Angular Response Functions for Airborne Gamma-ray Spectrometer

Suk-Hoon Kim[a*], Ju-Youl Kim[a], Hyeong-Ki Shin[b]
[a]*FNC Technology, Rm.#312, Bldg.#135, Seoul Nat'l Univ., Shilim9-dong, Gwanak-gu, Seoul, 151-742, Korea*
[b]*Korea Institute of Nuclear Safety, 34 Gwahak-ro, Yuseong-gu, Daejeon, 335-338, Korea*
[*]*Corresponding author: kuni0808@fnctech.com*

1. Introduction

During a radiation emergency involving the nuclear accident or weapon fallout, it is very important to assess the ground contamination and resulting exposure in planning and executing the countermeasures and controls if required.

Aerial gamma spectrometry is a very effective method for quickly surveying a large area which might be possibly contaminated. This technique is useful in identifying the contaminating radionuclide and assessing the magnitude and/or extent of contamination.

For the purpose of building the radiological survey system using the aircraft (i.e. fixed-wing or helicopter), the airborne gamma-ray spectrometer was recently introduced from Sweden in South Korea, as shown in Figure 1. A NaI crystal, which has a dimension of 4″x4″x16″ and has been commonly used in gamma measurement systems, exists in the spectrometer.

Fig. 1. The spectrometer introduced from Sweden

This paper describes Monte Carlo investigations on the angular response functions for the aerial gamma-ray spectrometer.

2. Methods and Results

2.1 Computer Code System

The MCNP5, which is one of the most commonly used radiation transport code, was used to simulate the angular response function of the spectrometer. The MCNP code has proved to be very effective in modeling the detector response providing that the detection system can be simulated accurately.[1]

In this work, the response functions for the combination (i.e. 27 cases) of the following variables were simulated using MCNP5 code.

- Type of source: Point
- Photon energy emitted from a source: 1.765MeV (This is owing to ^{214}Bi, which is a daughter product in the ^{238}U decay series)
- Distance (from a source to center of spectrometer): 1, 5, 10m
- Angle: 0, 30, 45, 60, 90, 120, 135, 150, and 180 degrees (Refer to Figure 2.)

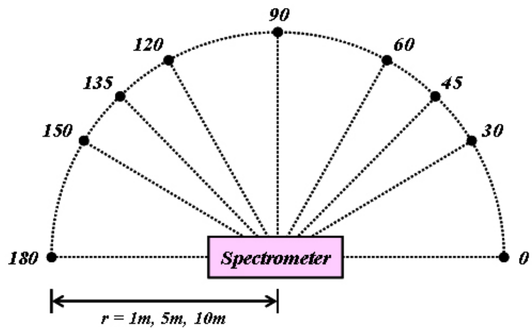

Fig. 2. Angles to be simulated in this work

2.2 Geometry Modeling

Figure 3 shows the geometry of the spectrometer that was modeled. Due to the limited information on the spectrometer, some reasonable assumptions are applied.

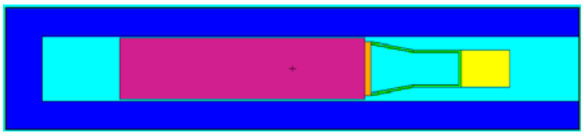

Fig. 3. Modeling of the spectrometer – Vertical cut

2.3 Material Compositions and Cross-section Library

For the MCNP simulation, it is necessary to input the data on isotopic composition and density of each material – NaI detector, optical window, PMT (photomultiplier tube), metal shield, filling, housing, and etc. Detailed information used is omitted in this paper.

MCNP provides four photon transport libraries and two electron data libraries. MCPLIB04 and EL03 are applied for photons and electrons, respectively.

2.4 Tally

The response functions were calculated by performing a photon-electron transport calculation using F8 (especially called 'pulse-height') tally. This tally provides the energy distribution of pulses created in a cell that models a physical detector (NaI Crystal in the spectrometer) by radiation.

