Advanced Digital Mammography

Ronald B. Schilling, John D. Cox, and S.R. Dev Sharma

Mammography is the most effective method for early detection of breast cancer and yet, 10% to 30% of women who have breast cancer and undergo mammography have negative mammograms. Furthermore, of the women who are sent to biopsy, only 20% to 40% actually have breast cancer. Quantitative analysis of the radiographic features of microcalcifications and masses may help radiologists improve their specificity.

KEY WORDS: mammography, digital, slot-scan, low dose.

THE CURRENT state-of-the-art in screening and diagnostic mammography[1,2] is still conventional film-screen mammography. However, the efficacy of film-screen mammography is limited by its dynamic range, low contrast resolution, film noise, dose-inefficient scatter reduction, and film processing artifacts. It offers low diagnostic specificity in the range of 20% to 30% resulting in a high number of false-positive film-screen initiated biopsies, the cost of which alone is estimated at several hundred million dollars. It is currently estimated that one of every four women screened annually for 10 years by film-screen mammography will experience the anxiety and cost of a screening initiated false-positive mammogram (benign biopsy).

PGI (Los Altos Hills, CA) is currently developing two primary x-ray, slot-scanned digital mammography (DXM-1) prototype units based on high performance direct x-ray detection hybrid sensors. The system is schematically shown in Fig 1. The heart of this system is the semiconductor x-radiation sensors. As shown in Fig 1, the transmission is similar to a conventional (screen-film) mammography system except for a moving aperture. It consists of a x-ray tube and a beam collimating aperture that rotates about the tube focal spot. The moving aperture protects the patient from 'unsensed' x-rays by providing a fan shaped beam synchronous in its motion to the sensor assembly on the receptor side.

The key system specifications are listed below.

Field of view. The system must image an area of similar size to that of a conventional mammography system (180 × 240 mm) and must be able to record this image with sufficient pixels to maintain the desired resolution.

Exposure time. The image must be acquired in a time consistent with reasonable comfort for the patient and in a way that the susceptibility to patient motion is no worse than a conventional film-screen system.

Image quality. The quality of the image produced (sharpness, contrast, signal-to-noise ratio [SNR]) should be significantly superior to conventional film-screen systems at moderate and high spatial frequencies, and at a minimum, equal to conventional systems at low spatial frequencies.

Dose efficiency. System should have high dose quality efficient (DQE) to reduce dose to the patient without sacrificing image quality.

The high predicted DQE of the DXM-1 system allows x-ray exposure to be reduced by a factor of up to 5 from the typical film-screen exposures while maintaining the same signal to noise ratio at low spatial frequencies. Even at this reduced exposure, this system will have a better signal to noise ratio at 13 lp/mm than film-screen at 10 lp/mm.

Figure 2 shows assembly of a direct x-ray sensing hybrid semiconductor sensor employed in the DXM-1. The sensor is a hybrid structure incorporating a detector and a readout/multiplexer. The detector is a silicon PiN diode array with a thickness of 1.5 mm. It is hybridized to a low noise readout IC (silicon) through indium metal interconnects. The hybrid sensor has a significant advantage that the detector IC and the readout IC can be designed, optimized, and fabricated separately. Each sensor is about 6 mm wide and 23 mm in length. As shown in Fig 3, eight of these sensors are aligned to form a staggered array for a cross-scan dimension of about 180 mm. With an in-scan motion for 4 seconds, it provides a normal size mammogram (180 mm by 240 mm).

Figure 4 shows the predicted and measured values of quantum efficiency for 1.0 mm and 1.5 mm thick detectors with molybdenum and tungsten x-ray spectra. As shown in this figure, the measured DQE data are consistent with the predicted values.

From PGI Corporation, Los Altos Hills, CA.

Address reprint requests to Ronald B. Schilling, PhD, 13650 Paseo del Roble, Los Altos Hills, CA 94022.

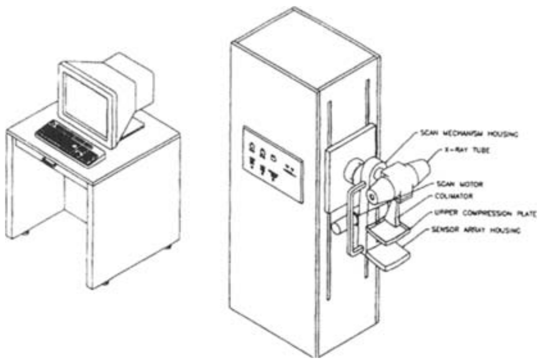

Fig 1. Slot-scan and semiconductor detectors replace film in otherwise conventional system configuration.

