Design and Application of Radio Frequency Identification Systems

M.J. Uddin

Department of Electrical and Computer Engineering
International Islamic University Malaysia
E-mail : jasimuddin.iium@yahoo.com
Tel: +603-61964000 Ext. 2841

M.I. Ibrahimy

Department of Electrical and Computer Engineering
International Islamic University Malaysia

M.B.I. Reaz

Department of Electrical, Electronic and Systems Engineering
Universiti Kebangsaan Malaysia

A.N. Nordin

Department of Electrical, Electronic and Systems Engineering
Universiti Kebangsaan Malaysia

Abstract

The recent world, development of effective technologies for linking the object wireless information is being prompted in various fields. Radio frequency identification (RFID) is the latest technology for automatic identification which allows the transmission of a unique serial number wirelessly. The purpose of this paper is to review RFID systems and its various components infrastructure. The components and features are still under research and being integrated in existing systems to create a marketable and potential new system. To achieve higher performance; low cost, low power RFID tag with efficient anti-collision technique which provides a large throughput and flexible security mechanism is required. The review has shown different types of readers, antennas and tags which would becomes a bottleneck to reduce the RFID cost. The paper has shown details the entire components where RFID researchers will get benefit for the development of future technology. The challenges of RFID system design with the entire components (Reader, Tag and Antenna) and its advantages, disadvantages are briefly explained.

Keywords: RFID, Reader, Tag, Antenna.

1. Introduction

RFID (Radio Frequency Identification) is an automatic identification method. The great appeal of RFID technology allows storing and reading the data without requiring either contact or a line of sight

between the tag and reader. RFID consists of three basic component such as transponder (tag), interrogator (reader) and antenna. In a typical communication sequence, RFID system performs a

Figure 1: Configuration of RFID system
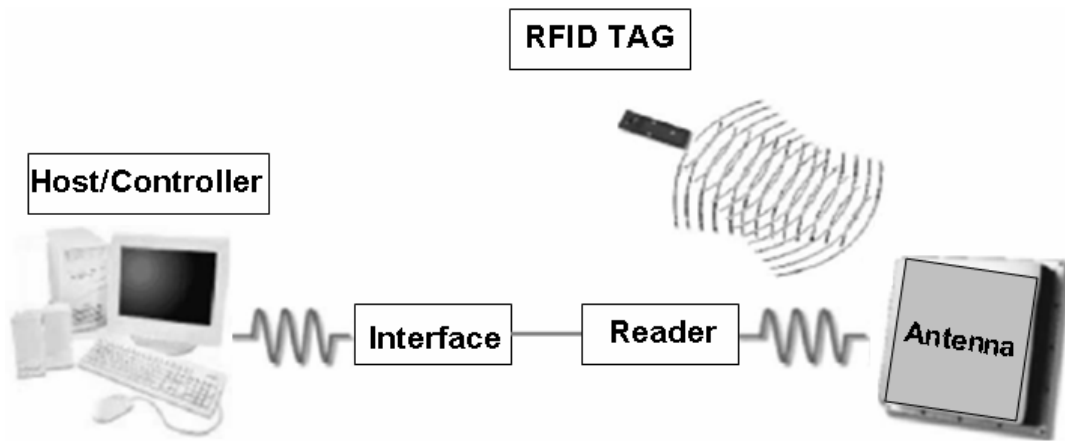
number of functionalities between reader and tag. RFID reader emits a continuous RF carrier sine wave. When a tag enters the RF field of the reader, the tag receives energy from the field. Further, receiving sufficient energy, it begins to modulate the carrier signal to the data storage on the tag. The modulating carrier signal is resonated from the tag to the reader. The reader detects the modulating signal from the tag, and decodes signal in order to retrieve the data from the tag. However, the information relays to the host computer where more manipulation data will be stored and finally will be displayed to the user. RFID is basically based on wireless communication making use of radio waves, which is a part of the electromagnetic spectrum (Wenting et al., 2007).

Moreover, RFID follows the standard frequency ranges, which are low frequency (120-135 KHz), high frequency (10-15 MHz), ultra high frequency (UHF) (850-950 MHz), and microwave frequency (2.45 GHz). Matt Ward and Rob van Kranenburg (2006) says RFID is a wireless communication device, it follows a number of standards. There are several standard bodies involved in the development and definition of RFID technologies including: International Organization of Standardization (ISO); EPCglobal Incorporation; European Telecommunications Standards Institute (ETSI); Federal Communications Commission (FCC). RFID systems have a number of limitations for integration, streaming and large volume of data. The accuracy of current RFID is improving, but there is still erroneous readings error, such as duplicate readings or missing readings. Fusheng Wang and Peiya Liu (2005) presented RFID data which are normally generated swiftly and automatically. It also accumulates the data for tracking and monitoring. The generated data volume can be enormous, but the problem which requires a scalable storage scheme. It is essential to assure the efficient queries and updates. A. Gupta and M. Srivastava (2004) presented RFID data which integrates with existing applications for product tracking and monitoring. This requires an RFID data management system that can be easily configured to be integrated into different applications, with minimum integration cost. Nowadays, fabrication techniques are also improving, so the reliability and the read range of the passive RFID system continues to improve the cost effective way. Figure 1 shows the basic configuration of RFID system.

2. RFID Standard

RFID systems do not support lack of standards. These standards are normally describes the physical and the link layers, covering aspects such as the air interface, anti-collision mechanisms, communication protocols and security functions. Several RFID standards exist and their applications are under debate within the RFID development community.

Nowadays, numerous standards are developing for improvement RFID. This can be compared to developments in barcodes and wireless local area network (WLAN) (Burnell J., 2003). In these case, it is not achieved widespread and developed until the international standards were adopted for these systems. In 2004, the food marketing institute of information technology committee tried to recover standard problems. They invented the national and international formal standards. Ron Weinstein (2005) classified RFID development standards which have a number of debates. Ron Weinstein also showed the international standards organization (ISO) three standards for RFID: ISO 14443 (for contactless systems), ISO 15693 (for vicinity systems), and ISO 18000 (to specify the air interface for a variety of RFID applications). Moreover, in terms of all important air interfaces ISO 18000 and the electronic product code (EPC) standard are incompatible. Pedro Peris-Lopez et al. (2006) presented one special integrated circuit card, ISO 7810, which used special type of identification card without contact. According to the communication range, three types of card can be distinguished: (i) close-coupled cards (ISO 10536); (ii) proximity cards (ISO 14443); (iii) vicinity cards (ISO 15693).

