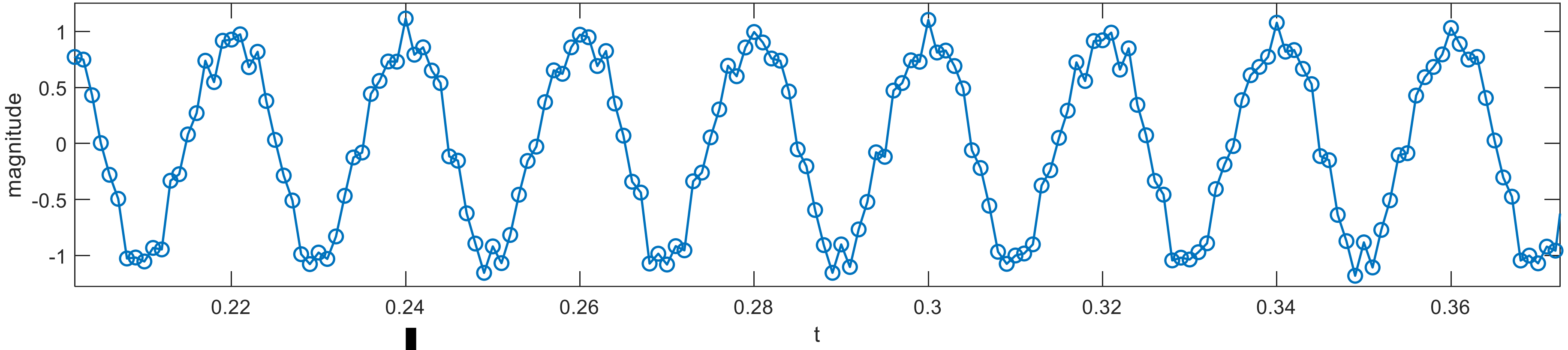
Extended Morlet Wavelet-Based FIR Phasor Estimation Using Fake Samples

Presenter: Xin Liu

Background: Phasor Estimation

$$s = A \cdot \cos(2\pi f(t+\phi)) + A_{h1} \cdot \cos(2\pi f_{h1}\,(t+\phi_{h1})) + A_{h2} \cdot \cos(2\pi f_{h2}\,(t+\phi_{h2})) + \cdots$$

Give a noisy sampled signal, for example, at 1k Hz.



Phasor Estimation Algorithm

$A \quad f \quad \phi \quad ROCOF$

Morlet Wavelet-based Two-Point FIR (MW-FIR)

Input Signal

$$s(t) = U_0 \cdot \cos(2\pi f_0 t + \phi_0)$$

Morlet Wavelet

$$\boldsymbol{\psi}_k(t) = e^{-\frac{t^2}{a}} \cdot e^{i2\pi f_{c\_k} t}$$

Convolution

$$\boldsymbol{y}_k(t) = \psi_k(t) * s(t)$$

$$\boldsymbol{y}_k(t) = \frac{1}{2} \cdot [\Psi_k(f_0)\boldsymbol{A}_0^+(t) + \Psi_k(-f_0)\boldsymbol{A}_0^-(t)]$$

$$\boldsymbol{A}_0^{\pm}(t) = U_0 e^{\pm i(2\pi f_0 t + \phi_0)}$$

$$\Psi_k(f) = \sqrt{\pi a} \cdot e^{-a\pi^2 (f - f_{c\_k})^2}$$

$$\boldsymbol{y}_k(t_c) \approx \frac{1}{2} \cdot \Psi_k(f_0)\boldsymbol{A}_0^+(t_c)$$

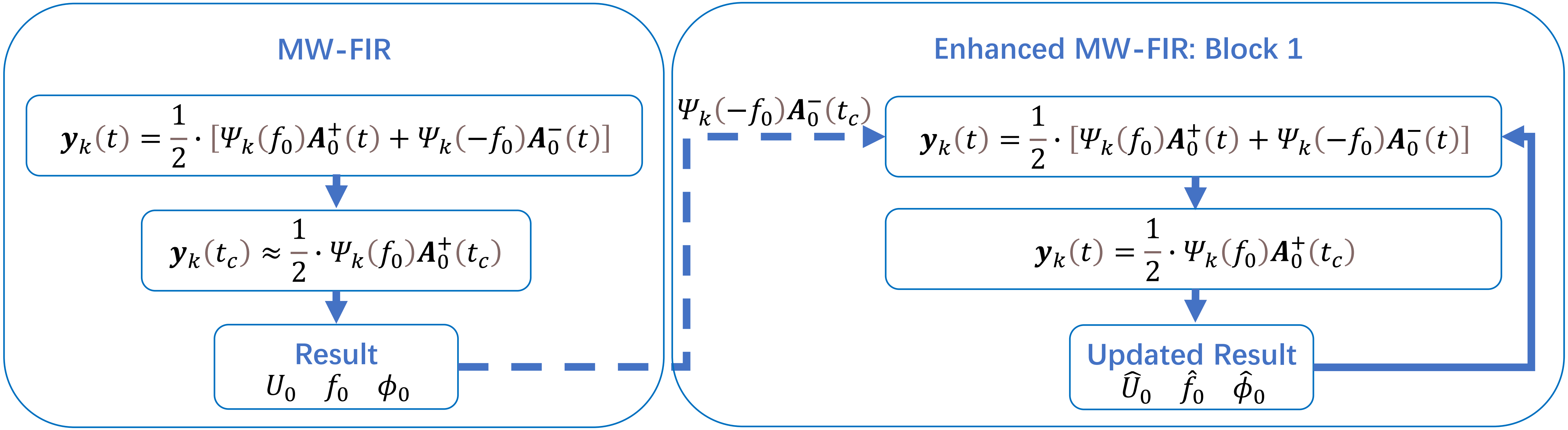
$$|\boldsymbol{y}_1(t_c)| = \frac{1}{2} \cdot U_0 \cdot \sqrt{\pi a} \cdot e^{-a\pi^2 (f_0 - f_{c\_1})^2} \qquad |\boldsymbol{y}_2(t_c)| = \frac{1}{2} \cdot U_0 \cdot \sqrt{\pi a} \cdot e^{-a\pi^2 (f_0 - f_{c\_2})^2}$$

