Performance evaluation of CZT radiation detector mounted on unmanned aerial vehicle for aerial radiation measurement

MinBeom Heo [a*], BeomKyu Kim [a], HeeKwon Ku[a], HwaJeong Han[b], Byung Gi Park[b] and SangHun Shin [a]
[a]*FNC Technology Co. Ltd, Heungdeok IT Valley, Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, Korea*
[b]*SoonChunHyang University, 22, Soonchunhyang-ro, Asan-si, Chungcheongnam-do, Korea*

[*]*Corresponding author: ssh9431@fnctech.com*

1. Introduction

Radioactive materials emitted from nuclear facility accidents such as the Fukushima nuclear accident spread widely depending on the weather and adversely effect on the human body and the environment. Therefore, monitoring environmental radiation around nuclear power plants through investigation and evaluation of radioactive contamination information and radioactive material behavior is important for rapid emergency response. In addition, the measurement of aerial radiation that diffuses into the atmosphere has limitations in measuring aerial radiation because it is difficult for humans to access or there is a problem in tracking the movement path of the plume before radioactive fallout.

Therefore, it is essential to develop a monitoring system for early response and environmental preservation through aerial radiation monitoring in normal and emergency situations around nuclear power plants. In addition, it is very important to build an environmental radiation database so that it can be used in the event of an accident by accumulating aerial radiation measurement data. To this end, it is necessary to select a radiation detection device capable of detecting the level of environmental radiation dose and to develop a radiation detector using it.

Among the radiation detection device, Cadmium Zinc Telluride (CZT) has been actively studied recently as a compound semiconductor detector. Compared to other radiation detection device, it has a high atomic number, so it has a high density, so it has excellent detection efficiency.[1] In this study, the measurement parameters of the CZT radiation detector that can be used when designing an aerial radiation detection device for mounting unmanned aerial vehicles were set and the performance evaluation was conducted.

2. Test Equipment and Methods

The CZT radiation detector has an excellent energy resolution for its small volume. And it has the advantage of being able to operate at room temperature, and it is possible to identify radionuclides at the same time as measuring the radiation intensity. The volume of the CZT sensor crystal used in this study is about 500 mm^3, and the full width at half maximum (FWHM) at 662 keV energy is 9.9±0.5 keV, which is suitable for nuclide discrimination. In addition, the MCA module connected to the rear end of the CZT radiation detector is controlled and measured from a PC using Winspec software. The radiation source used for the performance evaluation was Cs-137 in the form of a disk, and 50 nCi of the radioactivity was used.

In order to measure aerial radiation, variable such as measurement distance, time, and angle should be considered. In this study, the correlation between measurement distance and measurement time was analyzed and basic research was conducted to reflect it when designed a detection device for mounting on an unmanned aerial vehicle.

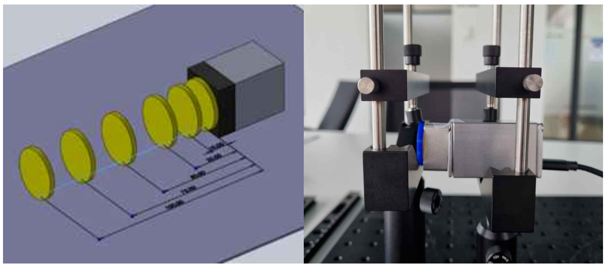

Fig. 1. Configuration of performance evaluation experiment according to measurement distance and time

The measuring distance between the detector and the radiation source was set to 0, 1, 2.5, 5, 7.5 and 10 cm as shown in Fig. 1, and the energy spectrum was measured according to the distance. In addition, the minimum detectable time for measuring the low radiation intensity Cs-137 source was evaluated by fixing the distance between the detector and the radiation source to 0 mm and setting the detection time of 10 to 1200 seconds.

