

## Effective Utilization of Radiation Resistant RF Tag in the Decommissioning Work Management

Kunio ITO<sup>1</sup> and Nobuyuki TERAURA<sup>2</sup>

<sup>1</sup> *Japan NUS Co., Ltd., 7-5-25, Nishi-Shinjuku, Shinjuku-Ku, Tokyo, 160-0023, Japan*

<sup>2</sup> *Terrara Code Research Institute, Kagiya-Cho, Tokai-Shi, Aichi, 477-0032, Japan*

### ABSTRACT

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RF tags have excellent characteristics in the management of moving items for traceability and identification, and are utilized in various fields including nuclear power plants. In this paper, we discuss the effective utilization of RF tags at nuclear power plants, especially for radioactive waste management during the decommissioning works. In its application to radiation field, it is necessary to prevent the corruption of the data stored in RF tag memory due to radiation damage. Especially, for the decommissioning work in high-level radiation environments at the Fukushima Daiichi reactors, the radiation resistant RF tag which has been developed by the authors is particularly effective.

### KEYWORDS

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RFID, RF Tag, Radiation Resistant, Identification, Traceability, Radioactive Waste, Decontamination, Decommissioning, Work Management, Fukushima

## 1. Introduction

Radio Frequency Identification (RFID) is an item's identification technology which uses radio wave. In this technology, RF tag is used to manage the items for its identification, traceability and so on. RF tags include the active RF tag which has a voltaic cell, and a passive RF tag without a voltaic cell. Among them, since it is cheap and can be used over a long period of time regardless of a battery life, the passive RF tag is used in various fields.

As reported in our previous papers[1,2,3], RF tags are used for equipment maintenance of factories or power plants, and the application examples are widely reported in nuclear power plants [4-10] and others[11,12]. Several frequencies are used for RF tag, and RF tag of UHF has a communication range comparatively as long as about 10m, and a remote reading is possible. When it is used in radiation environment at nuclear power plant, the remote reading can contribute to the reduction of worker's unnecessary radiation exposure.

In the normal RF tag, the circuitry operator part is formed with the semiconductor, therefore, under the radiation such as a gamma ray irradiated environment, a recoverable soft error and unrecoverable hard error will occur due to radiation induced damages to semiconductor. For that reason, the RF tag may not be used depending on the level of radiation.

## 2. Development of Radiation resistant RF tags

As reported in our previous papers[1,2,3], authors have newly developed a radiation-proof RF tag by attaching a mechanical shielding and an error correction software function, and its radiation-proof function has been verified by various irradiation tests. This research and development work has been started around in 2005 as a co-research with Japan Atomic Energy Agency (JAEA) for possible application to Low Level Waste (LLW) management. The unique technology developed here has acquired patent in Japan[13,14].

Two memory device structures, currently in use for RF tags, are the EEPROM (Electrically Erasable Read Only Memory) and the FRAM (Ferroelectric Random Access Memory). FRAM stores data by a magnetic principle and has a strong resistance to gamma radiations. However, FRAM does perform a destructive readout. When radiation influences the FRAM control part during reading operations, incorrect data may be written in the memory. An EEPROM stores data with a cumulative electronic dosage, and it has relatively weak resistance to radiations, as the data transformation may

occur. However, EEPROM has no major weakness in reading and writing data under radiation. Consequently, when FRAM is used in radiation environments, the reading and writing operations has to be made under radiation-free environment. When the use of RF tags and the data reading/writing is performed under radiation environments, the use of EEPROM memory which has radiation resistant function is desired.

The technology of radiation resistant RF tag developed by authors has been designed for EEPROM type memory for the use of the above conditions, and its radiation resistance function has been verified by various type tests using the High-energy Gamma ray and Low-energy gamma ray.

As reported in our previous papers[1,2,3], we confirmed that our RF tag we used for the test can withstand radiation up to 0.35kGy for Low-energy Gamma ray and 5kGy for High-energy Gamma ray.

