NOISE POWER SPECTRUM OF COMPUTED MAMMOGRAPHY AND FULL FIELD DIGITAL MAMMOGRAPHY

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To my beloved ibu, ayah and my

Lovely siblings

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In the name of ALLAH, the most merciful and beneficial

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ABSTRACT

Noise in medical imaging is one of the parameters that need to be measured in image analysis. Noise of an image can be measured by noise power spectrum (NPS). A comparison of two types of mammography imaging machine namely Hologic Lorad Selenia Full-field Digital Mammography (FFDM) and Hologic Lorad M-IV Series Computed Mammography (CM) has been made to identify the system of mammography that has higher noise level. Both types of machine use automatic exposure control (AEC) for image acquisition. A potential of 30 kVp and 110 mAs-120 mAs has been applied. The images that are obtained from both of machines are analysed using MATLAB programme MATLAB Version 7.8.0 (R2009a). The best technique of NPS computations, Dobbin's method has been applied. NPS is shown using 2-Dimensional mesh plot and 1-Dimensional graph taken from the extraction of 2-Dimensional graph where the noise power spectra versus values spatial frequency are shown. Noise level of the images from both machines are studied and compared. The sensitivity of NPS is at lower spatial frequency.The comparison shows that at lower spatial frequency, CM image has higher noise level compared to FFDM image, and at higher frequency, FFDM image has higher noise level compared to CM image. The noise level is in the range of 10^{-3}-10^{-6} mm^2. In conclusion, CM has higher noise compared to FFDM.

ABSTRAK

Hingar dalam pengimejan perubatan merupakan salah satu parameter yang perlu diukur dalam menentukan kualiti sesuatu imej. Hingar imej boleh dikira melalui spektrum kuasa hingar. Perbandingan antara dua jenis mesin mammografi iaitu Hologic Lorad Selenia Full-field Digital Mammography (FFDM) dan Hologic Lorad M-IV Series Computed Mammography (CM) dilakukan untuk menentukan mesin mammografi yang mempunyai hingar yang lebih tinggi. Kedua-dua jenis mesin menggunakan pengawalan dedahan automatik (AEC) untuk penghasilan imej. Dedahan sebanyak 30 kVp dan 110-120 mAs digunakan. Imej yang terhasil daripada kedua-dua jenis mesin dianalisis menggunakan program MATLAB, MATLAB Versi 7.8.0 (R2009a). Teknik terbaik untuk mengira spektrum kuasa hingar adalah menggunakan kaedah Dobbin. Spektrum kuasa hingar dipaparkan menggunakan graf 2-Dimensi dan graf 1-Dimensi diperoleh melalui hirisan graf 2-Dimensi dimana spektra kuasa hingar melawan frekuensi ruang. Spektrum kuasa hingar untuk kedua-dua jenis mesin dianalisis dan dibandingkan. Sensitiviti pengiraan spectrum kuasa hingat terletak pada frekuensi ruang yang rendah. Perbandingan menunjukkan pada frekuensi ruang yang rendah, imej CM mempunyai nilai hingar yang tinggi, dan pada frekuensi ruang yang tinggi, imej FFDM yang mempunya nilai hingar yang lebih tinggi. Nilai hingar yang diperoleh terletak antara julat 10^{-3}-10^{-6} mm^2. Kesimpulannya, imej CM mempunyai nilai hingar yang lebih tinggi daripada imej FFDM.

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LIST OF SYMBOLS AND ABBREVIATIONS

I	-	Intensity with film
I_0	-	Intensity without film
$\bar{I}$	-	Average background intensity
(x, y)	-	Spatial coordinates
(u, v)	-	Spatial frequency coordinates
$\Delta_x\Delta_y$	-	Pixel sizes in *x* and *y* axis
L	-	Length of FFT
N_x,N_y	-	Number of element
$\Delta D(x, y)$	-	Radiographic fluctuating components
BaFBr	-	Barium fluorobromide
BaFI	-	Barium flourohalide
Eu	-	Europium
a-Se	-	amorphous selenium
CaI	-	Caesium Iodide
ADC	-	Analogue Digital Converter
OD	-	Optical Density
CCD	-	Charged Couple Detector
CR	-	Computed Radiography
FFT	-	Fast Fourier Transform

