ТЕХНИКА ЯДЕРНОГО ЭКСПЕРИМЕНТА

IMAGE RECONSTRUCTION USING INDUSTRIAL GAMMA RAY TOMOGRAPH WITH DIFFERENT SCATTER ENERGY WINDOWS

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Scattered gamma rays have beneficial information for reconstructing an image. Therefore, it is important to count both attenuated and scattered rays. For achieving this aim, an industrial computed tomography (CT) system was designed and developed on the base of a first generation CT system. The CT scanner consists of a 5.08 cm NaI(Tl) detector in diameter and a ^{137}Cs (30 mCi) radioactive source. The position of phantom is defined by three motors. The CT scans are taken out by scanning 180° to collect attenuated beams. Several experiments were performed with different widths of scatter energy windows and full absorption peak window. The full peak window was 530–761 keV, Compton scatter window changed, 200–530 keV, 300–530 keV and total count peak window was 200–761 keV. Finally, the quality of images with different scatter area widths is analyzed and compared by computing the RMS contrast of each image.

1. INTRODUCTION

Tomography imaging consists of directing γ-rays onto an object from multiple orientations and measuring the decrease in intensity along a series of linear paths. This decrease is characterized by Beer's law, which describes intensity reduction as a function of γ-ray energy, path length, and linear attenuation coefficient of material [1–5]. Some gamma rays that reach the detector, are produced by scattering in the object, mainly incoherent (Compton) scattering [6–8]. By using scattered photons, an image can be produced.

In this study in addition to full peak energy window two scatter windows with different widths 200–530 keV and 300–530 keV were selected. In addition, total count was used with 200–761 keV width (Fig. 1). Each scatter window produced an image without fusion with full peak window. The results of root mean square (*RMS*) contrast demonstrated the effect of full peak, scatter and total count window on reconstructed image contrast. *RMS* contrast is defined as the standard deviation of the pixel intensities:

$$RMScontrast = \sqrt{\frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}(I_{ij} - \bar{I})^2},$$

where I_{ij} is intensity ij-elements of the two-dimensional image of size M by N. $\bar{I}$ is the average intensity of all pixel values in the image [9–11].

As a result, the produced images from scatter window combined with full peak window caused higher quality on reconstructed image contrast.

2. EXPERIMENTAL SET-UP

A single-source – single-detector gamma computed tomography (CT) scanner system was used in this study. In this system a 2 × 2 inch NaI(Tl) detector was located opposite the center of the ^{137}Cs (30 mCi) source at the 55 cm distance. The position of phantom was defined by three motors. The phantom rotated by steps $\Delta\theta = 4°$ and moved along the axis with $\Delta r = 3$ mm. The CT scans were taken out by scanning 180° to collect attenuation beams. There were 50 × 50 projections for producing of image and time of each projection was 5 s.

A polyethylene phantom (0.93 g · cm^{-3}) was used to determine the 2D imaging quality of the designed industrial CT system. The phantom was made in a cylindrical geometry on which 3 holes of 15 mm in diameter were improvised. The holes were filled with mercury (13.53 g · cm^{-3}), iron (7.874 g · cm^{-3}) and air (1.184 mg · cm^{-3}).

Nuclear electronic system consists of a NaI(Tl) detector (2 × 2, 905-3 model, Eberline company), and a specialized MCA (PSS-1, NSTRI, Tehran, Iran) which consists of pre-amplifier, amplifier, high voltage (HV) and a data acquisition system. In this MCA, dedicated software can simultaneously read positions and steps, control the motors and MCA. After that, the image is reconstructed from the measured projections by the filtered back projection method to bring about the inverse Radon transformation. The produced image is due to 2000 projections.