Result

$U_0 \quad f_0 \quad \phi_0$

Source: X. Liu, M. Lewandowski and N. K. C. Nair, "A Morlet Wavelet-Based Two-Point FIR Filter Method for Phasor Estimation," in IEEE Transactions on Instrumentation and Measurement, vol. 70, pp. 1-10, 2021

Enhanced MW-FIR Block 1

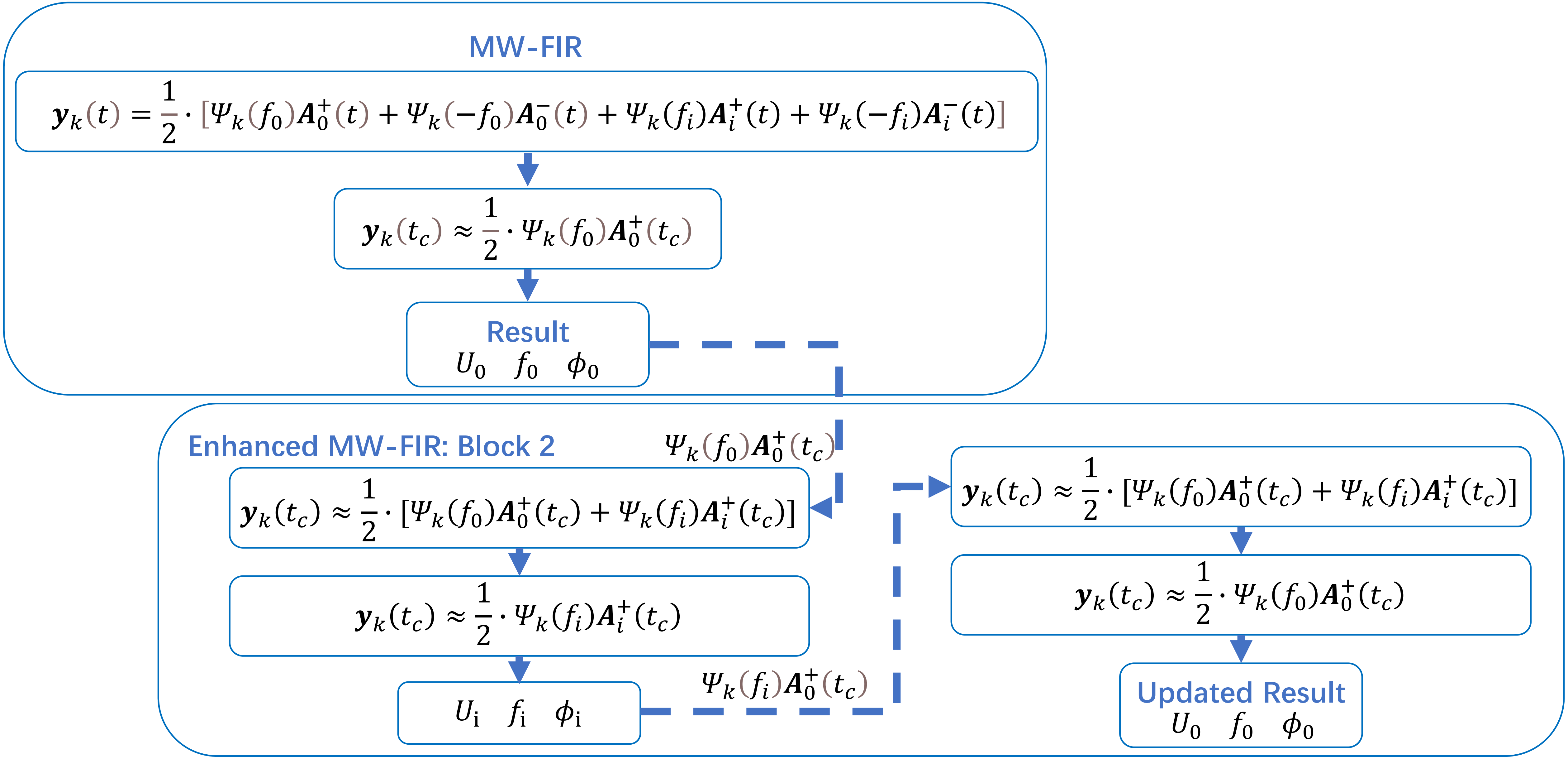


Source: X. Liu and N. K. C. Nair, "Enhanced Morlet Wavelet-Based Two-Point FIR for Phasor Estimation," in IEEE Transactions on Smart Grid, vol. 13, no. 6, pp. 4704-4715, Nov. 2022

Enhanced MW-FIR Block 2

Input Signal

$$s(t) = U_0 \cdot \cos(2\pi f_0 t + \phi_0) + U_i \cdot \cos(2\pi f_i t + \phi_i)$$



