

EVALUATION OF NEW DIGITAL DETECTORS FOR HIGH RESOLUTION RADIOGRAPHY

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Abstract:

In the actual study, two digital detectors were investigated : an amorphous silicon flat panel and a TDI multilinear detector. The contrast and IQI sensitivity was selected to compare flat panel and film radiography. The influence of X-ray conditions was assessed in the case of flat panel. Spatial resolution of both digital detectors was assessed by adapting the geometrical magnification for each, in order that their equivalent pixel size was comparable.

Introduction:

Film radiography is still in use in a number of industries, due to the high spatial resolution obtained, which allows detecting very small defects. However, new generations of digital detectors become more and more competitive towards film, in terms of contrast resolution and sensitivity. Even if the spatial resolution of films remains better, the digital detectors have good contrast performance and high grey-level dynamic range, which has already proved good defect sensitivities for some applications [1]. However, it is impossible to say in an absolute manner « this detector is better than film ». For each application, it is necessary to optimise the acquisition conditions in order to get the required image quality.

Our study is carried out in the low energy range, typically from 40 to 70 kV, on aluminium plates.

Some general elements of comparison are detailed in Table 1, between the two digital detectors in reference, with respect to film.

The flat panel detector under study consists of an amorphous silicon array covered by a Gadolinium oxysulfide scintillator screen. This detector features an active area comparable to film radiography, a high dynamic range, and a medium pixel size. The multilinear detector pixel size is much lower and its main peculiarity is the possibility to integrate several lines while the object under test is moving (time delay integration).

Table 1 : General elements of comparison between the two digital detectors with respect to film

<i>Flat panel</i>	<i>Film</i>	<i>Multilinear TDI</i>
Pixel size (127 µm)	Small grain size (~10 µm)	Pixel size (27 µm)
Short exposure time (~ sec)	Exposure time rather long (~ min)	Short exposure time (~ sec)
Image size 2300 * 3200 pixels		Image size 2048 pixels x <u>unlimited</u>
Large field (30 x 40 cm)	Large field (typical 30 x 40 cm)	TDI along 400 elements
		Speed 27 mm/s
Gd ₂ O ₂ S phosphor screen		Gd ₂ O ₂ S phosphor screen
Digital image (14 bits)	Digitization possible	Digital image (12 bits)

Some results obtained with flat panel in terms of contrast sensitivity and spatial resolution are detailed in the following section, and compared with film radiography. Then, spatial resolution of both flat panel and multilinear detector is compared (section 2) by means of the modulation transfer function.

1. Performances in terms of contrast and Image Quality Indicators sensitivity

As a first comparison, a visual determination of the smallest visible hole was carried out, at the same high voltage, using AFNOR Image Quality Indicators (IQI). The smallest visible hole was 0.4 mm in diameter for the flat panel image, by enhancing the grey-level contrast through histogram normalisation. The same hole was visible on the radiographic film (Kodak MX). Next figure shows the corresponding images, where the film was digitised (pixel size was fixed to 50 μm , and thus the image quality is not as good as the film itself).

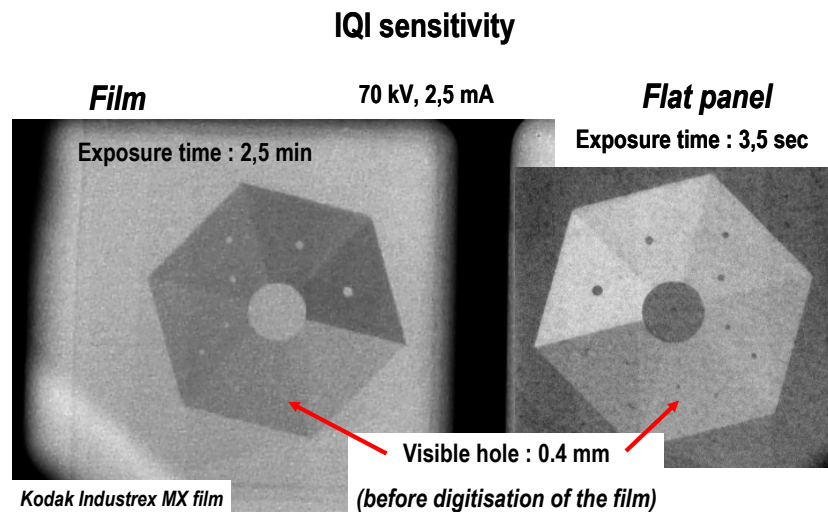


Figure 1 : Visual comparison of digitised film and flat panel image in the same X-ray conditions. In order to avoid a subjective decision by eye, a more precise study was carried out by analysing the grey-level profile obtained on wire type IQI, for flat panel images only. We decided not to digitise films, because it is well known that the digitisation will influence the spatial resolution [2], and thus the sensitivity to small details. However, for the sample under test (2mm aluminium plate), we checked that the smallest wire of the IQI was visible using film radiography (Kodak film AA).

