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Adaptive Matched Filtering Of XRF Detector Signals

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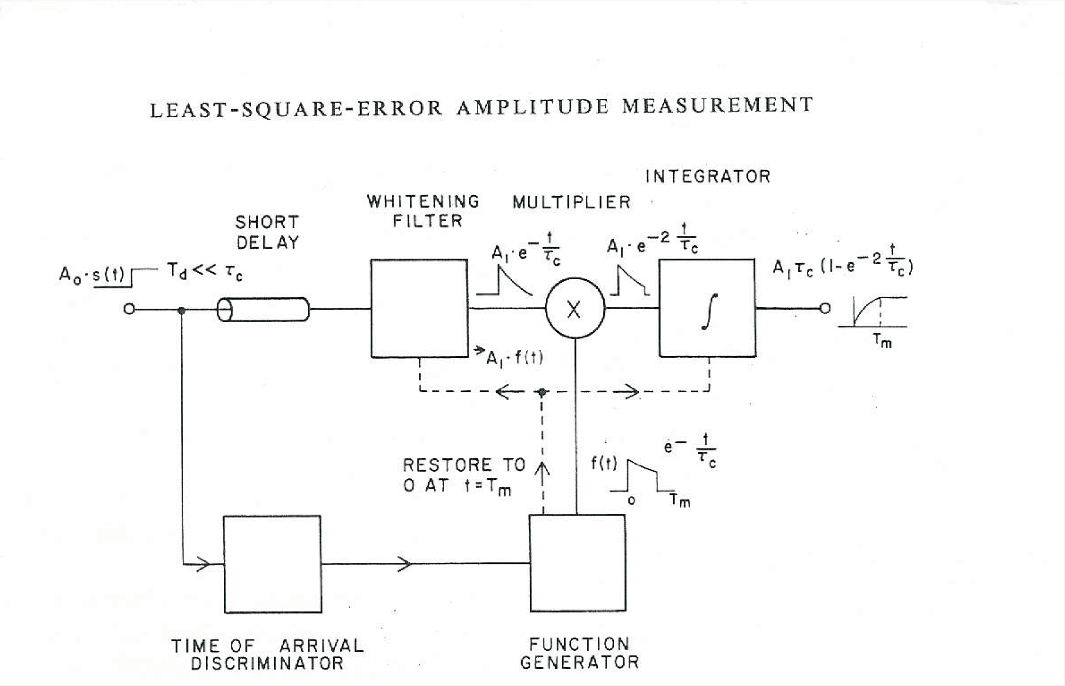
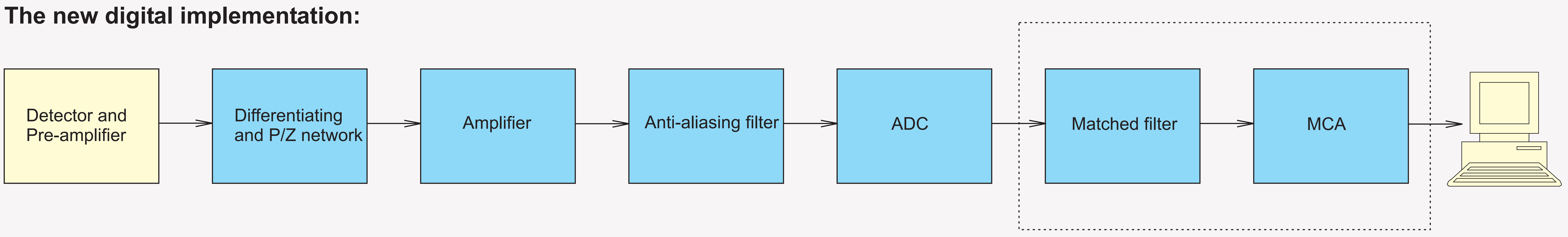
Matched filtering was proposed back in 1967 by V.Radeka and N.Karlovac[1] as "perfect" solution for white noise cancellation.
Unfortunately analog implementations are not practical due to number of reasons, some of which are:
- unstable components, especially the analog multiplier
- extremely tight tolerances required

On the other hand, digital filtering is known as extremely stable.



As proposed by V. Radeka and N. Karlovac

The new digital implementation:



The matched filter is a convolutional one. Its coefficients should match the shape of the expected pulse.
The discrete form of the convolution is a sum of multiplications.

$$A=\sum_{i=1}^{L}(s(t_i).c(i))$$
$$s(t_i)=A.f(t_i)+n(t_i)$$

Where:
- A is amplitude measured
- c are filter coefficients
- f is expected signal
- s is actual signal, including noise
- n is noise
- L is filter length

Implementation:

Filter coefficients are calculated in the adaptation phase, using input signal shapes, before the measurement is started.

$$c(i)=R.\sum_{j=1}^{k}s_j(t_i)$$

Where:
- R is normalizing constant
- k is number of pulse shapes used in adaptation phase

For a given k, the noise in the coefficients is sqrt(k) times lower. Such filter is matched because its coefficients "describe" the real signal shape at ADC input. This ensures best filtering for a given detector.

