Radiation Effects of a Commercial Wireless Communication Module for Nuclear Power Plants

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1. Introduction

Today's nuclear power plants (NPPs) are sought for one of the environmentally friendly and sustainable energy sources. Since the recent Fukushima accident, interest in the safety and reliability of nuclear power plants has greatly increased. [1-2]

Modern NPP systems use mostly wired communication networks for secure communications that are not exposed to electromagnetic waves. The wired network is connected to thousands of cable bundles, making it difficult to maintain and repair nuclear power plants. [3]

In order to increase the safety and reliability of such NPP`s accident situation, one solution is to replace part of the wired communication network of the existing nuclear power generation system with the wireless communication network. Replacing a part of the wired communication network can reduce the cost of the system configurations, effectively facilitating the arrangement of the necessary electronic equipment in nuclear power plants, and greatly improving the convenience of maintenance and repair. Moreover, if it is designed as an emergency communication network in addition to existing wired system, safety and reliability can be increased.

Unfortunately, the tiny sensor system would be vulnerable to the high radiation environment with the relatively high dose rate of 10 - 100 Gy/h, unlike the outer space field dose rate of 10-3 - 10-4 Gy/h [4]. In the harsh radiating environment, electronics could be not operated properly due to additional electron hole pairs (EHP) formed in the oxide layer which behaves like an insulator in a semiconductor device. The holes of EHPs can be trapped because of its lower mobility rather than electron inside the oxide layer. This results in total ionizing dose (TID) effects which cause electrical malfunctions with triggering threshold voltage shift, noise increase, and leakage current increase [5-6].

In this study, the characteristics of various wireless communication were compared and analyzed to confirm applicability of wireless technologies in NPPs, by selecting a wireless communication module divided into hardware / communication models for irradiation tests.

2. Comparison and Analysis on Wireless Communication Technologies

As seen in Table. 1, Both Wi-Fi and Bluetooth are superior to ZigBee in terms of communication speed. Interestingly, for the instrumentation and control (I&C) system in NPPS, the requirement of data transmission is relatively lower than other applications. Instead, the ZigBee has advantages in terms of accessibility of maintenance, connectivity for a large number of nodes, and low power consumption.

In addition, ZigBee's proprietary mesh network topology increases network redundancy by using all sensor nodes as routers, making it more suitable for mission critical systems such as NPP. [7]

In this study, the test was carried out with the DIGI's TH (S2C) -XB24CZ7SIT-004 ZigBee module.

3. Test Environment

As seen in Table. 2, The test procedures take place at the radiation facility of the ARTI (Advanced Radiation Test Institute) at KAERI (Korea Atomic Energy Research Institute). Total Ionizing Dose (TID) tests were conducted by using Cobalt-60 Gamma ray.

In order to meet the high dose rate condition of 1 kGy in this TID test, a high level gamma irradiation device in the Radiation Research Institute located in Jeong-up was used.

4. Irradiation Test

As seen in Fig. 1, The first observed parameter is the current of the ZigBee modules that indicate whether the electronic system is malfunctioning or not due to TID. A 10 ohm resistor was coupled on the power supply line to measure the current flow that was multiplied by the power supply of 3.3 V for calculating its power consumption.

The second observed parameter is the packet error rate, which indicates how much error packets are

Table 1. Wireless Communication Technical Summary

Item	ZigBee	Wi-Fi	Bluetooth
Standard	802.15.4	802.11b	802.15.1
Data rate	250Kbps	11Mbps	1-3Mbps
Range	10-100m	50-100m	10-100m
Nodes per master	64,000	32	7
Power	Very Low	High	Medium
Network Topology	Ad-hoc, peer to peer, star, mesh	Point to hub	Ad-hoc, very small networks

Table 2. High-level gamma irradiation system specification

	Manufacture : MDS Nordion, Canada Radiation Source : Cobalt 60 Capacity : 490KCi Radiation Shield : Water Type : Pencil Water tank(m) : 1.9 x 3.5 x 5.15(H) Test bench(m) : A side : 1.9 x 3.5 x 1.3(H) B side : 1.9 x 1.9 x 1.3(H)

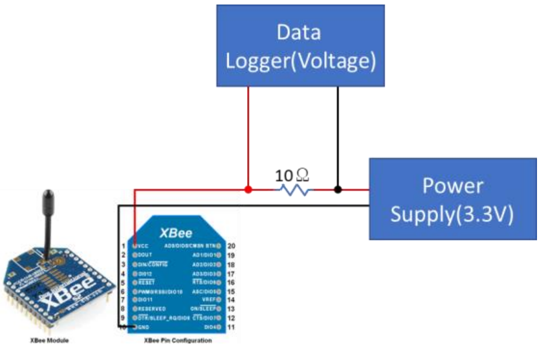

Fig. 1. The test configuration with ZigBee module

generated by the TID during transmission and reception. We have collected data of ZigBee module from transmission / reception communication model and latency transmit model.

As seen in Fig. 2 and 3, the TID of the latency transmit communication model was increased by 20% from 997 Gy to 1177 Gy compared to the request / response communication model. The PER (Packet Error Rate) showed about 2% error rate until survival time, and the latency transmit communication model showed 0% error rate during the survival time.

5. Conclusion and Future Work

In this study, to apply the wireless communication system into a nuclear power plant, the measurement data of current consumption and PER for the two communication modules of the commercial wireless products under the irradiation tests are presented.

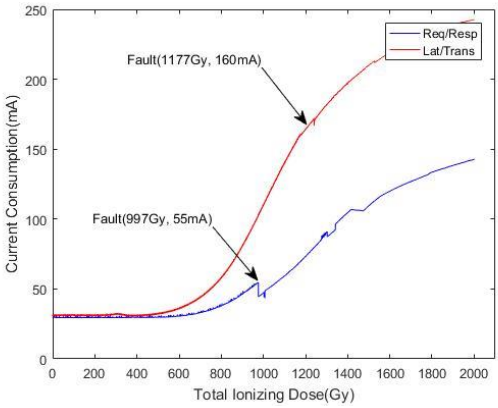

Fig. 2. Leakage current increase with the increase of radiation dose.

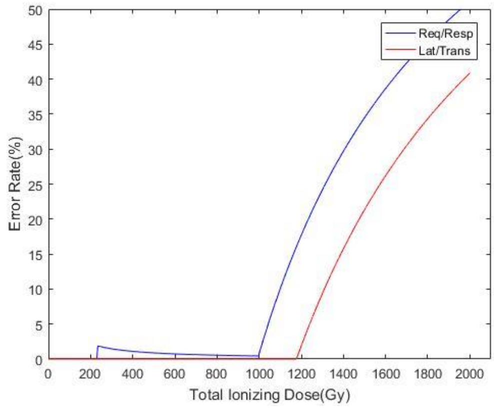

Fig. 3. PER increase with the increase of radiation dose.

Between current and conference presentations, we plan to collect more data from repetitive surveillance tests and analyze various test results, such as different radio center frequencies, shielding effects, received signal strength indicators (RSSI), and conference rooms.

The final data should be radiation intensified to provide what parts of the wireless communication system would be vulnerable and should develop specific techniques for applications such as, for example, severe accident monitoring systems and unmanned systems as well as nuclear disposal.

Acknowledgements

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