Several images under different high voltages and intensity conditions were acquired, while calibrating the detector at the same level with respect to its saturation threshold.

1.1 Results obtained on wire type IQI with flat panel detector

Acquisition conditions Flatpanel (Flashscan)

High voltage 37 to 50 kV

Current 1 to 15 mA

Magnification 1.05, geometrical unsharpness 0.22 mm

Sample Aluminium plate 2 mm, IQI 10AL EN (wires 0.1 to 0.4 mm)

Calibration gain with 2.5 mm Al at 80 % of saturation level

Integration of 16 images (integration time 3.4 s per image)

On each image acquired, a grey-level profile is extracted and the respective grey-levels of each wire and neighbouring background are measured, as detailed in figure 2.

The relative contrast is then obtained by :

$$C_r (\%) = 100 \frac{n_0 - n_1}{n_0}$$

Background noise is measured on a square zone of 30 pixels area as the standard deviation of the grey-levels (σ_0), and thus it is possible to compute the contrast to noise ratio CNR :

$$CNR = \frac{n_0 - n_1}{\sigma_0}$$

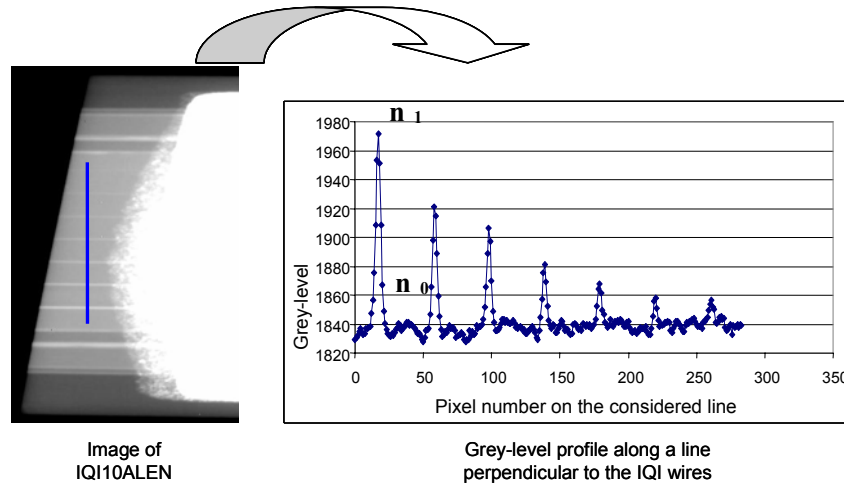


Figure 2 : Extraction of a grey-level profile and measurement of signal level of each wire (n_1) and background signal (n_0). Background noise is measured on a square zone of about 30 pixels area.

The following graph shows the evolution of the relative contrast versus wire diameter, for different high voltage conditions. Although the smallest wire is visible on the images, the signal as extracted on a single line profile does not show a significant contrast with respect to the background level. Integration of several line profiles would enhance its contrast, however, the 0.1 mm diameter is nearly the pixel size, and thus, not only the contrast but the spatial resolution is also responsible for its difficult detection.