The energy deposition was evaluated using 128 bins within the energy of 0~3MeV in order to simulate the energy channels of the spectrometer. The zero and epsilon (1e-5) bins are used to catch the non-analog knock-on electron negative scores and scores from particles that travel through the cell without depositing energy, respectively.[1]

The number of particle history (i.e. 'nps' variable in MCNP) set to be fairly large to achieve a statistically reasonable and accurate result. For each run, statistical behavior of the result was assessed by checking the associated tables in the tally fluctuation chart bin.

2.5 Variance reduction technique

In all cases simulated, the source particles were directionally biased, which is one of the easiest non-analog techniques. It allows the production of more source particles, with suitably reduced weights, in preferred directions, generally towards tally regions. In the present version (i.e. v5.1.40) of MCNP5, source biasing is the only variance reduction technique allowed with F8 tallies having energy bins.

2.6 Results

As previously stated, the angular response functions were simulated for a directionally biased point source that emitted a discrete energy (i.e. 1.765MeV) of photon at 1m, 5m, and 10m from the center of the spectrometer.

Figures 4 through 6 provide the photopeak and peak-to-total ratios as a function of angles presented in Figure 2 at 1m, 5m, and 10m, respectively. The peak-to-total ratio of simulated spectrum can be easily calculated by simply integrating and comparing the area under the peak and the entire spectrum.[2]

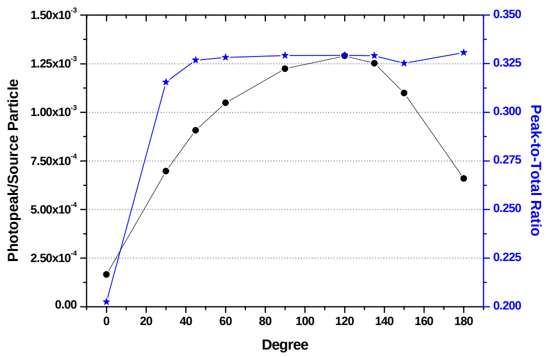

Fig. 4. The photopeak and peak-to-total ratios versus various angles at 1m

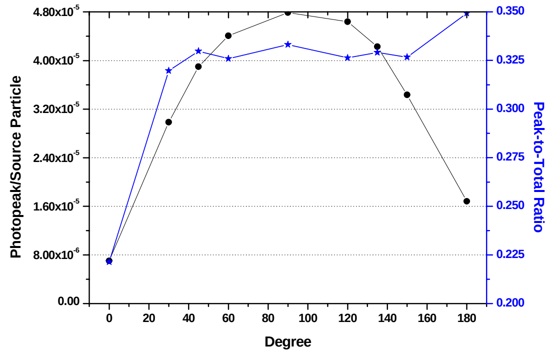

Fig. 5. The photopeak and peak-to-total ratios versus various angles at 5m

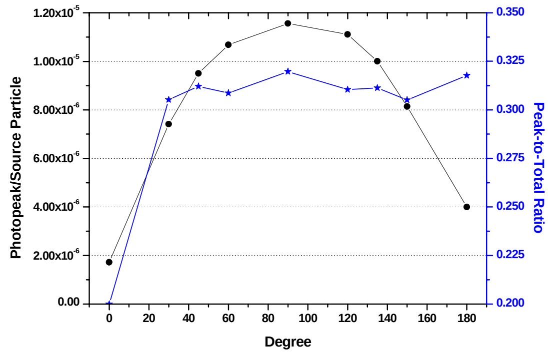

Fig. 6. The photopeak and peak-to-total ratios versus various angles at 10m

3. Conclusions

In this paper, the response functions of NaI detector with three source-spectrometer distances were simulated for different angles by using the MCNP5 code. The value of photopeak was directly extracted from the MCNP output, and the peak-to-total ratios were calculated based on the simulated results. These results are shown in Figures 4 through 6.

From these figures, it is found that the peak-to-total ratios are similar in value excluding the case of 0 degree and the maximum value of photopeak appears in the vicinity of 90 degree. It is judged that these results can be used as the basic data for building the aerial gamma-ray spectrometry system providing that the results are supported by the experimental investigations.

REFERENCES

[1] MCNP-A General Monte Carlo N Particle Transport Code, Version 5, LA-UR-03-1987, Release 1.40, November 2005.
[2] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, pp.612-613, 1999.