3. Result

The graph of the measurement distance performance evaluation for the 662 keV of Cs-137 is shown in Figure 2, and it can be confirmed that identification is difficult when the measurement distance is more than 7.5 cm. From the experimental results, it can be seen that in order to measure radiation of a low energy level, the distance to the measurement target should be minimized. As shown in Table 1, the FWHM analysis result between 0 ~ 5 cm was calculated to be about 5 ~ 13 keV, and the energy resolution within the measurable distance is about 1%, which shows sufficient performance for nuclide discrimination. [2]

Table I: Energy resolution analysis results according to the measurement distance

Distance (cm)	0	1	2.5	5	7.5	10
Peak counts	213	74	26	12	6	-
FWHM (keV)	12.38	11.00	5.93	12.44	11.16	-
Energy Resolution	1.87	1.66	0.89	1.88	1.68	-

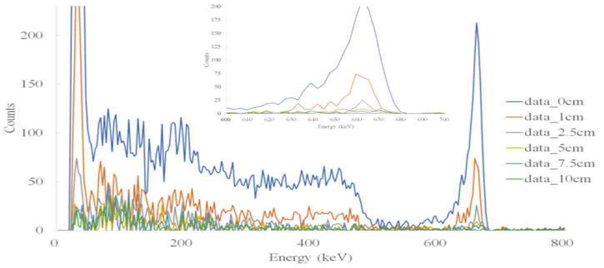

Fig. 2. Energy spectrum according to measurement distance

Figure 3 shows the energy spectrum results measured according to the measurement time. Peaks can be identified at a measurement time of 60 seconds or longer, but the number of counts within 10 to 30 seconds does not differ from the number of background counts, so peak identification is unclear. The FWHM for an experiment of 60 seconds or longer that can identify a peak is 5 to 15 keV, and the energy resolution is also about 1%. If sufficient time is secured for the analysis of nuclide, it is considered that it will be possible not only to measure the radiation intensity for low-level radioactivity but also to discriminate the nuclide.

.

Table II: Energy resolution analysis results according to the measurement time

Time (sec)	10	20	30	60	120
Peak counts	11	15	21	41	80
FWHM (keV)	-	-	-	8.15	9.81
Energy Resolution	-	-	-	1.23	1.48
Time (sec)	180	240	300	600	1200
Peak counts	107	166	169	376	622
FWHM (keV)	12.11	10.23	11.81	11.31	11.94
Energy Resolution	1.83	1.55	1.79	1.71	1.56

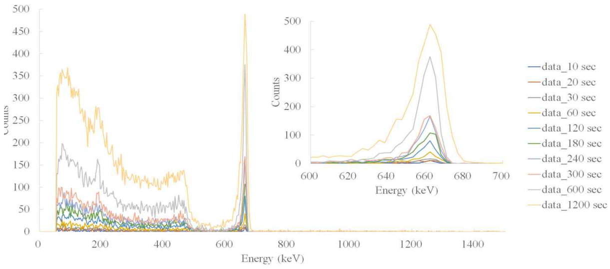

Fig. 3. Energy spectrum according to measurement time

4. Conclusions

In this study, basic research was conducted using a CZT radiation detector and a radiation source to design a radiation detection device for mounting an unmanned aerial vehicle that measured aerial radiation. Using Cs-137 with low radiation intensity, the FWHM and energy resolution were calculated and analyzed through performance evaluation experiments according to the measurement distance and time. Through the experimental results, the efficiency according to the measurement conditions of the CZT radiation detector was confirmed. In addition, it is considered that it will be possible to apply it to the design of the radiation detection device to prepare a measurement standard for low-level radiation when measuring aerial radiation. In particular, the CZT radiation detector has the advantage of efficient energy resolution compared to the volume, and can be used for dosimetry and nuclide analysis at the same time.

The future research direction is to set the radiation detection device operation and data analysis method when measuring aerial radiation through performance evaluation of various energy spectrum areas, and to conduct research for the design and development of a mounted on unmanned aerial vehicle for aerial radiation measurement.

4. Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2020M2D2A2062538)

REFERENCES

[1] B.K. Seo, G.W. Lee, W.J. Oh, J.H. Woo, K.H. Kim, “A State of the Art on the Measurement of the Radioactive Contamination in the Inner Surface of the Pipe”, KAERI, 2004

[2] W.R. Lee, G.H. Jung, M.J. Kang, Y.Y. Ji, “Development of the critical technology of the radiological environment protection and nuclear accident preparedness system”, KAERI, 2017