CT AEC characterisation and optimisation using a noise-power spectra analysis framework

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Overview

- Introduction
  - Why bother?
- Method
  - IQWorks analysis trees
- Results
  - Z-DOM vs D-DOM vs Fixed mAs
- Conclusions

Introduction

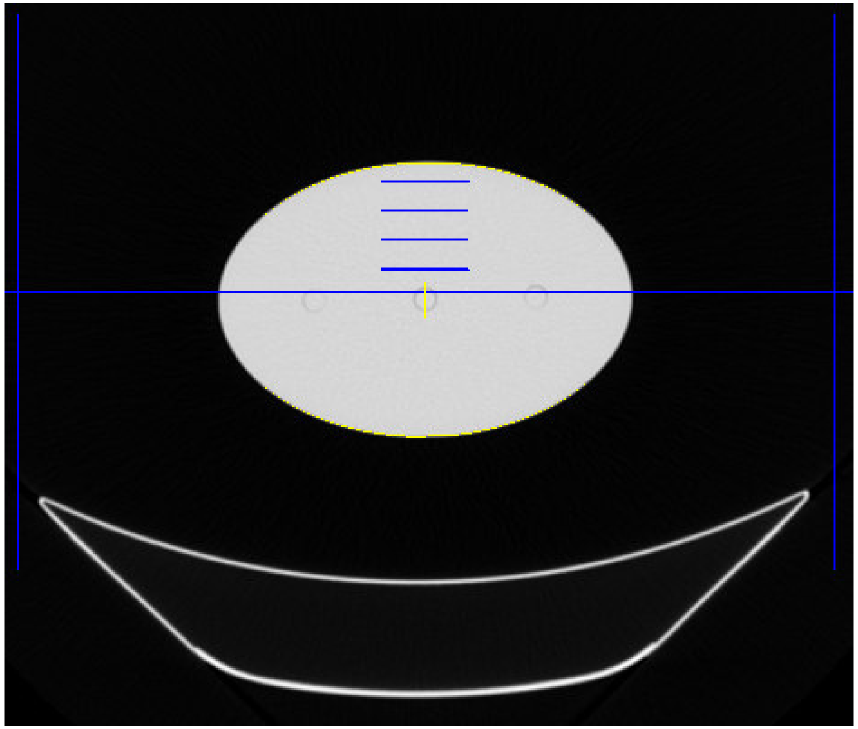
Introduction

- The technique of using simple uniform AEC phantoms is fairly well established now
- Use measurements of standard deviation to quantify noise in the image
  - Plot as a function of phantom size, compare with baseline, etc
- Standard deviation is a generally acceptable way of quantifying noise, but does not necessarily give the whole story...
  - e.g. Iterative reconstruction techniques are known to change the noise ‘texture’. Matching standard deviations can be obtained, but image noise appears quite different due to the spectral composition
- So, does a noise power spectrum based analysis framework offer any advantages (or disadvantages) over more conventional techniques?

Method

Method

- Scan the relevant region of the AEC phantom (same image set as earlier)
- Use IQWorks analysis trees to perform NPS analysis on each slice
  - **Not** normalised (how would you do this for CT?)
  - 32 x 32 ROIs overlapping by half (4 in total)
  - No data windowing, 2D trend removal applied, etc
- Average results for each section of the phantom



