Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 105 (2017) 40 – 45

Procedia Computer Science

2016 IEEE International Symposium on Robotics and Intelligent Sensors, IRIS 2016, 17-20 December 2016, Tokyo, Japan

Impact of Cobalt-60 Gamma Radiation Source on Electronic Devices using Geant4

[1]Abd. Hafiz Zakaria, [1]Yasir M. Mustafah, [2]Jaafar Abdullah, [1]Nahrul Khair, [2]Hanafi Ithnin

[1]*Department of Mechatronics Engineering, Kulliyah of Engineering, International Islamic University Malaysia, P.O Box 10, 50728, Kuala Lumpur*
[2]*Department of Industrial Technology, Malaysian Nuclear Agency, MOSTI, 43000, Kajang, Selangor*

Abstract

This paper discusses the evaluation of performance of the Atmel Atmega328 under exposure of Cobalt-60(Co-60) source. Geant4 software is used to simulate the passage of particles through matter and calculate the absorb dose rate using Monte Carlo Methods. In the simulation using the Geant4 software, we vary the distance of IC from the source. Experiments also was conducted to measure radiation level of actual Cobalt-60 source using Atmel Atmega328 based Geiger Muller Tubes sensor. The result of the simulation experiments were discussed based on the inverse square law theorem. Following the advantages and limitations of this paper, some recommendations for future researchers were also presented.

Peer-review under responsibility of organizing committee of the 2016 IEEE International Symposium on Robotics and Intelligent Sensors(IRIS 2016).

Keywords: Arduino Uno, Atmega328, Geant4, Monte Carlo; Inverse Square Law; Cobalt-60, Geiger Muller Tube.

1. Introduction

On 11th March 2011, Fukushima Daiichi nuclear disaster occur initiated by massive tsunami and Tohoku earthquake. The destruction of the Fukushima Daiichi nuclear power plant had caused massive radioactive contamination of the Japanese mainland. It was reported that 11,580 square miles of the land surface of Japan has been contaminated by long-lived radioactive cesium and some 4,500 square miles was found exceed the Japan allowable exposure dose rate of 1mSv(milisievert) per year [1].

The first mission of the emergency response was initiated to detect the radiation energy dose rate and observe the damage to the reactor building. Since the contaminated area cannot be accessed by human, mobile robot such as TALON, Quince and JAEA-3 was deployed to enter the high level radiation area [2][3]. However, in many occasions, high radiation source had caused damages to the mobile robots. Hence, more study on development of mobile robot to explore the harsh radiated environment is very crucial.

Basically the mobile robot is a sophisticated device which consists of mechanical and electrical system. Electrical system such as sensors, control system and communication system was reported to be highly vulnerable towards the high radiation levels [4]. It is also reported that, sensors such as Laser Range Scanner and other sensors can be damaged after reaching a certain Total Ionizing Dose (TID) to the radioactive particles [5][6][7]. Thus extensive research was carried out to test and determined the radiation tolerance for electric components. Some tolerance test was carried out to evaluate electrics components such as CCD camera, Servo driver and communication links as reported in [8] and [9].

* Abd. Hafiz Zakaria. Tel.: +60-389251082; fax: +60-389251082.
E-mail address: abdhafizakaria@gmail.com

Peer-review under responsibility of organizing committee of the 2016 IEEE International Symposium on Robotics and Intelligent Sensors(IRIS 2016).
doi:10.1016/j.procs.2017.01.187

In this paper, the investigation on the TID effects on the Atme1 Atmega328 using Geant4 software. This microprocessor is used on Arduino UNO which is a popular open-source platform that are widely used in many mobile robotic projects. The simulation test will be conducted using Geant4 software. Cobalt-60 will be used as the radiation source in this study.

2. Radiation exposure

Radiation exposure can be divided into two categories which is acute and chronic. Acute exposure can be defined as a high dose radiation energy absorbed in short time period which can caused non-stochastic and stochastic effects. While chronic exposure is radiation exposure that absorbed over long period of time usually from 7 to 70 years. In order to prevent exposure of harmful radiation energy, three basic things can be controlled which is time, distance and shielding. In this paper we will discuss only time and distance.

2.1 Time

Absorbed dose rate is usually used to define the radiation exposure towards object of interest. Symbol used for the absorbed dose rate in SI unit is gray/hour (Gy/h). Radiation dose usually defined as "rad". For example, 100 rad = 1 Gray (Gy). Gy is the SI unit which is defined by amount of 1 Joule of energy per kilogram (J/kg). By using the information of total absorbed dose rate, the object of interest can be radiated within specific time without any damage. Moreover, it can be mathematically described that the radiation dose emit by sources is directly proportional to the time spent in radioactive environment as shown in equation 1. Therefore, the more extended period of time exposed in radiation environment will increase the radiation dose towards the object of interest.

$$\text{Dose} = \text{Dose Rate} \times \text{Time} \qquad (1)$$

2.2 Distance

Another method to reduce the harmful effect of radiation energy is by varying the distance of object form the radiation sources. This is because, the radiation intensity emit by the sources from a far distance will decrease the radiation received dose. Besides, as radiation energy travel through a medium such as air, energy will tends to spread out which result in becoming less intense. Theoretically, the intensity of radiation dose with respect to distance can be calculated by using inverse square law as shown in equation 2.

$$I_1 / I_2 = (D_1)^2 / (D_2)^2 \qquad (2)$$

3. Experimental setup

Our experiment was divided into two parts. Part 1 of the experiment is to simulate the absorbed dose rate using Geant4 software while part 2 to detect the radiation source using Geiger-Muller Tubes (GMT).

4.1 Geant4 simulation using Gamma sources (Co-60)

Geant4 software are widely used in radiation field to simulate the passage of particles through matter by using Monte Carlo Methods. Geant4 software is named derived from the word 'Ge' ometry and 'T'racking (GEANT). Geant4 are developed by European Organization for Nuclear Research which is also known as CERN (Conseil Européen pour la Recherché Nucléaire) in order to study the particle physics. Geant4 software basically allows user to specify the radiation particles and their energy. Besides, user also can define their own geometry and select the respective materials object for the experiment. It allows the user to specify the response of the detector during the simulation. Then, primary events will be generated in order to simulate the experiments.

In our work, Geant4 simulation is used to investigate the absorbed dose rate of an object when varied at a distance from the radiation sources. In our simulation, the microcontroller of Arduino Uno (Atmel Atmega 328) was exposed under radiation from Cobalt-60 sources. The Atmel Atmega328 which is represented by silicone material of 69mm x 53mm x 2mm in dimension at an outdoor environment at different distance. The material object was used to represents the microcontroller under the radiation effects as shown in Figure 1. The Geant4 simulation software was run using Linux OS on a Computer with Intel Core i5 processor and 8GB RAM.