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RFID in Agriculture

Matthew N. O. Sadiku[1], Uwakwe C. Chukwu[2], Abayomi Ajayi-Majebi[3], Sarhan M. Musa[1]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Department of Engineering Technology, South Carolina State University, Orangeburg, SC, USA
[3]Department of Manufacturing Engineering, Central State University, P.O. Box 1004, Wilberforce, OH, USA
Email: sadiku@ieee.org; uchukwu@scsu.edu; ajayi-majebi@centralstate.edu

Abstract Radio frequency identification (RFID) is an emerging technology that makes use of wireless communication. It uses radio frequency to transmit product information and identify objects without having any contact. The agriculture industry has started to use the RFID technology for tracking, monitoring, packaging, and enhance food quality. The main reasons for the rapid adoption of RFID in the time-honored industry of agriculture include disease control, cost control, safety, crime prevention, and improvement in customer service. This paper provides an introduction on the various uses of RFID in agriculture and also explains the benefits and challenges of this technology.

Keywords RFID, barcodes, agriculture, farming

Introduction

Since time immemorial, farmers have found ways to adopt the latest tools and technologies to improve agriculture. Today, there is a need to switch from traditional agriculture to the modern agriculture. In recent years, the radio frequency identification (RFID technology has found its way onto the farm, where is used to track items of all types: crops, animals, and farm workers.

RFID technology emerged as Frederick Hertz experimentally discovered radio waves in 1886. Since then RFID has been used to detect and track entities on land, in space, and in the air. RFID was the first explored in the 1940s as a means of identifying allied airplanes. It is a new technology which enables wireless labeling and identification of objects, humans, and animals It has also been used extensively in supply chain management to track goods in warehouses. Encryption is supported on RFID. RFID technology can save organizations time and money by providing real-time traceability, identification, and location data for people and resources. We encounter several RFID systems daily [1]. They are present in stores as a theft prevention measure, office buildings as a gatekeeping tool, and in cars with transponders for collecting tolls.

What is RFID?

RFID is an acronym for "radio-frequency identification." It refers to technologies that use radio waves to identify objects, animals, or people. It is more efficient than standard barcode technology by reading multiple tags at once. Due to its low energy consumption and adaptability to different environments, RFID has found applications in various fields such supply chain management, transportation, manufacturing, agriculture, pharmaceutical industry, healthcare, and libraries [2].

RFID serves the same purpose as a bar code or magnetic strip on a credit card or ATM card. It may work with or replace bar codes. The advantages of RFID systems over bar codes include [3]: (1) physical line-of-sight scanning is not needed, (2) several RFID tags can be read simultaneously, (3) information on the tags is

dynamic, (4) can endure harsh environment, (5) has a faster response time and process time. Just as the bar code must be scanned to retrieve information, the RFID card needs scanning identification.

Basically, RFID uses radio waves to read the information stored on a label (or tag) attached to an object, such as a pallet or bin. A typical RFID system consists of three main components, which as illustrated in Figure 1 [4] and explained as follows [5,6].

Figure 1: Components of an RFID system [4]

(1)Tags: A tag or label usually consists of a chip and an antenna. The antenna is usually in the form of spiral metal coil. The tag stores information such as serial number, manufacturer code, assembly location, date of installation, country of origin, and other data. It can store information from 64 bit to 8 MB. It can assume a variety of shapes and sizes. It may be passive, active, or intelligent, indicating the three types of tags. A passive tag is smaller and cheaper because it does not use a power source such as a battery. A typical passive RFID tag is shown in Figure 2 [7]. An active tag is battery-assisted to power up its circuitry and periodically transmits its signal. An intelligent tag is similar to active RFID tag in that it uses battery-powered sensors. The tags are attached to objects or persons. RFID tags do not have chips are called chipless tags. The implementation of chipless tags can significantly reduce the tag price. There are billions of tags in circulation and the number increases yearly. The tags are becoming part of the infrastructure of the Internet of things.

