

Environment Influence on PSPL-based Digital Dental Radiology Systems

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ABSTRACT

Photo-stimulable phosphor luminescence technology (PSPL) has been used in Digora (Soredex, Finland) and Denoptix (CEDH Gendex, Italy) digital dental radiology imaging systems. PSPL plates store X-ray energy during exposition, being later processed by a laser reader and digitizer. Afterward they are erased and re-used. The large band of energy absorption provides PSPL systems with an extensive dynamic scale but at the same time a high sensibility to the incoming noise of environmental radiations. We have measured environment influences (electromagnetic radiation) for Digora and Denoptix plates after X-ray exposure and before digital processing. We have first compared the processing of PSPL plates "in dark" against "in light" environments. In another experiment, the exposed plates were also processed after being positioned 10 cm away from a 17 inches video monitor screen and to its laterals for 5, 10, 15, 20, 25 and 30 minutes (plates protected against light). The acquired images were used to calculate the noise power spectra (NPS) in each case. We have noticed that there was an increase in the noise spectra energy of "in light" processing compared to "in dark" processing. There was also an increment in the NPS energy when the images were processed after the exposition of the plates to the radiation emanated from video monitor.

Keywords: Digital dental radiology, quality assurance in radiodiagnostics, noise power spectra, photo-stimulable phosphorus luminescence.

1. INTRODUCTION

Digital methods of obtaining radiographic images are now widely available in general radiology. The advantages of these new methods over film-screen radiology¹ include faster examination times, digital image archive/communication, image processing and, usually, lower exposures². The most important methods are based on amorphous selenium (a-Se) and amorphous silicon (a-Si) photoconductive solid-state detector, selenium drum, charge-coupled device (CCD) and PSPL detectors^{3,4}. However, the influence from clinical environment and user operation procedures on image quality is not yet fully established.

The PSPL technology is based on europium-doped barium fluoroaluminum plates⁵, called storage phosphor or PSPL plates. When the storage phosphor plate is exposed to X-rays, electrons are excited to the conduction band, creating electron/hole pairs in the crystalline lattice. Half of stimulated electron/hole pairs preserve a metastable state, forming a latent image. The latent image can be recovered by a stimulated luminescence of these trapped electrons. Digora (Soredex Orion Corporation, Helsinki, Finland) and Denoptix (CEDH Gendex Dental System, Milan, Italy) systems uses PSPL plates to store energy during the X-ray exposure, being later processed by a laser reader (latent image recovering) and digitizer. Once the storage phosphor plate is read, it is flooded with light to erase any remaining image and prepare the plate to the next X-ray exposure. The erasing processes are accomplished automatically in the Digora system and manually on Denoptix system by PSPL plates exposition to negatoscopes light.

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The PSPL plates have a large band of energy absorption⁵, providing PSPL systems with an extensive dynamic scale but at the same time, a high sensibility to the incoming noise of environmental radiation. Our objective in this investigation was to evaluate environment electromagnetic radiation influences to Digora and Denoptix plates after exposing them to X-ray and before their processing by the laser reader. Both systems manufactures suggest to place the X-ray exposed PSPL plates in the laser reader on a poor enlightened environment, referred is this study as “in dark” condition. The effect in noise increment by placing plates in the laser reader under normal illumination (referred is in this study as “in light” condition) is not yet fully established. Another source of environment influence is the radiation leakage by video monitor screens (CRT) that it is still not fully established. The influence of both sources of noise in PSPL plates is studied in this paper.

2. MATERIAL AND METHODS

We have exposed PSPL plates to X-ray radiation. All exposures were carried out using the same dental X-ray unit, a GE 1000 (General Electric Company, Milwaukee, USA), operated at 60 kV_p, 10 mA, 32 cm focus-to-receptor distance and 0,3s exposure time, given a 840μGy dose. The system has an inherent 2.7mm Al pre-filtration plate. To provide a clinically comparable beam quality at the receptor, the beam was filtered with an extra 0.1mm Cu plate. All X-ray exposure measurements were carried out using a Victoreen 06-526 ionization chamber (Nuclear Associates, New York).

