Mass Data Read/Write Technology for UHF-Band RFID Tags

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Passive radio frequency identification (RFID) tags operating in the 860 to 960 MHz ultra-high frequency (UHF) band have a wider communication area than RFID tags operating in other frequency bands such as 13.56 MHz or 2.45 GHz. It is expected that UHF-band RFID tags will be used widely in physical distribution, manufacturing, and supply chain management (SCM) fields. To extend the RFID market, accurate data communication with RFID tags is indispensable. We have therefore developed a read/write middleware technology that improves the precision of reading from and writing to multiple RFID tags collectively. This technology uses infrared sensors for RFID position detection and optimizes the data read/write function. A system using this technology can communicate with 100 tags moving at 1 m/s with a read/write success rate of 99.999% or higher. These tags contain a Fujitsu RFID LSI having a built-in high write-performance FRAM that conforms to the ISO/IEC 18000-6 Type B air-interface protocol. This paper describes some of the problems in reading/writing multiple tags and describes a technology we developed to overcome them.

1. Introduction

Radio frequency identification (RFID) technology is a radio communication technology used to access the data of tags attached to or placed inside articles. An RFID tag consists of an RFID LSI chip about 1 mm square and a film antenna. Passive RFID tags have no batteries and operate using power acquired by rectifying the radio waves transmitted to the tags for data access. Because passive RFID tags have a very simple structure, they can be mass-produced at low cost. RFID tags that operate in the ultra-high frequency (UHF) radio band have a longer read distance (several meters) and a wider read area than RFID tags that operate at other frequency bands. When multiple package cases or articles with UHF-band RFID tags are placed on a pallet and passed through a gate, the data of each tag can be automatically and collectively read with high efficiency. These tags also assure effective article traceability during physical distribution and are of great benefit in supply chain management (SCM) and other manufacturing systems.

In April 2005, the Ministry of Internal Affairs and Communications permitted the use of 952 to 954 MHz UHF-band RFID systems as private radio stations in Japan. Then, in January 2006, the Ministry permitted the introduction of technologies preventing mutual interference among RFID reader/writers and the use of specific small-power systems operating at up to 955 MHz. As a result, full-scale introduction of RFID technology was started in Japan. However, there are several problems with RFID technology. For example, automatic operation and higher reading efficiencies are difficult to achieve because accurate reading of radio data from tags is often prevented due to reflections and interference of radio waves. For RFID tags to be widely used, accurate data reading technology is indispensable, and it is especially important to be able to read and write data from and to multiple RFID tags that are moving.

This paper describes some of the problems in reading/writing multiple tags and describes a technology we have developed to overcome them.

2. Experimental application of RFID tags to physical distribution

Now that the use of UHF-band RFID tags has been permitted, they are increasingly being used in experiments in stock/shipping management of physical distribution and put to practical use. For example, on May 24, 2006 Fujitsu introduced a parts incoming/shipping management system that uses UHF-band RFID tags between its Nasu Plant and Oyama Plant, which supplies parts to the Nasu Plant. However, most RFID systems that have been introduced are read-only systems. That is, the ID data of RFID tags is read with a radio unit (also called a reader/writer [R/W]), sent to a server, and collated with article data, but no data is written to the tags. Providing a function for writing data to RFID tags will improve efficiency because:

1) Real-time processing in an offline environment can be done.
2) The load on servers and networks can be reduced.
3) The introduction period can be shortened because a linkage with the upper-level system is not necessary.

The ability to process moving RFID tags is important for efficient processing. To provide this ability and demonstrate accurate data reading/writing in a wide range of RFID applications, we performed an experiment on a lending management RFID solution for folding plastic containers. In this solution, RFID tags are attached to the containers, lending management data is read from the tags, and data is written to the tags about the gates through which they pass.

The details of the experiment were as follows. Each tag contained an RFID LSI with a Fujitsu FRAM having high-speed write characteristics.[1),2)] The air-interface protocol conformed to ISO/IEC 18000-6 Type B. The length of the data read from the tags was 8 bytes, and the length of the data written to the tags was 4 bytes. We set the number of processed tags to 100 because we estimated a minimum of 100 tags could be processed within the four seconds of continuous reader/writer RF transmission allowed under the Radio Law. The tag moving speed was set to 1 m/s, which is a typical walking speed. Each tag was attached to a folding plastic container that was 4.65 cm thick. The containers were loaded onto a carrier in four groups of 25, and the carrier was moved through gates that were 2 m wide (**Figure 1**).

