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ТЕХНИКА ЯДЕРНОГО ЭКСПЕРИМЕНТА

STUDY OF BEAM WIDTH ON RECONSTRUCTED IMAGE CONTRAST USING THE FIRST GENERATION GAMMA RAY TOMOGRAPH

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Different factors may influence the image quality of the first generation computed tomography (CT) system single-source – single-detector. One of the factors in the improvement of the reconstructed image quality is the related characteristics of the beam width. These characteristics depend on the shape of collimator and dimension of collimation apertures. For studying the effect of beam width an industrial CT system was designed and developed. 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 was defined by three motors. The CT scans were taken out by scanning 180° to collect attenuation beams. The images are reconstructed from the measured projections by the filtered back projection method to perform the inverse Radon transform. In this study we have investigated the beam width on reconstructed image contrast. To go through the process, several experiments were performed with different collimation apertures. Finally, the contrast of different images is compared by computing the RMS contrast of each image.

1. INTRODUCTION

Here we study the image quality of the first generation computed tomography (CT) system single-source – single-detector. The goal of industrial gamma ray CT is to produce internal images of object with sufficient detail to detect important features. The visibility of an image depends on the difference in gamma rays attenuation between the features and its background. In the reconstructed image, contrast which is a valuable characteristic is usually used to assess the performance of a gamma ray CT [1–5].

Contrast is the difference in visual properties that makes an object (or its representation in an image) distinguishable from other objects and the background. RMS contrast is defined as the standard deviation of the pixel intensities:

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

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 [6, 7].

In gamma ray CT, the contrast is affected by several factors. These factors are density of phantom, detector, performances, photon energy, counting time, etc [8–10]. In this study, we considered the effect of beam width with different collimation apertures on reconstructed image contrast. The source and detector collimators play an important role in removing scattering influence and improving the reconstructed image contrast. Scattered photons are sometimes measured and they reduce the accuracy of reconstructed image and deteriorate the contrast. For studying this effect source and detector collimators were used with different geometries. The result root mean square (RMS) contrast will demonstrate the effect of above factors on reconstructed image contrast.

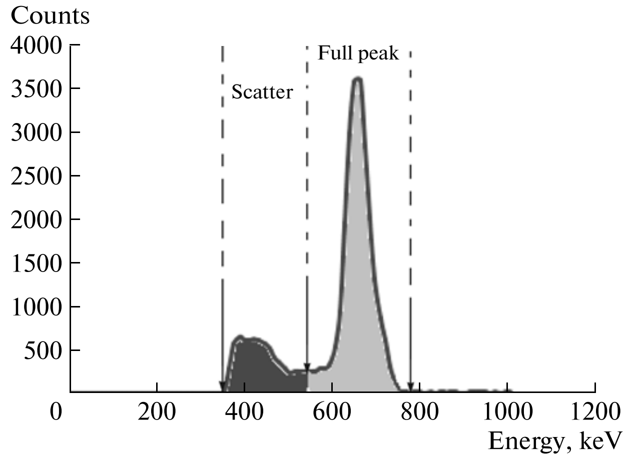

Fig. 1. The counts of full peak and scatter area.

Fig. 2. Configuration of source and detector collimator.

Further there are descriptions of the experimental set-up, and Monte-Carlo calculation and experimental results.

2. MONTE-CARLO CALCULATION RESULTS

To investigate the effects of beam width with different collimation apertures in gamma-ray CT on the counts of full peak and scatter area, we performed the simulations using MCNP- 4C code for several types of collimators (Fig. 1). The simulation results for examined geometries were demonstrated in two cases, separately. In the first case, the aperture of source collimator was constant 2 mm in diameter and the apertures of detector collimator were selected 5, 10 and 15 mm in diameter. In the second case, the aperture of detector collimator was constant 5 mm in diameter and the apertures of source collimator were selected 5, 10 and 15 mm in diameter. These geometries were selected through several cases which have acceptable condition experimentally. Also, the aperture of detector collimator should not be so large to increase dead time of detector.