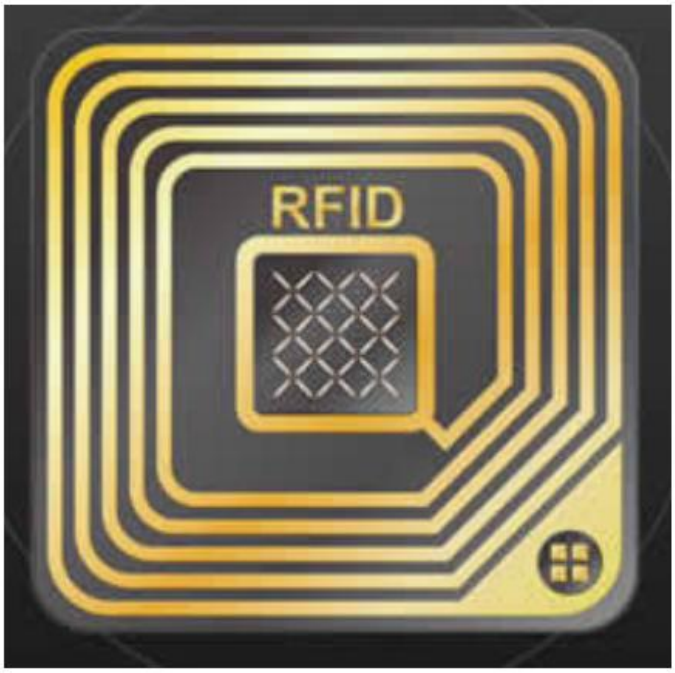

Figure 2: A typical passive RFID tag [7]

(2) *Readers:* These are also known as interrogators. They read and write data on the tags. Readers can be real-only, write-only or read-write. RFID does not require a line of sight to read data on the tags. The tag and reader

exchange information wirelessly. An RFID system may consist of several readers. A reader can communicate with more than one tag at the same time. This may require anticollision algorithms.

(3) *Controller*: This is a host computer to host data. It may take the form of a PC or workstation and control application software. It is the brain of the RFID system. It connects multiple readers and centrally processes information that is collected by the readers. RFID systems operate at different frequency bands. In the United States, the FCC has allocated four different bands:

- Low frequency (LF), between 30 kHz and 300 kHz
- High frequency (HF), between 3 MHz and 30 MHz
- Ultra-high frequency (UHF), between 300 MHz and 1 GHz
- Microwave, between 1 GHz and 5.8 GHz

Figure 3 shows RFID frequency allocation [8]. Different uses of RFID label are shown in Figure 4 [9].

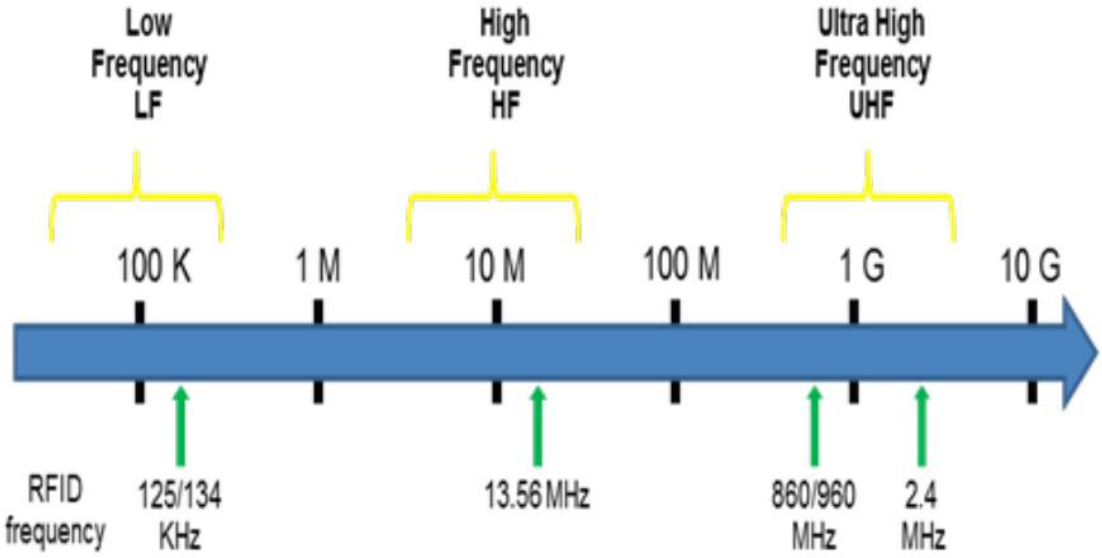

Figure 3: RFID frequency allocation [8]