NPS	-	Noise Power Spectrum
NNPS	-	Normalized Noise Power Spectrum
NQE	–	Noise Equivalent Quanta
MTF	–	Modulation Transfer Function
DQE	-	Detective Quantum Efficiency
CM	-	Computed Mammography
FFDM	-	Full-Field Digital Mammography
T	-	Transmittance
PSP	-	Photostimulable Phosphors Detector
PSL	-	Photostimulated Luminescence
PMT	-	Photo Multiplier Tube
TFT	–	Thin Film Transistor
QA	-	Quality Analysis
WS	-	Wiener Spectrum
ROI	-	Region of Interest
SNR	-	Signal Noise Ratio
TORMAM	-	Test Object Mammography
CDMAM	-	Contrast-detail Mammography

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Breast cancer is the most common cancer among women. In 2007, it is recorded in Malaysia breast cancer contributes 32.1 % meanwhile the other 67.9 % is for other cancers (Omar and Ibrahim, 2011). Technology developments in radiographic imaging insist clinicians in order to cure the cancer hence to reduce this percentage. Radiographic imaging specially mammography is used to detect the existence of breast cancer. The first mammography that was invented is film-screen mammography followed by computed mammography and full field digital mammography for current technologies.

Development of technology in medical fields especially in medical imaging field aids in image analysis. Digital system shows many advantages compared to analogue system. This includes low spatial resolution, higher contrast resolution and post processing techniques confer much improved image quality. Other than that, digital mammography also erases the use of film storage. In spite of that, there are some technical differences between digital and analogue that affect the reader's analysis of lesion (Gay *et al*., 2010).

1.1.1 Analogue Mammography System

Analogue system also known as conventional screen film system. This system is the pioneer system for recent radiography system (digital). This system has high resolution, simple, established, large areas and cheap. However, this system has limited dynamic range, need post-processing, and low speed. Basically, this system needs the usage of film. Composition of film usually, tabular grain emulsion, cubic grain emulsion and film emulsion which is silver halides (AgBr and AgI). It is bonded in a gelatine base. After exposure, latent image will be formed, which altered chemical bond. During film processing, latent image is visible by chemical reduction of the silver halides into metallic silver grains.

The image formed by film or in the form of a TV voltage, makes it harder to analyse the image. Subjective or semi-quantitative test objects are needed to analyse the image hence assess the image quality. Test object mammography (TOR MAM) and contrast-detail mammography (CDMAM) 3.4 (c-d) test objects are commonly test objects that are used. Test objects help in controlled input signal when imaged under standard conditions and observer needs to analyse the image. Objective image quality was measured by noise power spectrum (NPS) and modulation transfer function (MTF) (Marshall, 2006).

The parameter being measured for screen film radiography is the optical density (OD) of the film. OD is the degree of darkness measured by densitometer. As the exposure high, the film becomes darker. Transmittance (T) depends on the intensity of exposure.

$$T = \frac{I}{I_o} \tag{1.1}$$

$$OD = -\log(T) \tag{1.2}$$

where, I: Intensity with film

I_o : Intensity without film

Equation 1.1 shows relationship between intensity with film existence and transmittance. Equation 1.2 indicates that as transmittance increases, the OD decreases. If light totally transmitted, it has 0 OD. If OD is 4, meaning that no light transmit through film. Typical range OD of film for base density and fog density could exceeded of 0.25. Figure 1.1 indicates graph of X-ray exposure that has nonlinear (sigmoid) relationship with optical density of film known as The Hurted & Driffield (H&D) Curve (Testagrossa *et al*., 2012).

