Monte Carlo Simulation-Based Feasibility Study of Novel Digital Mammography System to Reduce Scattered Radiation

Yongsu Yoon[1], Ph.D., Junji Morishita[1], Ph.D., Kihyun Kim[2], Ph.D., and Jungmin Kim[2], Ph.D.

[1]Department of Health Sciences, Faculty of Medical Sciences, Kyushu University, Fukuoka, JAPAN,

[2]School of Health and Environmental Sciences, Korea University, Seoul, KOREA

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INTRODUCTION

The conventional anti-scatter grid with a repeating structure of radiopaque and radiolucent material has been used to remove scatter radiation in film/screen systems since the early 1900's and there were no any new innovative changes in the era of digital radiography. Therefore, we consider this study to be innovate because the concept of novel indirect FPD system (Fig.1 and 2) is newly designed for removing scattered radiation which degrades the image contrast according to the structure of digital radiography system, especially aims to the mammography with low energy of incident X-ray and small image size.

Fig. 1

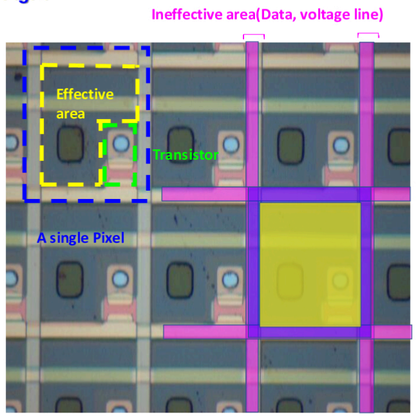
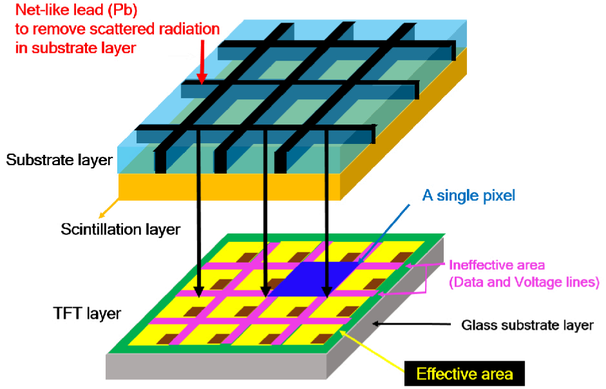


Fig. 2



The indirect FPD comprises three layers: a substrate, scintillation, and thin-film-transistor. (TFT layer) The TFT layer has a matrix structure with pixels. There are ineffective dimensions on the TFT layer, such as the voltage and data lines; **(Fig.1)** therefore, we devised a new FPD system having net-like lead in the substrate layer, matching the ineffective area, to block the scatter radiation so that only primary X-rays could reach the effective dimension. **(Fig. 2)**

MATERIALS AND METHODS

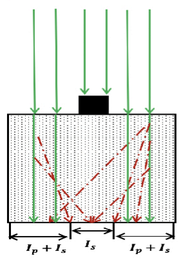
Figure 3 shows the geometry for calculating the scatter fractions (SFs). The source to detector distance (SID) is 65 cm and the lead (Pb) cylinder with 0.6 cm diameter and 1 cm of height is placed on the top of PMMA phantom, thus only scattered radiation would be detected. SF is calculated by using the equation :

$$SF = \frac{I_s}{I_p + I_s} \times 100$$

Table. 1

Matrix size	257 × 257
Total Pixel Size (μm²)	81.5
Thickness of lead (Ineffective area, μm)	20
Effective area in each pixel (μm²)	71.5
Thickness of CsI (μm)	200

Fig. 3



MATERIALS AND METHODS (CONT'D)

We have been proposed the novel indirect FPD system for general radiographic examination. Proposed FPD has a net-like Pb in the substrate layer matching the ineffective area on the thin film transistor (TFT) layer, thus Pb does not block the effective area where detect the signal from the scintillation layer. According to previous study, the novel FPD system indicated better performance for low range of incident X-ray (~40kV), therefore we have introduced this novel concept into the FPD for mammography.

To evaluate the performance of proposed system for mammography, we conducted a Monte Carlo simulation using MCNPX 2.7.0 software. RQA-M2 (28kVp, Mo/Mo, 2 mm Al-filtration) of continuous spectrum was exposed to 2, 4, and 6 cm-thickness Polymethyl methacrylate (PMMA) phantom to compute scatter fractions (SFs) with 3 different systems such as no-grid, linear grid (5:1 grid ratio), and the novel system. Simulated indirect FPD system (**Table 1**) has 81.5 μm2 of pixel size with 10 μm-ineffective area in the border of pixels, thus the effective area of pixels is 71.5 μm2. 10 μm-thickness of Pb was embedded in substrate layer matching the ineffective area on TFT layer for the novel system only.

RESULTS AND DISCCUSIONS

Figure 4 shows scatter fractions (SFs) of novel system (~7%) were lower than those of system with linear grid (~10%) and no-grid system (~32%) at 4 cm-thickness PMMA phantom. Similar tendency of performance for reducing scattered radiation was shown at 2 and 6 cm-thickness PMMA phantom. According to the previous study for experimental data, SFs of no-grid system (~38%) and those of linear grid (~14%) with same grid ratio (5:1) and same energy of incident X-ray (28kVp) were similar tendency with our simulation data. In addition, the artifacts resembling a Moiré pattern appeared on the simulated image of the system with linear grid in **Figure 5**. However, our novel system uses a Pb net-like structure to match the ineffective area on the TFT layer, thus the shadow of the Pb structure does not appear on the image and the scatter radiation is removed.

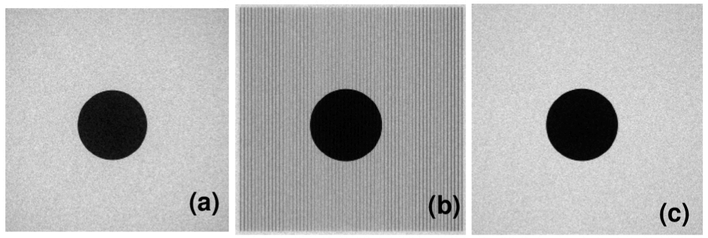


Fig. 5 Simulated images from 3 different systems in 4 cm-thickness PMMA phantom (a: no-grid system, b: system with linear grid, c: novel system),

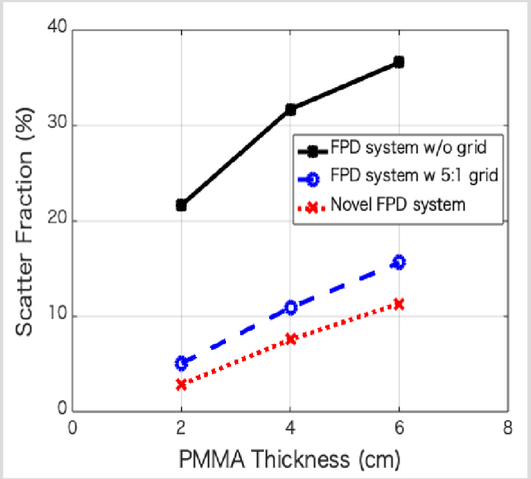


Fig. 4

The result of scatter fraction for 3 different systems with various thickness of PMMA phantom

CONCLUSION

The novel FPD system to remove scattered radiation showed the potential usefulness on the digital mammography with lower energy of incident X-ray and smaller pixel sizes.

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