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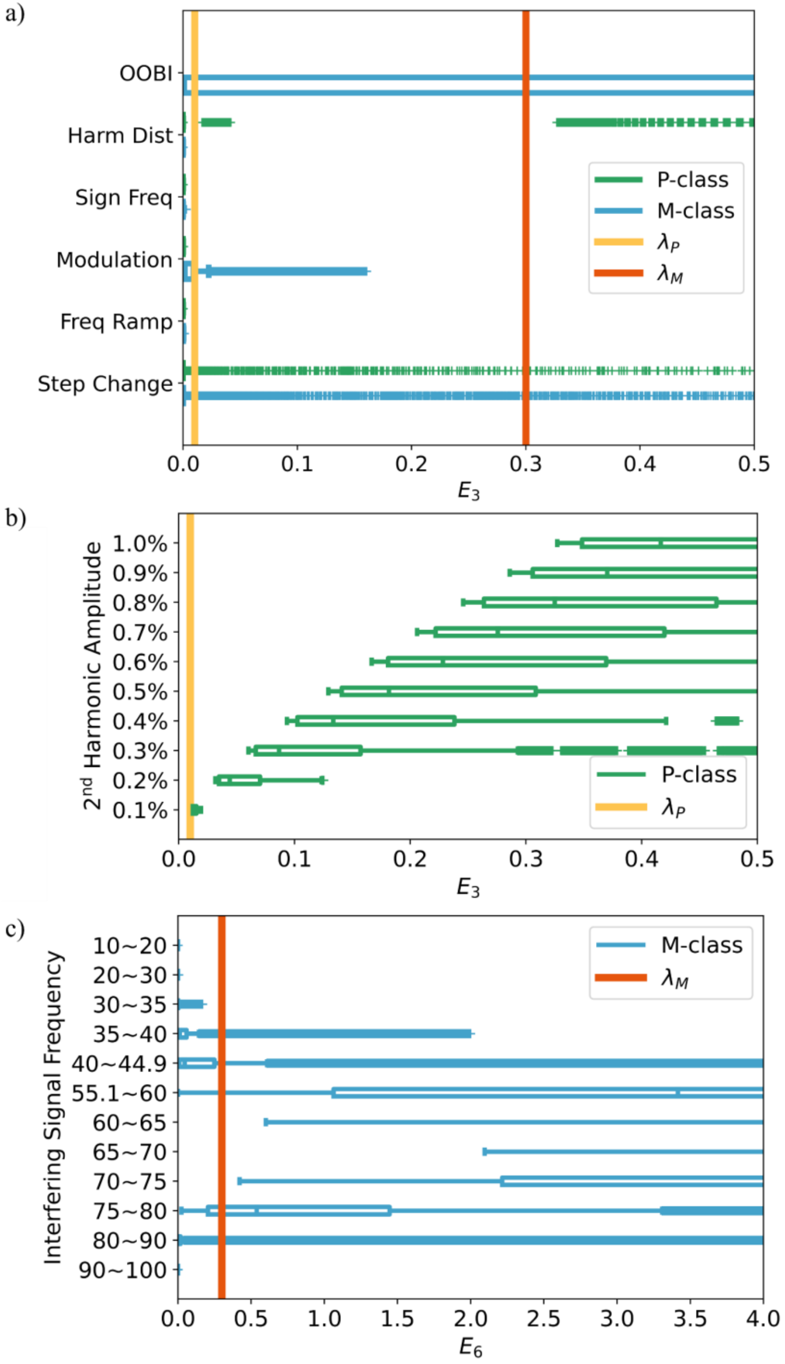
Enhanced MW-FIR

Input Signal

$$s(t) = U_0 \cdot \cos(2\pi f_0 t + \phi_0) + U_i \cdot \cos(2\pi f_i t + \phi_i)$$

Ratio E_k

$$E_k = \frac{|\boldsymbol{y}_k(t_c) - \boldsymbol{x}_k(t_c)|^2}{|\boldsymbol{y}_k(t_c)|}$$



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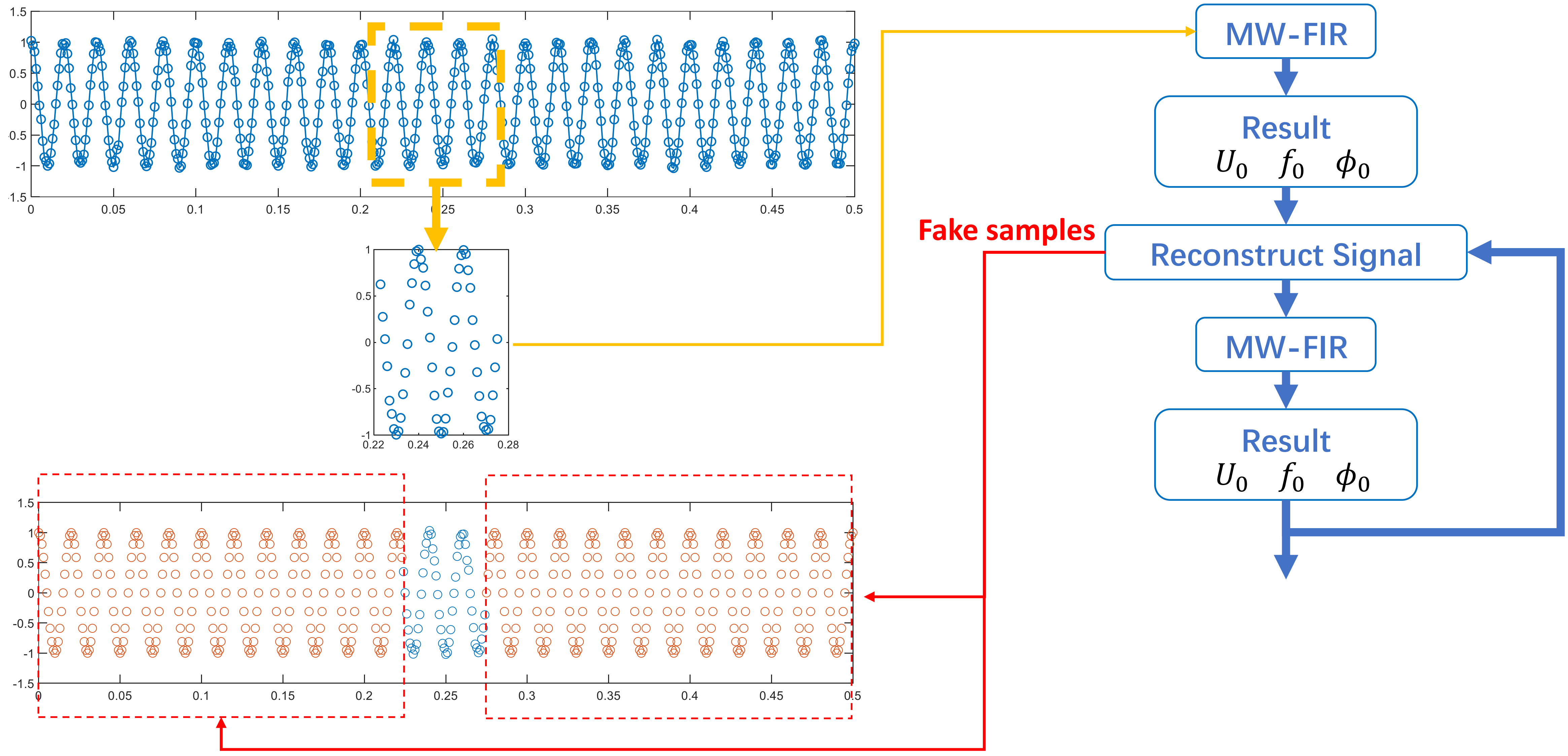
Extended MW-FIR using Fake Samples



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Extended MW-FIR using Fake Samples