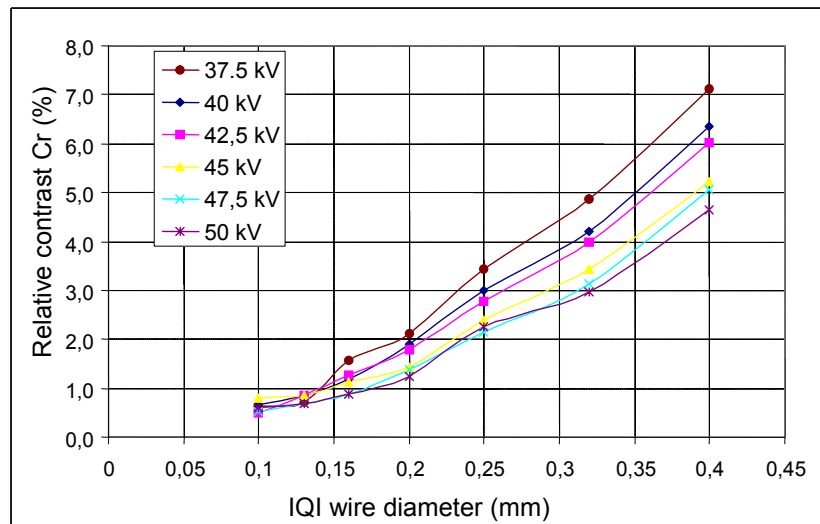


Figure 3 : Evolution of the relative contrast versus wire diameter, for different high voltages. The X-ray tube current (mA) is modified for each high voltage, in order to have the same signal with respect to detector saturation.

It is clear that the lowest the voltage, the better the relative contrast. The current level has no direct influence on the relative contrast, but it is well known that the signal to noise ratio is better when a higher photon flux is used.

Hence, the contrast to noise ratio was evaluated for two of the wires, at different current levels and 40 kV (figure 4). The highest the current, the better the CNR, due to the higher number of photons involved in the image. Although the CNR is not a parameter usual for film radiography, it is commonly used for assessing quality of digital images, as CNR is directly related to detectability of defects when using automatic image processing tools.

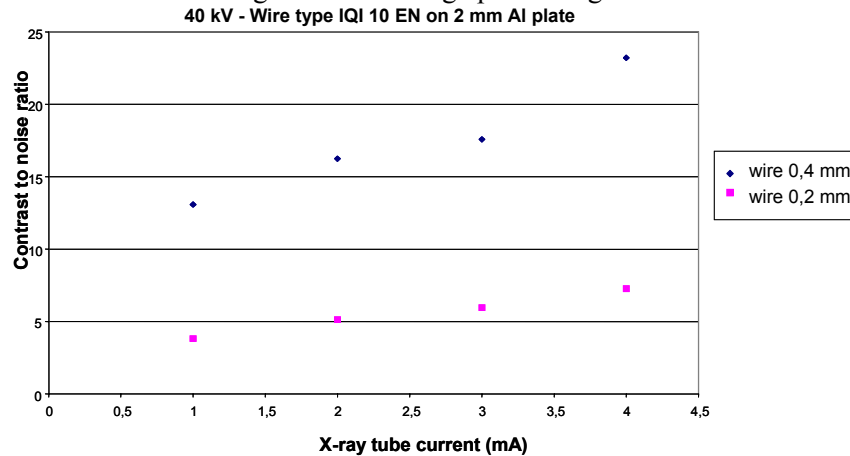


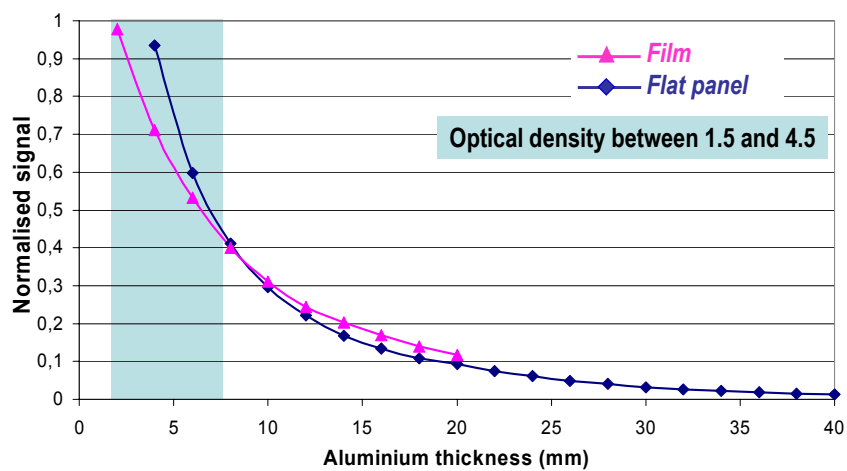
Figure 4: Evolution of contrast to noise ratio as a function of current, for 0.2 and 0.4 diameters wires, at 40 kV.

