

MEASUREMENT OF ASYNCHRONOUSLY SAMPLED HARMONICALLY DISTORTED WAVEFORMS

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Goal

Fast and precision estimation of frequency, amplitude and phase of asynchronously sampled harmonically distorted signal

Available solutions

- Four parameter sine fit (4PSF)
- Interpolated DFT
- Spectral interpolation, ...

Proposed algorithm: mathematics used

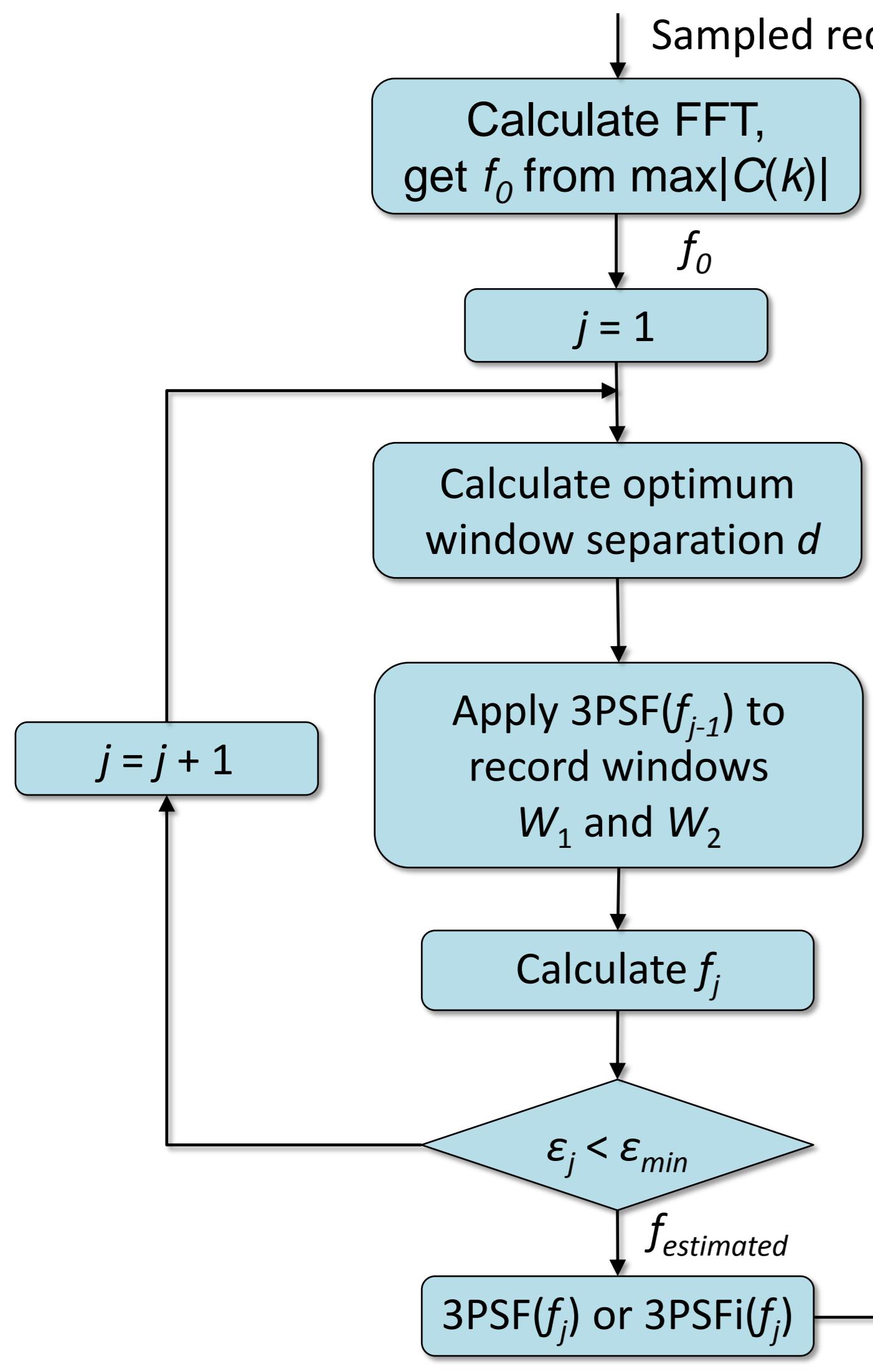
FFT

$$C(k) = \sum_{n=0}^{N-1} x(n)e^{-j\frac{2\pi}{N}nk}; k = 0, \dots, N - 1$$

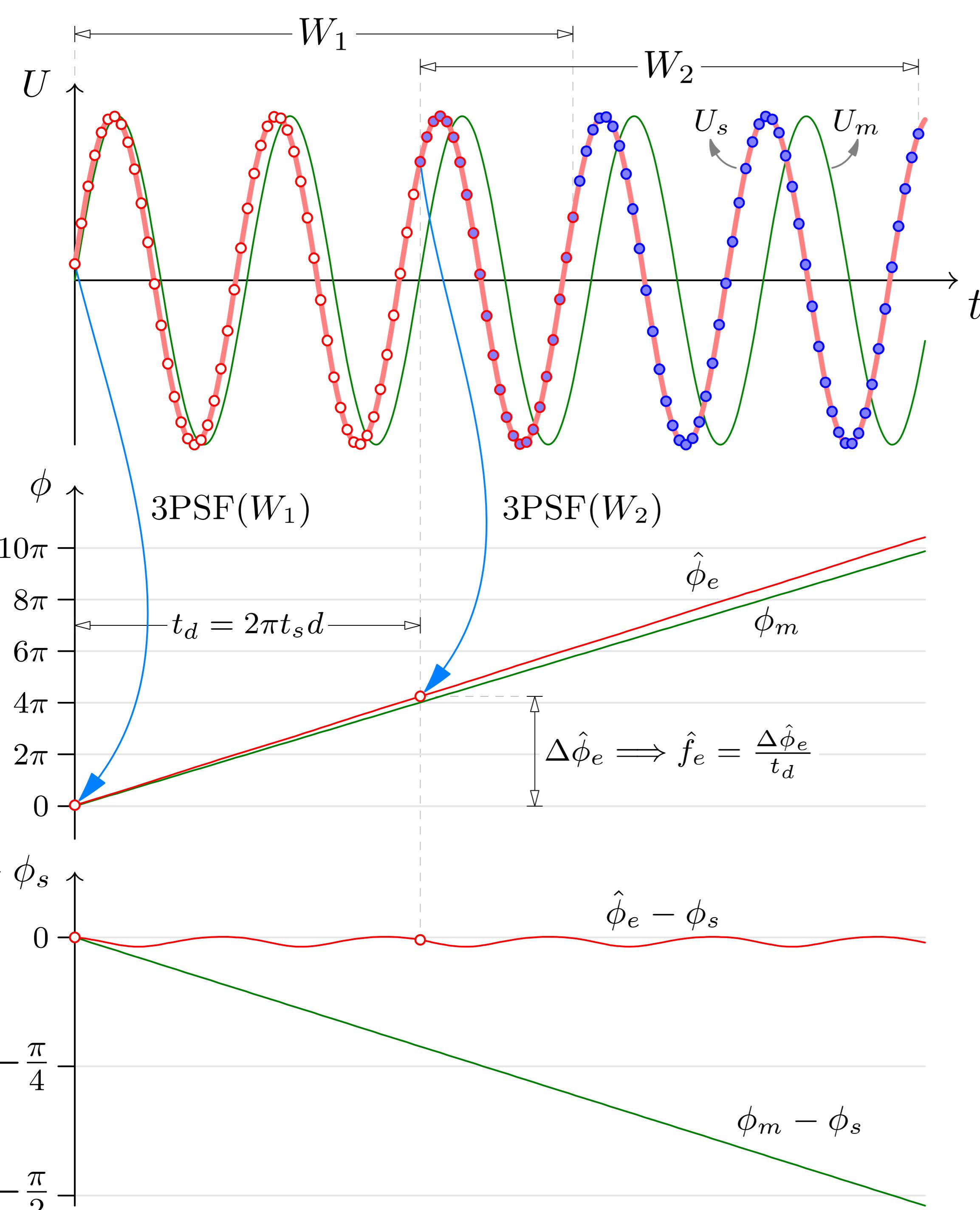
3PSF

$$\min \left(\sum_{n=0}^{N-1} (x(n) - A_0 \cos(\omega_0 t_n) - B_0 \sin(\omega_0 t_n) - C_0)^2 \right)$$