Prior to experiments the Digora system was calibrated⁶ by exposing an imaging plate to an 840μGy direct and uniform exposure. The X-ray exposure represents the maximum exposure for all experiments. During calibration, the device reads the plate and sets the maximum voltage that the photomultiplier tube can use. Once the calibration was complete, a new gain was selected each time a plate was exposed and read in an attempt to optimize the gray scale. This second gain calibration was also performed for the Denoptix system that does not need the first calibration procedure.

To quantify the imaging degradation influences by environment electromagnetic radiation, we have calculated the noise power spectrum⁷⁻¹⁰ (NPS) of processed imaging plates exposed to electromagnetic radiation sources commonly found in clinical situations. We have first compared the "in dark" and "in light" environments influences on PSPL processed plates for both systems. In another experiment, the exposed plates were also processed after being positioned 10 cm away from a 17 inches video monitor screens (CRT) and to its laterals for 5, 10, 15, 20, 25 and 30 minutes (plates protected against light by a plastic cover).

The laser reader processed images were used to calculate the noise power spectra (NPS) in each case. For each image, a region of interest (ROI) of its central portion was selected. For each case, we have used 30 uniform (flat-field) exposed images. The final calculated NPS was obtained by averaging¹⁷⁻²⁴ the NPS from 450 two-dimensional non-overlapping 64x64 pixels noise traces. Care had to be taken to prevent contributions from picture elements witch are not useful for analyses. These so-called “defective-pixels”¹¹ are usually generated by PSPL plates scratches. Only defective-pixels free noise traces has been considered.

As stated by researchers¹²⁻¹⁴, we believe the information contained in two dimensions is important. Therefore we obtained the resulting two-dimensional power spectra of all noise trace and computed the radial average result. Each two-dimensional noise trace NPS was calculated as modulus squared of the Fourier transform of the noise trace. Prior to calculating the Fourier transform, each flat field noise trace was background subtracted using an average of all samples employed. To adjust the magnitude of the NPS to units of mm², we have multiplied the result by the square of the pixel pitch in mm and divide by the square of the linear dimension of the sample window. The general expression to NPS measurement is shown below^{12,15,17-19}:

$$NPS(u, v) = \frac{p^2}{(n-1)N^2} \sum_{i=1}^n \left| \mathfrak{F} \left(S_i(x, y) - \frac{1}{n} \sum_{j=1}^n S_j(x, y) \right) \right|^2 \quad (1)$$

In equation 1, $S_i(x, y)$ if the flat-field sample, n is the number of flat-flied samples, p is the pixel pitch, NxN is the sample window size and the operator \mathfrak{F} denotes the two-dimensional discrete Fourier transform operation. The standard error in the NPS estimation is given by^{15,16}:

$$SE = \frac{1}{\sqrt{n \cdot \Delta w}} = \sqrt{\frac{p}{n \cdot N}} \quad (2)$$

Where Δw is the NPS measurement spatial frequency resolution.

3. RESULTS

Figure 1 shows Denoptix and Digora noise power spectra for manufacturer suggested environment conditions (plates processed “in dark” immediately after exposure to X-ray). Note that Denoptix system is intrinsically noisy than Digora for the same conditions. Figure 2 shows the effect of “in light” and “in dark” plate manipulation (placement in the laser reader) on the noise power spectrum for both systems. Note that for the Digora system NPS seems to show no influence by “in light” processing while we clearly see a noise increment for the Denoptix system.

Figure 3 and Figure 4 shows Digora noise power spectrum when the plate has been left in front of the CRT screen and to the lateral of the CRT monitor for different periods of time. For both cases it is observed a noise increment (image degradation) by influence of CRT radiation. We can observe in Figure 5 the comparison between CRT screen and lateral influence on the exposed plates.

