Experimental Measurement of Modulation Transfer Function (MTF) in Five Commercial CT Scanners

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Abstract— **The modulation transfer function (MTF) is the technical description of spatial resolution for most imaging systems. the MTF describes how well an imaging system processes signal [1,4]. There are several methods for calculation of MTF that can be categorized in theoretical and experimental methods. In this study, in order to compare the performance of five different commercial CT scanner, an experimental method was used to calculate MTF in all scanners. The MTF curves were calculated for both axial and helical scanning mode and also for different slice thickness. The method for experimental measurement of MTF which called SD method is based on calculation of the standard deviation (SD) of CT numbers in different regions of scanned phantom and determination of coefficient modulation. The results calculated in this study using simple experimental measurements were in good agreement with published technical specification by manufacturers [5].**

Keywords— **Computed Tomography, Spatial Frequency, MTF, SD method.**

I. Introduction

The modulation transfer function (MTF) is the technical description of spatial resolution for most imaging systems. Generally, the MTF describes how well an imaging system processes signal. There are several methods for calculation of MTF that can be categorized in theoretical and experimental methods. In theoretical methods the MTF of the imaging system is calculated using the Fourier transform of the line spread function (LSF) or point spread function (PSF), while in experimental methods various resolution phantoms can be used for calculation of MTF [2,3].

In this study, in order to compare the performance of five different commercial CT scanner, an experimental method was used to calculate MTF in all scanners. In all experimental measurements the GE performance phantom which is water filled cylindrical phantom with Plexiglas envelope including slits with different spatial frequency was used, it should be noted that the resolution part of phantom was made with Plexiglas as well. The phantom includes slits with spatial frequencies of 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4.5, 6, 7, 9 lp/cm and each group includes 5 slits. The phantom was scanned in five different commercial CT scanner made by GE Healthcare Technologies company using a tube voltage of 120 kVp and 400 mAs with 5 mm and other slice thickness.

The MTF curves were calculated for both axial and helical scanning mode and also for different slice thickness. The method for experimental measurement of MTF which called SD method is based on calculation of the standard deviation (SD) of CT numbers in different regions of scanned phantom and determination of coefficient modulation. The results calculated in this study using simple experimental measurements were in good agreement with published technical specification by manufacturers. The dependency of MTF to scanning mode and slice thickness were not high and we could not see considerable differences between them. The SD experimental method for calculation of MTF validated in this study, our group plan to use this method for performance comparison of wider range of commercial CT scanners design by different manufacturers [5].

II. Material and methods

In this study, in order to compare the performance of five different commercial CT scanner, an experimental method was used to calculate MTF in all scanners. In all experimental measurements a water filled cylindrical phantom with Plexiglas envelope including slits with different spatial

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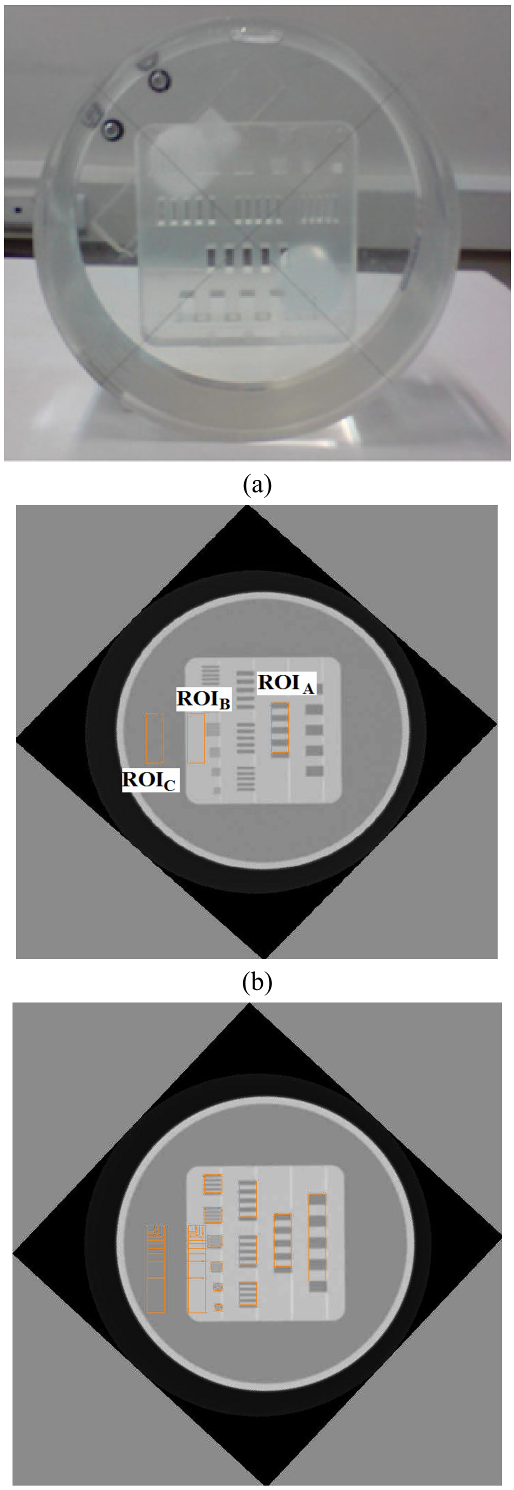