A good CNR is obtained on both wires, showing a good contrast sensitivity of the flat panel detector. However, the sensitivity is not sufficient to measure a contrast to noise ratio on the smallest wire (0.1 mm), although it is visible by eye on the image.

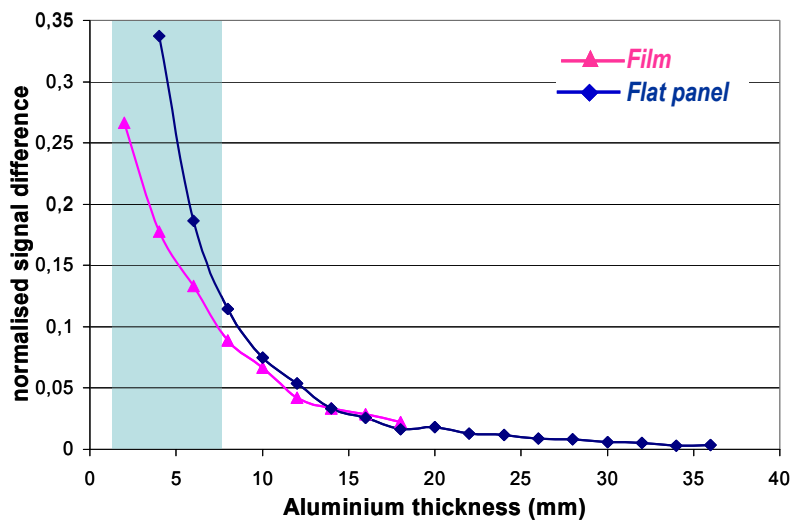
In order to compare the contrast sensitivity of the flat panel with film in a objective way, we chose to measure the signal obtained (where signal refers to the grey-level for flat panel, and optical density for film) as a function of aluminium thickness. This is explained in the following sub-section.

1.2 Comparison of contrast sensitivity with film radiography

An aluminium stepwedge was used to measure the contrast between two different thicknesses, for both flat panel and film (Kodak M100). The experiment is carried out at a high voltage of 60 kV, and the signal is normalised by the maximal value (grey-level of 4096 for flat panel, and optical density of 4.5 for film). The optical density was measured using an optical densitometer, without digitization of the film in order to prevent a signal degradation due to spatial resolution.



a)



b)

Figure 5 : Comparison between flat panel and film radiography(Kodak M100), at 60 kV : a) evolution of normalised signal versus aluminium thickness, b) normalised signal difference relative to a 2 mm thick step, as a fonction of aluminium thickness. The grey area highlights the range of optical density for which the film is required to be used (1.5 to 4.5).

The evolution of signal is very similar between flat panel and film. The normalisation value has a slight influence on the comparison, and we tried to find a comparable value for both, and we can see that the contrast evolution is equivalent between film and flat panel.

It is worth noting that, although all the grey-level range of digital detectors can be used, the contrast performance is of course better in the high grey-level range, and it should be important to define a standard to use digital detectors in the optimal exposure range, as it is done for film radiography.

2. Performances in terms of spatial resolution

Here we tried to compare flat panel detector with multilinear detector. As both detectors do not have the same pixel size, their spatial resolution was compared using a magnification factor for the flat panel, in order that the equivalent pixel at the object level be similar. Thus, a microfocus source was used in the case of flat panel, in such a way that the geometrical unsharpness does not influence the measurement.

Figure 6 details the geometrical arrangement of the experiments, and modulation transfer function obtained is plotted in figure 7.