Similarly, Figure 6 and Figure 7 show Denoptix noise power spectrum when the plate has been left in front of the CRT screen and to the lateral of the CRT monitor for different periods of time. For both cases it is also observed a noise increment (image degradation) by influence of CRT radiation. We can also observe the same features shown in Figure 5, observing the comparison between CRT screen and lateral influence on the exposed plates in Figure 8.

4. DISCUSSION

The radiological image quality optimization has been a strong motivation for researchers in developing alternative X-ray imaging devices¹², we can observe that the influence from clinical environment and user operation procedures on image quality are not yet fully understood. This work tries to map the quantitative influence of ambient light and CRT radiation leakage on the PSPL plates for good image quality. Our approach to the problem was to measure the noise increase on the final image²⁰⁻²². As shown in Figure 2, there was an increasing noise on the Denoptix system “in light” processing. That effect was not shown in the Digora system because the plate plastic cover is only removed inside the laser reader, thus reducing considerably the exposure of the plate to the environment light. On the Denoptix system, on the contrary, the plates are removed from the plastic cover, and then placed one by one in a laser reader carousel, so the light exposure was not negligible. In our opinion, main factor influencing the image degradation in the Denoptix system was not PSPL plate sensibility to the common light but the way the plates are left in the laser reader carousel.

Another source of imaging degradation evaluated in this study was the radiation leakage of video monitor (CRTs). We have founded that CRT influences can be showed if the plates are exposed to their radiation for long periods of time (up to 30 minutes). Nowadays, the CRT proximity to the plates is not considered in quality control routines. We have noted that the influence of the radiation measured on the lateral of the video monitor is more intense than that due to its screen. In our opinion, this occurs because the modern video monitors have radiation shield protection for their screen but no extra protection for their side panels.

We have observed that the use of these digital systems in a routine service contemplates our experimental procedures. For instance, it is a common practice to leave the X-ray exposed plates near video monitor screens and also exposed to room light before being processed by the laser reader. This implies that clinical procedures must change and the radiologists should not leave the Denoptix X-ray exposed plates without protection against common light. It also point out to the problem of a safe distance between the plates storage and video monitors.

5. CONCLUSION

We have studied the influence of common light and proximity to video monitor on PSPL plates. We have shown that it occurs image degradation (increase of noise power spectrum of the image) and it was possible to improve image quality if the PSPL plates are left at safe distance from video monitors and protected against common light exposure .

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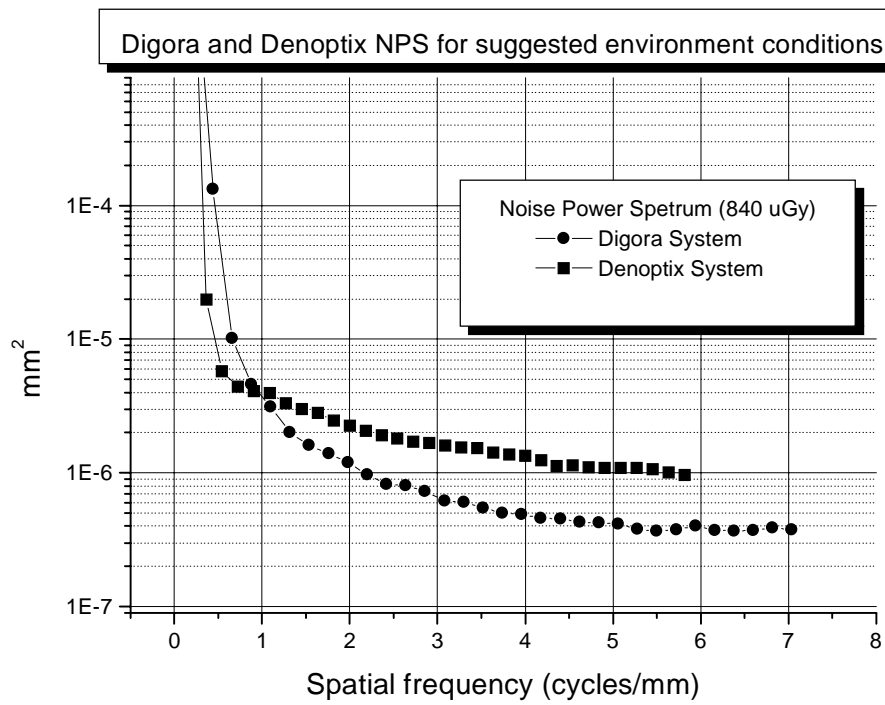