3. RFID Privacy, Legislation and Security

According to consumer scenarios, it has been updated the performance ability to use RFID to track a customer's movement around the global market. This concept is not new for modern consumers. Nowadays a number of customers are familiar with closed circuit television (CCTV) tracking. However, RFID tracking logs are significantly smaller than CCTV output and are machine-processable. According to S. J. Engberg et al. (2004) approaches, as an invasion of privacy, many people are accepted RFID tracking technology. Furthermore, there have more advantage when shopkeeper encoded the records that are traceable to identifiable customers. It has been occurred when RFID tag's unique ID can be send to reader. Reader also can make a link to the back-end RFID infrastructure, connect the unique ID to detail tag information and the purchase transaction. T. Weber (2004) further has improved RFID system security. Weber says if RFID systems attempts to improve security at the heart of the design then these kinds of privacy invasion would not be possible. Ari Juels (2005) presented four essential factors for RFID privacy concerns such as wireless barcode manifestation; RFID tags wireless barcode verity; RFID tags hypothetical scanning range; and RFID tags on products for harvesting inventory information. Based on this approach, Ron Weinstein (2005) presented a number of new security system such as RFID building control access system, usage of ID card for automatic fare payment in mass-transit systems (smart trip card). Nowadays, many organizations are using these modern technologies for solving security systems. Presently a number of companies especially privacy enhancing technologies are trying to leverage and achieve legislatively dictate security and privacy goals. M. R. Rieback et al. (2005) presents a number of uniting legislation for RFID privacy enhancing technologies such as visibility of RFID tags and readers, access and modification of RFID tag data, usage of privacy-enhancing technologies, visibility of high level query, consent withdrawal, confidentiality of personal data and the contribution of technology.

4. RFID Brief History

During the first century Chinese were first used magnetic fields. From the 1600s to 1800s was growing the base of mathematically related observation for electricity, magnetism and optics. In 1846, the experimentalist expert Michael Faraday presented the light and radio waves which are the part of electromagnetic energy (cited in D. J. Land, 2005). In 1864, Scottish physicist James Clerk Maxwell presents his theory on electromagnetic fields. James has been concluded electric and magnetic energy travel in transverse waves that propagate at a speed equal to that of light. In 1896, Guglielmo Marconi invented successfully transmission of radiotelegraphy across the Atlantic, and it became very famous. In 1906, Ernst F. W. Alexanderson demonstrates the first continuous wave (CW) radio generation and transmission of radio signals. These signals are the beginning of modern radio communication where all aspects of radio waves can be controlled. In the early 20th century, approximately 1922, was

considered the birth of radar. During the Second World War radar was developed by the Manhattan Project at Los Alamos Scientific Laboratory. Radar sends the radio waves; detecting and locating an object by the reflection of the radio waves. This reflection can determine the position and speed of an object. Some people think that in 1945 Russian Government first use of real RFID devices and it predates from that time. During the Second World War United Kingdom used RFID and they distinguished between the English airplane and German airplane (History of RFID tags, Palowireless, 2005). Harry Stockman (1948) presents "Communication by Means of Reflected Power," where Stockman laid out the basic concepts about RFID. According to 1930s and 1940s F. L. Vernon (1952), the development of radio and radar was an era of exploration for RFID techniques. In the late 1960, Sensormatic and Checkpoint with a number of industries such as Knogo, developed electronic article surveillance (EAS) equipment to counter theft. EAS is arguably the first and most widespread commercial use of RFID (cited in F. L. Vernon and Jr., 1952, PP.110-116). In 1963- 1964, R. F. Harrington et al. studied the electromagnetic theory and these techniques used to RFID and made two papers "Field measurements using active scatterers" and "Theory of loaded scatterers". In 1975, Radio Corporation of America (RCA) and Fairchild developed an Electronic identification system. Moreover, in 1977, F. Sterzer of RCA also developed an Electronic license plate for motor vehicles (R. J. Clench, 1975). Furthermore, T. D. Meyers and A. P. Leigh (1978) of Fairchild again developed a new component of RFID "Passive encoding microwave transponder". In 1980, RFID reached into the new exploration world, that time gave more attention to enhance tracking and access application in manufacturing and other environments (William E. Barlow et al., 2006). 1990's were a significant decades for RFID innovation and it comes true application. The United States first deployed the electronics toll collection technology using RFID (R.S. Foote, 1981). Important deployments included several innovations in electronic tolling. In 1991, the world's first highway electronic tolling system was opened in Oklahoma, where the vehicles could pass at highway speed through the tolling point station. In 1992, Harris County Toll Road Authority first installed the combination of the toll collection system and the traffic management system.

5. RFID Systems Architecture

This section has mainly focused on RFID infrastructure in each of the component. There are a number of methods and different components which are followed by the system as a whole.

5.1. RFID Antenna

The system of RFID antenna also can be classified into two ways, such as, interrogator (reader) antenna and transponder (tag) antenna. In this section has been reviewed these two components.

5.1.1. RFID Reader Antenna

A wave development of large and well-established players in antenna design and manufacture has led to tremendous technical advances in the performance of reader antennas for RFID. RFID reader antennas should have a number of characteristics such as: (i) good data transfer rate, (ii) robust, (iii) inexpensive, (iv) high radiation efficiency, (v) low side-lobe to reduce interference.

S.K. Padhi et al., (2003) presented a dual polarized aperture coupled micro-strip patch antenna and C-band (5.8GHz) and S-band (2.4 GHz). According to the design of proposed antennas, two coupling apertures are placed in right angle under the radiation patch to generate two orthogonal polarizations such as T_X and R_x. High gain and high isolation between the two coupling aperture input ports make the array very much suitable candidate for RFID reader module for 2.4 GHz band. Xianming and Ning (2004) presented aperture coupling feed technique, which is adopted in this antenna. The antenna is reasonably compact because the feed circuit is fabricated on a separate substrate under radiating patch. In addition, this feed technique has following advantages: (1) the feed circuit is isolated from the radiating element by the ground plane which prevents spurious radiation; (2)

active devices can be easily fabricated in the feed substrate for system size reduction; (3) there are more degrees of freedom for the designer.

Figure 2: Top view of aperture coupled feed antenna (Xianming and Ning, 2004).
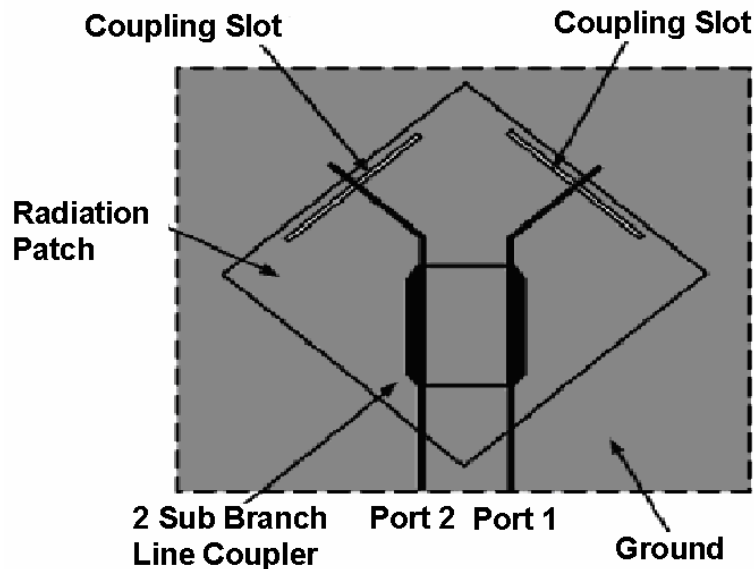