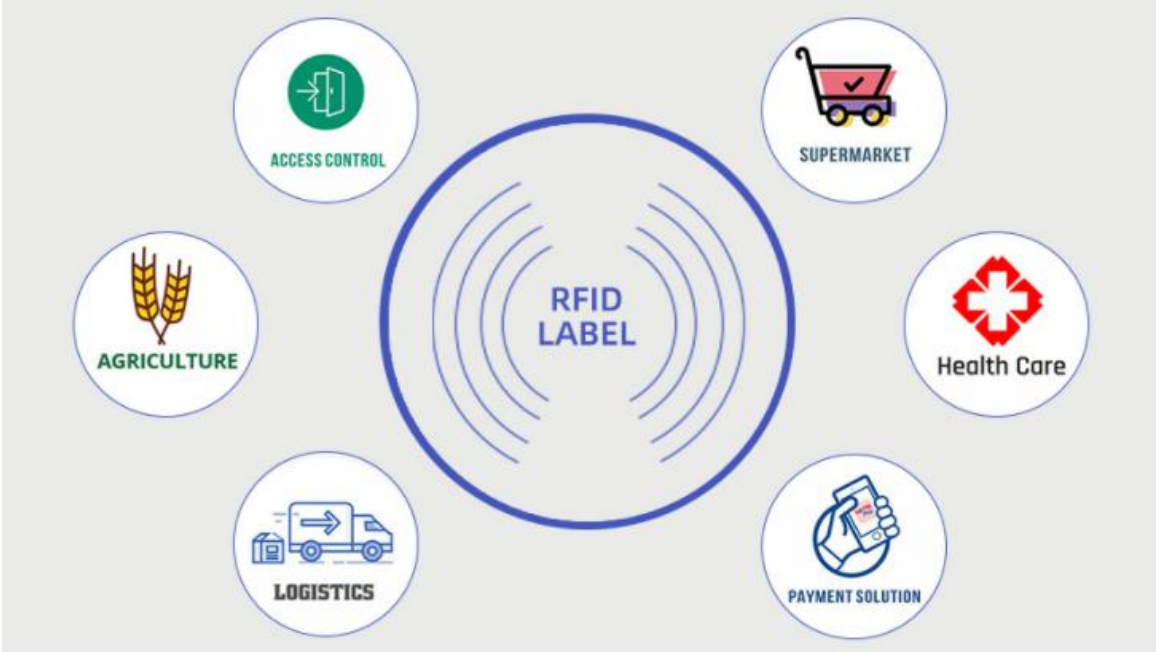

Figure 4: Different uses of RFID label [9]

RFID can be compared with barcoding. The major advantage RFFID has the advantage over barcodes is that the RFID tag data can be read without being seen, whereas barcodes must be seen so that an optical scanner can read it. RFID label can be read in-motion from several feet away. Barcode can only be scanned while motionless and in close proximity. RFID tags are becoming the next generation of barcodes.

Applications of RFID in Agriculture

RFID is useful to busy farmers. It is non-contact. It has a high identification rate, mass memory, secure access, and can easily be integrated into an existing system. The applications of RFID technology in agriculture are many and varied. RFID is very promising in several fields such as environmental monitoring, packaging, irrigation, livestock, greenhouse, inventory management, asset tracking, controlling access to restricted areas, food logistics, and supply chain management. The following applications of RFID in agriculture are common [10,11]:

- *Packaging:* By attaching RFID tags to agricultural products' packages, farmers can determine the health condition of the products and add information on the tag.
- *Tracking:* The purpose of tracking is to guarantee accurate traceability from the farm to the final consumer. One may obtain traceability going forward or backwards in the production and tracking of processes. The farmers can track their goods via a computer network. They can grow five crops annually by tracking conditions such as soil chemistry, humidity, sunlight levels, and temperature. By reading the information stored on a RFID tag, a decision could be made whether a temperature shift will do harm to a fresh agricultural product or not. Personnel Tracking System can track and monitor workers, when they report for work and their various positions on time. Attaching RFID tags to your equipment helps to track its location. Figure 5 shows an example of RFID ear tag for animal tracking [12].

Figure 5: RFID ear tag for animal tracking [12]

- *Monitoring:* To increase agricultural productivity in modern agriculture, it is imperative that farmers monitor the field environment, crop conditions, and farming operations. Several approaches have been developed to monitor farming operations according to the varied needs of farms. These include writing notes manually, using equipment with an automatic recording, and monitoring operations with IT-based tools. Environmental monitoring of intensive farms requires a wide range of sensors. RFID technology offers monitoring systems for both crops and cattle. It can be employed to monitor the chain of perishable food. It can be used in fields like environmental monitoring, irrigation, and farm machinery. It can also be used to monitor climate conditions during transportation. RFID can be

employed to detect unauthorized openings of shipments during transportation, storage, distribution, and sales. RFID is used to evaluate the quality of apples by monitoring gases produced by apples such as ethylene [13].

