Preliminary Modulation Transfer Function Study on Amorphous Silicon Flat Panel System for Industrial Digital Radiography

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Abstract. Modulation Transfer Function, ω (MTF) is the scientific means of evaluating the fundamental spatial resolution performance of an imaging system. In the study, the modulation transfer function of an amorphous silicon (aSi) sensor array is measured by using Edge Spread Function (ESF) Technique which is extracting a profile from the linearised image of the sharp edge. The Platinum foil is used to determine the ESF. The detector under study was a 2,304 (h) x 3,200 (v) total pixel matrix, 127 μm^2 pixel pitch, 57% fill factor and using Gd2O2S:Tb Kodak Lanex Regular as the conversion screen. The ESF measurement is done by using 75 – 100 kV range of x-ray with constant mA.

1.0 Introduction

Radiographic Technique (RT) is the most common and well-established Non-Destructive Testing (NDT). RT is known to be used sub-surface detection and internal defects in material. RT is a process of testing materials that uses penetrating radiation such as X-rays or gamma rays passed through an object and the image is recorded either by film or electronic detector. However, method of using film as a medium to get image has been in industry for more than 100 years.

The advancement of computer technology allow process of recording, detecting, acquiring the image in radiography being computerised so that it becomes easier and more effective, resulting to an establishment of film replacemnet technology. Nowadays, the demand for faster, reliable and easily retainable result is increasing without even artifact and image degradation over time, resulting availability to various types of digital detectors or imaging system. In order to have the digital detector valid for measurement or assesment of materials plant, physical image quality test needs to be performe. The assesment is a complicated multivariate quantity related to the contrast, resolution, and noise properties of imaging systems. It is a quantitative measurement and a requirement of ASME (Section 5, Article 2 (Mandatory Appendix)), EN (EN 14784-1) & IEC (62220-1).

Modulation transfer function, ω(MTF) is commonly measured for an evaluation of the spatial resolution properties of screen-film systems [1]. A measurement of sharpness for imaging system for component of a system and measured in lp/mm. It is a transfer function analysis where linearity and shift invariance conditions or ispoplanatism of the system must meet requirement before such assessment to be performed. MTF also describes the transfer of sinusoidal inputs in spatial frequency domain. There are at least three methods to measure the MTF namely, the slit, the square wave response function (SWRF), and the edge spread function methods (ESF). This paper describe preliminary findings of pre-sampled MTF by using ESF and the digital detector under study is build from amorphous silicon (A-Si) as an image receptor consisting of an array of individual sub-millimetre photodiodes.

Figure 1: Schematic of concept for MTF determination using ESF

2.0 Experimental Approach

2.1 Equipment

The equipment is an A-Si flat panel system. Its large-format (12" x 16" active image area) and 14-bit wide dynamic range eliminate the need for X-ray film in many radiographic applications. It has 248 mm x 195 mm active area, 2048 x 1536 pixels format and 127µm pixels size and 57% fill factor. It is coupled with scintillator screen ($Gd_2O_2S:Tb$ Kodak Lanex Regular) which converts x-rays into visible light.

2.2 Experimental approach

A series of ESF experiments were conducted on A-Si flat panel system operated in a continuous time mode at 70 kV and 2 mA. A Platinum (Pt) foil machined square edge were used as a test object in order to get the sharpest edge image. The foil is 0.5 mm thick and 75 x 100 mm dimension.

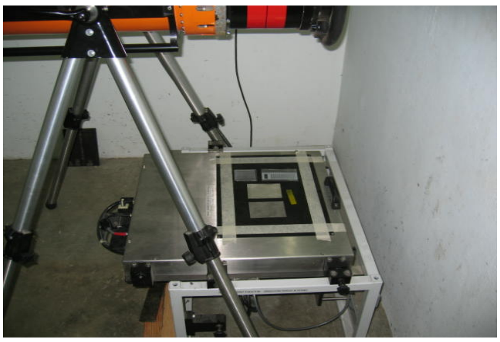


Figure 2: Experiment setup

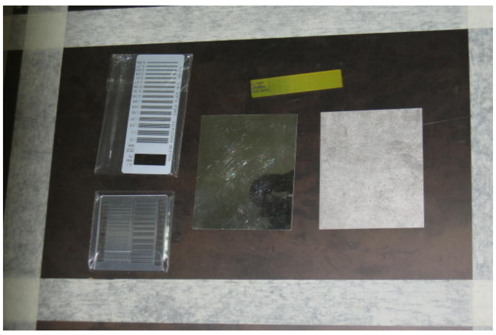


Figure 3: Test object for image quality assessment

The source of x-ray comes from panoramic 600 W continuous rating, 0.5 x 5.5 mm nominal focal spot size, and Tungsten as anode material. Exposure was done for 4 frames and 3.4 ms exposure time with some bad pixel map and shading corrections applied. Source to detector distance (SDD) was 680 mm due to limitation of x-ray tube stand.

3.0 Analysis techniques

Information regarding grey value level on image that being captured is acquired by using MATLAB. Image is cropped at its sharpest edge.