Aperture coupling feed antenna top view is shown in Figure 2. The disadvantage of this proposal that it is very sensitive to the slot dimensions. To overcome this problem, their position, length and width should be selected carefully. Paso Raumonen et al., (2004) presented a compact and very low profile spiral curl antenna. This method has been used in electromagnetic band gap (EBG) structure. But, the drawbacks of this method are the axial ratio bandwidth; the input match bandwidth and the gain are reduced. Jong Moon Lee et al. (2005) found a number of limitations using a dielectric substrate, single feed single-element patch antennas, which are usually narrow circular polarized (CP) bandwidth of about 2% or less. To overcome these types of limitation, Jung Moon Lee et al. presented a single feed circularly

Figure 3: Geometry of the circularly polarized metallic patch antenna (Jong Moon Lee et al., 2005).
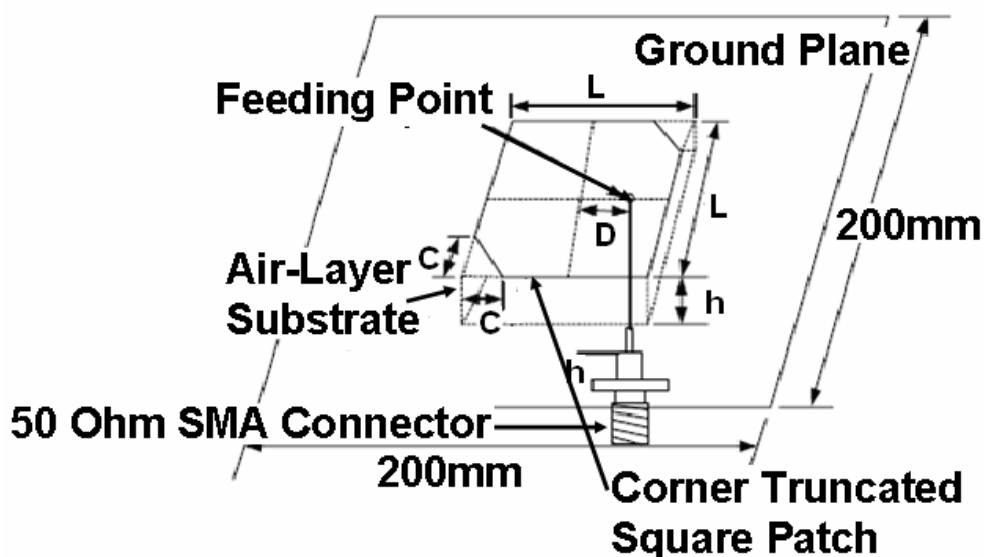
polarized metallic patch antenna for RFID reader applications shown in Figure 3. The proposed antennas main advantages are the feed structure with the probe feed placed in between the antennas radiating patch and ground plane. Jong-Sung Kim et al. (2006) presented Polarization and space diversity antenna using inverted-F antenna in RFID reader applications. The benefit of the use of polarization and space diversities at the transmitter or receiver found to reduce the error rate for two to four orders of magnitude.

Figure 4: Geometry of Inverted F-antenna (Jong-Sung Kim et al., 2006).
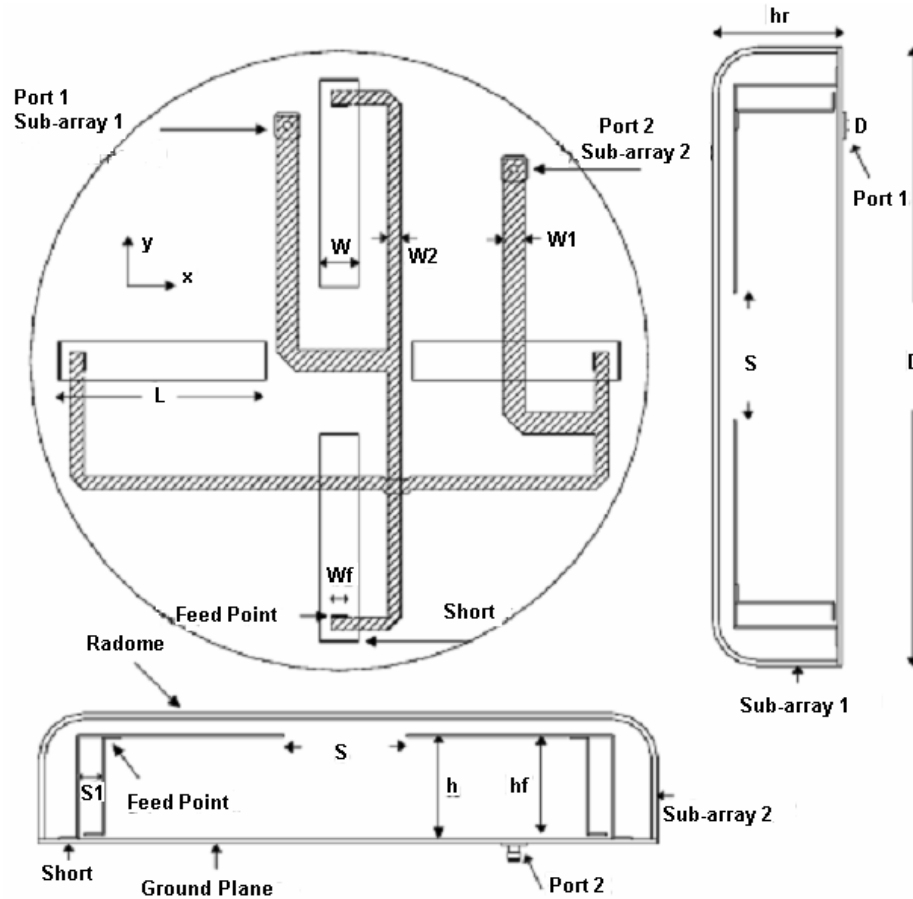
The drawbacks of the polarization and space diversities antenna radiation directions are limited to the broadside direction of the micro strip patch. Figure 4 shows the geometric structure of inverted-F antenna (IFA). It shows a dual-feed 1 2 IFA array in which each sub-array is located horizontally and vertically on a circular ground plane with a diameter of 320 mm. The input signal of port 1 is equally divided in two IFA's with equal phase, while two IFA's of the sub-array 2 are excited by two signals with equal amplitudes. It opposite phases by the corresponding propagation delay of feed network from port 2. All vertical shorting lines in the patch of four IFA's are placed near the outer boundary of the circular ground plane. The side views of sub-arrays 1 and 2 with a radome cover, which has a permittivity of 3.2 and a thickness of 5 mm, are drawn at the right and bottom sides of Figure 4, respectively.

5.1.2. RFID Tag Antenna
Generally, the tag antenna is preferred to ensure identification from all directions. Because of their lightweight, low profile, and their ability to conform to non-planar structures, antenna can be applied in RFID applications.