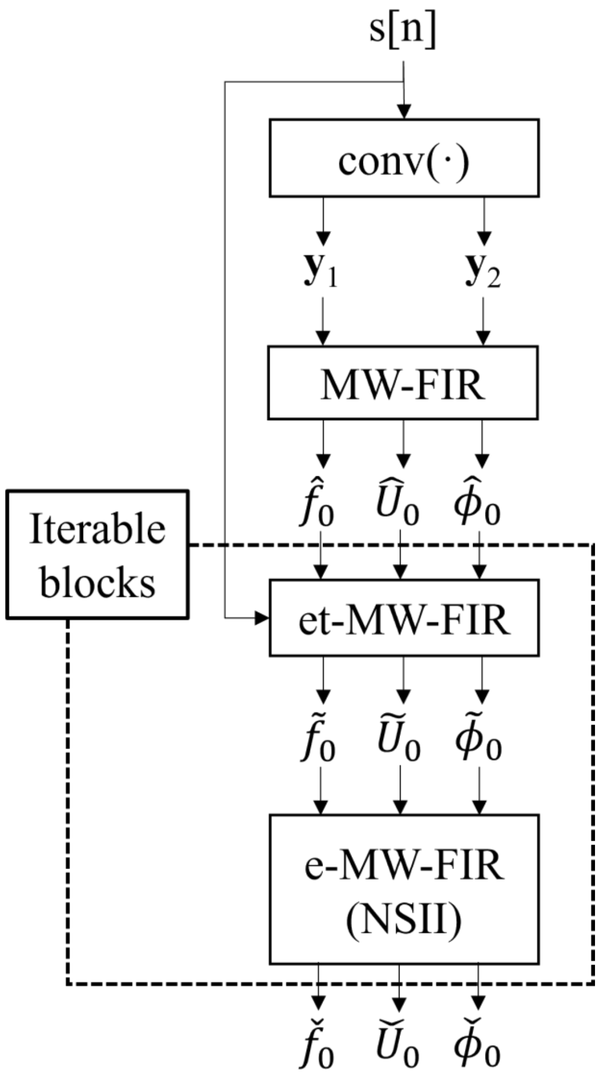
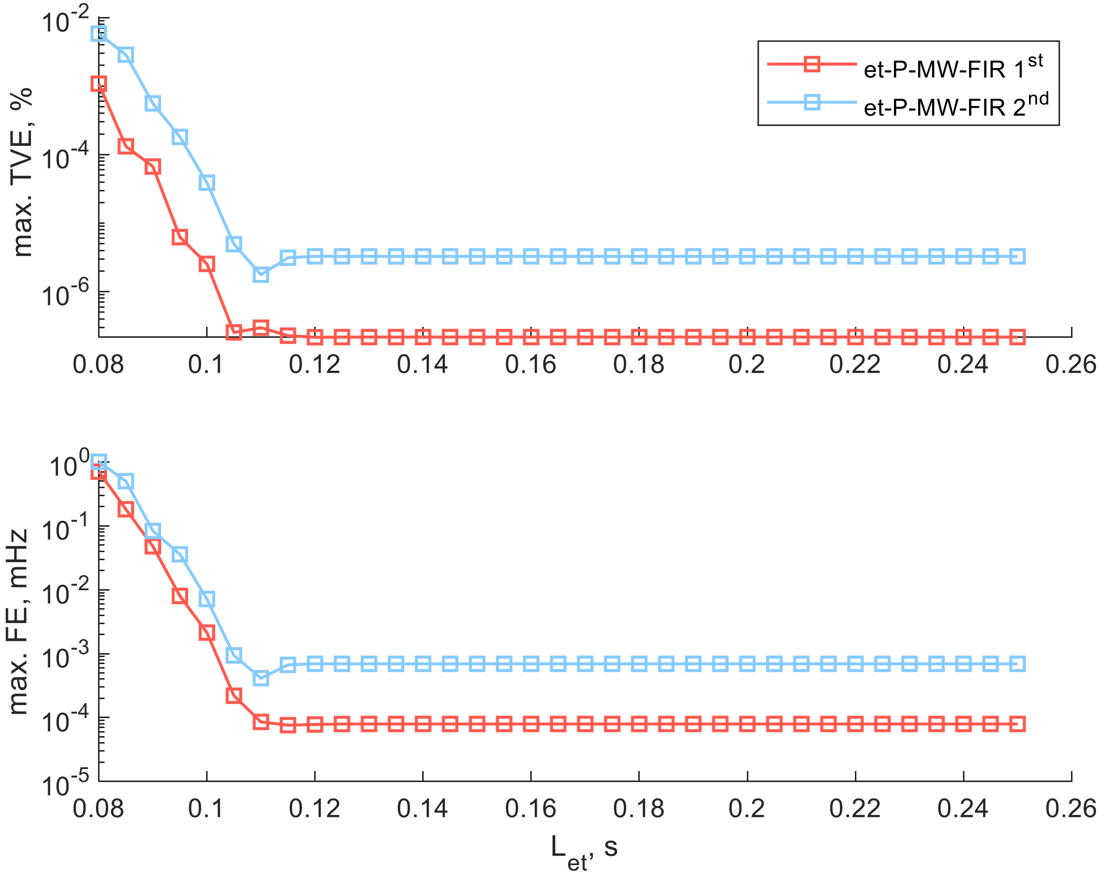


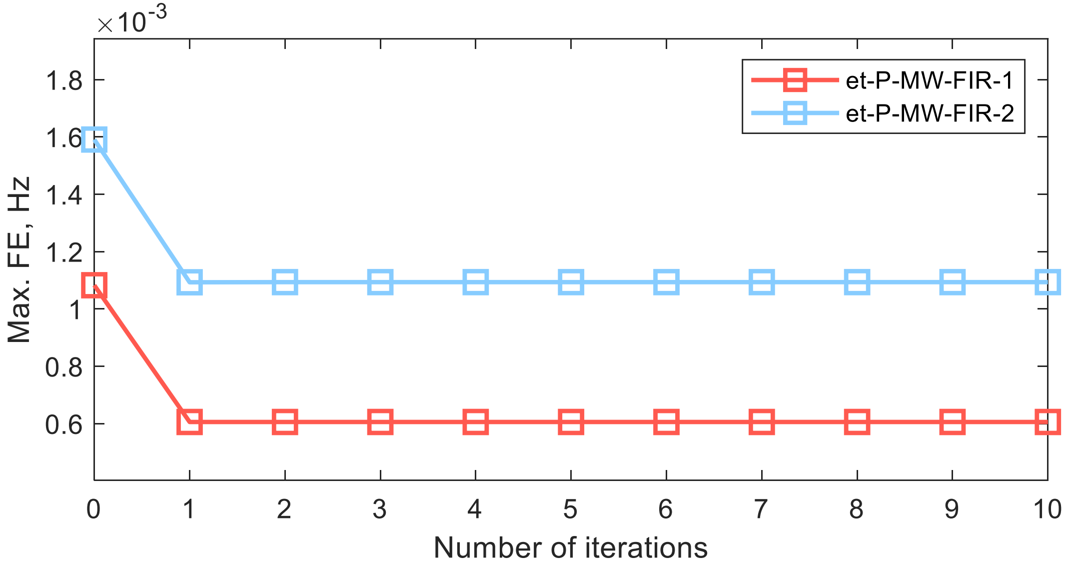
Diagram of the proposed et-P-MW-FIR estimator.