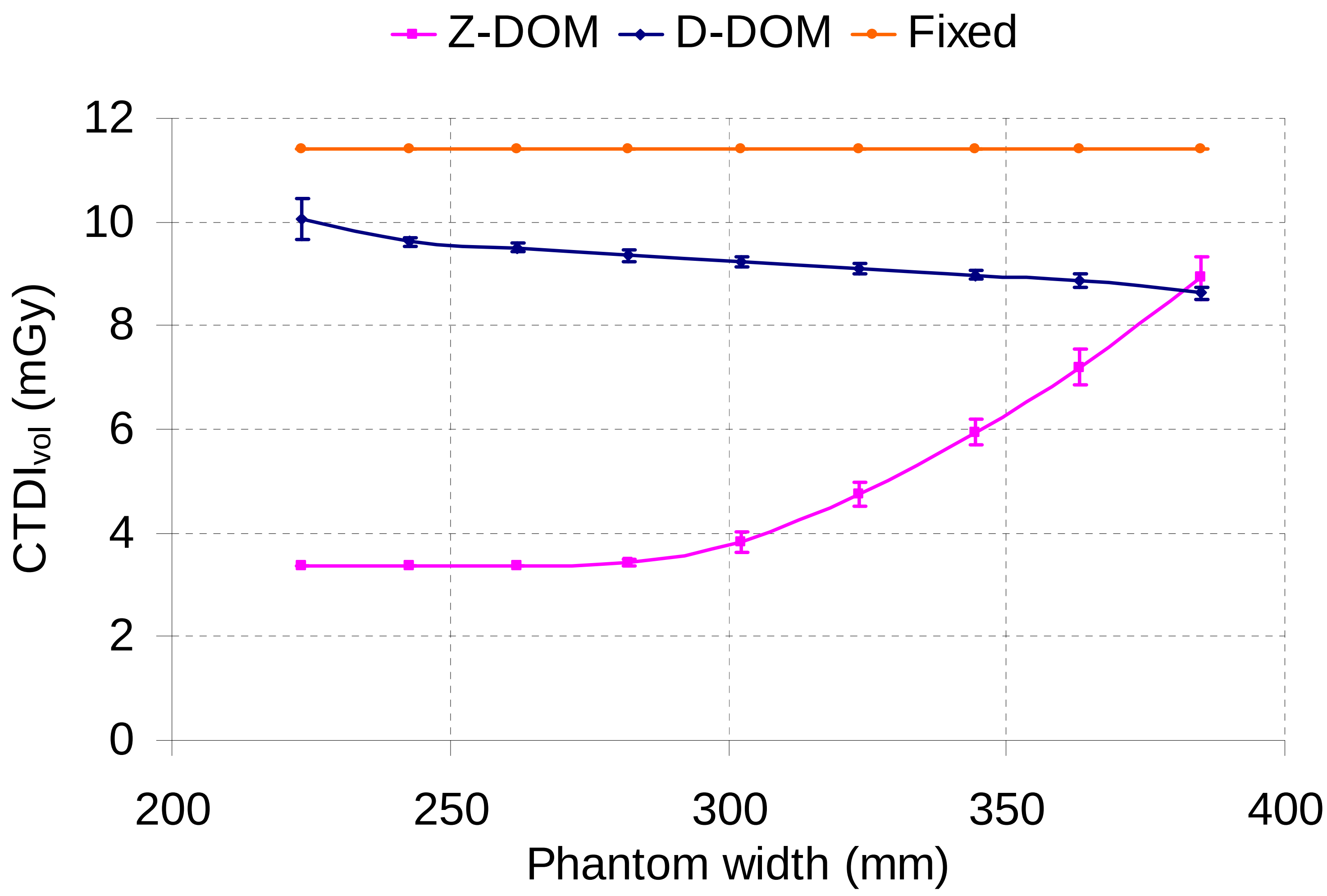
Method

- IQWorks offers a range of outputs from the calculations
  - NPS plots
  - NPS spectrum
  - Summary stats, etc
- Also splits the NPS into stochastic and static noise components
  - For the purpose of this analysis, only considered the stochastic component
- Dump the relevant quantities into a .csv file for further analysis
  - Stochastic integral NPS, NPS plots (x & y), etc