3. Problems with moving tags

Figure 2 shows the top view of the communication areas of the read/write antennas in the experiment. Because the communication area of each antenna is limited, the antennas must be switched sequentially to trace the moving RFID tags. When the antennas are switched, the reader/writer temporarily stops sending the signal to be transmitted to the tags, and since the RFID LSIs derive their power from this transmission, they temporarily lose power; this problem must be solved. In addition, the problem of radio wave reflection from the floor and walls must be solved. **Figure 3** shows the electric field from a read/write antenna in a room as calculated using the finite difference time domain (FDTD) method. The areas with a weak electric field are indicated with a light shade in this figure and are caused by reflections. When the RFID tags pass through these areas, they may lose their power.

4. Preventing duplicate processing of tags

When an RFID LSI loses its power, its

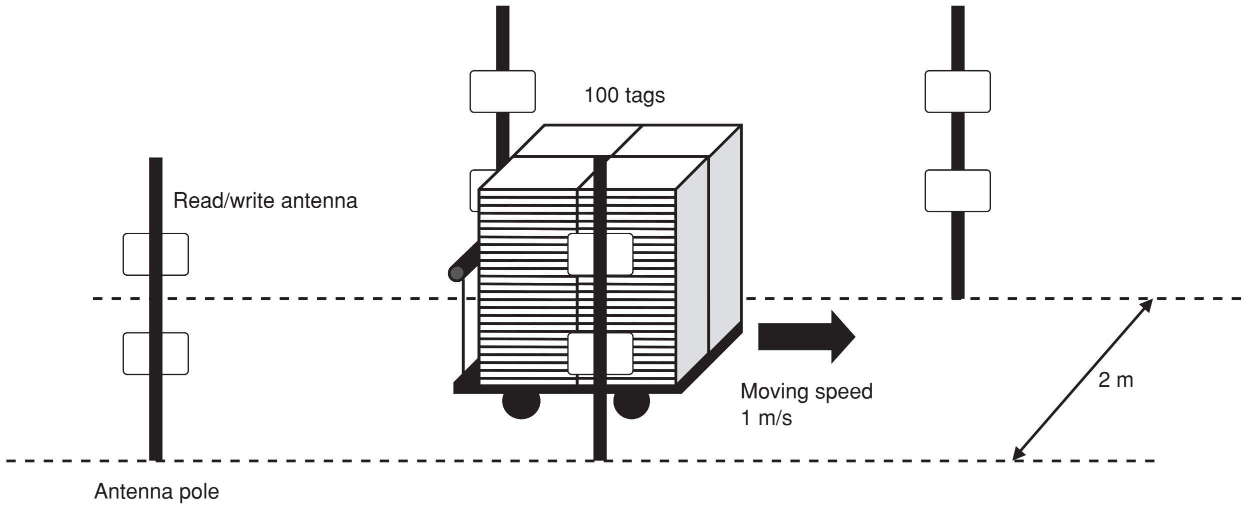

Figure 1
Outline of experiment.

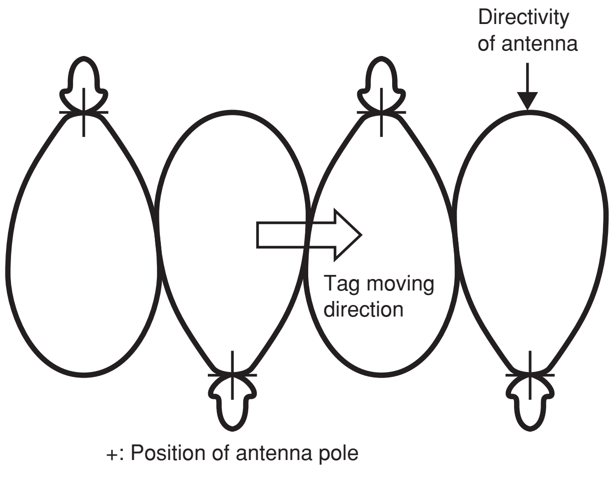

Figure 2
Antenna communication areas.

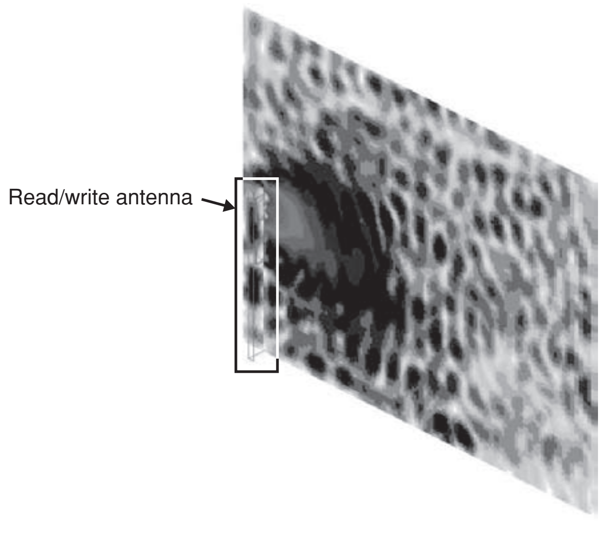

Figure 3
Calculated electric field from read/write antenna.

