Contribution of Scattered X Rays to Signal Imaging with Anti-scatter Grids

Koji Maeda [a, c], Hidetaka Arimura [a], Kaoru Morikawa [a],
Hitoshi Kanamori [b] and Masao Matsumoto [c]

[a] Faculty of Health Sciences, Hiroshima International University, Hiroshima 724-0695, Japan
[b] Prof. Emeritus, Kyoto Institute of Technology, Kyoto 606-8585, Japan
[c] Faculty of Medicine, Osaka University, Suita 565-0871, Japan
E-mail: k-maeda@hs.hirokoku-u.ac.jp

ABSTRACT

We have investigated the contribution of the scattered x rays to the signal imaging in the radiographs acquired with anti-scatter grids of several grid ratios by separating the line spread functions (LSFs) derived from the signal edge image into the primary and the scatter components. By using a 1.0-mm lead plate in the scattering material, the blurred signal edge images were acquired by use of an imaging plate at a tube voltage of 80 kV with the anti-scatter grids of grid ratios for 5:1, 6:1, 8:1, 10:1 and 12:1. The edge profiles of the signal images were scanned and those in relative exposure were differentiated to obtain the LSFs. To investigate the contribution of the scattered x rays to the signal imaging, we proposed a method for separating the LSFs derived from the signal images into the primary and the scatter components, where the scatter component was approximated with exponential function. Our basic approach is to separate the area of the LSFs by ratios of the scattered x-ray exposure to the primary x-ray exposure, which were obtained for the grid ratios by use of a lead disk method. The LSFs and the two components were Fourier transformed to obtain the modulation transfer functions (MTFs) and their two components. As the result, we found that, by using the anti-scatter grids, the scattered x rays were reduced, but the shape of the LSFs of the scatter component hardly changed. The contributions of the scatter component to the MTFs were not negligible (more than 10 %) for spatial frequencies lower than about 1.0 mm^{-1} and that was greater as the grid ratio decreasing. On the other hand, for higher frequencies, the primary component was dominant compared with the scatter component.

Keywords: scattered x rays, anti-scatter grid, line spread function (LSF), modulation transfer function (MTF), computed radiography.

1. INTRODUCTION

The scattered x rays yielding in the patient body give great influence on the sharpness and the contrast of the signal images on the radiographs. The anti-scatter grids have been used to reduce the scattered x rays so that the detectability of signals by radiologists or computer-aided diagnostic systems can not decrease. Although several studies have been made about the effect of the scattered x rays on the contrast of the signal image[1, 2] or the signal-to-noise ratio[3, 4], little is known about the contribution of the scattered x rays to the signal imaging[5, 6] with the anti-scatter grids. The purpose of this study is to investigate the contribution of the scattered x rays to the signal imaging by separating the line spread functions (LSFs) into the primary and scatter components. For the purpose, we propose the method for separating the LSFs into their two components. The LSFs and their two components were Fourier transformed to obtain the modulation transfer functions (MTFs) and their two components.

2. MATERIALS AND METHODS

2. 1. Acquisition of the signal edge images and the line spread functions

The experimental set-up used for producing the signal images was shown in Fig. 1. The x-ray source was a Shimadzu Circlex 0.6/1.2 P38DE-80 tube coupled to an inverter x-ray generator Shimadzu UD150B-30. The tube voltage was set at 80 kV. To obtain the signal images with anti-scatter grids, the thin lead plate (10 mm × 10 mm × 1.0 mm) was placed in the center of the scattering materials made of the polymethyl methacrylate (PMMA, 30 cm × 30 cm × 20 cm). An anti-scatter grid of the grid ratio for 5:1, 6:1, 8:1, 10:1 or 12:1 was placed on the front of an imaging plate (IP, Fuji ST-V_N, BaFBr: Eu^{2+}). The source-to-detector distance of 110 cm and the rectangular exposure field of 20 cm × 20 cm at the surface of the scattering material were chosen. The signal images on the IP were digitized with a pixel size of

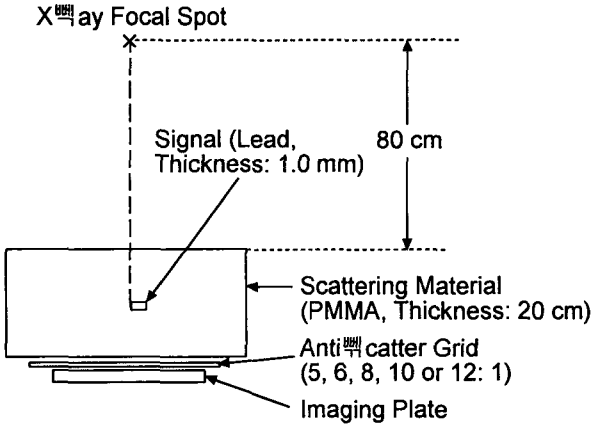


Fig. 1 Experimental set-up for producing the signal images.