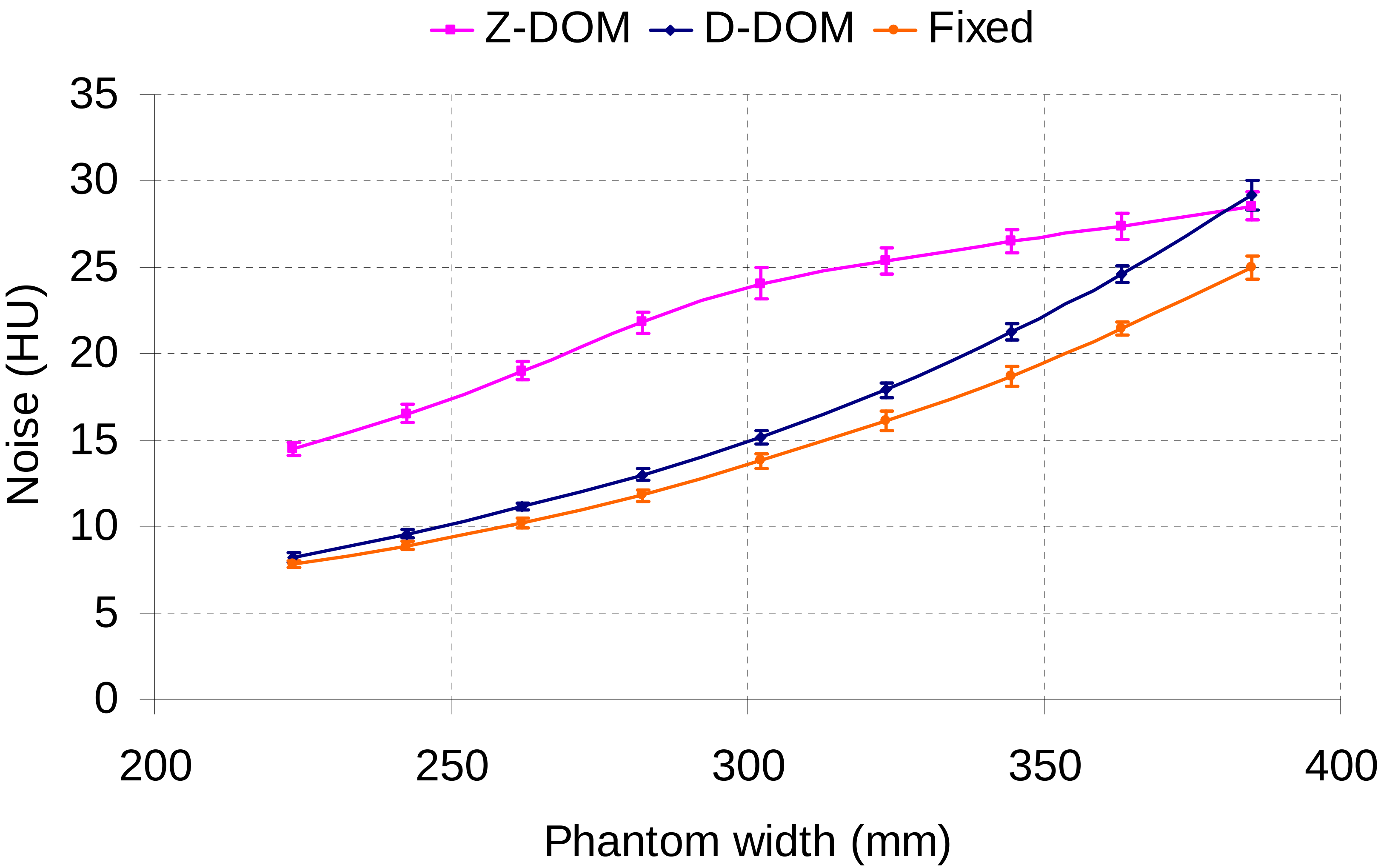
Results

From earlier, using the standard deviation technique…

Z-DOM vs D-DOM vs Fixed mAs



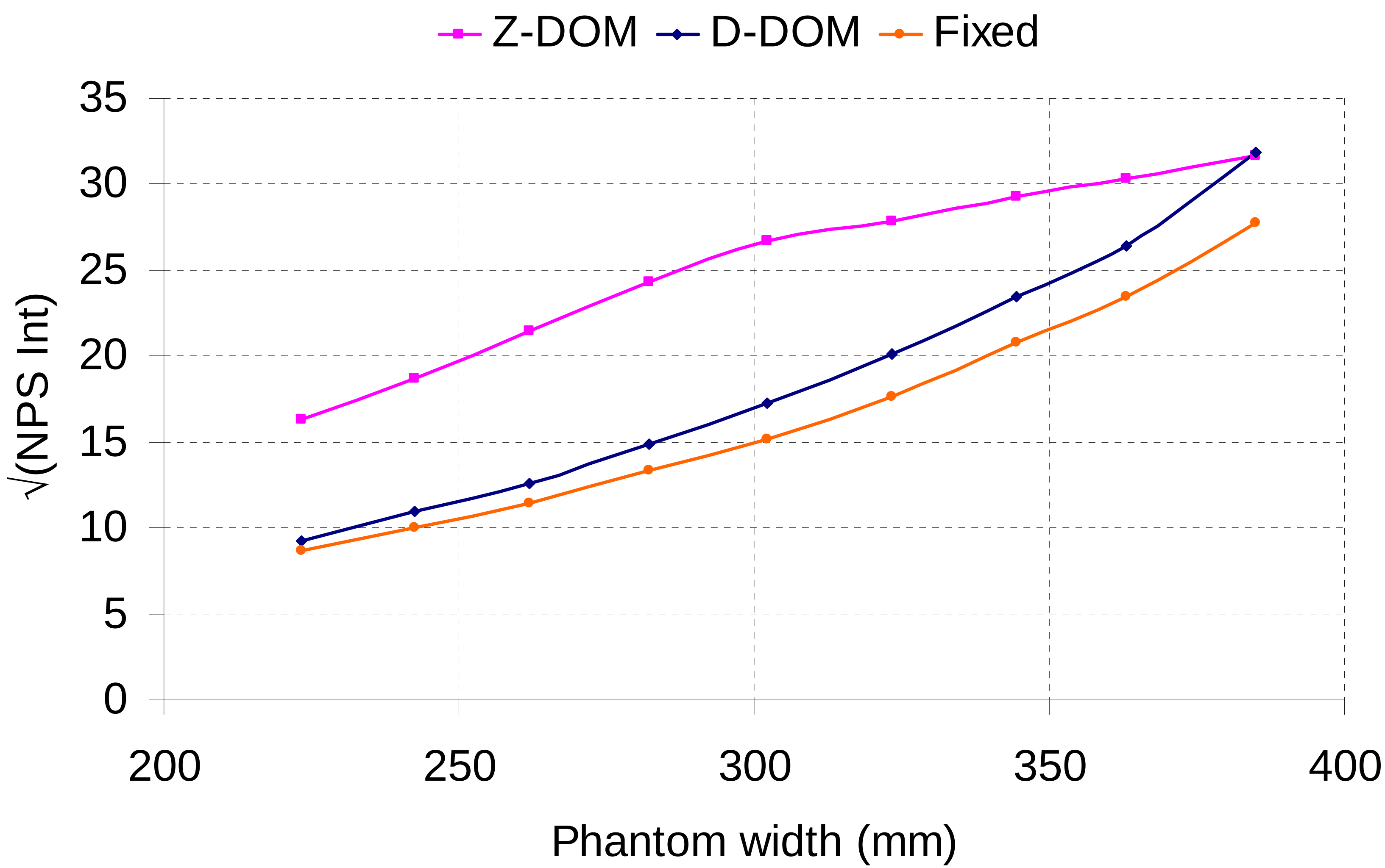
Z-DOM vs D-DOM vs Fixed mAs



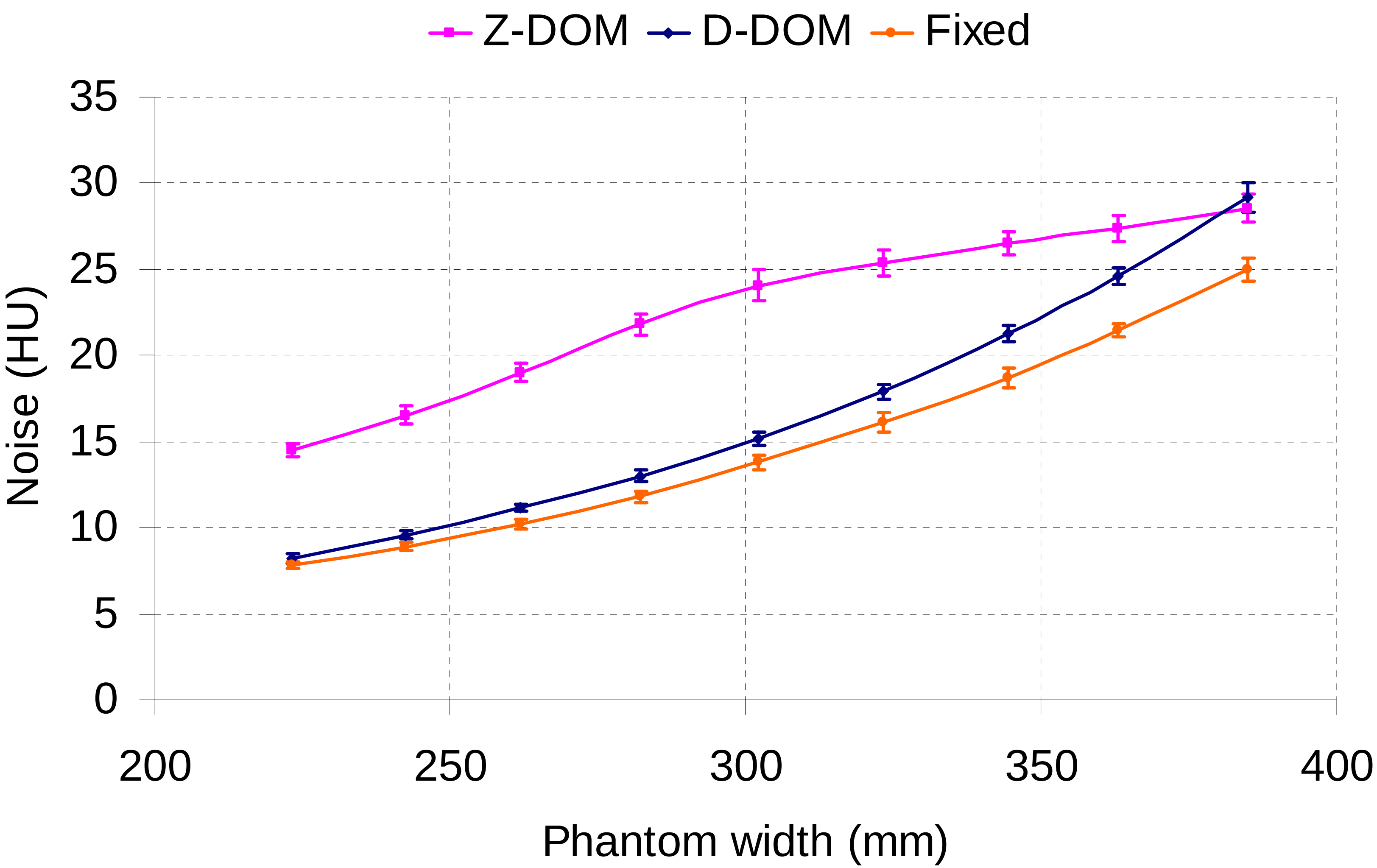
Z-DOM vs D-DOM vs Fixed mAs

- Can use the same data for the NPS analysis
- IQWorks gives the stochastic integral NPS
  - Parseval's theorem states that this quantity is simply the variance in the image at that location
  - Hence, square root of this value, should be the same as the standard deviation from earlier
  - Will not be exactly equivalent as;
    - Using different ROI
    - Processing applied in NPS calculation
    - Only looking at the stochastic noise component in this analysis – should reduce the effect of ring artefacts, etc?