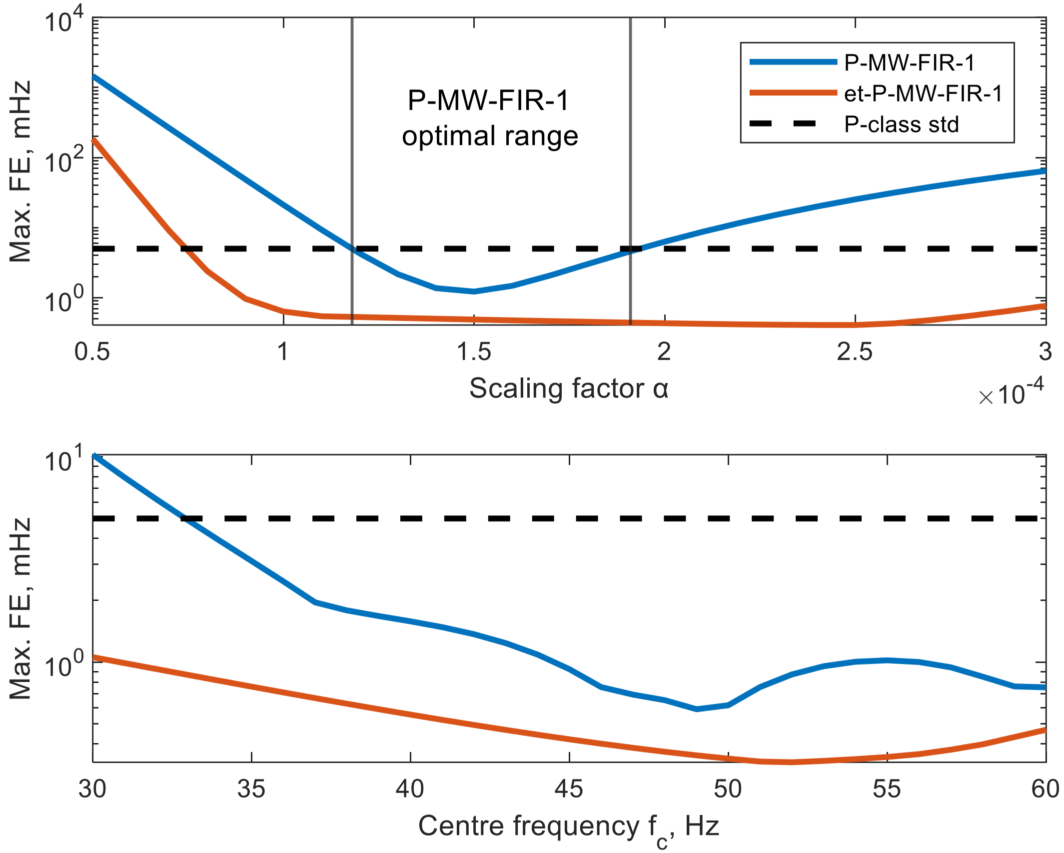
Simulation results for accuracy assessment of the different extended window length.

Source: X. Liu, K. I. -K. Wang and N. K. C. Nair, "Extended Morlet Wavelet-Based FIR Phasor Estimation Using Fake Samples," in IEEE Transactions on Industrial Informatics, 2023.

Extended MW-FIR using Fake Samples



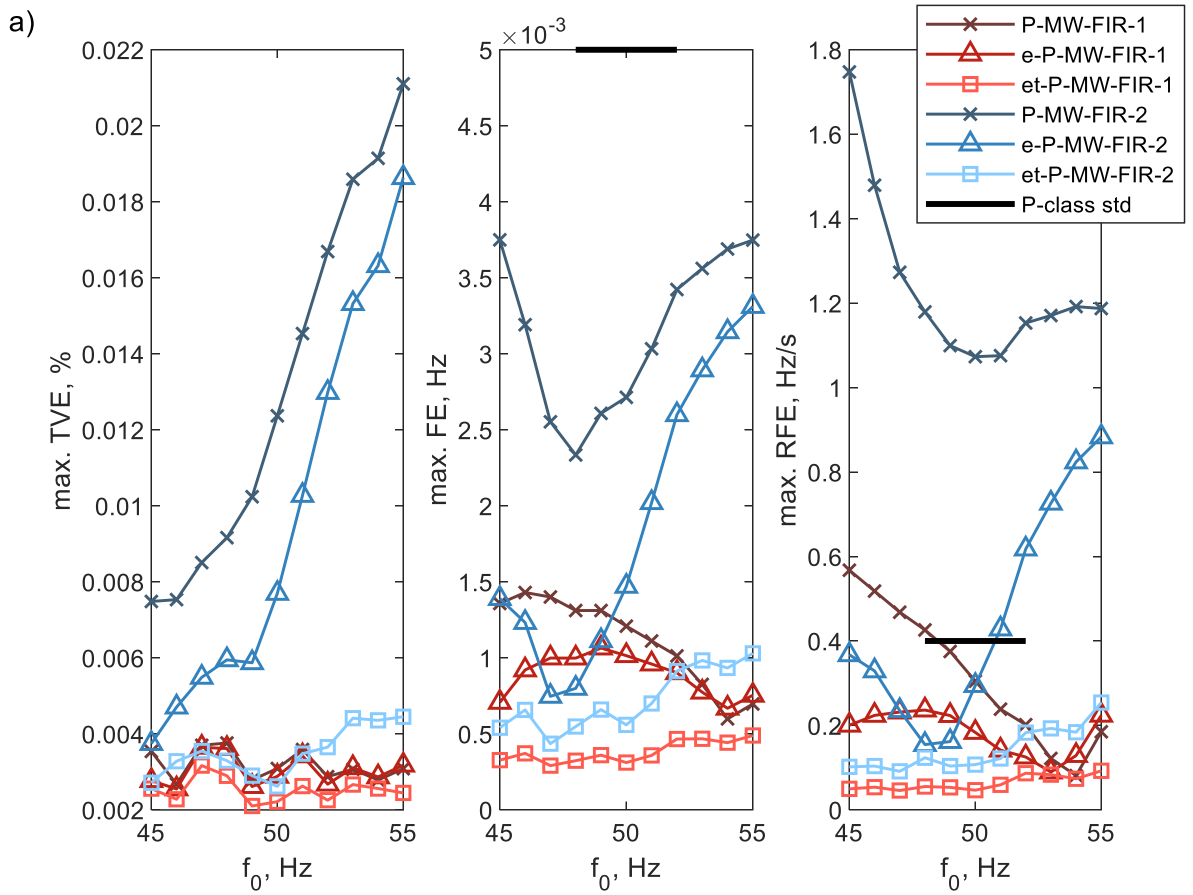
Maximum frequency estimation error regarding the number of iteration.



