Can A 44-Year-Old Idea Improve XRF Detection Limits Today?

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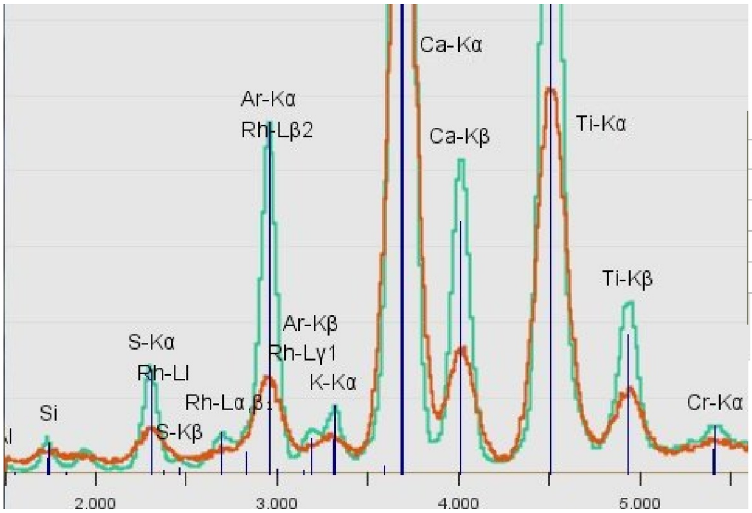
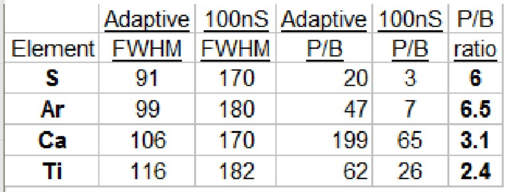
In an extraordinary and prescient series of 3 papers[1] published in 1975, Henriecus Koeman built and developed the theoretical foundations for an all-digital pulse processing system which used all available information in the X-ray detector preamplifier signal by adapting its integration time pulse-by-pulse to the random and Poisson distributed arrival intervals between X-rays, which is impossible with analog semi-Gaussian shapers. Koeman demonstrated that adaptive shaping had significantly better energy measurement accuracy as measured by FWHM of the peaks.

The analog-to-digital converters (ADCs) of the time did not have the speed, bit depth, and linearity to match the performance of the best analog processors, and the technology languished for 18 years until the first commercial adaptive processor was introduced in 1993, receiving an R&D 100 award the following year. The idea still was not widely adopted, because the resulting spectrum peaks were not pure Gaussians and energy resolution varied with incident count rate as the X-ray arrival interval distribution changed. Peak width stability with rate has long been regarded as a measure of system performance, and it was accepted dogma that standards-based analysis was not possible otherwise, but peak shapes and widths under adaptive shaping are predictable from the input count rate. Recent software developments for electron-excited spectra have shown accurate quantitative results with samples and standards having substantially varying count rates and energy resolutions[2].

Work will be presented extending those results to XRF spectra. A further advantage of adaptive shaping is the ability to operate at low dead times with minimal loss of energy resolution, as shown in the spectra and table below, reducing the tube power required for a given level of counting statistics. This is of interest for battery life in portable instruments. Dead time was 15% for the red spectrum and 10% for cyan (shorter minimum peaking time). Both spectra were acquired for 10s real time, the red one with 100nS peaking time and the cyan one with adaptive peaking times ranging from 64nS to 512 nS. Low-energy peaks show the most dramatic effect from improved energy resolution. At very low energies, up to a six-fold improvement in P/B was observed. Note the visibility of Si and (just barely) of S-Kβ, and the separation of the Ar-Kβ and K-Kα peaks in the cyan (adaptive) spectrum. Higher peak-to-background (P/B) ratios imply better detection limits for peaks without severe overlaps.





Element	Adaptive FWHM	100nS FWHM	Adaptive P/B	100nS P/B	P/B ratio
S	91	170	20	3	**6**
Ar	99	180	47	7	**6.5**
Ca	106	170	199	65	**3.1**
Ti	116	182	62	26	**2.4**

Spectra courtesy National Gallery of Art

[1] Nuclear Instruments and Methods 123 (1975) pp. 161-187
[2] Microscopy and Microanalysis 20 (Suppl. 3, 2014) pp. 706-707