(a)

(b)

(c)

Fig. 1 (a) GE performance phantom. (b) The CT image of GE performance phantom containing 11 different spatial frequencies with three ROI regions A, B, C. (c) The ROIs for all spatial frequencies

frequency was used, it should be noted that the resolution part of phantom was made with Plexiglas as well, The phantom in this study called GE performance phantom. The phantom includes slits with spatial frequencies of 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4.5, 6, 7, 9 lp/cm and each group includes 5 slits (Figure 1.a). The phantom was scanned in five different commercial CT scanner made by GE Healthcare Technologies company listed in table 1 using a tube voltage of 120 kVp and 400 mAs with 5 mm and other slice thickness. The MTF curves were calculated for both axial and helical scanning mode and also for different slice thickness.

The method for experimental measurement of MTF which called SD method is based on calculation of the standard deviation (SD) of CT numbers in different regions of scanned phantom and determination of coefficient modulation. Three region of interest (ROI) were selected for each specific spatial frequency. First ROI was selected as it includes all slits of that spatial frequency (ROI_A), second ROI with the same dimension lied in a region which includes Plexiglas (ROI_B) and third ROI was determined by the same dimension in background region (ROI_C) (Figure 1.b). Then the contrast scale between ROI's in Plexiglas regions and background material was calculated, which is difference between average CT numbers in two regions. In next step, the SD of CT numbers in ROI_A and also the average SD for ROI_B and ROI_C which named ROI_{Ave} were calculated. By using these values, the coefficient modulation based on Eq. (1) was calculated and the then the MTF value for related spatial frequency can be calculated by replacing contrast scale and coefficient modulation values in Eq. (2). Thereafter, the MTF curve plotted by calculating the MTF value in different spatial frequencies using SD method.

$$Modulation = \sqrt{SD_A^{\;2} - SD_{Ave}^{\;2}} \quad (1)$$

$$MTF = 2.2 \times (Modulation / Contrast\ Scale) \quad (2)$$

III. Conclusions

Different commercial CT scanners (Table 1.) used in this study for calculate MTF curve by this method. MTF curve in different scan mode and slice thickness calculated.

Table 1

Scanner Number	Scanner Model	Number of Slices
CT 1	HiSpeed LX/i	Single slice
CT 2	BrightSpeed	Four slice
CT 3	HiSpeed FX/i	Single slice
CT 4	CT/e Plus	Dual slice
CT 5	HiSpeed NX/i	Dual slice

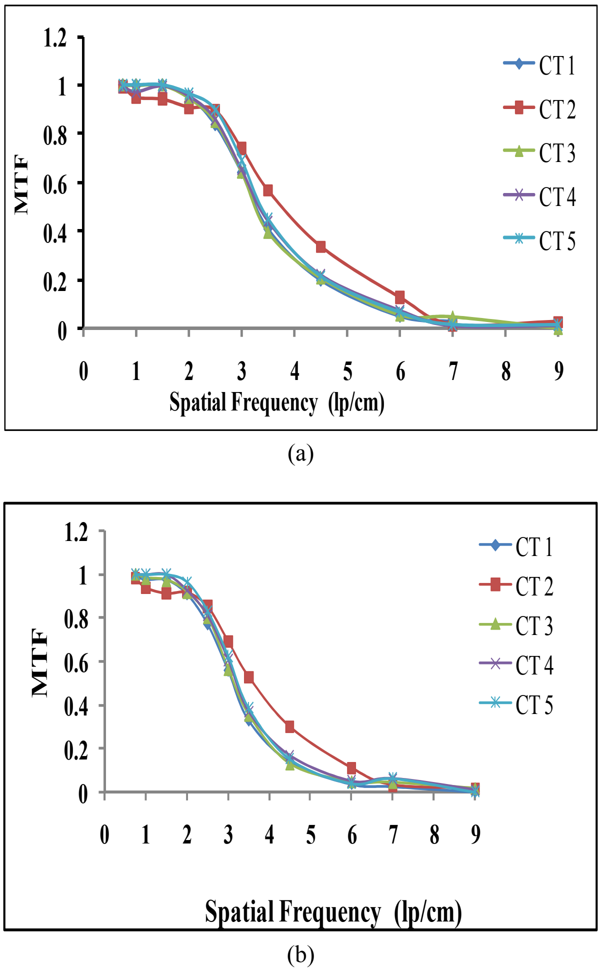


Fig. 2 (a) MTF curves in axial mode and 10 mm slice thickness for different CT scanners. (b) MTF curves in helical mode and 10 mm slice thickness for different CT scanners