Figure 1. Denoptix and Digora noise power spectrum for suggested environment conditions (plates processed “in dark” immediately after exposure).

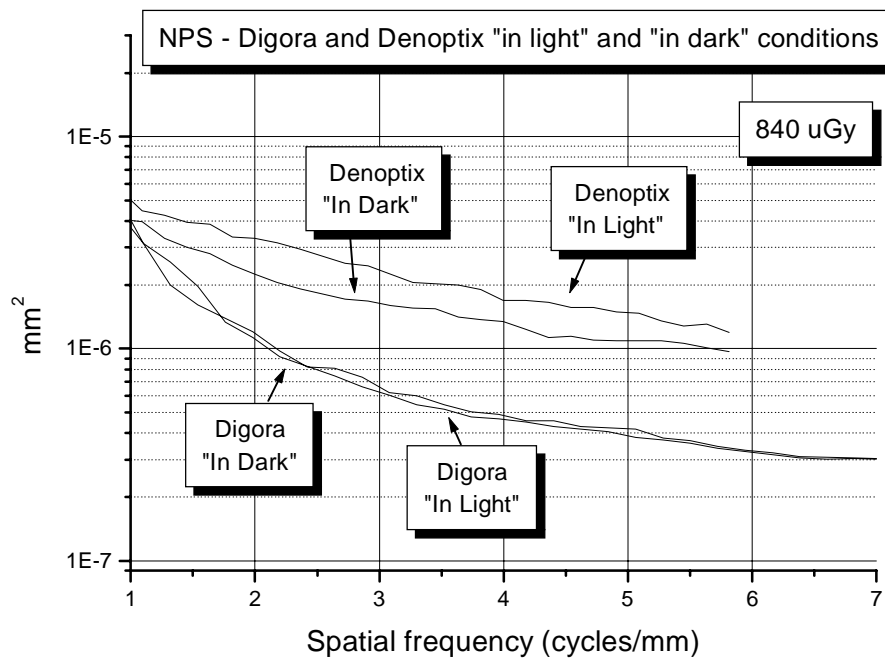


Figure 2. Comparison between Denoptix and Digora noise power spectra for “in light” and “in dark” environment conditions.

