354,099	Electronic identification system
4,463,353	Animal feeding and monitoring system
4,473,825	Electronic identification system with power input-output interlock and increased capabilities
4,481,428	Batteryless, portable, frequency divider useful as a transponder of electromagnetic radiation
4,490,718	Radar apparatus for detecting and/or classifying an agitated reflective target
4,494,545	Implant telemetry system
4,510,495	Remote passive identification system
4,525,713	Electronic tag identification system
4,546,241	Electronic proximity identification system

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Vernon, F. L.; "*Application of the microwave homodyne*", IRE Trans, 1952, AP-4, pp 110-116

Vogelman, J. H.; "*Passive data transmission techniques using radar echos*", US Patent 3,391,404, 1968.

Works, G. A., Murray, J. C., Ostroff, E. D. and Freedman, N.; "*Remotely powered transponders*", US Patent 3,745,569, July 1973.

Zaleski, J. F.; "*Passive microwave receiver-transmitter*", US Patent 3,836,961, Sept 1974.

Other:

Information about Ernst Alexanderson: http://www.invent.org/book/book-text/0.html

(Others such as Marconi can also be found through this web site at http://www.invent.org/book/book-text/indexbyname.html).

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