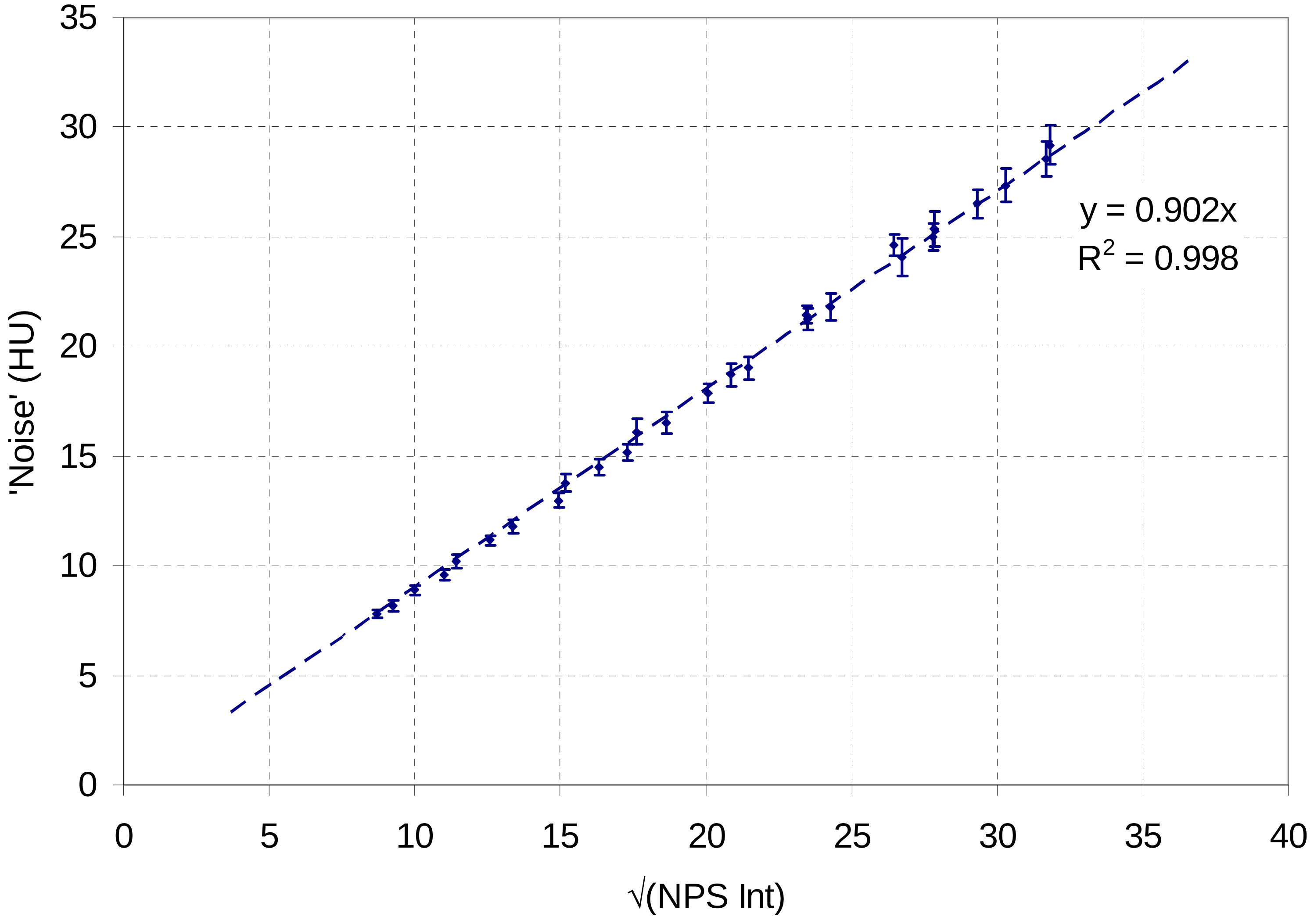
Z-DOM vs D-DOM vs Fixed mAs



Z-DOM vs D-DOM vs Fixed mAs



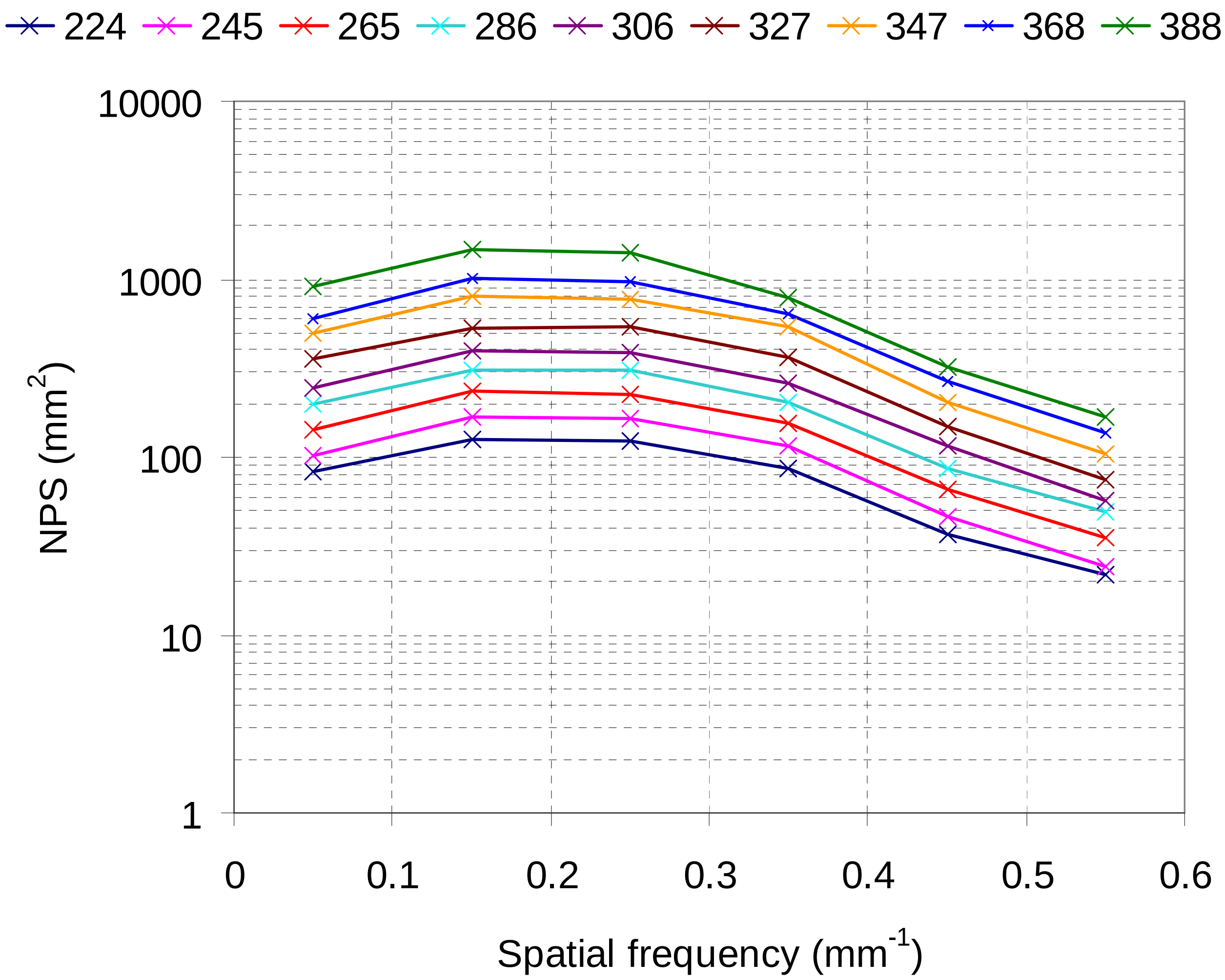
Z-DOM vs D-DOM vs Fixed mAs



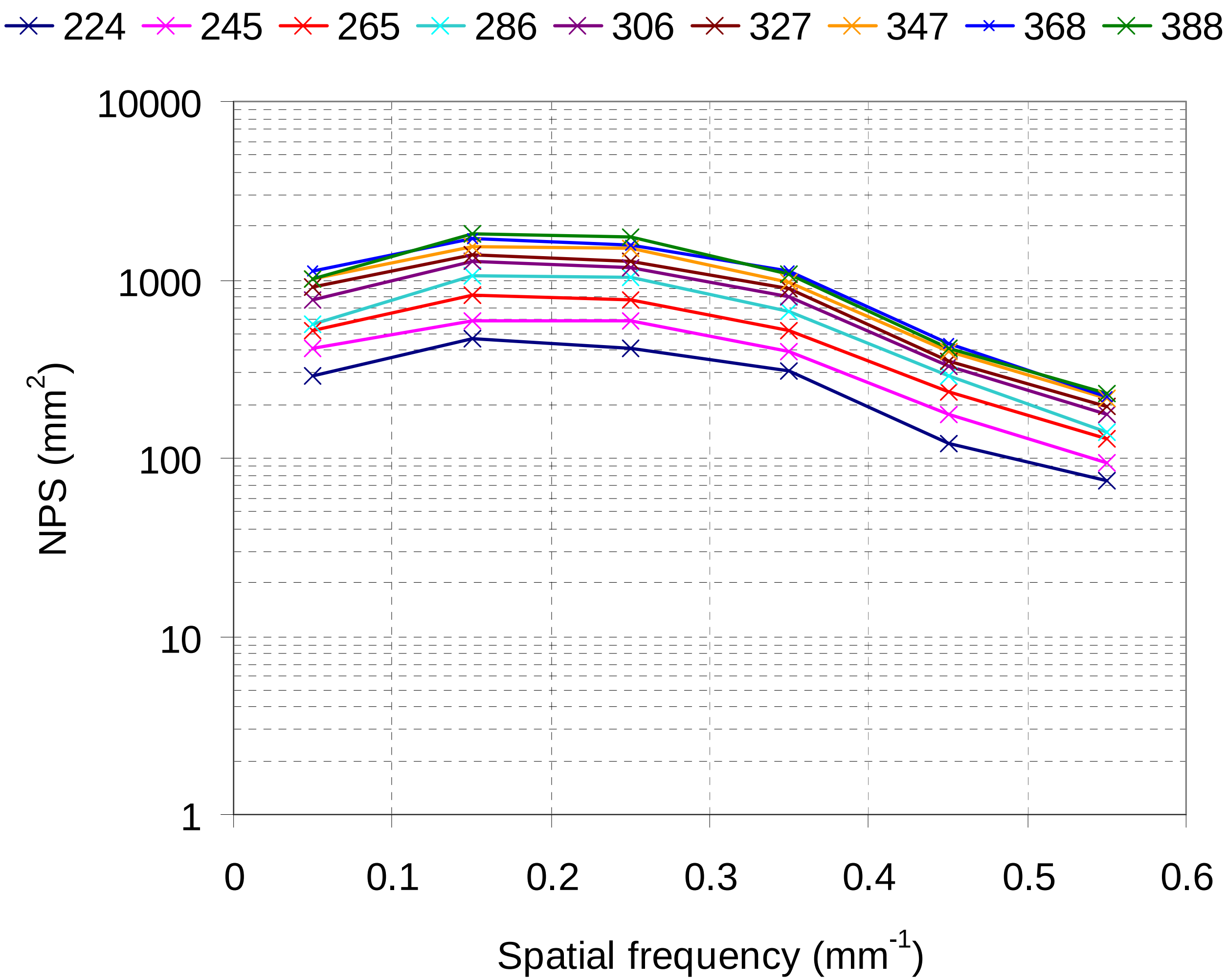
Z-DOM vs D-DOM vs Fixed mAs

- So using this technique, it is possible to arrive at the same conclusions determined using the standard deviation based analysis
- So what's the point?