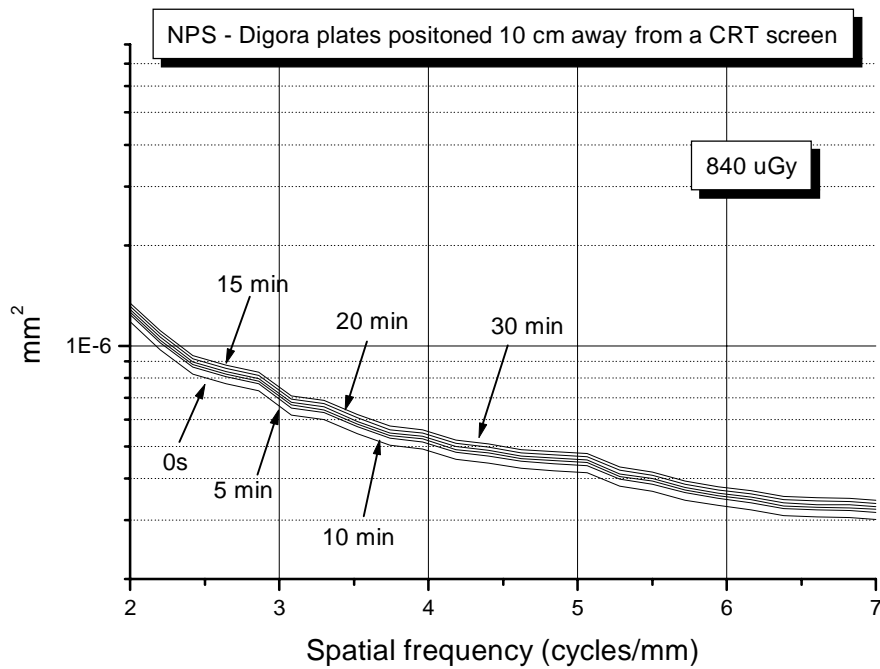


Figure 3. Digora noise power spectrum of the image of the PSPL plate exposed to the CRT monitor screen for several periods of time.

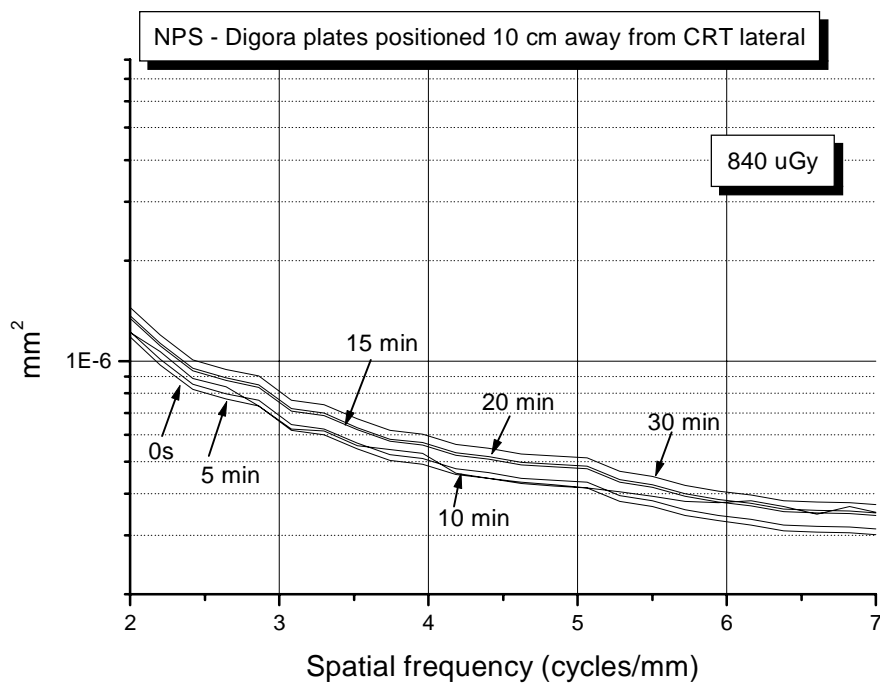


Figure 4. Digora noise power spectrum of the image of the PSPL plate exposed for the side panel of the CRT monitor for several periods of time.