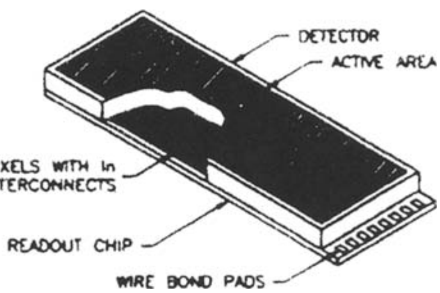

Fig 2. Hybrid radiation sensor allows for optimization and fabrication of the detector and the readout/multiplexer IC's separately.

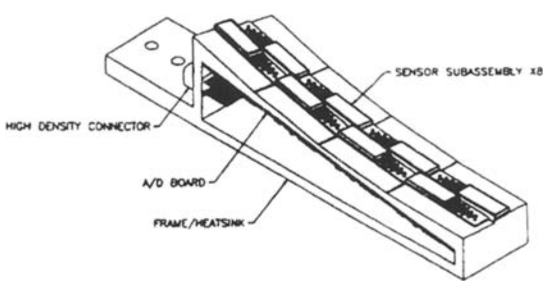

Fig 3. Eight hybrid sensors in cross-scan give a normal size mammogram. (180 mm × 240 mm).

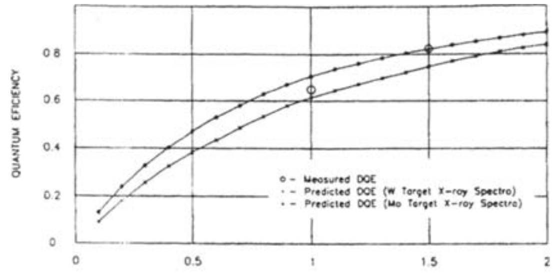

Fig 4. The measured and predicted quantum efficiency data is consistent with predicted values.

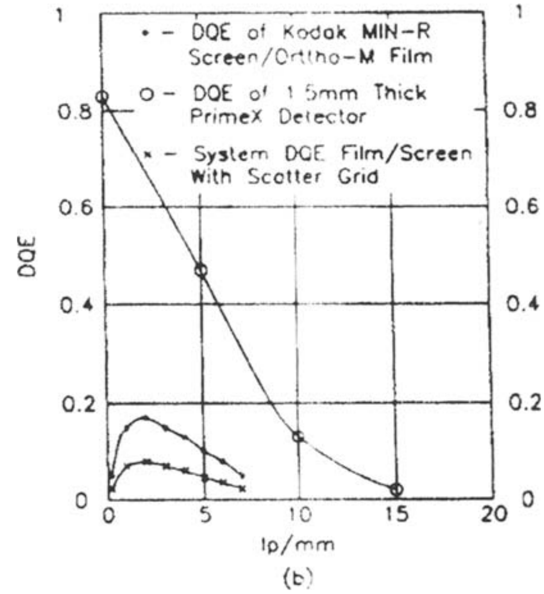

Fig 5. Primary slot scan system DQE is significantly higher than the film-screen mammography system.

As shown in Fig 5, the PGI direct x-ray sensing system DQE is significantly better than the film-screen system. The measured quantum efficiency of a 1.5 mm thick detector is over 80%. On the other hand, scatter and grid effects reduce the film-screen system DQE to about 7% to 20%. Figure 6 shows that the modulation transfer function (MTF) data approaches the predicted values. At 10 line pairs/

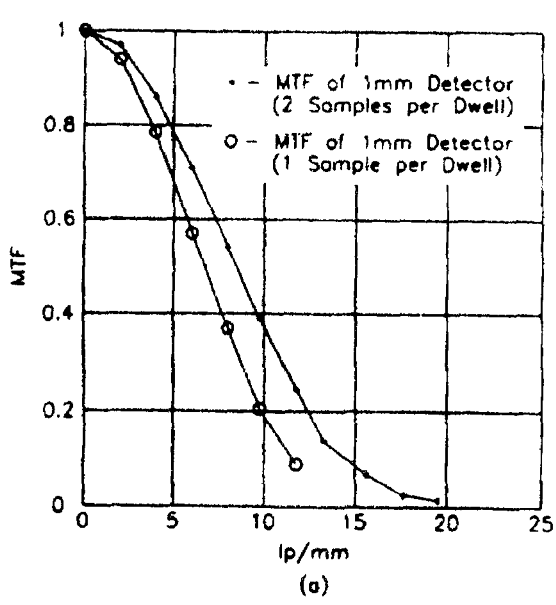

Fig 6. Measured MTF data is consistent with the predicted values.

mm, the system MTF is 20% when the sensor is operated in one sample per dwell mode and almost 40% when the sensor is operated in the two samples per dwell mode. This MTF performance is far superior to a film-screen system.

PGI has been awarded a contract from the US Army Medical Research and Materiel Command through a Broad Agency Announcement for Breast Cancer Research. The 3-year contract began on July 1, 1996 and will provide funding to complete the development of the prototype DXM-1 low-dose digital mammography system and pursue a vigorous technical and clinical evaluation. The clinical evaluation will evaluate film screen versus digital mammography using 1,000 women as volunteers.

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