Figure 5: A microstrip patch antenna (Lena Ukkonen et al., 2004).
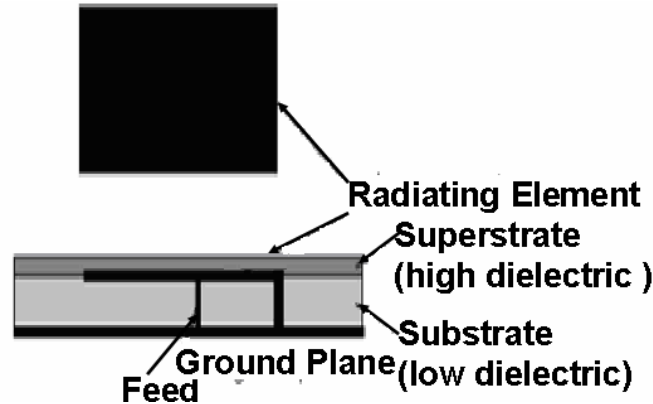
At the beginning of year, Lena Ukkonen et al., (2004) presented novel inverted-F antenna (IFA) designs for RFID tag application. A microstrip patch antenna is shown in Figure 5. According to their theory, one of the biggest challenges is tagging an object that consists of metal or other conductive material. Meander dipole tag antenna proposed by K.V. Seshagiri Rao et al. (2005) has received considerable attention, particularly in antenna design. However, the proposed antenna is better controlled over the antenna resistance. One loading bar has been added with the same width as the meander trace. Figure 6 shows the prototype of RFID tag with loaded meander antenna. This antenna can be easily tuned by trimming. Lengths of meander trace and loading bar can be varied to obtain optimum reactance and resistance matching. C. C. Chang and Y. C. Lo (2006) presented broad-band RFID tag antenna using two bent dipoles and a modified double T-matching network.

The desired tag antennas three main design goals are: (i) a small and planar profile, (ii) a high efficiency and bandwidth product (EB), and a quasi-isotropic radiation pattern. Wonky Choi et al. (2005) presented a planar inverted-F antenna (PIFA). It is an example of single shorting pin that can reduce the antenna size and improve the bandwidth. Figure 7 shows planner inverted-F antenna. Planner inverted-F antenna has a number of limitation regarding size and bandwidth which does not satisfy all the desired properties for RFID tag application. Kyeong-Sik Min et al. (2005) updated his theory and presented two types of antenna for RFID tag applications such as printed

Figure 6: Prototype of RFID tag with loaded meander antenna (K.V. Seshagiri Rao et al., 2005).
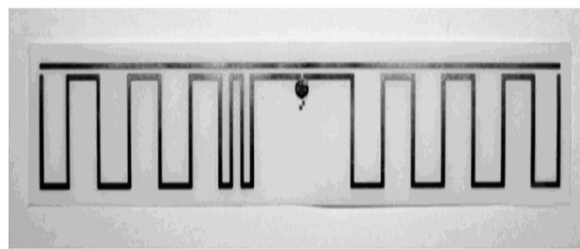
dipole antenna and loop antenna with parasitic element. Using theses types of antenna could change antennas capacity by ground panel. There are two ways that could change capacity such as: (i) dielectrics way and, (ii) conductor and magnetic substances way. K. V. Seshagiri Rao et al. (2005) discovered that straight dipole (left) and meander dipole (right) antennas from silver Ink can be used in RFID tag application. The proposed antennas performance and read range can be calculated by
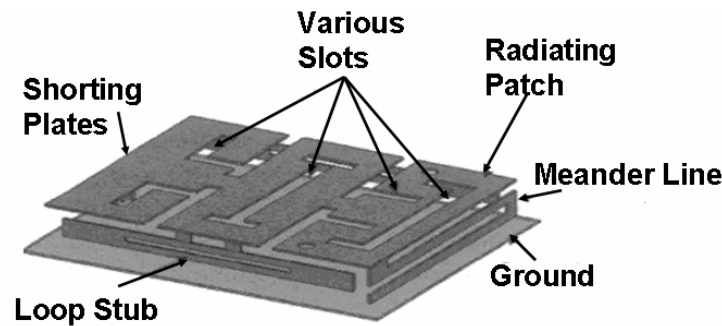
$$r = \frac{\lambda}{4\pi} \sqrt{\frac{P_t G_t G_r \tau}{P_{th}}} \tag{1}$$

Where λ is the wavelength, P_t is the power transmitted by the reader, G_t is the gain of the transmitting reader antenna, G_r is the gain of the receiving tag antenna, τ is the power transmission coefficient given by

$$\tau = \frac{4R_c R_a}{\left| Z_c + Z_a \right|^2}, 0 \le \tau \le 1 \tag{2}$$

where $Z_c = R_c + JX_c$ is chip impedance and $Z_a = R_a + JX_a$ is antenna impedance.

Figure 7: Planar inverted-F antenna (Wonky Choi et al., 2005).

5.2. RFID Reader

March in 2004, Nokia presented world's first RFID enabled global system for mobile communication. This RFID reader works with the Nokia 5140, a GSM phone that is water resistant and more rugged than a typical cell phone. Katariina Penttila et al. (2005) evaluated the previous models and selected a user interface (UI) of an RFID reader for smart mobile phone. The proposed reader has importance for reader antenna with high directivity. But, this proposal has data delivery and management related problems with delay on a network infrastructure. Joon Goo Lee et al. (2005) presents multi-protocol RFID reader for mobile device based on software architecture. Figure 8 shows the Multi-protocol RFID reader for mobile device. Since the proposed method is based on wireless internet platform for interoper-ability (WIPI) based mobile devices; it can easily interact with handset adoption layer (HAL). Any WIPI application can access this RFID reader system and query tags information from internet through HAL interfaces. A typical example of mobile-based RFID system has shown in RFID systems. S. S. Reyes and J.L.S. Perez (2005) first discovered the implementation of a mobile RFID reader using a personal digital assistant (PDA). The reader opens a serial port and then reads a tag to use it as an index key in the database to access and show the record associated to the tag. Inseop Kim et al. (2006) introduced a new and friendly mobile RFID reader protocol based on trusted agent and PKI method.
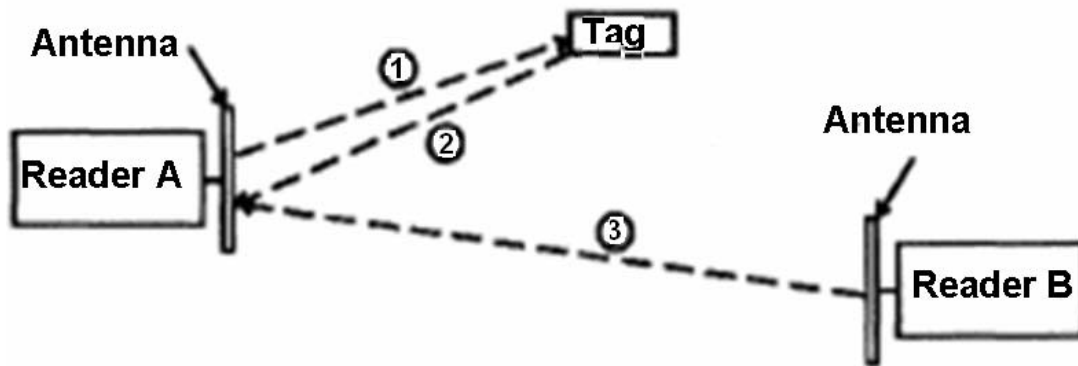
Figure 8: Multi-protocol RFID reader for mobile device (Joon Goo Lee et al., 2005).
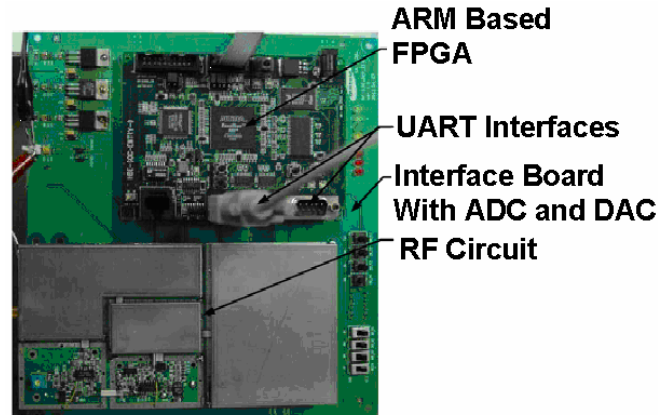
RFID reader module and PDA is shown in Figure 9. The advantage of this method is to provide trusted relationship and secure communication such as data integrity, non-repudiation and authentication between entities. RFID reader might interfere with the operation of another reader in an RFID system, when it communicates with tags within its communication zone. James Waldrop et al. (2003) presented color-wave anti-collision algorithm for RFID reader collision problem. Moreover, Kin Seong Leong et al. (2005) presented listen before talk (LBT) method for dense reader environment to solve the reader collision problem. The benefits of this method are: (i) to solve free space path loss, and (ii) to solve terrestrial or within building path loss. Figure 10 shows the interference of reader problem. It shows a rough idea on how the interrogation between Reader A and the tag occurs. The paths 1 and 2 are the signal paths. If we further assume that the efficiency of the tag is 10%, the signal will suffer another 10dB loss. All the losses (path loss + tag efficiency-tag antenna gain) summed up to be 74dB. Since Reader B is also using the same channel, channel C, the interrogation signal sent by Reader B will interfere with the in-channel backscattered signal from the tag.