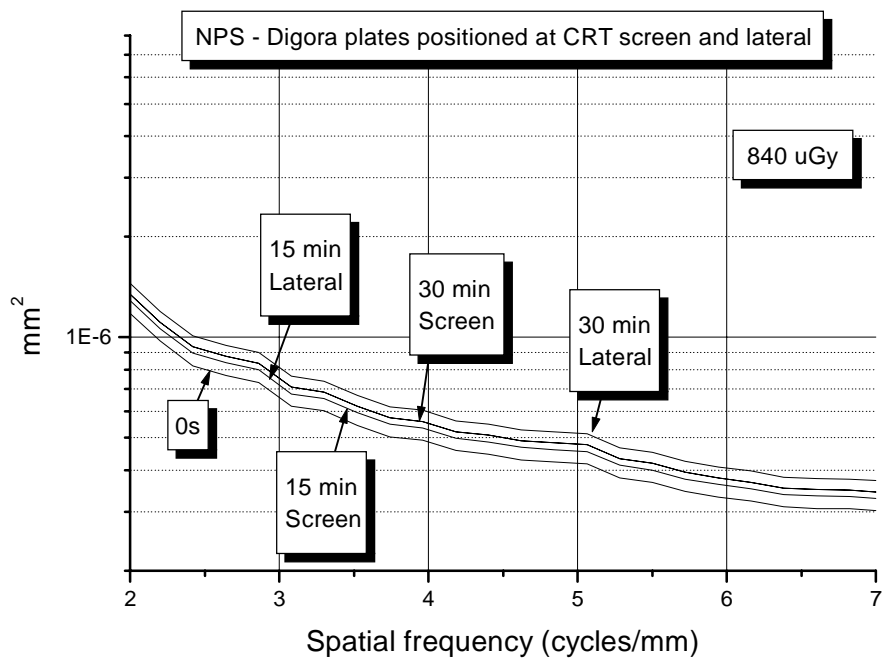


Figure 5. Comparison between the noise power spectra shown in Figures 3 and 4.

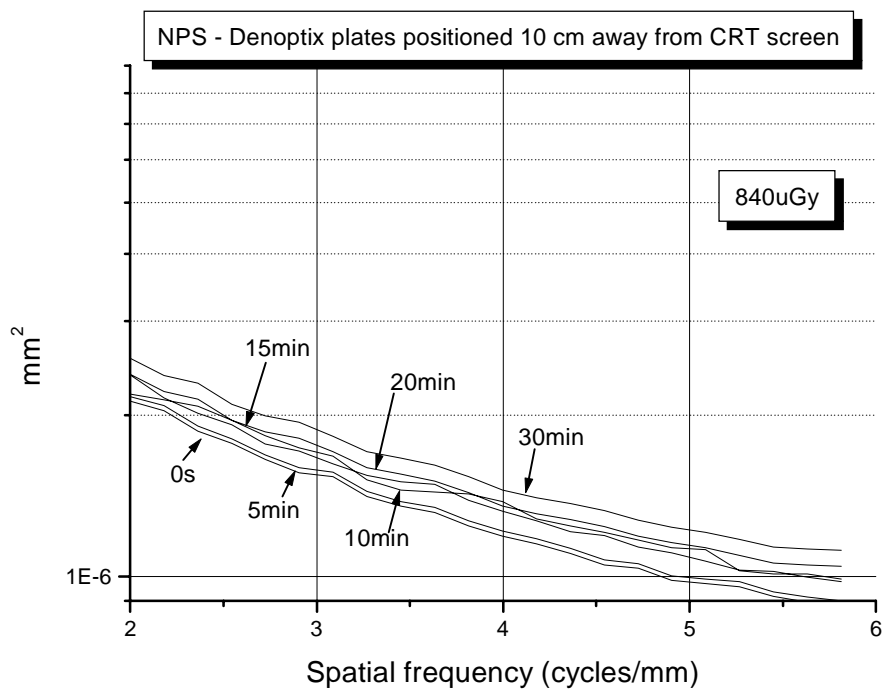


Figure 6. Denoptix noise power spectrum of the image of the PSPL plate exposed for the CRT monitor screen for several periods of time.