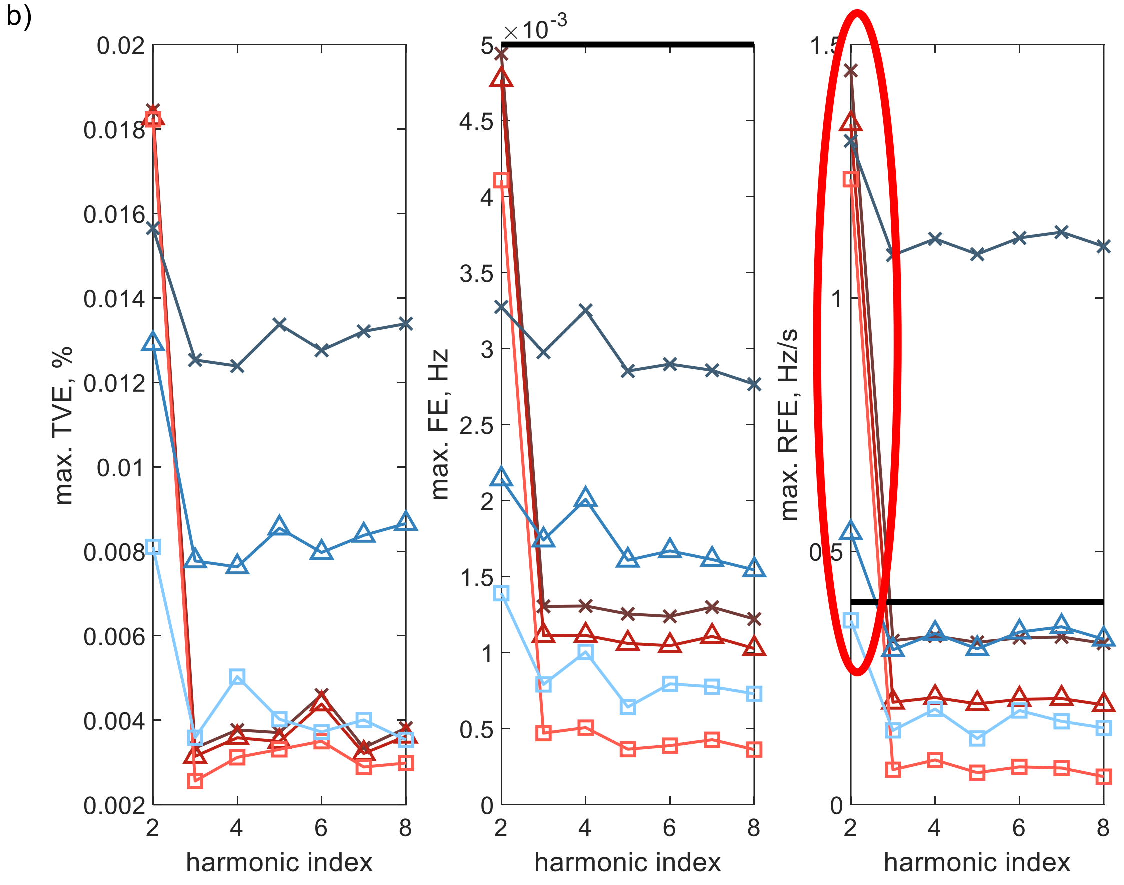
Maximum frequency estimation error regarding the scaling factor and centre frequency.

Source: X. Liu, K. I. -K. Wang and N. K. C. Nair, "Extended Morlet Wavelet-Based FIR Phasor Estimation Using Fake Samples," in IEEE Transactions on Industrial Informatics, 2023.

Extended MW-FIR using Fake Samples



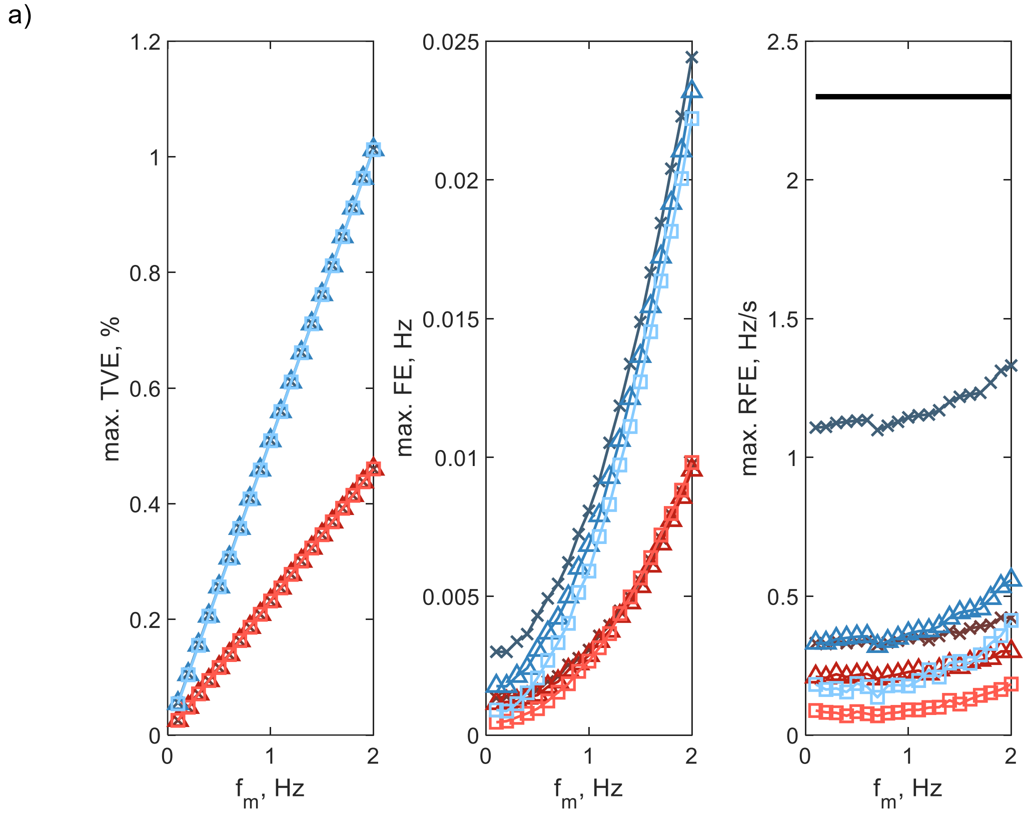
Frequency offset test.