Nowadays RFID reader network is using in various wireless communication systems. Again James Waldrop et al. designed color-wave medium access control (MAC) protocol for RFID reader networks. But the MAC algorithm has only limited applicability to the encountered RFID systems. Vinay Deolalikar et al. (2006) investigated and gave a new theory; the allocation of time and

Figure 9: RFID reader module and PDA (Inseop Kim et al., 2006).

frequency into various readers by examining perturbative solutions for scheduling problem in RFID reader network. This technique can also reduce the graph coloring problem with a coloring corresponding to a time scheduling. Wei Jiang et al. (2006) proposed a virtual route tracking (VRT) algorithm in RFID reader network. Figure 11 shows the principle of VRT algorithm structure. Figure 11 shows the black point stands for a RFID reader and the matrix is a RFID Reader Network. A transponder moves from reader (1, 1) to reader (2, 2), the straight line between them is regarded as the track of the transponder. Therefore, when moving along the thick curve in the figure, which denotes the real path of a person or object in the RFID Network. The transponder is interrogated by readers along the path and the virtual line (coined Virtual Route) is defined as the track of the transponder. So the track in Figure 11 is:

Track=Virtual Route= $(1, 1) \rightarrow (2, 2) \rightarrow (2, 3) \rightarrow (1, 4) \rightarrow (2, 5) \rightarrow (3, 5) \rightarrow (4, 4) \rightarrow (4, 3) \rightarrow (3, 2) \rightarrow (4, 1)$

It is noted that, when a reader interrogates are in one transponder, the next reader interrogating it along the track MUST be adjacent to the previous reader. It is obvious that the transponder at (2, 3) cannot jump to (2, 5) directly without activating reader (1, 4), (2, 4) or (3, 4). Hence, the next reader of (2, 3) along the track MUST be one of following readers:

{(1, 2), (1,3), (1, 4), (2, 2), (2, 4), (3, 2), (3, 3), (3, 4) }

Therefore, VRT algorithm must choose adjacent readers along the track. However, the proposed algorithm is not suitable for long range tracking for supply chain. This algorithm is specially designed to track mobile RFID transponders by using fixed reader.

Figure 11: Principle of VRT algorithm (Wei Jiang et al., 2006).
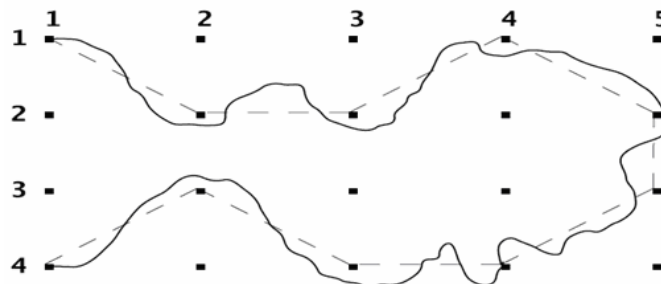

5.3. RFID Tag

In 1980, many time railroad companies have been wrestling with the problem of tracking rail cars. They also searched to use a cheap and cost effectively scanned ID system. In that time RF engineers have come up with a solution, using transponders mounted on the cars. Raymond (2006) invented a low power and low cost RFID transponder. Figure 12 shows the basic block diagram of hybrid RFID

transponder. According to Figure 12, the 915 MHz patch antenna has two connections, a DC return path connected at the zero impedance point and a transmission line matched to the 120 ohm impedance at the edge of the antenna. The transmission line routes the signal to CR1 for rectification. A DC tap on the 1830 MHz antenna provides the power connection for the Microcontroller unit (MCU). Careful placement of CR1 along the transmission line is crucial in creating the proper AC impedances for efficient frequency doubling. The 1830 MHz antenna becomes a 90 degree open stub at 915 MHz at the cathode of CR1, effectively giving the 915 MHz signal a low impedance trap to work against. Since the transmission line does not provide similar low impedance on the anode side of CR1, a 90 degree open stub at 1830 MHz must be added.

In the same year, Carl W. Pobanz and Tatsuo Itoh (1994) presented the transponder which is activated by a C-band interrogation beam to up-convert and radiate a digitally modulated identification tone. There are mainly two advantages over comparable optical RFID tag system: (i) better penetration of obstructing materials and (ii) easier electronic manipulation of the identifying signals. However, in