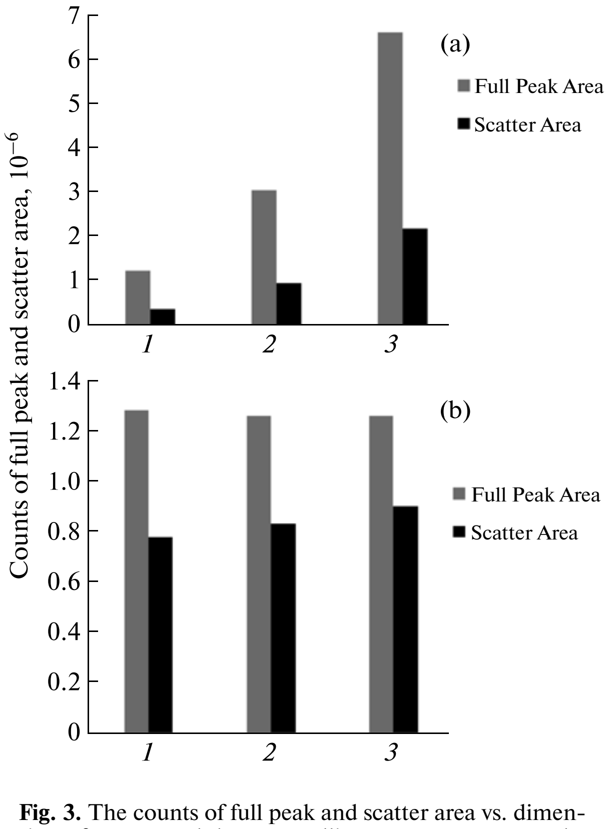

Fig. 3. The counts of full peak and scatter area vs. dimension of source and detector collimator apertures: **a** – the aperture of sources collimator is constant ∅2 mm and detectors collimator ∅5 (*1*), 10 (*2*), 15 mm (*3*); **b** – the aperture of detectors collimator is constant ∅5 mm and sources collimator ∅5 (*1*), 10 (*2*), 15 mm (*3*).

In this CT system detector was located opposite the center of the source in 550 mm distance and the phantom had 3 dimensional rotation capability using controller motors in the cylindrical coordinate (R, θ, Z) (Fig. 2). The obtained results from Monte Carlo simulations were given in Fig. 3.

3. EXPERIMENTAL SET-UP

A single-source – single-detector gamma computed tomography (CT) scanner system was used in this study. In this system a NaI(Tl) detector 5.08 cm in diameter was located opposite to the center of the ^{137}Cs (30 mCi) source in 550 mm distance. The detector and the source were aligned by a point semiconductor laser. The position of phantom was defined by three motors. The phantom rotated by step 4° ($\Delta\theta = 4°$) and moved in the direction of r with $\Delta r = 3$ mm. The CT scans were taken out by scanning 180° to collect attenuations beams. There were 50 × 50 projections to produce the image and time of each projection was 15 s. For better comparing of final reconstructed image was used interpolation to increase resolution. 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 as a cylindrical geometric figure 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}), air (1.184 mg · cm^{-3}). Nuclear electronic system consists of a NaI(Tl) (2 × 2, 905-3 model, Eberline company), and a specialized MCA (PSS-1, NSTRI, Tehran, Iran) consists of pre-amplifier, amplifier, high voltage (HV) and a data acquisition system. In this MCA, universal written 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 perform the inverse Radon transform.

4. RESULTS AND DISCUSSION

Measurements are made with a source of ^{137}Cs (30 mCi) and with the phantom with 3 holes. The results are represented using reconstructed images consisting of the RMS contrast. In this research, experimental conditions for improving contrast such as beam width were performed in different study cases (Fig. 4). The images Fig. 4a–4c represents the results with a source collimator ∅2 mm and a detector collimator ∅5, 10, 15 mm respectively. The images Fig. 4d–4f represents a detector collimator ∅5 mm and a source collimator ∅5, 10, 15 mm respectively. The RMS contrast of each image was given for collimators with different geometrics (Table).

RMS contrast for different source and detector apertures

Source collimator ∅, mm	Detector collimator ∅, mm	RMS contrast	Fig. 4
2	5	169.22	a
	10	468.10	b
	15	818.88	c
5	5	579.32	d
10		649.85	e
15		655.09	f