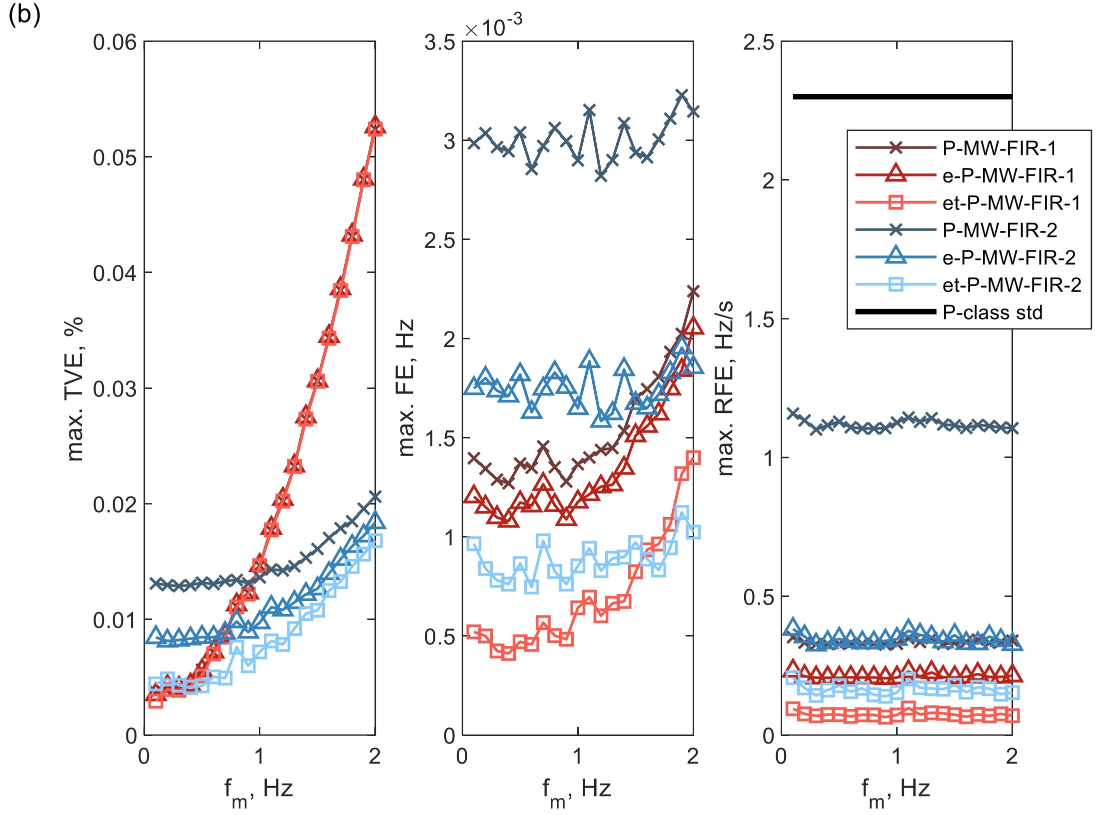
Harmonic distortion test.

Source: X. Liu, K. I. -K. Wang and N. K. C. Nair, "Extended Morlet Wavelet-Based FIR Phasor Estimation Using Fake Samples," in IEEE Transactions on Industrial Informatics, 2023.