**Figure 12:** Hybrid schematic of transponder circuit (Raymond, 2006).
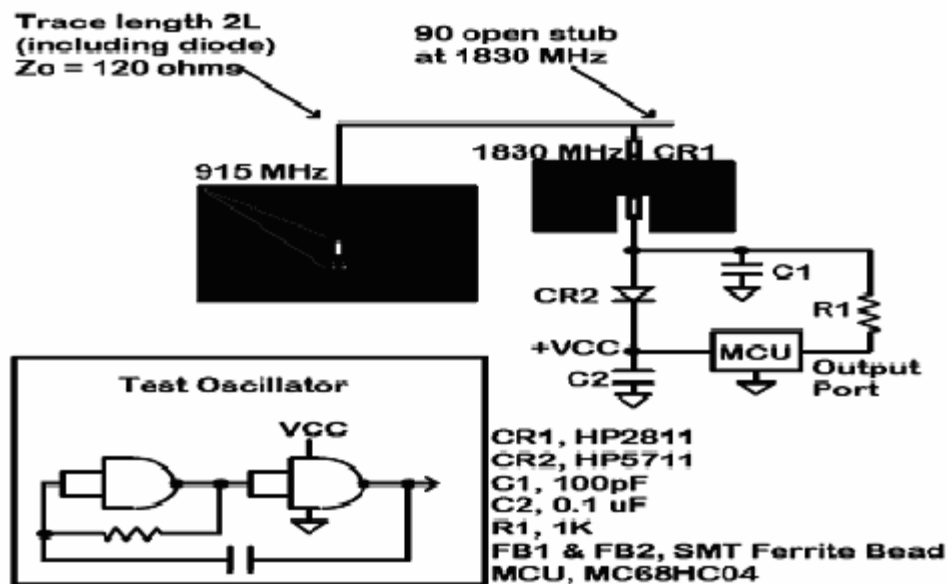
radio frequency technology, if the power consumption increases then it would cause a collision problem either from the transceiver or receiver side. To solve this problem Shoichi Masui et al. (1999) presented a 13.56MHz CMOS RFID transponder. Figure 13 shows the basic block diagram of RFID transponder. The proposed IC used binary tree search algorithm for anti-collision ID readout problem. Therefore, most of RFID tag is usually made with battery powered, active device. Texas instruments (TI) reported Sau-Mou Wu et al. (1996) have first generalized the method and presented battery-less, self-powered RFID transponder. This design first made by the Texas Instruments. Michael Bollerott (2000) discovered that, although the design by Sau-Mou Wu et al. does not satisfactory all the desired properties but the tolerance of the antenna variation is very good and it can work properly at temperature 0 to 100ºC. However, the drawback of the system design is that it usually supports low frequency. It is not perfect for wide band area frequencies. Michael Bollerotts (2000) replaced the model and presented a new multifunctional transponder which works as a mobile data memory and a data-logger

Figure 13: RFID transponder IC block diagram (Shoichi Masui et al. 1999).
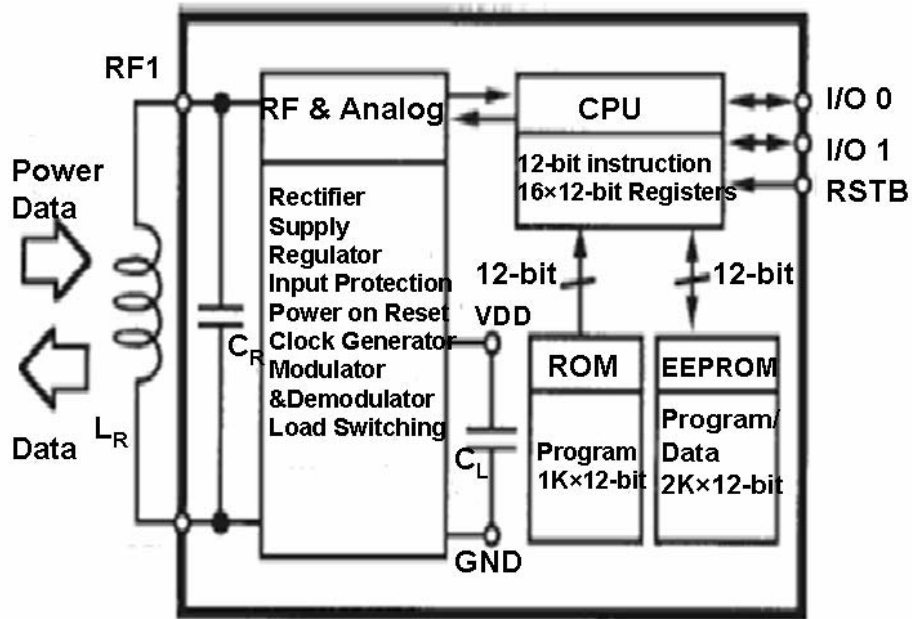
with the sensors. Figure 14 shows Michel's multifunctional active transponder. In 2001, Hitachi manufactured the world's smallest RFID tag for broadband communications. It is only 0.4mm × 0.4mm in size. Therefore, it is thin enough to be embedded in paper. The microchip is integrated with a 2.45GHz high-frequency analog circuit and a 128-bit ROM. The chip data is recorded in its memory during the semiconductor production process, and therefore cannot be rewritten, thus providing high resistance to tampering and guaranteeing its authenticity. However, Hitachi continued to improve, and the chip is only 0.05x0.05mm in 2007 presented by Mitsuo Usami (2007). This is not only a quantitative improvement, but a qualitative one, because it requires new processes for handling and testing, too. It is attached to a separately-provided external antenna when used, and communicates with the RFID tag reader via the 2.45 GHz band. Maximum communication range is 300 mm.

Figure 14: Schematic block diagram of the active transponder (Michael Bollerott, 2000).
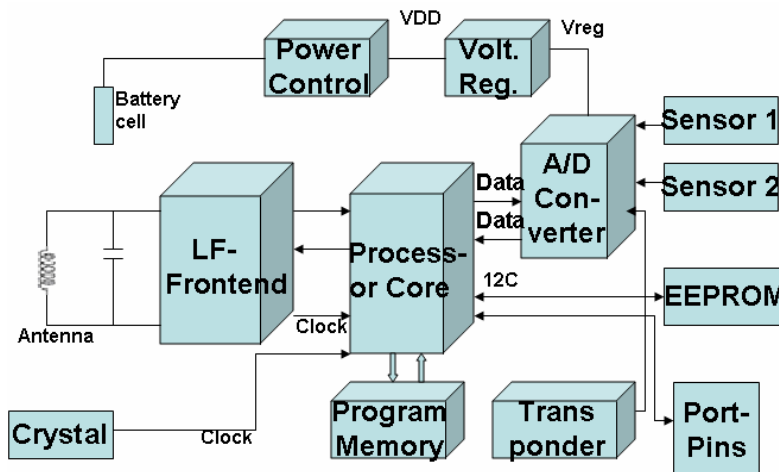
6. RFID Applications

Nowadays, RFID has been more attracting for industry and academic institutes. It has gained wide range of adaptation for low-cost and ubiquitous computing application, such as vehicle tracking, container tracking, object tracking, supply chain management tracking, asset tracking.