internal status data that indicates the point to which its data processing has advanced is lost. Therefore, if a tag whose data has already been read losses its power, when the power returns, the tag is redetected by a tag detection command from the reader/writer. This duplicate tag detection causes redundant processing and therefore reduces processing efficiency. Also, although tags passing through the areas of strong radio transmission were easy to detect, other tags were not detected easily because they passed through areas where the radio transmission was too weak. As a result, some tags were not detected. We repeated the experiment and found that the read success rate is reduced to about 90% if duplicate tag detection occurs.

Both the ISO/IEC 18000-6 Type B and C standards define a processing-flag memory function to indicate the processing status. When the inventory process of a tag terminates, this function sets a flag bit in the tag memory so that even if it loses power, its internal status is kept for several seconds. However, this function only provides the memory function for the inventoried status and does not memorize the data reading or writing status of the tag. Most currently available RFID LSIs that conform to ISO/IEC 18000-6 Type C have a single function for ID reading, and when these RFID LSIs are used the system will satisfy the Type C standard. However, this standard is insufficient to assure accurate data reading/writing. Therefore, a new technique must be developed that enables an RFID LSI to keep its information until all processing has been completed.

To check whether a reading or writing operation of a tag has been completed, we improved the reader/writer firmware and middleware to establish a new no-flag function that prevents duplicate processing of tags. With this new function, when all the ID detection, data reading, and data writing operations have been completed, data indicating the end of processing is written. The tag detection function of this system uses a group selection command of the ISO/IEC 18000-6 Type B standard so that only tags whose processing is incomplete are selected and detected. This prevents duplicate tag detection, reading, and writing and therefore can greatly improve the processing performance.

5. Control of read/write antenna commands

To ensure the moving tags are processed before they move outside the communication area of the read/write antennas, the antennas must be placed at appropriate positions and the timing of read/write command execution must be accurately controlled. To use the communication area of the antennas most effectively, we developed a control system consisting of infrared sensors for antenna poles and read/write control middleware that uses the information from the sensors. This system detects the time when the tags enter an antenna's communication area and the speed of the tags and adjusts the timing of the antenna switching command accordingly. **Figure 4** shows

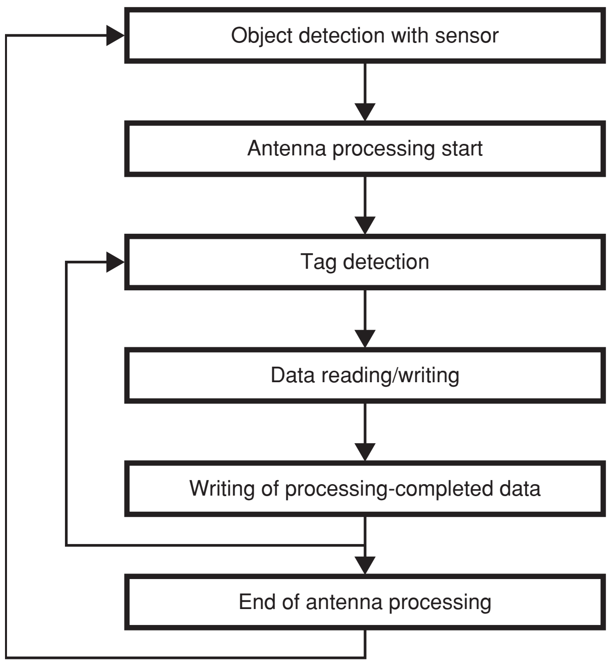

Figure 4
Processing flow.

the flow of processing, including that for preventing duplicate tag processing.

We applied these technologies to the reader/writer and middleware and optimized the respective parameters. We performed the gate passing experiment 1000 times and confirmed that data was read and written with no errors.

6. Conclusion

In an RFID system, a single read/write error can seriously affect work efficiency. Therefore, technology for high-precision reading and writing has an important role in such a system. The technology we developed can collectively read or write 100 moving tags with an accuracy of 99.999% or higher. This technology will sharply reduce the restrictions on gate installation and operation procedures. We have incorporated this technology in the latest Fujitsu long-range reader/writers and RFID middleware so engineers can easily develop high-precision read/write systems. This paper described a mass-read/write technology based on the results of experiments. We will support system installations based on these results and will advance the spread of UHF-band RFID products, which are currently not in wide use.

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