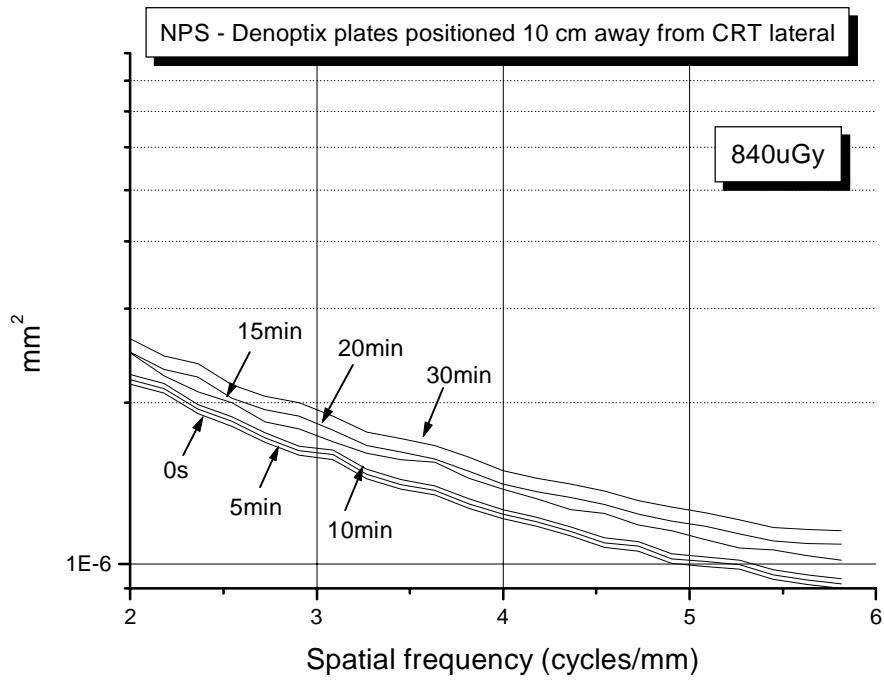


Figure 7. Denoptix noise power spectrum of the image of the PSPL plate exposed for the side panel of the CRT monitor for several periods of time.

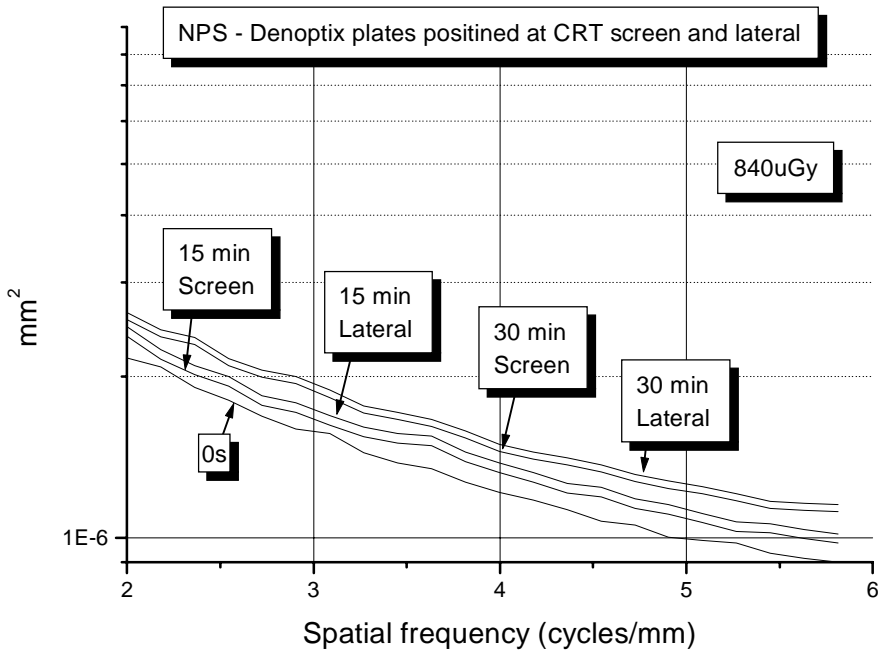


Figure 8. Comparison between Denoptix noise power spectra shown in Figures 6 and 7.