In Second World War RFID technologies were used in IFF (identification friend or foe) systems. These are consisted of tag installed on vehicle tracking. RFID takes an important part for container tracking systems. Perhaps, it started in 1960, but the technology started in the early of 1990s. Container tracking is the epicenter of RFID and its adoption curve is primed off now. In the early 1960s, biologists first used object tracking for radio transponders to track large mammals. This practice has been taken from the late 1960s and early 1970s. In 1990, Scientists observed the emergence of RFID that could be use in a variety of object tracking applications such as contact-less ID cards, marathon timing systems. RFID tags are used in rapid payment systems in gas stations and toll booths (Thinking about RFID, The Institute for the future (IFTF), 2005). Matthias Lampe and Martin Strassner (2003) presented smart asset in asset management which have a unique ID, and a memory. Using these features they are able to meet the requirements for good asset management systems. A. Fano and A. Gershman (2002) presented an efficient asset management that can be created by using the RFID infrastructure. In November 2003, Wal-Mart informed the largest 100 vendors that they would be required to start using RFID tags on pallets. The appeal of RFID technology lies in its capability to allow retailers to know the exact location and quantity of inventory without conducting time consuming counts presented by H. Sebastian Heese, (2007). Retailers seek to fulfill customer demand by ensuring that inventory is at the right place at the right time in the right amount (M. L. Fisher et al., 2000). R. D. Buzzell and G. Ortmeyer (1995) argued his comments saying that achieving this objective is difficult, and the operational complexity that retailers face has increased for a variety of reasons, including increasing product assortments, larger store sizes, and information requirements.

7. Discussion and Conclusion

This paper provides various methodologies to design RFID systems. Various components of RFID systems infrastructure, RFID standards, privacy, legislation, and security have been discussed along with their advantages and disadvantages. Cryptographic algorithm for modification and restoring RFID privacy has been explained. There has shown details trusted agent and PKI method to provide the relationship and secure communication such as confidentiality, data integrity, non-reputation and authentication between entities. While reviewing the optical RFID tag system we find two major advantages such as better penetration of obstructing materials and easier electronic manipulation. The study shows that circularly polarized metallic patch antennas feed structure with the probe feed are placed in between the antennas radiating patch and ground plane. The feed structure, a cone-truncated square patch antenna with a thick air-layer substrate, which can be excited with good impedance matching and good CP radiation characteristics. The study shows that the user interface RFID reader data delivery makes delay on network infrastructure. It has been reviewed RFID major application such as vehicle tracking, container tracking, object tracking, supply chain management tracking, asset tracking, library management, access control and environmental conditions monitoring.

References

[1] Gupta and M. Srivastava, 2004. "Developing Auto-ID Solutions using Sun Java System RFID Software". *Sun Microsystems*, Available from: http://java.sun.com/developer/technicalArticles/Ecommerce/rfid/sjsrfid/RFID.html.

[2] Ari juels, 2005. "RFID privacy: A technical primer for the non-technical reader". In K. Strandburg and D. Stan Raicu, editors, Privacy and Technologies of Identity: A Cross-Disciplinary Conversation, *Springer-Verlag*.

[3] Fano, A. Gershman, 2002. "The Future of Business Services in the age of Ubiquitous Computing". *Communications of the ACM* 45, Issue. 12, PP. 83-87 DOI: 10.1145/585597.585620.

[4] Burnell J., 2003. "Standard behavior: RFID maturation is following a well-worn technology development path". *Realtime* 6, PP. 15.

[5] C. Chang, Y. C. Lo, 2006. "Broadband RFID tag antenna with capacitive coupled structure". *Electronics letter* 42, Issue. 23, PP. 1322-1323. DOI: 10.1049/el:20062063.

[6] W. Pobanz and T. Itoh, 1994. "A Microwave non-contact identification transponder using subharmonic interrogation". *IEEE MTT –S International Microwave Symposium Digest* 2, PP. 753-756. DOI: 10.1109/MWSYM.1994.335246

[7] Dr. Jeremy Land, 2005. "Shrouds of time: The history of RFID". *IEEE Potentials* 1.0, PP. 1-11. DOI: 10.1109/MP.2005.1549751.

[8] Fusheng Wang and Peiya Liu, 2005. "Temporal Management of RFID Data". *Proceedings of the 31st VLDB Conference*, PP. 1128-1139.

[9] Food Marketing Institute Information Technology Committee, (2004). *Improving the receiving function using the EPC and RFID*, Available from: http://www.fmi.org/technology/FMI_it_rfid.pdf.

[10] F. L. Vernon, Jr., 1952. "Application of the microwave homodyne". *Transactions of the IRE professional Group on Antennas and Propagation* 4, Issue. 1, PP. 110-116.

[11] History of RFID tags, 2005. *Palowireless*, Available from: http:// www.palowireless.com/rfid/whatisrfid.asp.

[12] H. Stockman, 1948. "Communication by Means of Reflected Power". *Proceedings of the IRE* 36, Issue. 10, PP. 1196–1204.

[13] H. Sebastian Heese, 2007. "Inventory Record Inaccuracy, Double Marginalization, and RFID Adoption". *Production and Operation management Society (OMS)* 16, Issue 5, PP. 542-553.

[14] Inseop Kim, Byunggil Lee, Howon Kim, 2006. "Privacy-Friendly Mobile RFID Reader Protocol Design based on trusted Agent and PKI". *IEEE Tenth International Symposium Consumer Electronics*, Inst., Daejeon, PP. 1-6. DOI: 10.1109/ISCE.2006.1689530

[15] Jong Moon Lee, Nae Soo Kim, Cheol Sig Pyo, 2005. "A circular polarized metallic patch antenna for RFID reader". *Asia-Pacific conference on communications*, Perth, Australia, PP. 116-118.

[16] Jong-Sung Kim, Kwang-Ho Shin, Seung-Mo Park, Won-Kyu Choi, and Nak-Seon Seong, 2006. "Polarization and space diversity antenna using inverted-F antennas for RFID reader applications". *IEEE antennas and wireless propagation letters* 5, Issue. 1, PP. 265-268. DOI: 10.1109/LAWP.2006.875892.

[17] Joon Goo Lee, Seok Joong Hwang, Seon Wook Kim, Sunshin Ahn, KyungHo Park, Ji Hoon Koo, Woo Shik Kang, 2005. "Software Architecture for a Multi-Protocol RFID Reader on Mobile Devices". *Second International Conference on Embedded Software and Systems*, 16-18 December. PP. 8.

[18] James Waldrop, Daniel W. Engels, Sanjay E. Sarma, 2003. "Colorwave: An Anti-collision Algorithm for the Reader Collision Problem". *IEEE conference on communication* 2, PP. 1206-1210.

[19]   K. V. S. Rao, P. V. Nikitin, S. F. Lam, 2005. "Antenna design for UHF RFID tags: A review and a practical application". *IEEE, transactions on antennas and propagation* 53, Issue. 12, PP. 3870-3876.

[20]   Kyeong-Sik Min, Jin-Woo Kim, Chul-Kun Park, and Viet-Hong Tran, 2005. "A study of capacity change antenna for RFID tag depending on ground plane". *Asia-Pacific Conference (APMC) Proceedings* 5, PP. 320-324.

[21]   Katariina Penttila, Nina Pere, Mikael Soini, Lauri Sydanheimo, Markku Kivikoski, 2005. **"**Use and Interface Definition of Mobile RFID Reader Integrated in a Smart Phone". *Proceedings of the Ninth International Symposium on Consumer Electronics (ISCE)*, PP. 353-358. DOI: 10.1109/ISCE.2005.1502402.