Figure 4: Sharp test edge

The value is averaged horizontally to get a mach band effect [2] or a set of edge profile. The result is Edge Spread Function (ESF) which can be simply determined by the following formula.

$$\mathrm{Avg}(f(x,y)) = f(0,0) + f(0,1) + f(0,2) + \ldots f(0.N-1) \quad (1)$$

Once the edge spread function has been determined, the MTF can be calculated as follows. The line spread function (LSF) of the system is calculated by taking the numerical derivative of the equally spaced ESF samples (Formula 2). A Fast Fourier Transform is performed on the resulting LSF (Formula 3), the normalized magnitude of which yields MTF. Care must be taken in selecting the number of points calculated along the ESF with respect to the sampling rate in order to obtain the desired number of points in the resulting MTF.

$$LSF(x) = \frac{d(Avg(f(x,y)))}{dx} \quad (2)$$

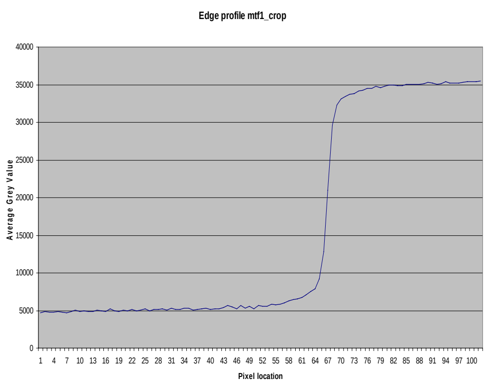
The dx value is taken as constant which is the pixel pitch. MTF (ω) is determined from fourier transformation of LSF.

$$\mathrm{MTF}\ (\omega) = \mathrm{FFT}\ \{LSF(x)\} \quad (3)$$

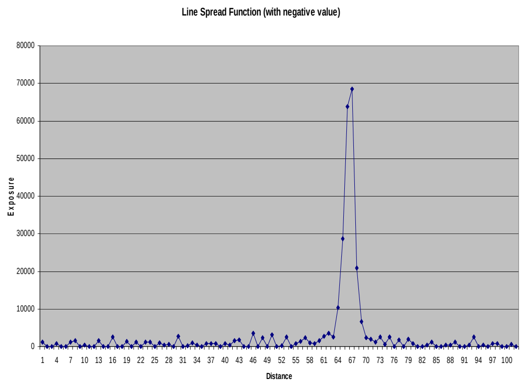
4.0 Result and discussion

The ESF graph for averaged grey value versus pixel distance along the horizontal axis is plotted in Graph 1. The graph shows system response to the input of an ideal edge.

From the averaged value, gradient were counted and some negative values exist. This is due to low Signal to Noise Ratio (SNR) which was measured by using iSee software developed in BAM-Berlin. The gradient is plotted which gives Line Spread Function (LSF) graph as plotted in Graph 2.

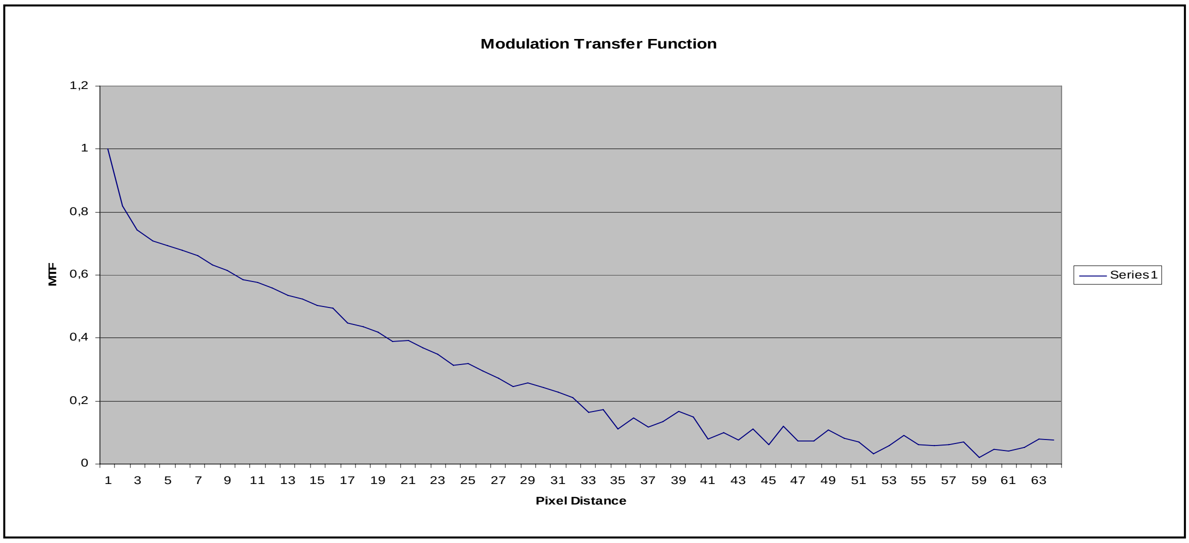


Graph1: Edge profile of the cropped image



Graph2: Line spread Function

The Fast Fourier Transform of LSF gave a result of Modulation Transfer Function. The maximum nyquist frequency for the detector 3.937 lp/mm. According to EN (EN 14784-1), the basic spatial resolution shall be determined from the MTF-value at 20% thus making the detector under test has an $MTF_{20\%}$ value of 1.9685 lp/mm.



Graph 3: Modulation Transfer Function (MTF)

However, the MTF curve which showed in graph 3 is a non well-behaved curve. It does not begins near to unity modulation at zero frequency and does not gradually becomes lower towards higher frequencies, until some point the modulation is not becoming zero and does not remains so for all higher frequency.

5.0 Conclusion

Edge method has its own advantages and disadvantages relative to the other method for MTF determination such as slit method. The advantage for edge method is, it produce LSF that has accurate measurement of the zero-frequency component. Second advantage for edge method is, it does not have the severe tube loading constraints of the slit method. In fact, edge technique is best used to determine MTF when combine with slit technique.

Ultimately, MTF is one component in characterizing the overall image quality performance of an imaging system. Other components include signal to noise ratio and radiometric accuracy.

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