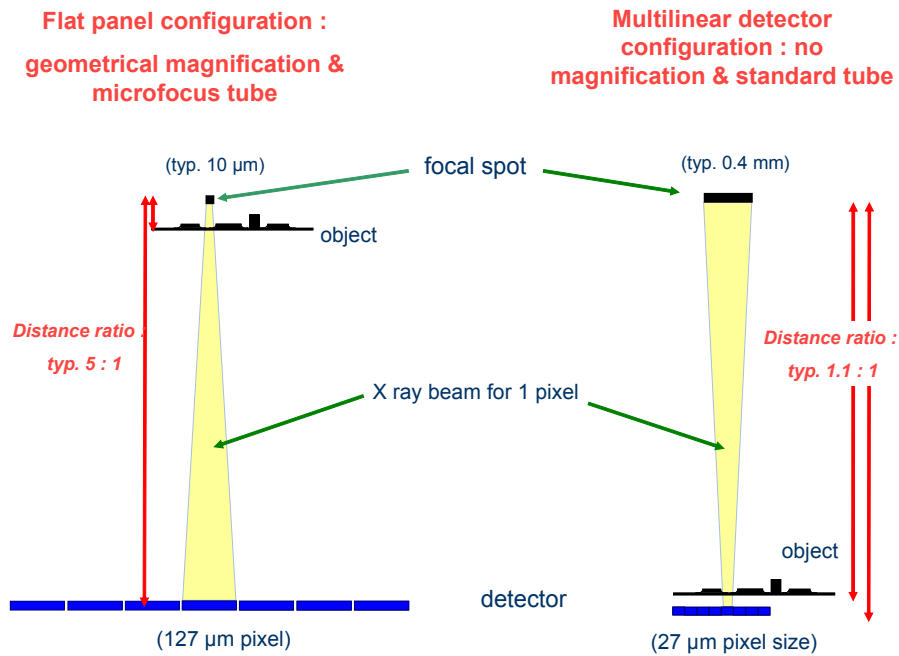


Figure 6 : Geometrical configuration of the experiment for both detectors [3] : equivalent pixel size at object level is similar. A microfocus tube is necessary for flat panel in order to prevent the geometrical unsharpness to influence spatial resolution measurement.

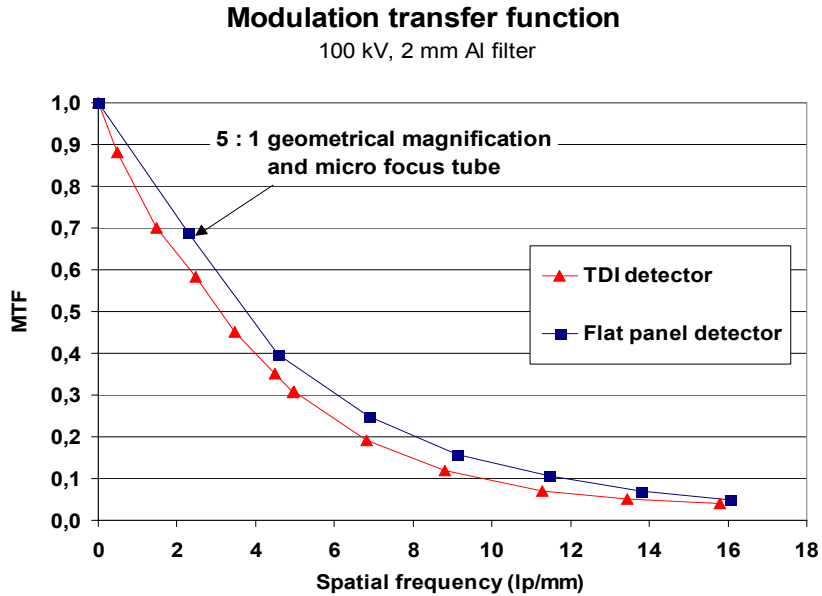


Figure 7 : Modulation transfer function obtained for both detectors in the same high voltage conditions, but using a microfocus tube in the case of flat panel in order to have a magnification factor of 5:1 [3].

The flat panel detector shows a slightly better transfer function, however, it requires the use of a microfocus tube.

Conclusions:

This preliminary study shows that it is now possible to get similar performances with digital detectors with respect to film radiography, especially as far as contrast sensitivity is concerned. Spatial resolution is still very hard to compete with, and from this point of view, the multilinear detector is very attractive because of its 27 μm pixel size, and its possibility to integrate several lines to enhance the signal to noise ratio. We have shown here that the spatial resolution of the multilinear detector is nearly the same as that of the flat panel used with a magnification factor of 5:1 (provided that a microfocus tube is used).

Our study is still on progress, and we will now investigate the contrast performance of the multilinear detector with respect to film, as we did for flat panel.

References:

- [1] M. Purshke, IQI sensitivity and applications of flat panel detectors and X-ray image intensifiers-a comparison, 8th ECNDT, Barcelona 2002,
- [2] U. Zscherpel and al. Comparative analysis of radiological detector systems, 8th ECNDT, Barcelona 2002,
- [3] J-M Casagrande, A. Koch, B. Munier, Comparison between a Flat Panel Detector and a Multi-linear Detector for X-ray NDT, ASNT conference, Totowa, USA, July 2003.