[22]   Kin Seong Leong, Mun Leng Ng, Peter H. Cole, 2005. "The Reader Collision Problem in RFID Systems". *International Symposium on Microwave Antenna Propagation and EMC Technologies for Wireless Communications* 1, PP. 658-661. DOI: 10.1109/MAPE.2005.1617996.

[23]   L. Ukkonen, L. Sydänheirno, M. Kivikoski, 2004. "A novel tag design using inverted-F antenna for radio frequency identification of metallic objects". *IEEE/Sarnoff symposium on Advances in wired and wireless communication*, PP.91-94.

[24]   Matt Ward and Rob van Kranenburg, 2006. "RFID: Frequency, standards, adoption and innovation". *JISC Technology and Standards Watch*. Available from: www.rfidconsultation.eu/docs/ficheiros/TSW0602.pdf.

[25]   M. R. Rieback, B. Crispo, A. S. Tanenbaum, 2005. "Uniting Legislation with RFID Privacy-Enhancing Technologies". *Proceedings on 3rd Conference on Security and Protection of Information*, Brno, May, Czech Republic.

[26]   Michael Bollerott, 2000. "Multifunctional Transponder System". *Fraunhofer-Institute for Microelectronic System (IMS)*. Available from: www.ims.fraunhofer.de/uploads/media/multifunctional_transponder_system_en_01.pdf.

[27]   Mitsuo Usami, 2007. "Hitachi Achieves 0.05-mm Square Super Micro RFID Tag". Further Size Reductions in Mind. Tetsuo Nozawa, Nikkei Electronics, Tech-On, 20th Feb., Available from: http://techon.nikkeibp.co.jp/english/NEWS_EN/20070220/127959/

[28]   Matthias Lampe and Martin Strassner, 2003. "The Potential of RFID for Moveable Asset Management". *Ubiquitous Commerce Workshop at Ubicomp*, 12th October, Seattle, WA.

[29]   M. L. Fisher, A. Raman, and A. McClelland, 2000. "Rocket science retailing is almost here— Are you Ready?". *Harvard Business Review* 78, No. 4, PP. 115-124. DOI: 10.1225/R00404.

[30]   Pedro Peris-Lopez, Julio Cesar Hernandez-Castro, Juan M. Estevez-Tapiador and Arturo Ribagorda, 2006. "RFID Systems: A Survey on Security Threats and Proposed Solutions". *The 11th IFIP International Conference on Personal Wireless Communications (PWC)* 4217, PP. 159-170.

[31]   P. Raumonen, M. Keskilammi, L. Sydanheimo, M. Kivikoski, 2004. "A very low profile CP EBG antenna for RFID reader". IEEE, *Antennas and propagation society international symposium* 4, 20-25 June, PP. 3808-3811. DOI: 10.1109/APS.2004.1330178.

[32]   R. Weinstein, 2005. "RFID: A Technical Overview and Its Application to the Enterprise". *IEEE IT Professional* 7, PP. 27-33, Issue. 3.

[33]   R. J. Clench, 1975. "Electronic identification system". *US Patent* 3, 914, 762.

[34]   R. S. Foote, 1981. "Prospects for Non-stop Toll Collection using Automatic Vehicle Identification". *Traffic Quarterly* 35, No 3, PP. 445-460.

[35]   R. D. Buzzell, and G. Ortmeyer, 1995. "Channel partnerships streamline distribution". *Elsevier* 28, No. 4, PP. 129-129 (1).

[36]   Raymond, 2006. "A Low Power RF ID Transponder". *Wenzel*. Available from: www.wenzel.com/pdffiles1/pdfs/rays.pdf.

[37]   S. J. Engberg, Morten B. Harning, Christian Damsgaard Jensen, 2004. "Zero-knowledge Device Authentication: Privacy & Security Enhanced RFID Preserving Business Value and

Consumer Convenience". *In Proceedings of the Second Annual Conference on Privacy, Security and Trust (PST)*, PP. 89-100.

[38] S. K. Padhi, N.C. Karmaker, and C.L. Law, 2003. "Dual polarized reader antenna array for RFID application". IEEE, *Antennas and propagation society international symposium* 4, PP. 265-268.

[39] S. Sandoval-Reyes, J. L. Soberanes Perez, 2005. "Mobile RFID Reader with Database Wireless Synchronization". *2nd International Conference on Electrical and Electronics Engineering (ICEEE)*, Mexico, 7-9 September, PP. 5-8. DOI: 10.1109/ICEEE.2005.1529560

[40] S. Masui, E. Ishii, T. Iwawaki, Y. Sugawara, and K. Sawada, 1999. "A 13.56MHz CMOS RF Identification Transponder Integrated Circuit with a Dedicated CPU". *International Solid-State Circuits Conference*, San Francisco, CA, 15-17 Feb., PP. 162-163.

[41] Sau-Mou Wu, Jeng-Rern Yang, and Tzen-Yi Liu, 1996. "An ASIC for Transponder for Radio Frequency Identification System". *Ninth Annual IEEE International ASIC Conference and Exhibition*, NY, USA, 23-27 Sept. PP. 111-114.

[42] T. Weber, 2004. "The future of shopping". *BBC news online business editor in Rheinberg, Germany*. Available from: http://news.bbc.co.uk/1/hi/business/3712261.stm

[43] T. D. Meyers, and A. P. Leigh, 1978. "Passive encoding microwave transponder*". US Patent* 4, 068,232.

[44] Thinking About RFID, 2005. *The Institute for the future (IFTF)*. Available from: www.iftf.org/system/files/deliverables/SR-926A_Thinking_RFID.pdf

[45] Vinay Deolalikar, Malena Mesarina, John Recker, Devaraj Dash, Salil Pradhan, 2006. "Perturbative time and frequency allocations for RFID reader networks". *EUC Workshops*, PP. 392-402.

[46] Wenting Wang, Shuzuo Lou, Kay W. C. Chui, Sujiang Rong, Chi Fung Lok, Hui Zheng, Hin-Tat Chan, Sau-Wing Man, Howard C. Luong, Vinvent K. Lau, and Chi-Ying Tsui, 2007. "A Single-Chip UHF RFID Reader in 0.18 μm CMOS". *IEEE Custom Integrated Circuits Conference (CICC)*, San Jose, USA, PP. 111-114.

[47] William E. Barlow Jr., Michael T. Brannon, Jonathan L. Jiannuzzi, 2006. "Radio Frequency Identification (RFID) Technology at DELL Computer Corporation". *Proceedings of the Southern Association for Information Systems Conference*, PP. 187-190.

[48] W. Choi, N. Seong, J. M. Kim, C. Pyo, J. Chae, 2005. "A planar inverted-F antenna (PIFA) to be attached to metal containers for an active RFID tag". *IEEE, Antennas and propagation society international symposium* 1B, PP. 508-511.

[49] Wei Jiang, Dan Yu, Yan Ma. 2006. "A Tracking Algorithm in RFID Reader Network". *Japan-China Joint Workshop on Frontier of Computer Science and Technology*, Fukushima. PP. 164-171.

[50] Xianming Qing, and Ning Yang, 2004. "2.45 GHz circularly polarized RFID reader antenna". *The Ninth International Conference on Communications Systems*, 7-7 Sept. PP. 612-615.