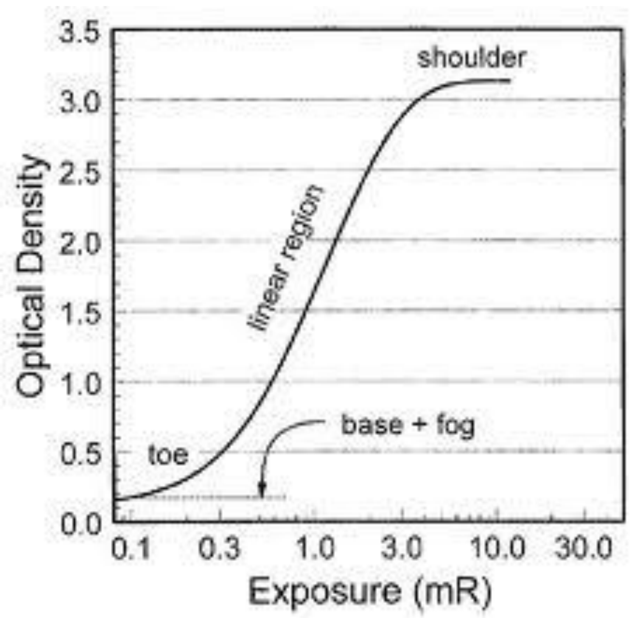

Figure 1.1: The Hurted & Driffield (H&D) curve describes optical density (OD) vs. the logarithms (base 10) of exposure (Testagrossa *et al*., 2012).

1.1.2 Digital Mammography System

Digital radiography system generally is higher resolution pixel detector than analogue radiography system. Digital radiography uses a digital signal processing. Fully digital mammography consists of direct and indirect conversion radiography system. Indirect conversion consists of image plated based on photostimulable phosphors detector known as computed radiography system (CR) and charged couple detector (CCD). Direct conversion consists of flat panels with amorphous Selenium or Caesium Iodide on amorphous Silicon detector known as full field digital mammography system (FFDM) and semiconductor pixel detector (MedipixI). CCD, CR and FFDM are based on integral read-out architecture; do not allow an effective noise rejection hence, detection contrasts become low of the signal while MedipixI operates in single photon counting mode that has high contrast detection (Bisogni *et al*., 2005).

CR system possesses half analogue and half digital system. CR uses film cassette and produces latent image (analogue picture). Signals produced in each pixel are analogue packet of charges (ADC) analogue to digital converter during image readout. Computed radiography is used as general digital radiography for applications that require moderate productivity, resolution and dose performance. However, because of some technical limitations, CR system could not produce the resolution performance of the state-of-the-art flat panel image receptor used in full-field digital mammography, FFDM (Smith, 2006).

Basically, amorphous selenium (a-Se) full field digital mammography system functions as breast assessment rather than screening. This system consists two distinct categories which are CR approach and integrated detector. CR involves the use of photostimulable phosphor plates held in cassette. Integrated detector uses an X-ray converter bonded to a thin film transistor (TFT) array which performs the image readout. Image is available directly on the hospital information network for integrated detector compared to CR which is manually handling (Marshall 2006).

1.2 Statements of Problem

Existence of noise produces low quality image, hence resulting a complex image, complicated for the radiologist to analyze. The performance of mammography is being compared in terms of noise. Noise can be quantitatively measured using NPS. The mammography machine with higher NPS is considered as low quality of mammography system. Although, there are some other quality measurements that need to be considered, this study mainly focus on NPS.

1.3 Objectives of Study

The general objective of this study is to identify the mammography system with higher NPS.

The specific objectives are:

1) To study and to analyze technique used to evaluate NPS.
2) To evaluate noise properties of two mammography systems by using Fast Fourier Transform (FFT) analysis of noise images.

1.4 Limitation of Study

This research is only focus on noise properties. Other physical properties such as spatial resolution and contrast could be analysed to conclude the efficiency of mammography thus, increase the image quality produced.

1.5 Significance of Study

It is important to know the noise power spectrum of mammography system. The information can be used to analyze the efficiency of the type of mammography itself. Hence, further research could be done to calculate the other physical properties, MTF of mammography thus, identify the source problem to improve the efficiency of the mammography machine. These parameters NPS and MTF are also part of the commissioning and routine quality analysis (QA) measurement in European Reference Organisation for Quality Assured Breast Screening and Diagnostic Services (EUREF) Digital Addendum, 2003 (Marshall 2006).

1.6 Thesis Outline

This thesis comprised of 5 chapters. Chapter 1 contains introduction and background of this thesis. Chapter 2 includes literature review that related to this thesis. Chapter 3 explains on how this research being done by using MATLAB programme to get NPS. Chapter 4 shows the results and discussion being made. Conclusion for this thesis and future work are expressed in Chapter 5.

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