  - It doesn't take any longer than the standard deviation approach (at least it doesn't when using IQWorks)
  - Separation of the stochastic and static noise components
  - Can get extra information on top of these basic curves that is useful for a fuller characterisation of the AEC
- So what do the actual NPS tell us?...

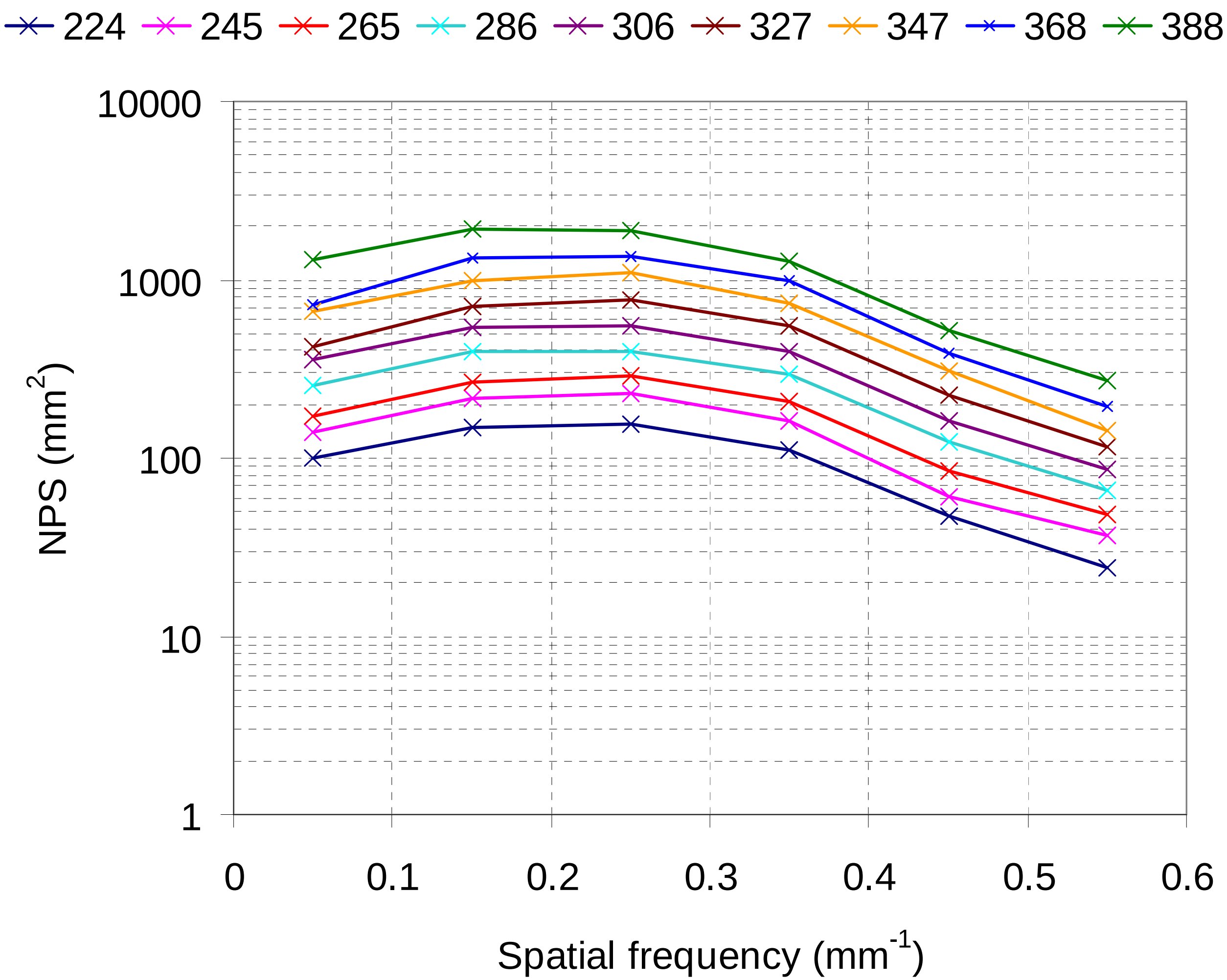
Fixed mAs NPS (x-axis)



Z-DOM NPS (x-axis)



D-DOM NPS (x-axis)