Proposed algorithm

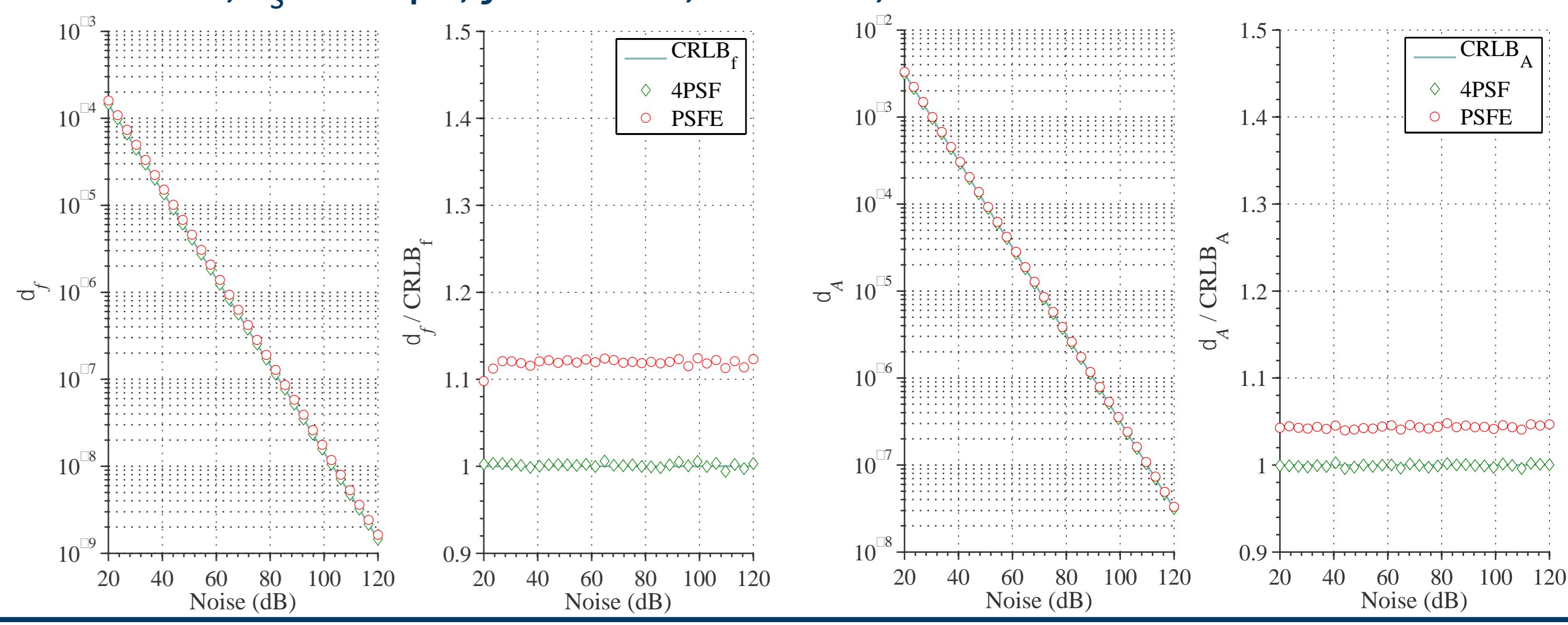


$x(n)$ sampled record
 f_0 initial frequency
 W_1 first record window
 W_2 second record window
 U_s sampled record
 U_m model waveform
 d window separation
 $\hat{\phi}_s$ sampled data phase
 ϕ_m model phase
 ϕ_e estimated phase
 t_s sampling time
 j loop iteration number