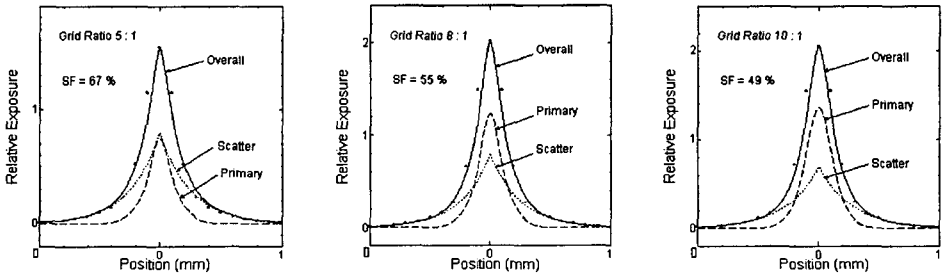
0.1 mm and 1024 gray levels by use of a computed radiography system (Fuji FCR-AC3 HQ). In each signal image, 60 profiles of the signal edge were obtained to average. The averaged edge profile in pixel value was converted into that in relative exposure and differentiated to acquire the LSFs.

2.2. Separation of the line spread functions into the primary and scatter components

In order to evaluate the contribution of the scattered x rays to the signal imaging, we propose a method for separating the LSFs of the signal edge images into the primary and scatter components. According to the theory of Barrett and Swindell[7], it is considered that the MTF of the signal images blurred by the scattered x rays and the imaging detector consists of the primary and scatter components. Hence, the LSF of the signal image is also composed of the primary and scatter components. In this study, the primary component of the LSF was derived from the MTF of the IP measured in another study[8], and the scatter component of the LSF was approximated with the exponential function. The area of the LSF was separated into the primary or scatter components by the ratio of the primary and scattered x-ray exposure to the total exposure. The ratios of the primary and scatter x-ray exposure to the total exposure were experimentally obtained with the lead disk method. Finally, the LSFs and the their components were Fourier transformed to obtain the MTFs and their two components.

3. RESULTS AND DISCUSSION

Figure 2 shows the primary and scatter components of the LSFs of the signal images for several grid ratios. In the tail part of the LSFs, the scattered components greatly contributed to the total LSFs for all grid ratios and the contribution was increased as the grid ratio decreased. As the grid ratio increased, the height of the scatter components for the overall LSFs were decreased, but the shape of the scatter components hardly varied. In other words, by using the anti-scatter grids, the scattered x rays were reduced, but the shape of the point spread functions of the scattered x rays hardly changed. Figure 3 shows the primary and scatter components of the MTFs of the signal images. The MTF values of the primary and scatter components at a spatial frequency of 0 mm^{-1} were equal to the primary and scatter fractions. Therefore, as the grid ratio increased, the MTF value of the scatter component at low frequencies became smaller. The contribution of the scatter component decreased with the grid ratio increasing, but that was more than 0.1 at frequencies lower than 1.0 mm^{-1} for all grid ratios. On the other hand, for higher frequencies, the primary component was dominant compared with the scatter component.



(a) (b) (c)

Fig. 2 The primary and scatter component of the LSFs of the signal images with anti-scatter grid of grid ratios for (a) 5: 1, (b) 8: 1 and (c) 10: 1.

4. CONCLUSIONS

By separating the LSFs and MTFs derived from the signal edge images into the primary and the scatter components, we investigated the contribution of the scattered x rays to the signal imaging in the radiographs acquired with anti-scattered grids of several grid ratios. To evaluate the contribution of the scattered x rays, we proposed a method for separating the LSFs derived from the signal edge images into the primary and scatter components. As a result, we found that, by using the anti-scatter grids, the scattered x rays were reduced, but the shape of the LSFs of the scatter component hardly changed. The contributions of the scatter component to the MTFs were more than 10 % for spatial frequencies lower than about 1.0 mm^{-1} and those were greater as the grid ratio decreasing. On the other hand, for higher frequencies, the primary component was dominant compared with the scatter component.

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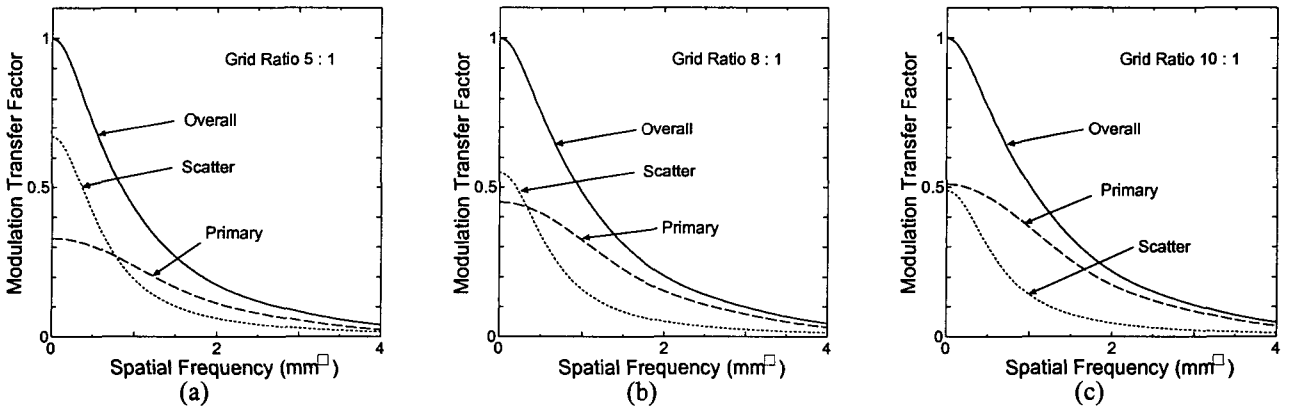

Fig. 3 The primary and scatter components of the MTFs of the signal images with anti-scatter grid of grid ratios for (a) 5: 1, (b) 8: 1 and (c) 10: 1.