- *Controlling Access:* Controlling access to restricted areas in the farm or production environment is necessary to ensure the safety and security of the workplace. Managing access to the farming environment provides the farmer with the peace of mind of knowing the property is secure and safe and access to heavy machinery is controlled. The RFID access system identifies breaches to zones to detect trespassers and grant access to only authorized operators of specific machinery. RFID technology can grant automated access to zones and specialized equipment, ensuring a safe work environment for everyone.
- *Greenhouses:* The automation and efficiency on greenhouse environment monitoring and control are crucial. In order to control and monitor the environmental factors, sensors and actuators are essential. Greenhouses use RFID tags to collect specialized data and these data help in equipment management, recording and measuring growth time. Access to greenhouse can be controlled using RFID technology. Data collection in greenhouses is also possible with specialized RFID tags and readers designed for appropriate conditions.

Benefits

RFID has been used for years in animal identification and tracking. The use of RFID to manage agricultural inventories allows valuable data to be collected for better decision making and forecasting. Specialized RFID tags and tag readers can work without any contact. They have a high recognition rate, store huge data, have secured access, and can be easily integrated into an existing system. RFID technology can be an effective tool for securing food safety and managing agriculture and livestock [14].

Other benefits of RFID in agriculture include [15]:

- RFID method of tracing is cheap and easy to implement
- RFID technology is benefiting precision agriculture
- Superior information handling
- Enhance recall and traceability
- Improve supply and distribution chain management
- RFID technology can increase profits
- RFID technology helps manage information on food materials
- Ensure that inventory is being properly managed
- Lowered costs through automation
- Reduce the risk of human error and costly mistakes
- Monitor overall farm work schedules more efficiently
- Organize farm data collection more quickly to make more effective decisions
- Manage access to your farming environment and ensuring property is secure
- Improve production throughput
- Enhance traceability
- Swift recall management

Challenges

RFID has some limitations, just as bar codes do. A hundred bar codes on items within a box cannot be read, but RFID tags can be read as long as the items are not in a metal box.

Other challenges faced by applying RFID in agriculture include [15]

- High startup costs
- Training designated employees
- Privacy and security concerns associated with the use of RFID tags
- Developing the RFID network requires supply chain partners to have compatible software

- Emerging privacy issues
- Tracking individual plants presents a complex challenge
- Accuracy of tag reading; RFID radio waves may be disrupted by environmental factors
- Huge volumes of data that are difficult to manage
- Identify the right frequency for each application
- Incompatible standards and the level of granularity
- RFID tags are often integrated permanently in agriculture
- Operate in harsh environments
- RFID system is affected by environmental factors such as dust, moisture, extreme temperatures, electromagnetic interference, etc.

Global RFID in Agriculture

Farming professionals who are involved in agricultural practices, especially in the farming of fruits, vegetables, and grains, produce a variety of food products to be sold worldwide. RFID solutions for agricultural practices help farmers to overcome the common challenges that they face on daily basis. Governments around the world are supporting farmers, providing them with funds and subsidies, and encouraging them to adopt RFID technology in order to boost the agricultural produce. This support to farmers is helping the governments of developing nations to increase their food security, create new jobs, and support a long-term economic growth. We now consider how RFID is applied in agriculture in various nations.