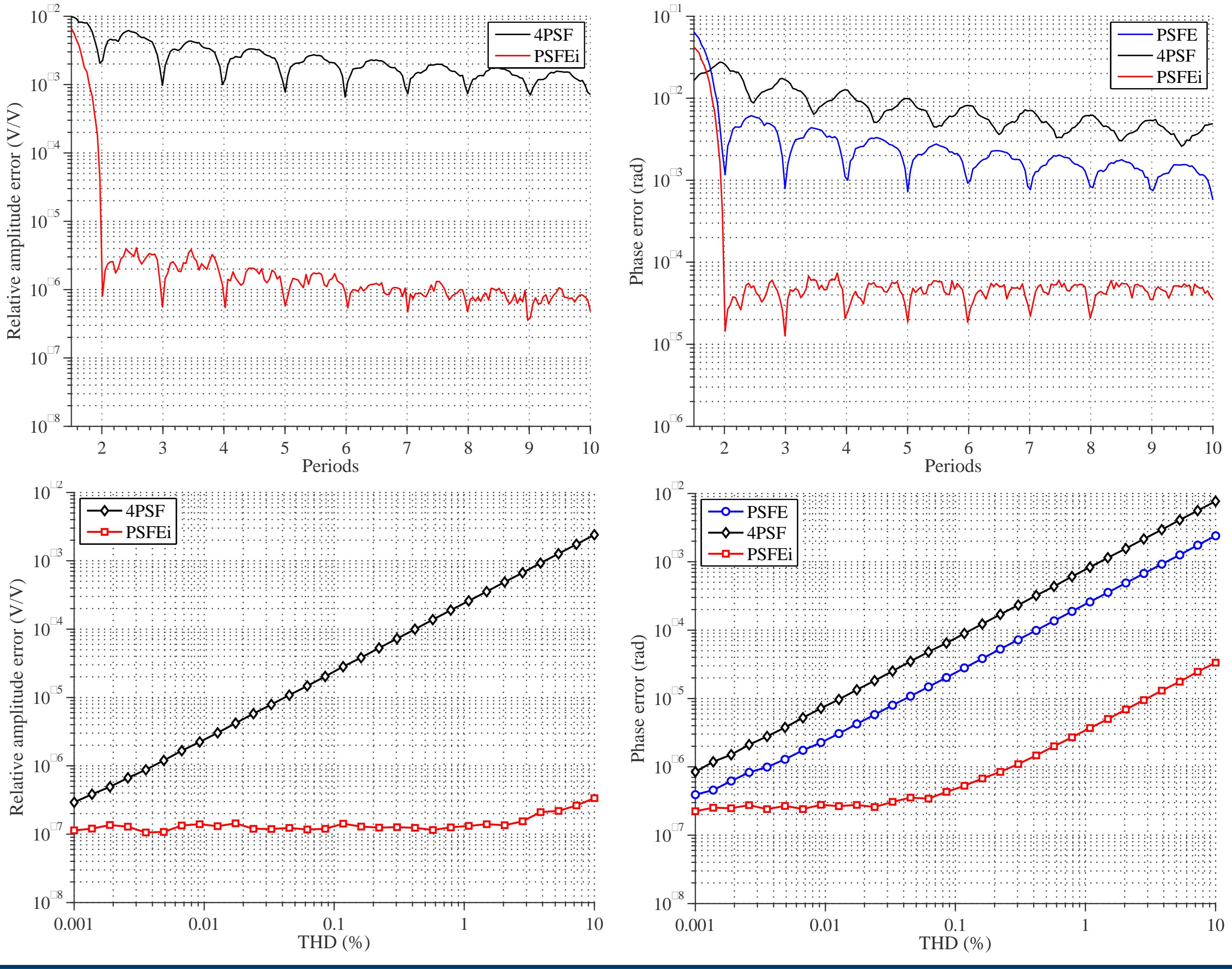
Simulations: noise performance

$N=2000, t_s = 50 \mu s, f=122 \text{ Hz}, \Phi \in [-\pi, +\pi]$:



Simulations: harmonic distortion performance

$N=2048, A_2=0.03A_1, A_3 = 0.01A_1, A_5=0.003A_1, \text{SNR} = 120 \text{ dB}$:



Measurements

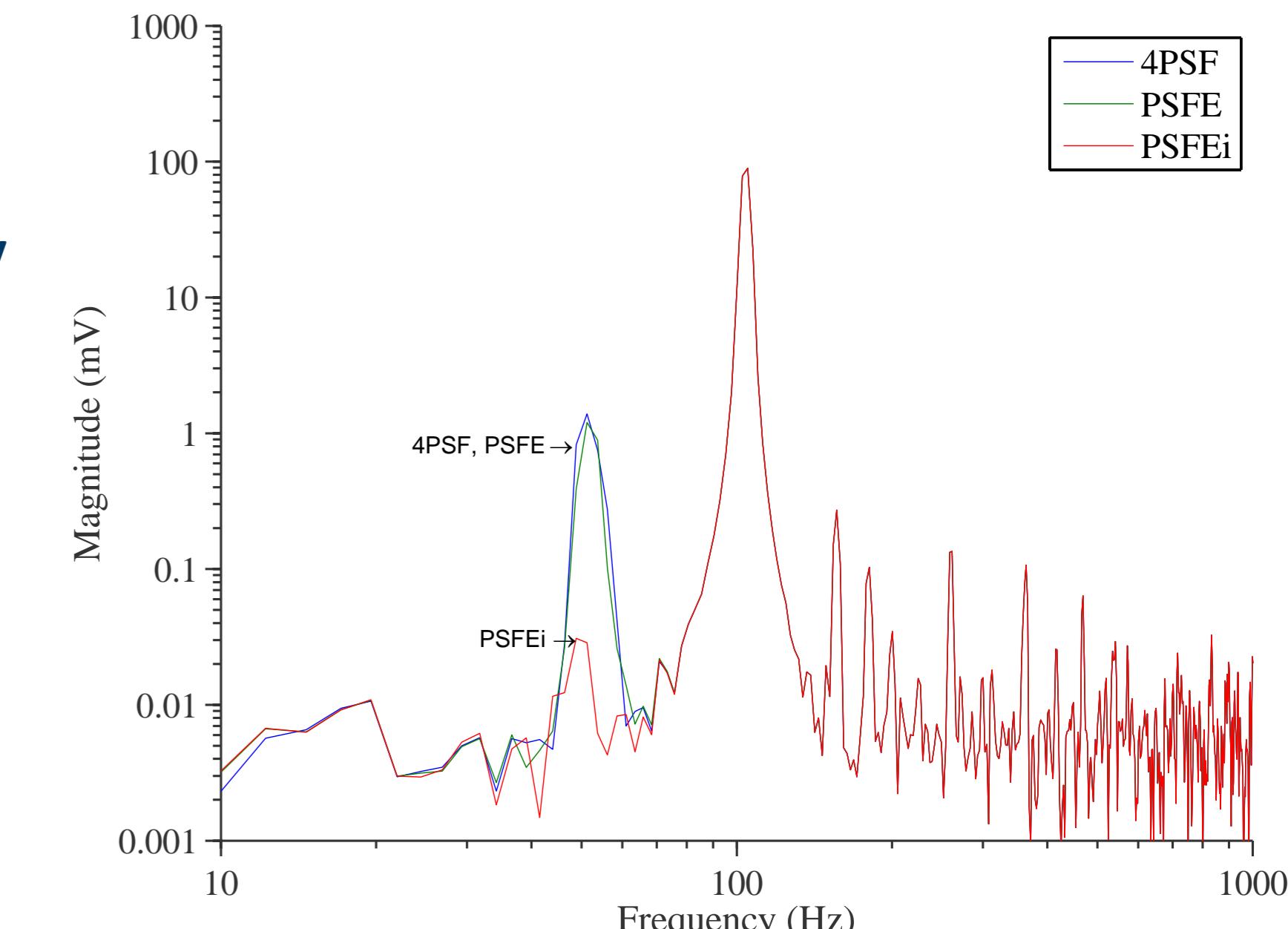
Generator: Fluke 6100A

Sampler: Agilent 3458A

$f = 52 \text{ Hz}, U_1 = 7 \text{ V}, U_2 = 70 \text{ mV}$
 $N = 8192$

Estimated signal subtracted from sampled signal

Residual spectrum calculated using Hann window



Conclusions

- Simple implementation, using only FFT and 3PSF
- Reduced sensitivity to harmonic distortions
- Slightly increased noise sensitivity
- Fast convergence, typically needs two to three iterations
- Robust, stable from 8 samples
- From 2 sampled periods up to 0.8 Nyquist frequency
- More accurate than 4PSF for harmonically distorted signals