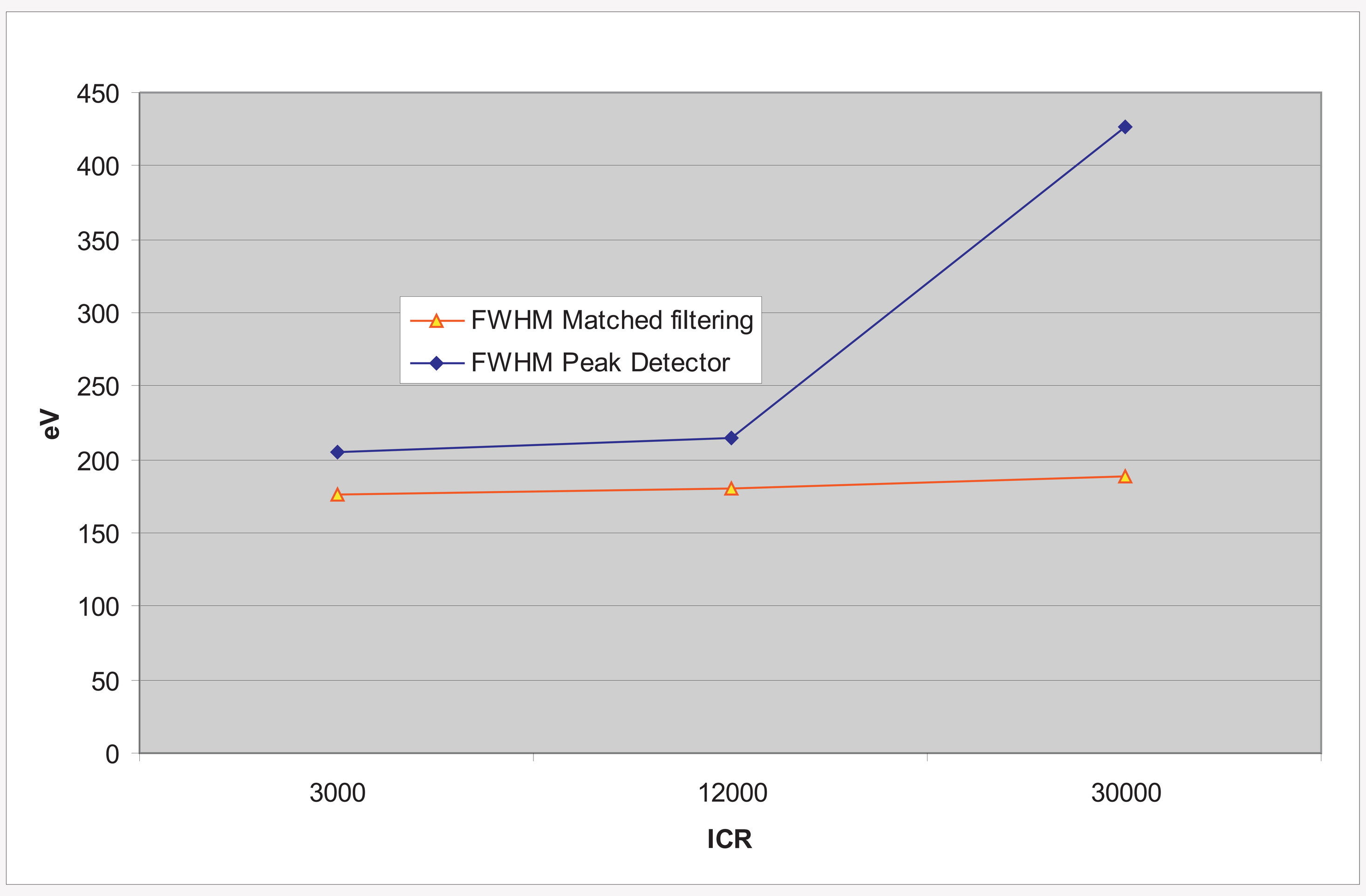
The proposed filtering method is implemented in a stand-alone device, based on custom designed DSP using FPGA.
It incorporates all necessary stages - differentiation, amplification, digitalization, filter calculations, signal processing, spectra capture (MCA) and USB interface to a PC.

Results:

The below graph represents comparison between matched filtering method using DSP and conventional PHA using pulse peak detection (Wilkinson style or other conventional ADC types).

Advantages:

- simplified amplifier
- stable operation
- high performance



Conclusion:

The method proposed can outperform the existing systems based on complex shaping amplifiers and conventional ADC.

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1. V. Radeka and N. Karlovac. Least-square-error amplitude measurement of pulse signals in presence of noise. Nucl. Instrum. Methods 52: 86–92, 1967.