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Development of Airborne Gamma-Ray Spectrometer Based on a CZT detector

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1. Introduction

According to the lessons learned from the accident of Fukushima Daiichi nuclear power plant (FDNPP), the importance of environmental radiation measurement increased with respect to the radiation protection for the proper response. Diverse survey platforms, such as ground-based and mobile gamma-ray spectrometry, have been developing in the field of emergency preparedness. Especially, the aerial survey method is developing for the purpose of a quick consequence management by characterizing radiations in the wide area and then making radiation map at the early, intermediate, and recovery phases of the accident.

Airborne gamma-ray spectrometry using unmanned aerial vehicle (UAV) was successfully applied to the radiation assessment around the widely contaminated area in JAEA (Japan Atomic Energy Agency) [1-3]. The dose rate maps at 1 m above the ground were made from these aerial surveys at the flight height with the help of technologies of positional coincidence with gamma-ray spectrometer and correction algorithm of survey results into a 1 m height. In the current situation of the domestic demands, the aerial measurements have been adopting as an appropriate method to quickly estimate the field radiations.

In this study, the airborne system, which was named as MARK-*A1* (Monitoring of Ambient Radiation of KAERI–Airborne 1), was developed to mount to the commercial drone. This system below 1 kg of payload consists of CZT (Cadmium Zinc Telluride) detector, signal processing unit, positioning and interface unit. In addition to Hardware components, the dose conversion algorithm was added to estimate the ambient dose rate from the measured energy spectrum during the flight. The performance test of developed airborne gamma-ray spectrometer was finally conducted by assessing the ambient dose rate around a certain site, after mounting it to a commercial drone (Inspire 1).

2. Methods and Results

2.1 Airborne gamma-ray spectrometer

A CZT detector with a size of 10x10x5 mm^3 was used to make a small airborne survey system of MARK-A1. As shown in Fig. 1, a developed airborne gamma-ray spectrometer consists of three parts, which are signal processing unit, GPS (Global Positioning System) and Bluetooth interface, and battery pack. The weight was about 1 kg including a CZT sensor and one battery pack.

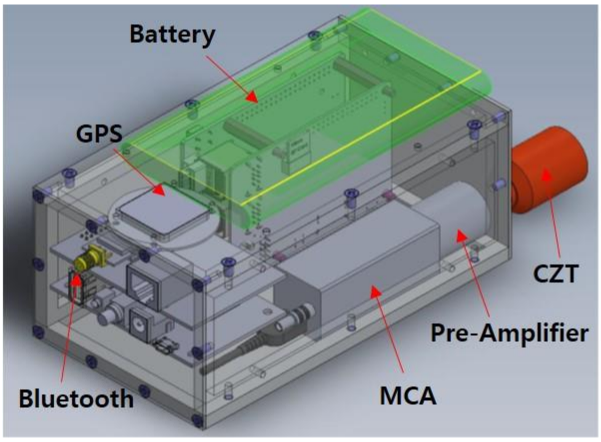

Fig. 1. Airborne gamma-ray spectrometer (MARK-*A1*)

The performance of developed airborne system was evaluated by checking the energy resolution. Figure 2 shows the measured energy spectrum in the case of positioning a point source of ^{137}Cs in front of the CZT sensor. A 2.2% resolution was achieved at the energy of 662 keV and this results was below a certificated value of 2.5% from a manufacturer (RITEC Inc, Latvia).

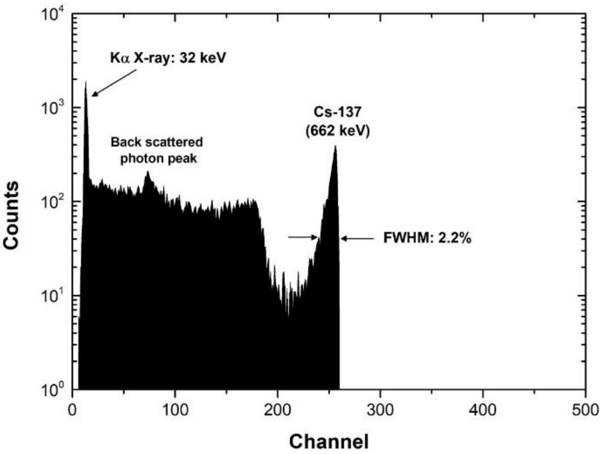

Fig. 2. The measured energy spectrum using a point source of ^{137}Cs

2.2 Dose conversion factor

To calculate the ambient dose rate from measured energy spectrum, a dose conversion factor of CZT detector was made from Monte Carlo simulation. Figure 3 shows the calculated dose conversion factor, G(E), of developed airborne gamma-ray spectrometry. An energy range of dose conversion factor was designated from 20 to 1500 keV and 8th order polynomial regression was successfully applied in the designated energy range.