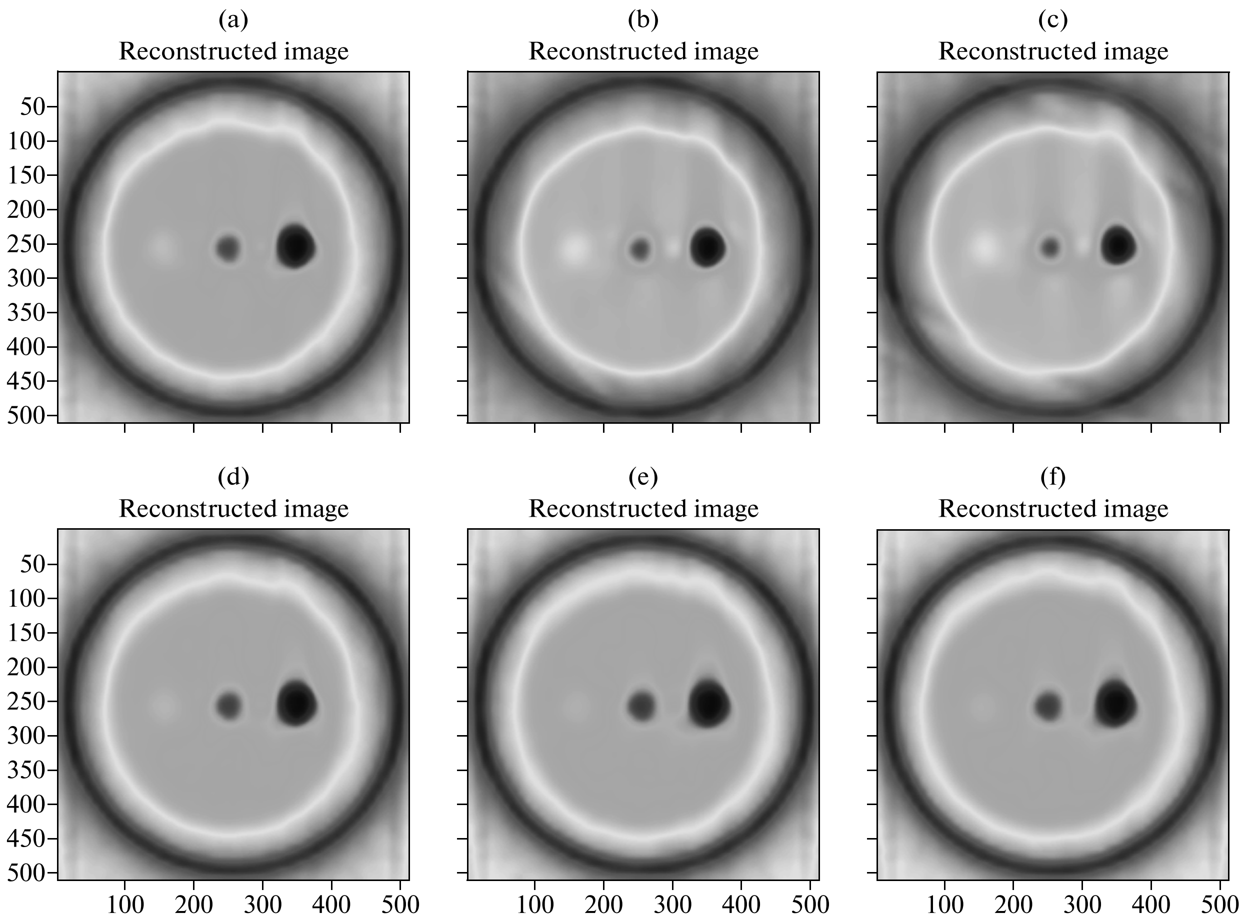

Fig. 4. Polyethylene phantom 2D image, mercury, iron, air holes with different collimation apertures: **a–c** – source collimator ∅2 mm, detector collimator ∅5, 10, 15 mm respectively; **d–f** – detector collimator ∅5 mm, source collimator ∅5, 10, 15 mm respectively.

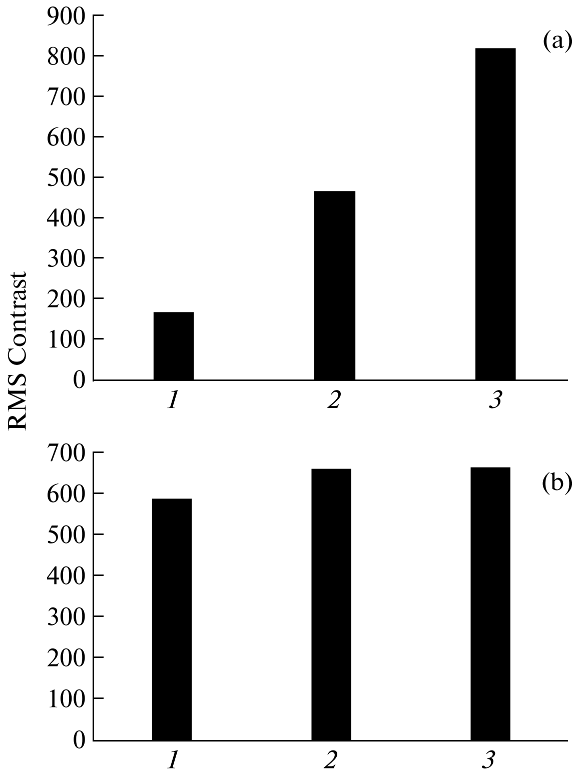

Fig. 5. RMS contrast as a function of different apertures in the source and detector collimator: **a** – the aperture of source collimator is constant ∅2 mm in diameter, detectors collimator: ∅5 (*1*), 10 (*2*), 15 mm (*3*); **b** – the aperture of detector collimator is constant ∅5 mm, sources collimator ∅5 (*1*), 10 (*2*), 15 mm (*3*).

5. CONCLUSION

The calculation and experimental results show that the changes of the beam width in the detector and source collimator has direct effect on reconstructed image contrast. For the constant source collimator aperture, the RMS contrast increases as the detector collimator aperture increases. Also, for the constant detector collimator aperture, the RMS contrast increases as the source collimator apertures increases, but this increasing is negligible.

Increasing the detector collimator aperture has better effect than increasing the source collimator aperture (Fig. 5). The acquired results of beam width can be performed on industrial and medical gamma ray CT to improve reconstructed image contrast and reduce absorbed dose and radiation exposure in patients and optimize the results of gamma ray CT.

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