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Preliminary Study of Position-Sensitive Large-Area Radiation Portal Monitor

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1. Introduction

The inspection method of the radioactive material can be categorized into two groups: the active detection method using the personal inspection system and the passive detection method using the radiation portal monitor (RPM). An RPM, which is a passive inspection method, is a system for monitoring the movement of radioactive materials at an airport, seaport, border, etc. [1]. To detect a γ-ray, an RPM using the plastic scintillator is generally used. The method of γ-ray detection using an RPM with a plastic scintillator is to measure lights generated by an incident γ-ray in the scintillator [2]. Generally, a large-area RPM uses one or two photomultiplier tubes (PMT) for light collection. However, in this study, we developed a 4-ch RPM that can measure the radiation signal using 4 PMTs. The reason for using 4 PMTs is to calculate the position of the radiation source. In addition, we developed an electric device for acquisition of a 4-ch output signal at the same time. To estimate the performance of the developed RPM, we performed an RPM test using a ^{60}Co γ-ray check source.

2. Methods and Results

2.1 Radiation Portal Monitor (RPM)

As shown in figure 1, the RPM system consists of three major parts, i.e., a scintillator, radiation signal measuring device, and data acquisition (DAQ) part. A scintillator is used as the radiation converter, which is used to convert radiation into light. A radiation signal measuring device includes four PMTs and amplifiers. In addition, analog-to-digital conversion and a digital data transmission are performed by the DAQ part.

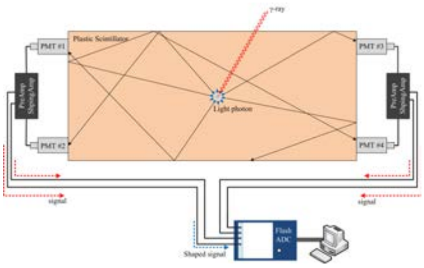

Fig. 1. Radiation portal monitoring system using a 4-ch photomultiplier tube.

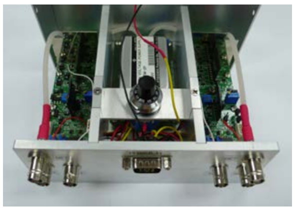

Fig. 2. Charge amplifier module: high-voltage generator, pre-amplifier, and shaping amplifier

2.1.1 Large-area Plastic Scintillator

The large-area plastic scintillator, which is made of polyvinyltoluene-based scintillation material, is an Eljen 200 model (Eljen Technology, Sweetwater, Texas, USA) in a 50 × 720 × 1800 mm^3 active area. The exterior surface of a scintillator is covered with thin foil (light-tight foil) for preventing light escaping outside, and black vinyl for preventing the penetration of light from the outside. To measure the light from a plastic scintillator, we installed four PMTs (Model R6094, Hamamatsu Photonics, Japan) in a 28 mm diameter at the outside of the scintillator, as shown in figure 1. The amount of generated light in the scintillator is about 10,000 photons/MeV. The generated light is emitted on all sides, and the emitted light is collected by the four PMTs.

2.1.2 Charge Amplifier Module

The collected light is converted into electrons by the PMTs, and the electrons are amplified in the PMTs. In

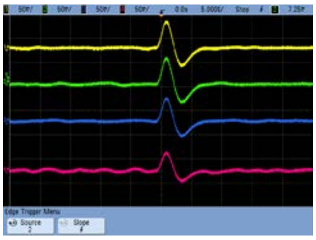

Fig. 3. 4ch output signal of radiation portal monitor

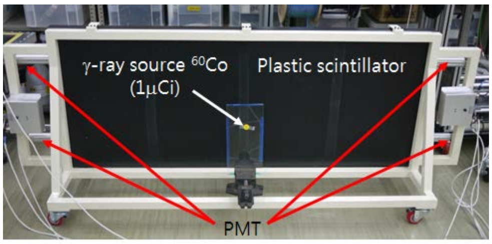

Fig. 4. Radiation inspection using a radiation portal monitor

addition, amplified electrons are converted into voltage by the electron amplifier module. The electron amplifier module is divided into three parts, i.e., a bias voltage generator, pre-amplifier, and shaping amplifier, as shown in Figure 2. The maximum voltage of the bias voltage generator, which is used to input the bias voltage into PMTs, is 2000V. A pre-amplifier, which is used to convert the current signal into the voltage signal, has a signal reaction of 1.5V/pC. In addition, the shaping amplifier part converts the input signal into a bipolar signal.

2.1.3 DAQ

An analog signal from the 4-ch electron amplifier modules should be transferred to the control computer after being converted into a digital signal, as shown in figure 3. To convert and transfer the signal, we used a flash ADC (Notice korea co., Anyang, GyeongGi-Do, Korea) with an 8-ch input.

2.2 Radiation Measurement Experiment

To estimate the performance of an RPM, we performed a radiation measurement experiment. The radiation source used for the experiment is ^{60}Co in 1μCi of activity, which has 1.1732 and 1.3325 MeV energy peaks. The configured RPM system is shown in figure 4. The implementation of the experiment was conducted in three different ways, as shown in figure 5. We measured the change in output according to the source position as follows.

1. point (0) to (1) : 10 cm step
2. point (0) to (2) : 10 cm step
3. point (0) to (3) : 10 cm step

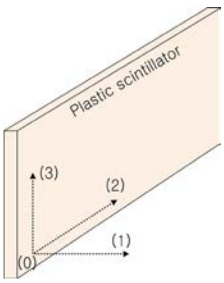

Fig. 5. Experiment for radiation signal measurement

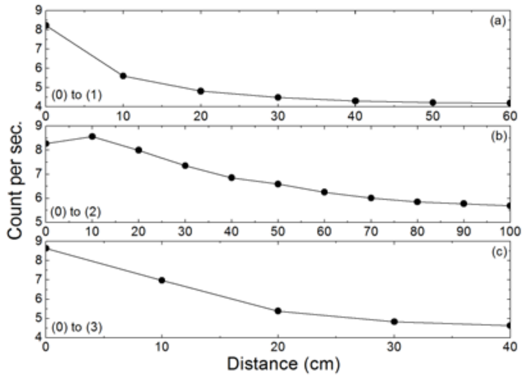

Fig. 6. Graph results of the experiments: (a) first, (b) second, and (c) third.

3. Results

As the position of the source moves farther from the scintillator surface, the number of signals decreases, as shown in figure 6(a). Figure 6(b) shows the results of the second experiment. From the results, the farther away from a PMT, the number of collected signals decreased as in the results of the first experiment. The other word, the decreasing ratio of the signal was lower than in the first experiment. The trend curve of the third experiment was similar to experiment 2, as shown in figure 6(c).

4. Conclusions

In this study, we performed the development of a 4-ch RPM. The major function of the typical RPM is to measure the radiation. However, we developed a position-sensitive 4-ch RPM, which can be used to measure the location of the radiation source, as well as the radiation measurement, at the same time. In the future, we plan to develop an algorithm for a position detection of the radiation. In addition, an algorithm will be applied to an RPM.

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