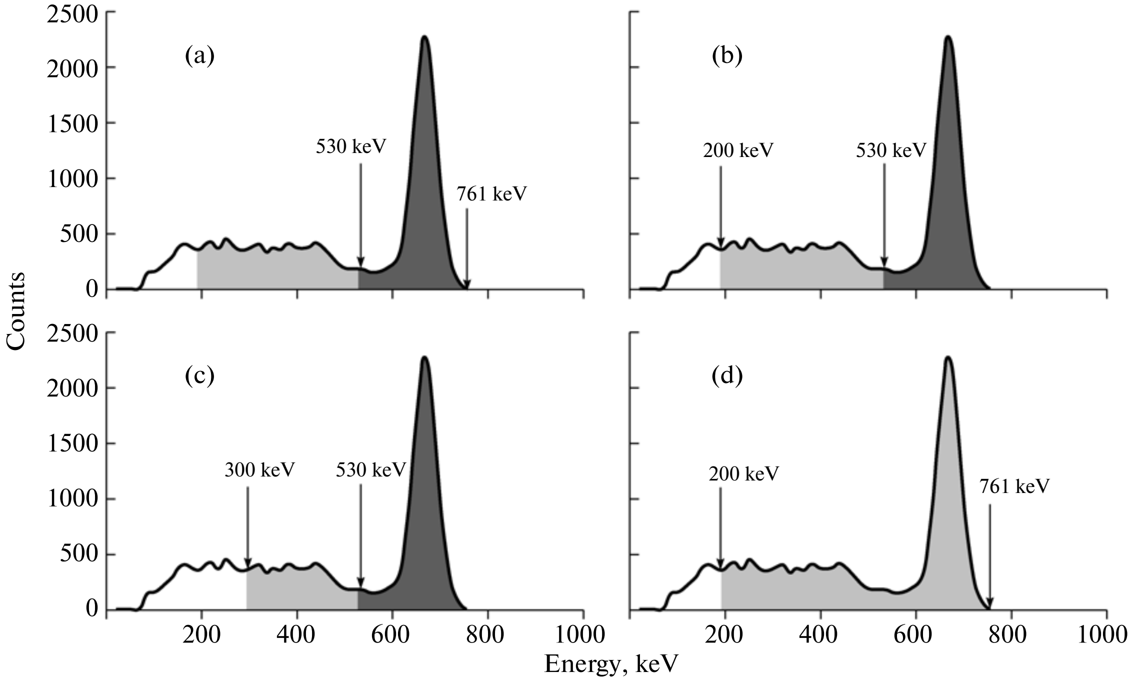

Fig. 1. The counts of full peak and scatter area with different widths: (a) Full peak area width 530–761 keV; (b) Scatter area width 200–530 keV; (c) Scatter area width 300–530 keV; (d) Total count area width 200–761 keV.

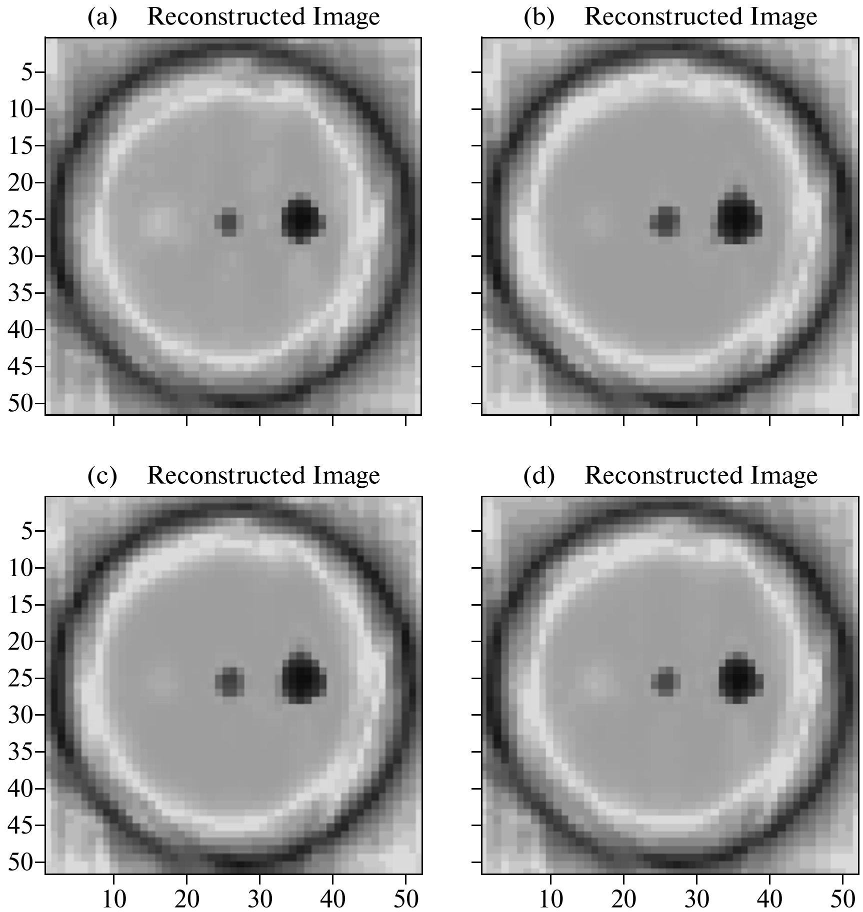

Fig. 2. Polyethylene phantom 2D image, mercury, iron, air holes for (a) Full peak area width 530–761 keV; (b) Scatter area width 200–530 keV; (c) Scatter area width 300–530 keV; (d) Total count area width: 200–761 keV.

RMS contrast of produced images with different widths of scatter window and full peak

Counts	Full peak window 530–761 keV	Scatter window, keV		
		200–530	300–530	200–761
RMS contrast	0.3418	0.2393	0.3433	0.1408

3. RESULTS AND DISCUSSION

In this research, scattered gamma rays that reached the detector had sufficient information to produce an image. Thus, the produced images with different widths of scatter energy window were tested. The first case (a) represented the results with a source of ^{137}Cs (30 mCi), a collimator (5 mm diameter), a phantom with 3 holes and the widths of full peak window 530–761 keV. The second case (b) represented the results with the widths of scatter window 200–530 keV. The third case (c) represented the results with the widths of scatter window 300–530 keV. The fourth case (d) represented the results with widths of total count window 200–761 keV. The counting time was 5 s for all the cases. The results of produced images with full peak window, different widths of scatter window and total count are represented in Fig. 2.

In addition, RMS contrast of produced images with different widths of scatter window, full peak window and total count window is given in Table. It is important to note that the RMS contrast and reconstructed image has normalized ratio to window widths.

4. CONCLUSION

The results showed that some scattered gamma rays that reached the detector have similar behavior in image reconstructing and each scatter area can reconstruct an image separately. The images produced from scatter window combined with full absorption peak window caused higher quality on reconstructed image contrast.

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