- *United States*: The US Department of Agriculture (USDA) prohibits discrimination in all its programs on the basis of race, color, national origin, age, disability, sex, and marital status. Walmart announced that its 100 providers must use RFID technology in 2005, and all providers must use it in 2006. RFID technology has become popular with growers of marijuana, who use RFID tags and RFID readers to simplify and streamline plant management. Because the drug is still illegal under the federal government, those states (such as Colorado) where it is legal have strict requirements to track plants from seed through supply [16]. In 2012, the Food and Drug Administration in sanctioned the use of RFID mainly for tagging citrus fruits. In 2020, the USDA's Animal and Plant Health Inspection Service (APHIS) allocated funds to purchase up to eight million RFID ear tags for cattle and bison, providing the new technology free of charge [17].
- *India:* Agriculture is the backbone of the Indian economy. It produces a great variety of products, which are influenced by a number of factors like weather conditions, spread of diseases or pests, deterioration of fresh produce after harvesting, geographical distances between areas of production and areas of consumption, etc. As the population is ever increasing, so is the demand of agricultural products. There is a need to minimize labor, limit the use of natural resource, and increase crop production [18].
- *Taiwan:* The Taiwanese fruit producer Je-Nong Cooperative Farm is using a RFID solution to track the receipt and processing of its fresh fruit. By using RFID tags, the company can monitor every phase that the fruit goes through, and the conditions of the fruit before it is transported to stores throughout Taiwan, China, Japan, and Korea. In Taiwan, council of agriculture popularized food traceability system and encouraged supermarkets to sell agricultural products with food traceability information. A food traceability system has been built for potato, rice, Chinese yam, grape, strawberry, and tea [19].
- *Europe:* In the European Union, the food safety is a growing concern. One way to ensure wholesome food product is to establish good traceability from field-to-fork. The European Safety Authority (EFSA) is responsible for food safety and establishing procedures to collect and analyze data in field of food (feed) in order to identify emerging risks [10]. European Commission has funded many study projects on the applicability of FRID systems in the livestock sector. Europe and Italy have conducted pilot projects to verify the actual applicability of RFID technology in the main food sectors. In 2007, the European Council mandated that each member state must establish a system for the identification of animals.

- *Japan:* The Japanese people have become increasingly concerned about food safety issues. The Japanese government and the Japan Agricultural Cooperatives have been promoting the development and application of food traceability systems (TFS) as national projects. RFID has shown promise for a more advanced and effective FTS. In cooperation with farmers, agrobusinesses, and supermarkets around Japan, there are ongoing field experiments on the integrated traceability system on various items of agricultural products. These experiments use RFID to reduce the cost of RFID utilization, to improve the workability of RFID handling [20].

Future of RFID in Agriculture

Since the early agrarian past, farmers have been witnessing transformation in the use of several innovative tools and technologies to improve their agricultural practices and produce. From hand tools to computer science, updated innovations have come a long way in saving time and labor, cutting costs, and improving yields. The agricultural industry has experienced a technological revolution moving from hand tools to machines to computer science. According to Technavio research analysts (Technavio is a leading global technology research and advisory company), the top three emerging market trends driving the global RFID tags market for agricultural application are [21]:

- Adoption of advanced technology in agricultural applications
- Advent of cloud-based RFID solutions to overcome data corruption issues
- Emergence and popularization of strategic industry alliances

Thus, one trend in the market is adoption of advanced technology in agricultural applications. The adoption of technologies like Global Positioning System (GPS), and wireless sensor network (WSN), Internet of things (IoT), drones, and RFID are intended to be used for advancement in the agriculture sector and to increase the efficiency of the supply chain network.

Conclusion

Identification systems of food products, animals, and farm workers are continuously evolving. Automated identification technology has been used in a diversity of applications in the agricultural supply chain. Recently, a non-contact automatic identification technology (RFID) is an emerging technology in agriculture industry and has gained considerable attention [22]. RFID technology is an information exchange technology that uses the radio frequency (or electromagnetic fields) for transmission of information to and fro between the various places. It is a technology providing considerable opportunities to improve quality control for perishable foods. RFID is useful for animals, food and farming. RFID cannot work alone; it needs the use of big-data capable IoT software platform to collect, filter, store, and analyze the farm data. More information about the uses of RFID in agriculture can be found in related journals:
RFID Journal and *Journal of Agricultural Science*.

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About the Authors

Matthew N. O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics and computer networks. He is a fellow of IEEE.

Uwakwe C. Chukwu is an associate professor in the Department of Industrial & Electrical Engineering Technology of South Carolina State University. He has published several books and papers. His research interests are power systems, smart grid, V2G, energy scavenging, renewable energies, and microgrids.

Abayomi Ajayi-Majebi is a professor in the Department of Manufacturing Engineering at Central State University in Wilberforce, Ohio. In 2015 he was honored by the White House as a Champion of Change for his significant contributions to the engineering education of minority students. He is a senior member of both the Society of Manufacturing Engineers and the American Society for Quality.

Sarhan M. Musa is a professor in the Department Electrical and Computer Engineering at Prairie View A&M University, Texas. He has been the director of Prairie View Networking Academy, Texas, since 2004. He is an LTD Sprint and Boeing Welliver Fellow. His areas of research interest include computational electromagnetics and computer networks.