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Effect of Scattered Photons on Image Quality in an Industrial SPECT

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1. Introduction

The single photon emission computed tomography (SPECT) systems, which provide three-dimensional images of radioactive material in the human body, is widely used in hospitals to obtain the functional information of the human body [1]. This technology also has new opportunities of industrial applications, for example, to examine the spatial distribution and mixing characteristics of flow, which are considered as crucial information in the mixing reactor vessel at a refinery and petrochemical plant [2,3]. The SPECT system to be used in the industry should be of different requirements and criteria because the size, shape, and material of the object are significantly different from those of a human body.

In the present study, the cross-sectional image of a lab-scale flow system containing ^{99m}Tc radioactive tracer was experimentally taken using an industrial SPECT system recently developed at KAERI, and the effect of the scattered photons on the image quality was investigated, by using a Monte Carlo simulation code MCNPX [4], in order to enhance the performance of the industrial SPECT.

2. Methods and Results

The lab-scale industrial SPECT has been developed by an optimization study with the limited number of detectors. The industrial SPECT consists of 24 NaI(Tl) scintillation detectors (diameter of 1.3 cm, height of 2.54 cm) in a hexagonal arrangement [5]. Figure 1 shows the experiment set-up with the industrial SPECT system.

Fig. 1. Experiment set-up with the industrial SPECT developed at KAERI. There are two cylindrical sources containing ^{99m}Tc inside the cylindrical basin.

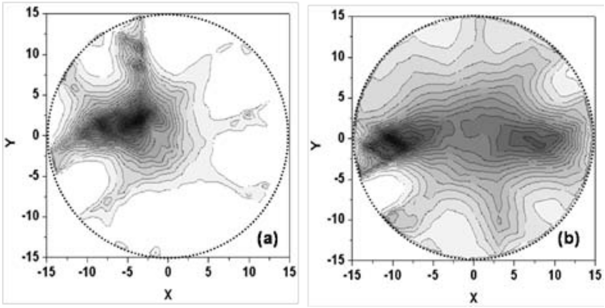

Fig. 2. Images taken by the industrial SPECT when only one cylinder is filled with radioactive tracer (a), and both cylinders are filled with radioactive tracer (b).

The scintillation light produced in a NaI(Tl) scintillator was converted to electric signal by a photomultiplier tube (PMT). Then, the signal was transmitted to an in-house signal processing circuit to trigger and generate TTL logic signal for counting. The measured counts in each detector were provided to the expectation maximization (EM) algorithm [6] to reconstruct the cross-sectional image of the distribution of radioactive tracer in the object.

2.1 Experiment with lab-scale flow system

The lab-scale flow system used in the present study was a cylindrical basin filled with water (Φ = 30 cm) containing two cylindrical sources of ^{99m}Tc emitting 140 keV gamma-rays. These cylindrical sources were placed 4.8 cm away from the center of the basin in the opposite directions as shown in Fig. 1. One of the cylindrical sources had ^{99m}Tc concentration of 3.69 mCi/L with the diameter of 5 cm and the other had 10.25 mCi/L with 3 cm diameter.

Figure 2 shows the images taken by the industrial SPECT for two different cases: (a) only the left cylinder is filled with radioactive tracer, and (b) both cylinders are filled with radioactive tracer. In case of (a), the image quality is marginally acceptable; however, in case of (b), the image quality is hardly acceptable and it is almost impossible to figure the distribution of the radioactive tracer from the given image. The performance of the current system was significantly deteriorated by the scattered photons. Note that the current system does not use an energy window and count every signals above the electronic noise level.

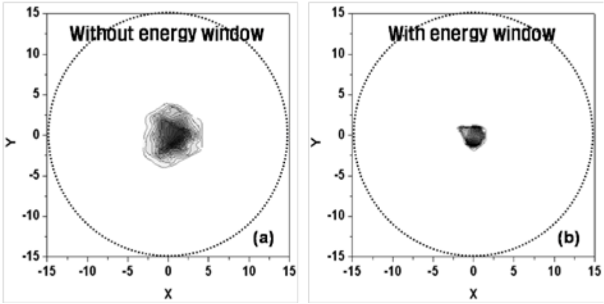

Fig. 3. Reconstructed image based on Monte Carlo simulated data for a point source at the center, without using the energy window (a), and with using the energy window (b).

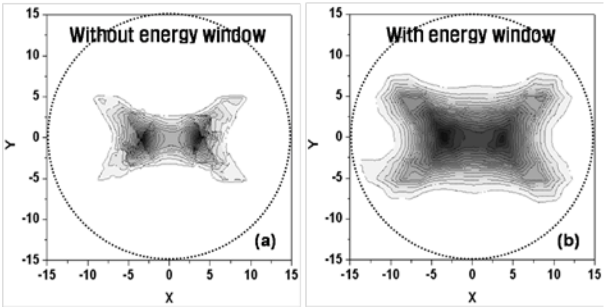

Fig. 4. Reconstructed image based on Monte Carlo simulated data for two cylindrical sources, without using the energy window (a), and with using the energy window (b).

2.2 Influence of scattered photons

In case of a point source situated at the center of the cylindrical basin, the portion of the scattered photons is estimated 82% of the total counts on average. In order to investigate the effect of the scattered photons on the image quality, the energy window of 7 keV around the source energy was applied and only the full-energy events were counted. Figure 3 shows the reconstructed image, based on Monte Carlo simulations, without and with using the energy window for a point source at the center of the basin. The result shows that the use of the energy window considerably improves the imaging resolution, i.e., from 3.0 cm to 1.9 cm in terms of full width at half maximum (FWHM). Figure 4 also shows that the use of the energy window significantly enhances the image quality.

3. Conclusions

The SPECT is considered as a promising technique to examine the multiphase flow system. It is found that the industrial SPECT developed at KAERI can image the source distribution of a flow system for a simple source geometry; however, further efforts are due necessary to obtain satisfactory result for a complicated source geometry. The energy calibration of the detectors in the industrial SPECT is a very time-consuming procedure, requiring additional electronics (e.g., MCA, pulse generator, and amplifier) in the field. Furthermore, in most cases, it would be a difficult task considering that the detectors should be calibrated after the installation of the industrial SPECT at a flow system in the field, possibly in very high temperature environment and/or with a minimal accessibility. The results of the present study, however, shows that the energy window should be used in the industrial SPECT for an acceptable image quality, especially when the distribution of the radioactive tracer is expected very complicated in the flow system.

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