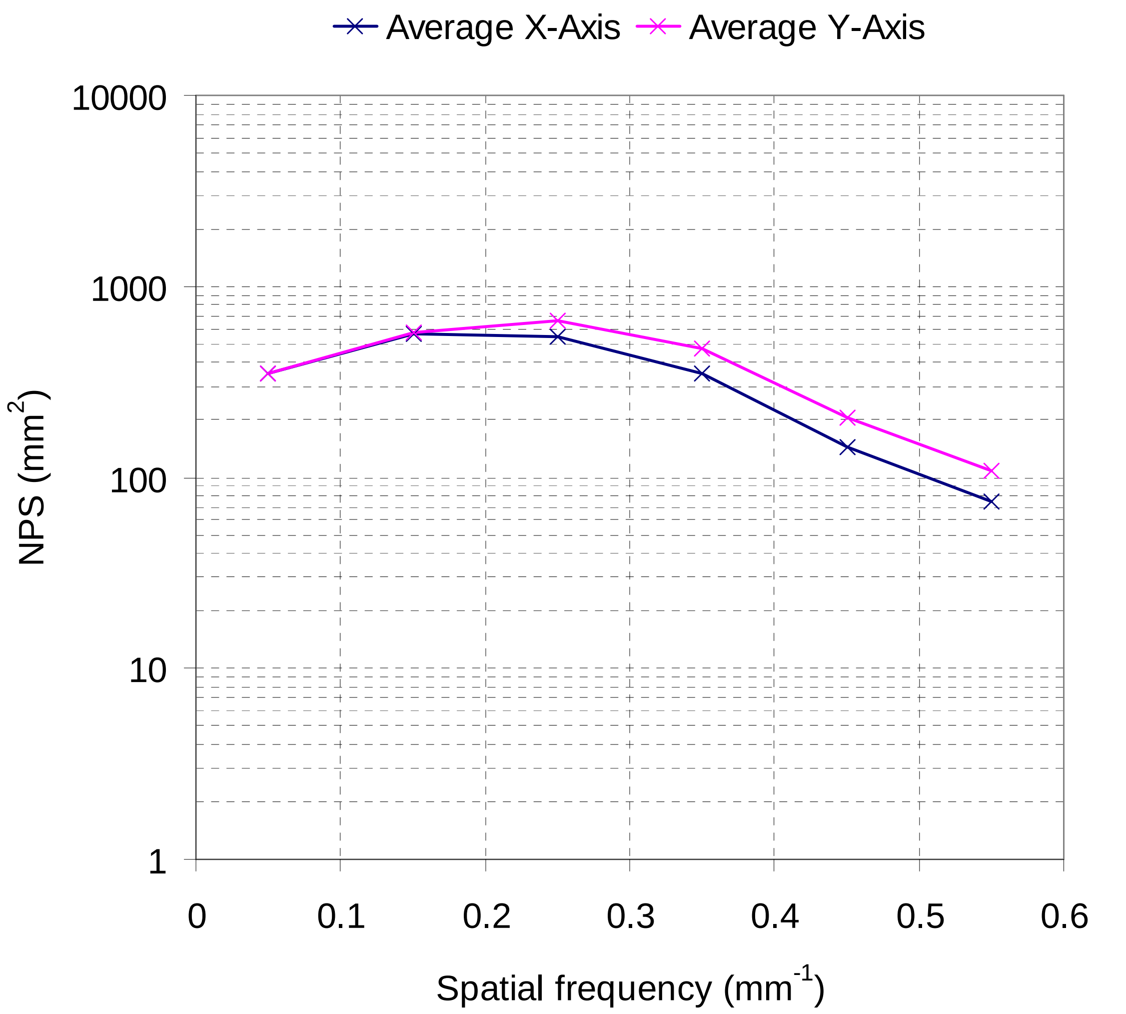
Z-DOM vs D-DOM vs Fixed mAs

- For all modes, the shape of the NPS does not change as the phantom gets thicker
  - Thicker sections of phantom offset to higher noise
  - Peak does not shift (no change in noise texture)
  - Plot of NPS for any given frequency with phantom width will give the same type of curve as for integral NPS and standard deviation
- **Fixed mAs**
  - Step change for different thickness on log scale, so as expected noise is exponentially proportional to phantom size
- **Z-DOM**
  - Equal exponential step change in noise when mAs constant, curves closer when AEC kicks in
- **D-DOM**
  - As for fixed mAs, noise exponentially proportional to phantom size