It is important to note that the radiation resistance of our RF tag will depend on the mechanical shielding design. The durability can be improved according to the strength of radiation environment the tag is to be used.

### 3. Review of Application experiences of RF tags in nuclear and radiation related field including radiation resistant RF tag

We have conducted literature/media research and review about the use of RF tags in the field of nuclear power, and the results are summarized in table 1. We found that the reports on the examples of utilization of normal RF tags in the field of nuclear power have been increased in overseas countries and the RF tags which have radiation resistant function have also been developed in these years.

**Table 1. Application experiences of RF tags in nuclear and radiation related field**

No	Development and Application of RF tags in nuclear/radiation field	Reference/date
1	Tego develops Radion tag for <b>gamma and radiation</b> RFID. Tego announced availability of the Tego Radion tag, a Gen 2 ultra-high frequency tag capable of surviving repeated gamma-sterilization and other radiation exposure commonly found in applications such as medical, life-science and food industries.	Note 1 Apr 6, 2011
2	RFID Tag with <b>Gamma Radiation Resistance</b> ? No Problem, AdvantaPure's new GammaTag easily attaches to components such as sample and production bags, tanks, filters, manifolds, tubing and hose, storage vessels, and to complete single-use systems.	Note 1 Dec 4, 2006
3	Hulk, RFID tags can <b>withstand gamma radiation</b> , SMARTRAC announced the launch of a RFID transponder capable of withstanding gamma radiation exposure of up to 45 kilogray (kGy). Radiation sterilization is often used in the medical industry to destroy the DNA of any micro-organisms which may be present in medical equipments.	Note 1 Jul 7, 2010
4	HID Global has debuted its IN Tag 300 8KB, a passive high-frequency (HF) transponder with eight kilobytes of FRAM technology, provided by Fujitsu Semiconductor. FRAM chips <b>withstands gamma radiation</b> up to 50 KGray to survive, for example, medical sterilization processes.	Note 2 Jul 24, 2014
5	RFID Technology Developed for Nuclear Applications. Companies in France and the U.S. have recently developed RFID tags with potential applications in nuclear plant welding inspections and nuclear medicine.	Note 4 Jul 28, 2014
6	French Nuclear Plant Service Provider Tracks Containers Via RFID, SPIE Nucléaire is using handheld readers to record the locations and conditions of equipment containers that it has fitted with passive UHF tags.	Note 2 Oct 20, 2014
7	Chinese Nuclear Plant Tracks Workers With RFID, The UHF RFID system, from Sun International, allows the Qinshan Nuclear Power Plant to confirm that all workers have left an area during an emergency, or identify any who still remain, as well as know if someone enters an unauthorized area.	Note 2 Nov 23, 2015

8	Nuclear Plant Operator Uses RFID to Promote Safety, Southern Co. employs a unique type of active tag to track employees' locations at its training center, as well as teach them how to avoid excessive radiation exposure.	Note 2 May 18, 2009
9	RFID Ensures Worker Safety at Nuclear Plant Archive, The archive, a storage site for blueprints of nuclear plants, uses active UWB tags to ensure workers are evacuated should a fire-protection system become activated, filling its chambers with nitrogen. Areva, is employing active RFID to ensure the safety of its personnel at a high-security document archive in Erlangen, Germany.	Note 2 Dec 24, 2008
10	Argonne/DOE ARG-US Radio Frequency Identification (RFID) Technology for Tracking Nuclear Materials in Storage, Transportation. ARG-US is an integrated radio frequency identification (RFID) system that consists of tags, readers, application software, a database, and web applications. ARG-US technology is unique in that it tracks the physical locations and monitors the environmental conditions and the state of health of containers of nuclear materials in storage and transportation 24 hours a day, 7 days a week.	Note 3

Note 1 ; <https://www.secureidnews.com>

Note 2 ; <http://www.rfidjournal.com/articles>

Note 3 ; <https://www.ne.anl.gov/packaging-certification-and-life-cycle-management/argus-rfid/>