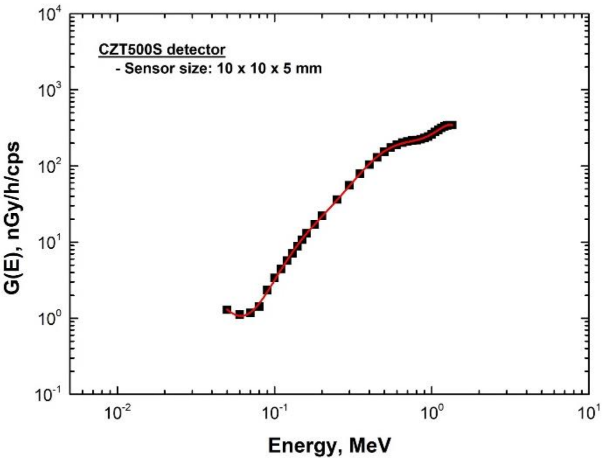

Fig. 3. The dose conversion factor of developed airborne gamma-ray spectrometer

2.3 Performance test

After mounting airborne gamma-ray spectrometer to a commercial drone (Inspire 1) using a bracket, as shown in Fig. 4, aerial measurements were conducted at about 10 m height and 1 m·s^{-1} speed. The maximum flight time was about 10 min, when one battery pack fully charged was inserted to a drone. The ambient dose rate was calculated from measured count rate and dose conversion factor, using Eq. (1).

$$\dot{X} = \int_{E1}^{E2} n(E)G(E)dE \tag{1}$$

where, $\dot{X}$ is the ambient dose rate, n(E) is the measured count rate, and E1 and E2 are minimum and maximum energy, which are 20 and 1500 keV, respectively.

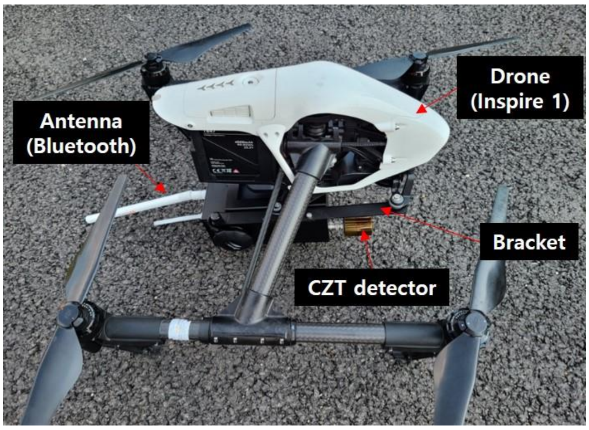

Fig. 4. The aerial measurement using a commercial drone and in situ gamma-ray spectrometry using a tripod.

For the experimental verification of airborne survey, ground-based gamma-ray spectrometry using a tripod was conducted in the survey site. Total cps and ambient dose rate accounted for about 7.15 s^{-1} and 118 nGy·h^{-1}, respectively, from in situ measurement at 1 m above the ground. A similar result was achieved between two methods, which mean airborne and ground-based gamma-ray spectrometry, in the survey site.

3. Conclusions

Airborne gamma-ray spectrometer, which can be mounted to a drone, was developed for the application to the circumstance with high dose rate level. The measured energy spectra linked with positioning data during the flight were automatically transferred to a PC in the ground through Bluetooth interface. The airborne survey was then conducted to make a performance test at the height of about 10 m. The ambient dose rate was successfully estimated from the calculation of measured energy spectra and dose conversion factor. Finally, the results were compared with those from in situ gamma-ray spectrometry using a tripod at the same survey site.

ACKNOWLEDGMENTS

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