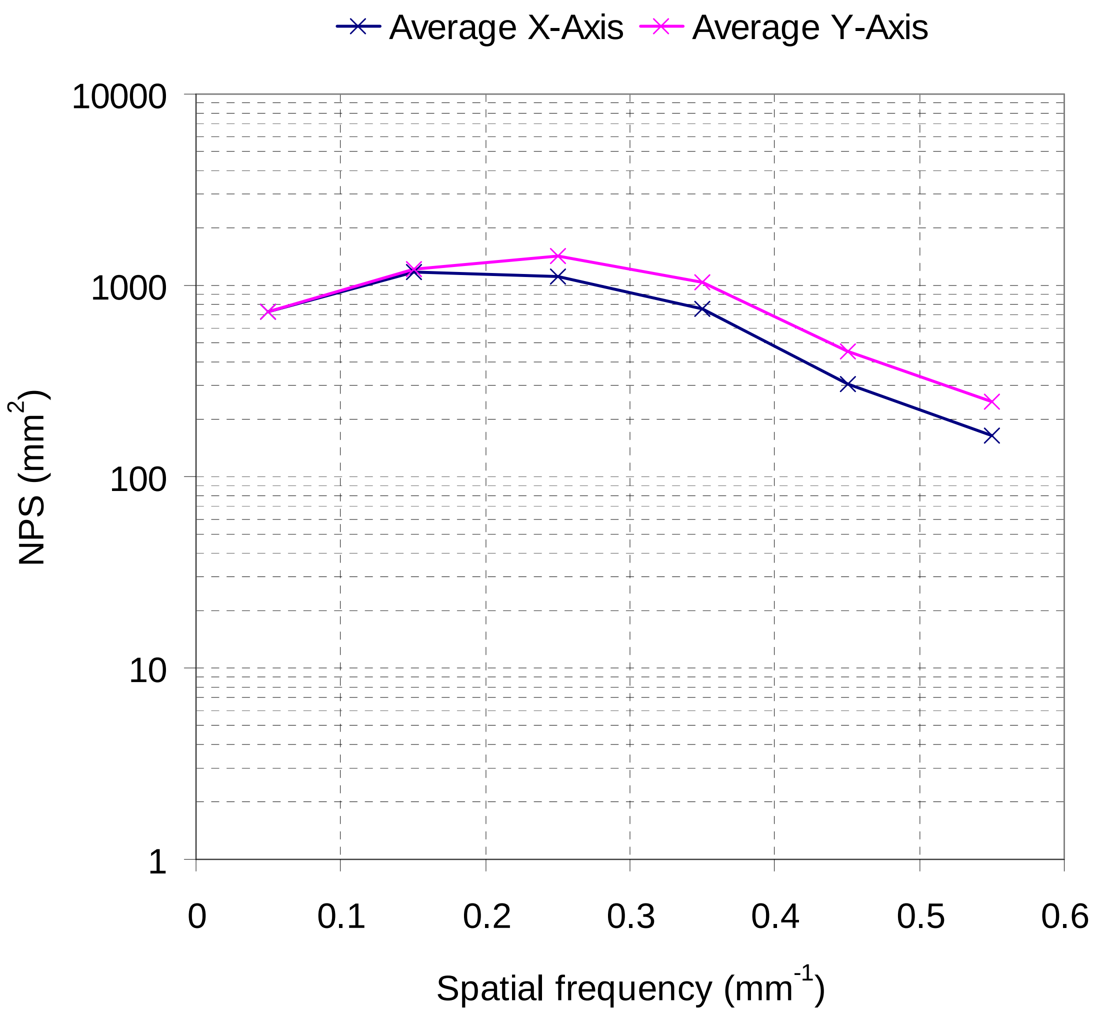
Z-DOM vs D-DOM vs Fixed mAs

- What about the effect of phantom asymmetry on the NPS?
- Determine average x-axis NPS for all phantom thicknesses and compare with average y-axis NPS…

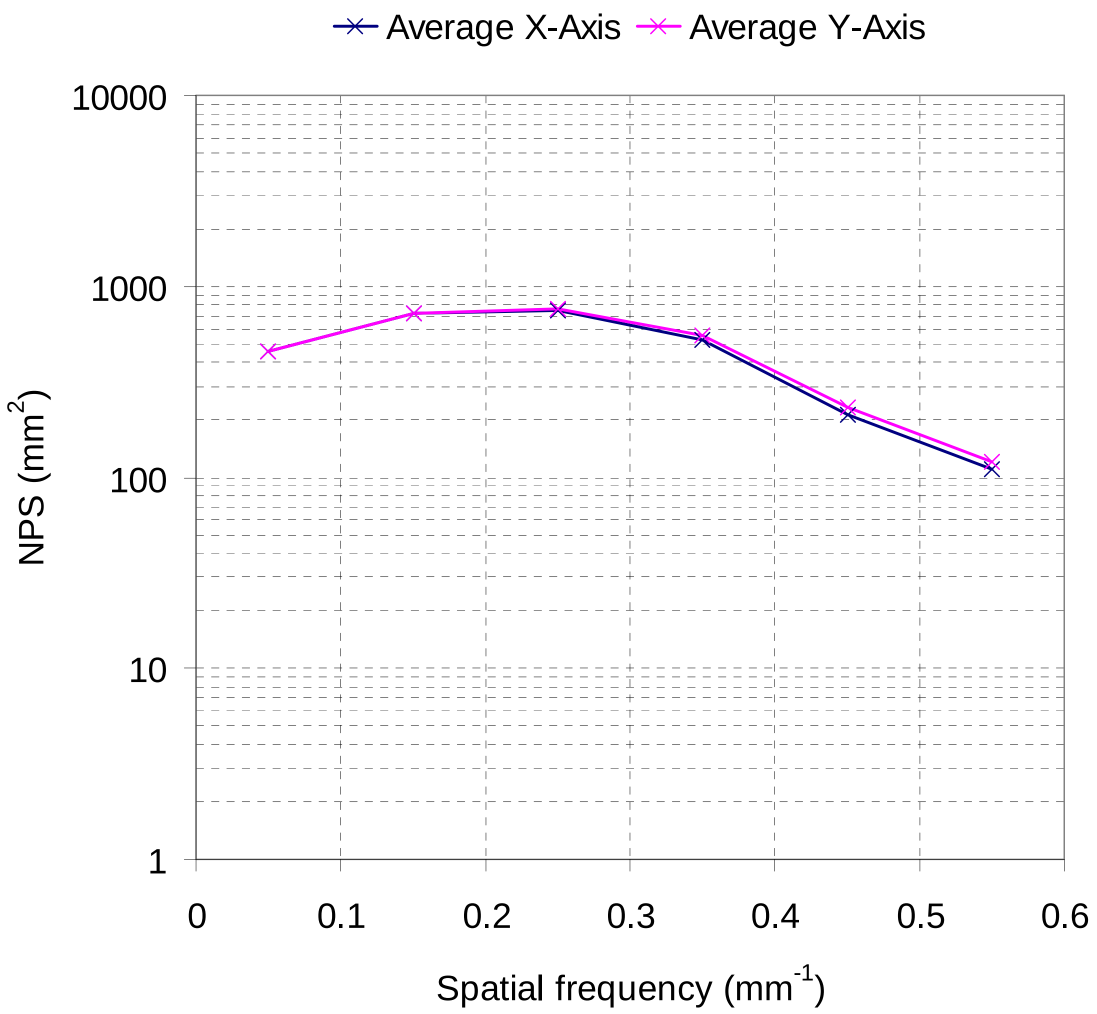
Average Fixed mAs NPS



Average Z-DOM NPS



Average D-DOM NPS



Z-DOM vs D-DOM vs Fixed mAs

- Fixed mAs and Z-DOM show clear difference in x- and y-axis NPS
  - Due to the un-even weighting of noise contributions from the lateral and A-P projections
  - Also demonstrates a (very) slight shift in the peak for x-axis NPS
- D-DOM shows very similar NPS in both directions
  - Even weighting of noise contributions from each direction

Conclusions

- Noise power spectrum analysis framework enables the same trends to observed as can be seen with a basic standard deviation technique
- Does not take any longer when implemented in something like IQWorks
- Can access additional information about how the AEC and tube current modulation works
- Expect a fully 3D/4D AEC system will have NPS that are matched in the x- and y-axis (like D-DOM), but with curves that are closer together (like Z-DOM)
  – To be confirmed with measurements on the Toshiba 64 Aquilion (this may actually result in NPS that closely overlap for all phantom thicknesses due to it being a standard deviation based AEC)