Note 4 ; [https://nuclearstreet.com/nuclear\\_power\\_industry\\_news/b/nuclear\\_power\\_news](https://nuclearstreet.com/nuclear_power_industry_news/b/nuclear_power_news)

From the above literature/media review, we noticed that there were several reports on radiation resistant RF tags from the following RF related manufacturing companies as below:

- ① Tego (USA)  
Radion tag. EPC tag which can endure gamma ray up to 100 kGy.
- ② SMARTRAC (Netherlands)  
Developed tags that can endure up to 45 kGy. Fujitsu FRAM chip. Product name SMART-IDISC-TAG.
- ③ AdvantaPure (NewAge® Industries) (USA)  
GammaTag; Durable to temperature -20C (-4F) to 85C (185F) up to 45 kGy gamma ray. Fujitsu MB89R118 chip. U.S. Patent No. 8519846.
- ④ HID Global (USA)  
Durable up to 50 kGy. There are many types of RFID tags such as IN Tag™. Fujitsu FRAM.
- ⑤ Authors (Japan)  
Durable up to 0.35 kGy (for Low-energy Gamma) and 5kGy (for High-energy Gamma ray). Besides mechanical shielding, it has a unique data correction software function. Japan Patent.

The above radiation-resistant tags which have been developed in the United States and Europe are aiming for the application in the nuclear power and others such as medical sterilization processes. However, it has to be noted that many of them use FRAM memory, which has relatively strong resistance to Gamma radiation. However, FRAM is not suitable for the use of it under the radiation where read/write is conducted as stated before.

The RF tag with EEPROM type memory developed by the authors has a unique software error correction function to prevent data corruption due to radiation, in addition to the mechanical shield attachment, which are not reported in the tags shown above. Also the tag has been tested under various radiation conditions including high and low energy Gamma radiation and neutrons, which are also not specifically mentioned in other tags.

#### **4. Possible utilization of radiation resistant RF tag in the decommissioning work management**

##### **4.1 Application example at ANL (Use experience of normal tag for radioactive waste management)**

It is interesting to note that the use of normal RFID to radioactive waste management has been

increasing recently. The notable application example is the one reported by Argonne National Laboratory (ANL) in the United States[4,5].

ANL has developed a waste management system, called ARG-US, for the real-time tracking and monitoring of nuclear material and waste packages during transport and storage. We believe that similar application can be made in the decommissioning waste management at nuclear power plants as well.

The ANL system is explained as below (excerpts from the reference [4], WM 2001, reprint permission is given by the author of Ref.[5]) :

*ARG-US has been developed for real-time tracking and monitoring of nuclear material and waste packages during transport and storage. The system allows for continuous monitoring from cradle to grave, including waste disposal. The system consists of active Radio Frequency Identification RFID tags attached to the packages; each tag has a suite of sensors that collect data on temperature, humidity, seal status, physical shock, and battery status. ...*