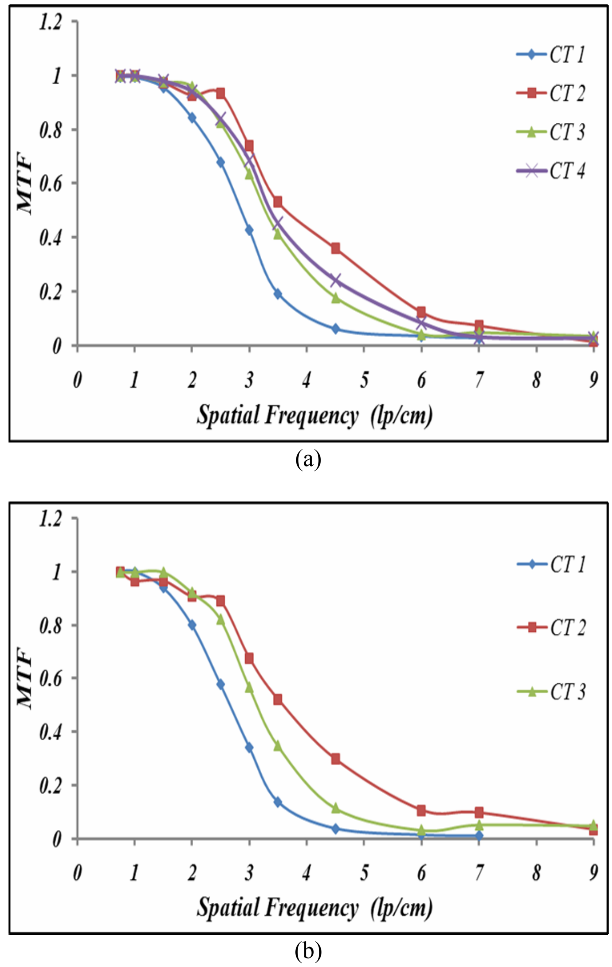
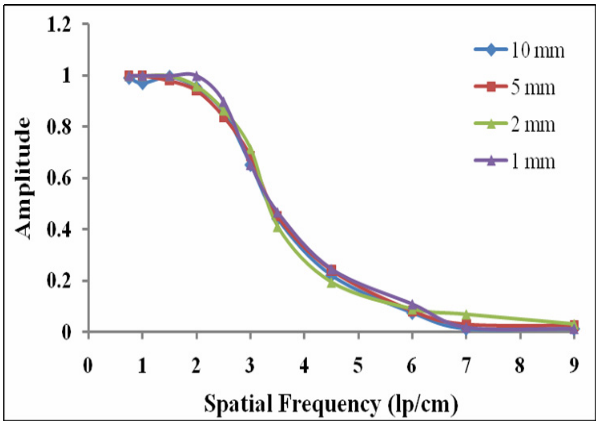


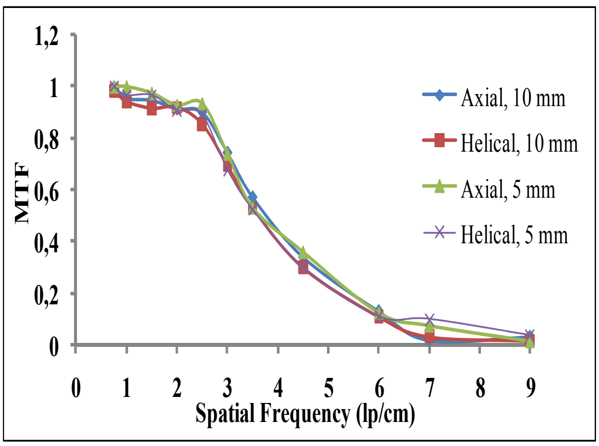
Fig. 3 (a) MTF curves in axial mode and 5 mm slice thickness for different CT scanners. (b) MTF curves in helical mode and 5 mm slice thickness for different CT scanners

Figure 2 shows the calculated MTF curves for different CT scanners in both axial and helical scanning mode in 10 mm slice thickness and Figure 3 shows the calculated MTF curves for different CT scanners in both axial and helical scanning mode in 5 mm slice thickness. Figure 4 shows the calculated MTF for CT4 (CT/e Plus) for different slice thickness and also different scanning mode.

The results shows better performance of GE BrightSpeed CT scanner (CT 2) in comparison to other scanner, as it was expected due to newer design of this scanner. The results calculated in this study using simple experimental measurements were in good agreement with published technical specification by manufacturers. The dependency of MTF to scanning mode in slice thickness of 10 mm was not high for different CT scanners and we could not see considerable differences between them but in slice thickness of 5 mm the difference between the calculated MTF curves dominant. Figure.4 shows the dependency of MTF to scanning mode and slice thickness were not high and we could not see considerable differences between them. The SD experimental method for calculation of MTF validated in this study, our group plan to use this method for performance comparison of wider range of commercial CT scanners design by different manufacturers.



(a)



(b)

Fig. 4 (a) MTF curves in axial mode at different slice thickness in CT4. (b) MTF curves in axial and helical mode at 5 and 10 mm slice thickness in CT4

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