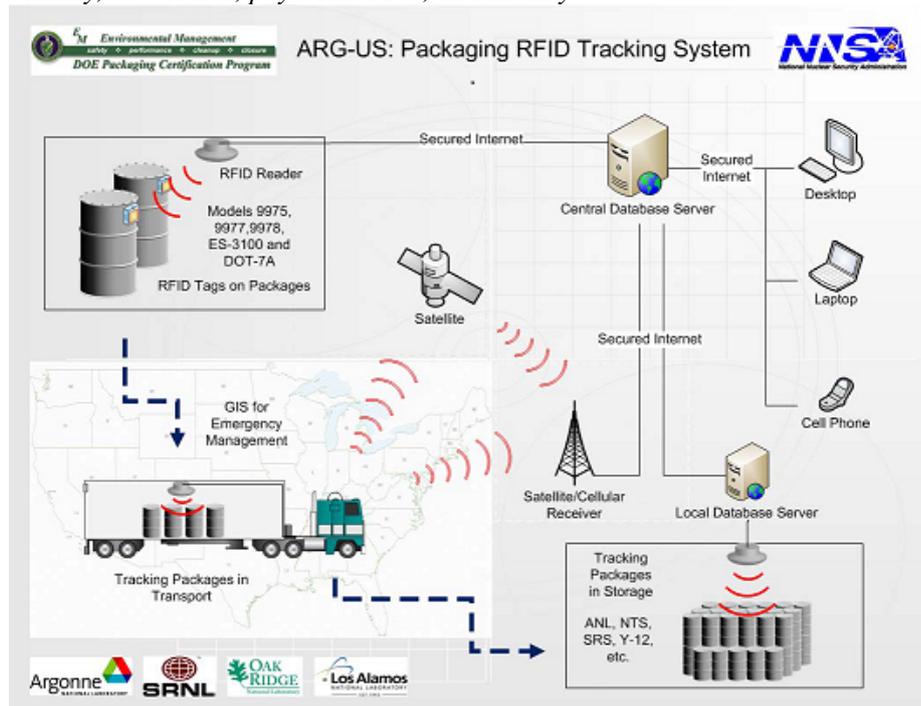


Figure 1. Schematic of ARG-US RFID Tracking System (Ref.[5], ICEM2010)

As the ANL system does not use radiation resistant tags, a concern about the radiation resistance of the tag is specifically noted as below:

*The current tag implementation uses standard commercial electronic components. In laboratory gamma irradiation tests with a calibrated Cs-137 source, tag electronics withstood radiation doses of up to 31 krad before the RF performance started to degrade. This dose level corresponds to  $\approx 17$  years of service in a field of 200 mR/h, which is the regulatory dose rate limit on the surface of Type B packages. For highly radioactive nuclear wastes packages, more radiation-resistant tags may be needed. Development of a next-generation tag that will integrate a radiation dosimeter into the sensor suite is under way....*

Although our radiation resistant RF tag technology has not been verified using active RFID tag, we believe that our technology will surely solve the above concern, and the application of the above ANL system will expand to further higher radiation area.

#### 4.2 Effective utilization of radiation resistant RF tag in the Decommissioning work management

A large amount of radioactive waste will be generated in the decommissioning work of nuclear power plants in Japan in the near future. Regarding these moving radioactive wastes, from the aspect

of securing security, it is important to timely and accurately identify and manage various information for each waste package, such as waste generated location, quantity, radiation level and the final or interim storage/disposal places along with the routes of the local transportations. Also it is necessary for workers to protect from the unnecessary radiation exposure during the decommissioning waste management.

In order to solve these problems, we propose the use of RF tags so as to improve the information management of waste containers and traceability, which will also lead to avoid the close contact with waste containers. When using the RF tag in decommissioning waste management, the following advantages are expected.

- Improvement of waste management. Can create a location map from tag information and can monitor the location of waste in real time. Improve security and enable advanced waste management according to the radioactive contamination level of the waste. Re-writing or addition of data is also possible during each phase of decommissioning work progress.
- Reduction of man-hours of workers and reduction of radiation exposure. As compared with the use of barcode or two-dimensional code, remote and/or automatic reading is possible with the RF tag, and the approach/exposure time can be shortened, so it is possible to greatly reduce the exposure dose of the worker. In addition to frequently used hand held readers or fix-placed record readers, the use of a light aircraft equipped with GPS (so-called drone) may be appropriate for reading tag information remotely when active tag is used.

If RF tag is used in the place with a high radiation level like the damaged Fukushima Daiichi reactors, the possibility of data corruption due to radiation becomes a real concern. In order to solve this problem, it is effective to use the RF tag with radiation resistance function developed by the authors, as our RF tag, in which EEPROM type memory is used, is suitable for the use under the radiation field where read/write is performed as stated before.

By effectively using RFID and its related technologies, such as remote or automatic data reading device and so on, individual data sorting by dose and location of radioactive waste generated in the decommissioning operation is possible, which leads to accurate logistics management and effective waste disposal operation management. The following figure shows a conceptual diagram of data reading, writing/rewriting operations by RF tag.

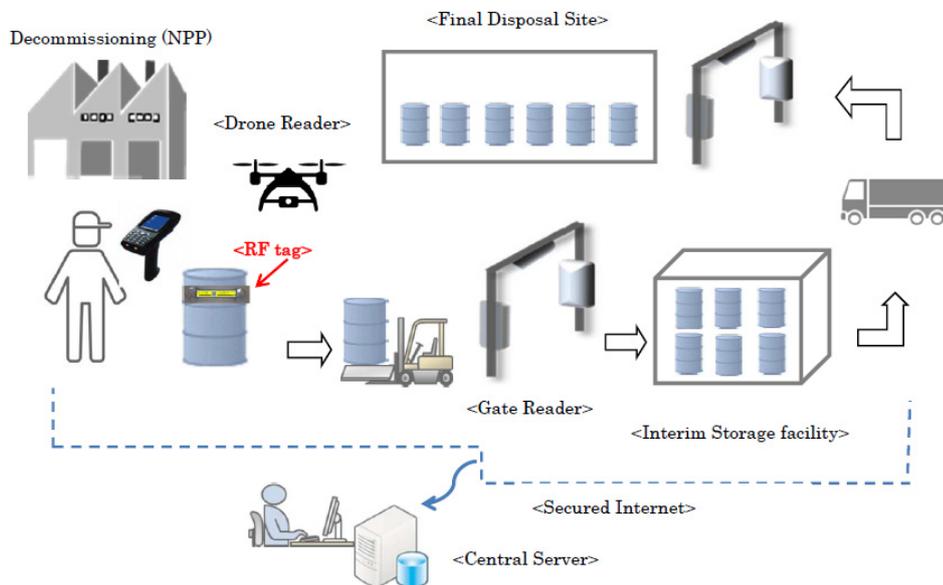


Figure 2. Proposed decommissioning waste management system using RF tag

Normally, a hand-held read/write device is used when reading RF tags data. However, in case when the manual reading is not a desirable condition, such as when RF tags attached to radioactive waste containers are to be read which are dispersed over a wide distance range beyond the range of movement of workers, as the solution, 1) fixed gate reading, or 2) light aircraft may be an option to be considered.

Recently, the use of light aircraft with GPS (so-called drone) for remote measurement is increasingly used in many areas as the reliability of the flight move is increased. When radioactive waste is transported using transport means such as a truck, the information recorded in the RF tag can be automatically read by the fixed reader installed in the transport path and data are transmitted to the central server.

In either case of hand held reader, drone, or fixed gate reader, it is possible that the server updates the location information of the individual waste ID to realize a real-time location map. (See figure)

## 5. Conclusion

- The use of RF tags is progressing including the nuclear power plants, and tags with radiation resistance function have been developed in recent years.
- However, it should be noted that many of the so called radiation resistant tags reported use FRAM type memory which relies on the inherent radiation shielding function of mechanical properties of the memory, and may not be suitable for the use case of data reading/writing under radiation environment.
- Whereas, the radiation-proof RF tags developed by authors use EEPROM type memory, which is suitable for the use case of data reading/writing under radiation environment. By attaching a mechanical shielding and uniquely designed error correction software function, the radiation-proof function had been verified by various irradiation tests.
- There is a wide applicability of tags to the field of decommissioning and radioactive waste work management. An example of the radioactive waste tracking system which utilized normal (without radiation resistance function) RF tag that has been put to practical use in US ANL (so called ARG-US) will be the reference case.
- In places with high radiation levels, it is desirable to use RF tags with radiation resistant function including the one developed by authors.
- The proposed use of radiation resistant RF tags in the decommissioning work management will provide a number of advantages, including enhanced safety, security and safeguards, reduced personnel exposure to radiation, and improved inventory control.

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