Extended MW-FIR using Fake Samples



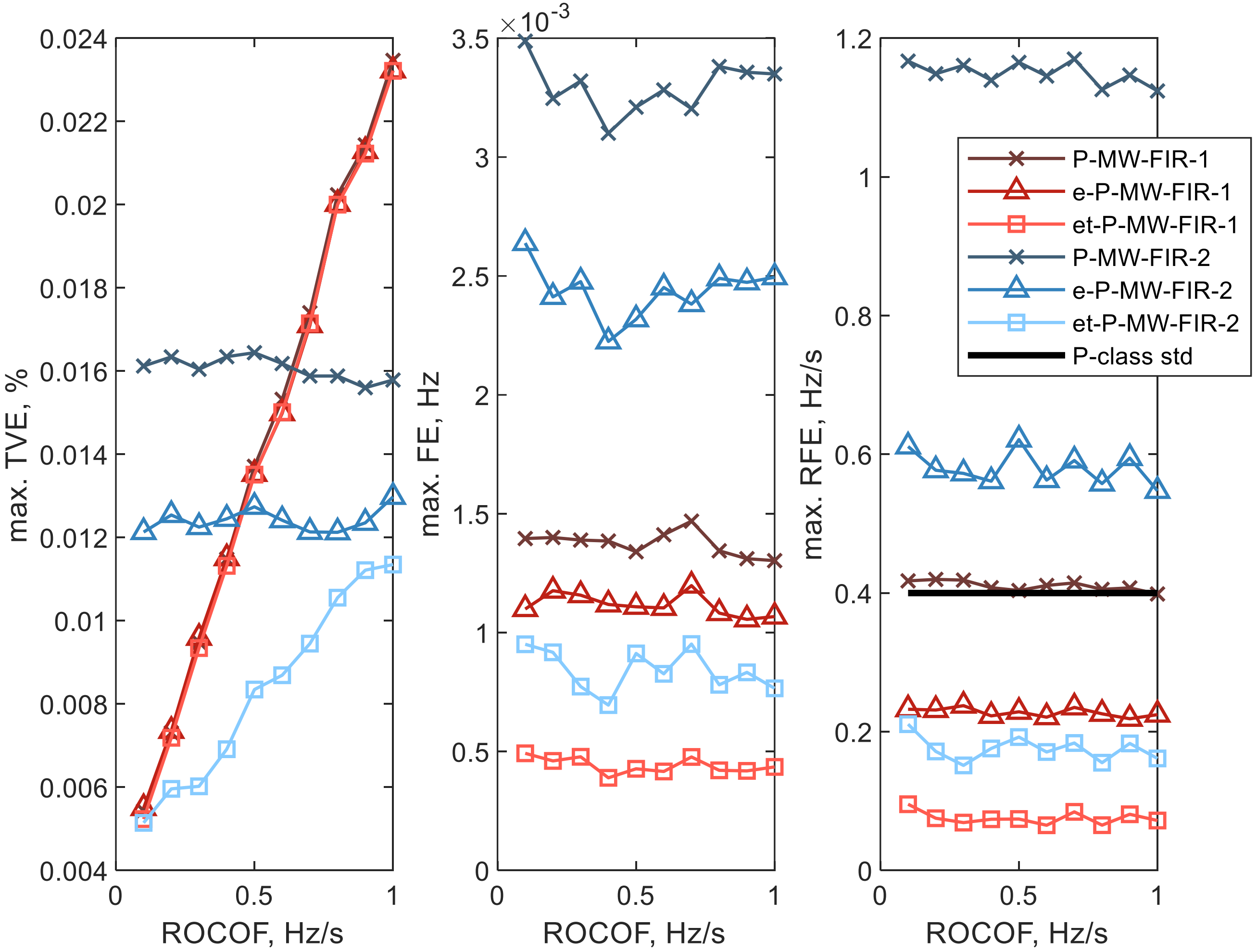
Amplitude modulation test.



Phase modulation test.

Source: X. Liu, K. I. -K. Wang and N. K. C. Nair, "Extended Morlet Wavelet-Based FIR Phasor Estimation Using Fake Samples," in IEEE Transactions on Industrial Informatics, 2023.

Extended MW-FIR using Fake Samples



Positive frequency ramping test.

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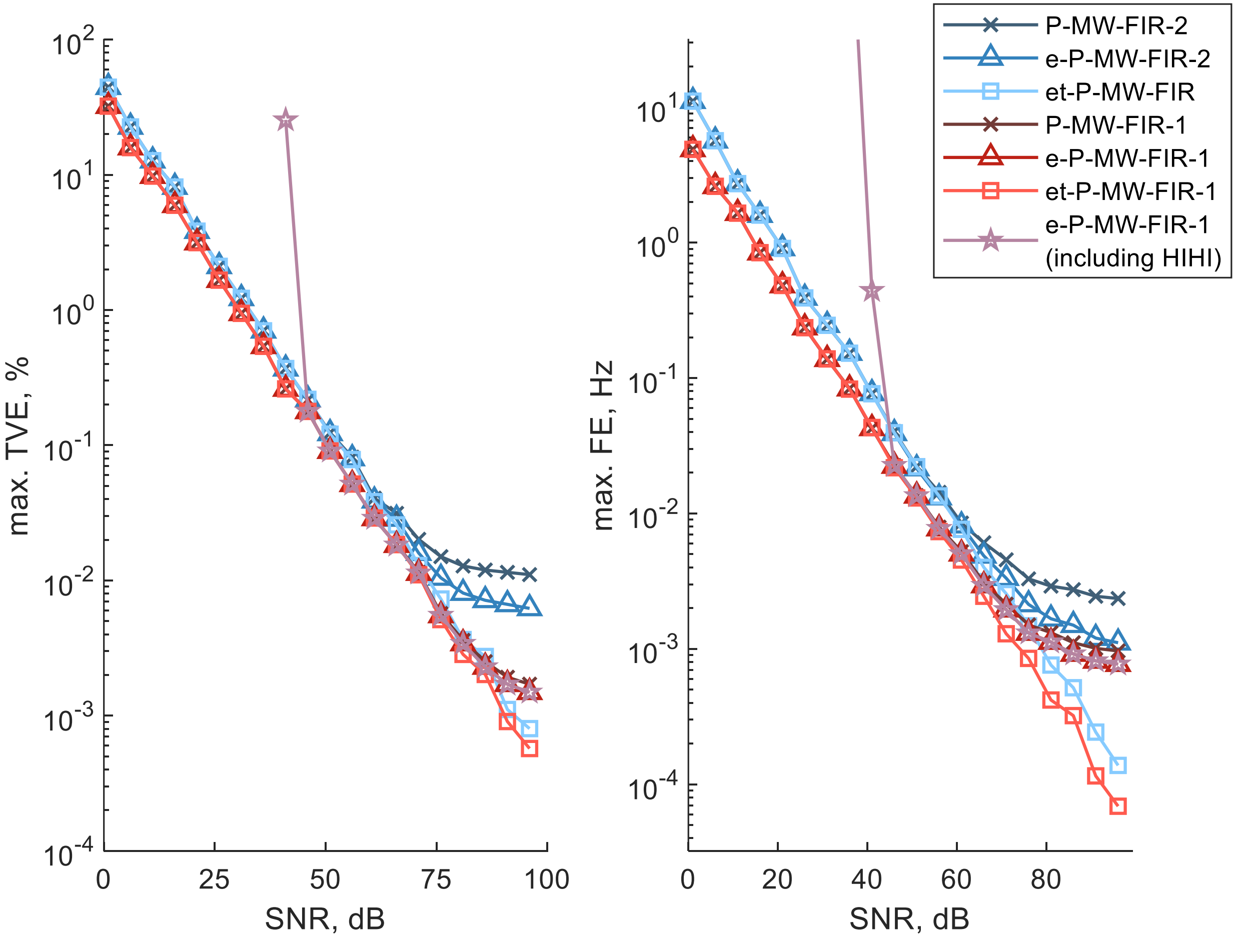
Extended MW-FIR using Fake Samples



Noise immunity test.

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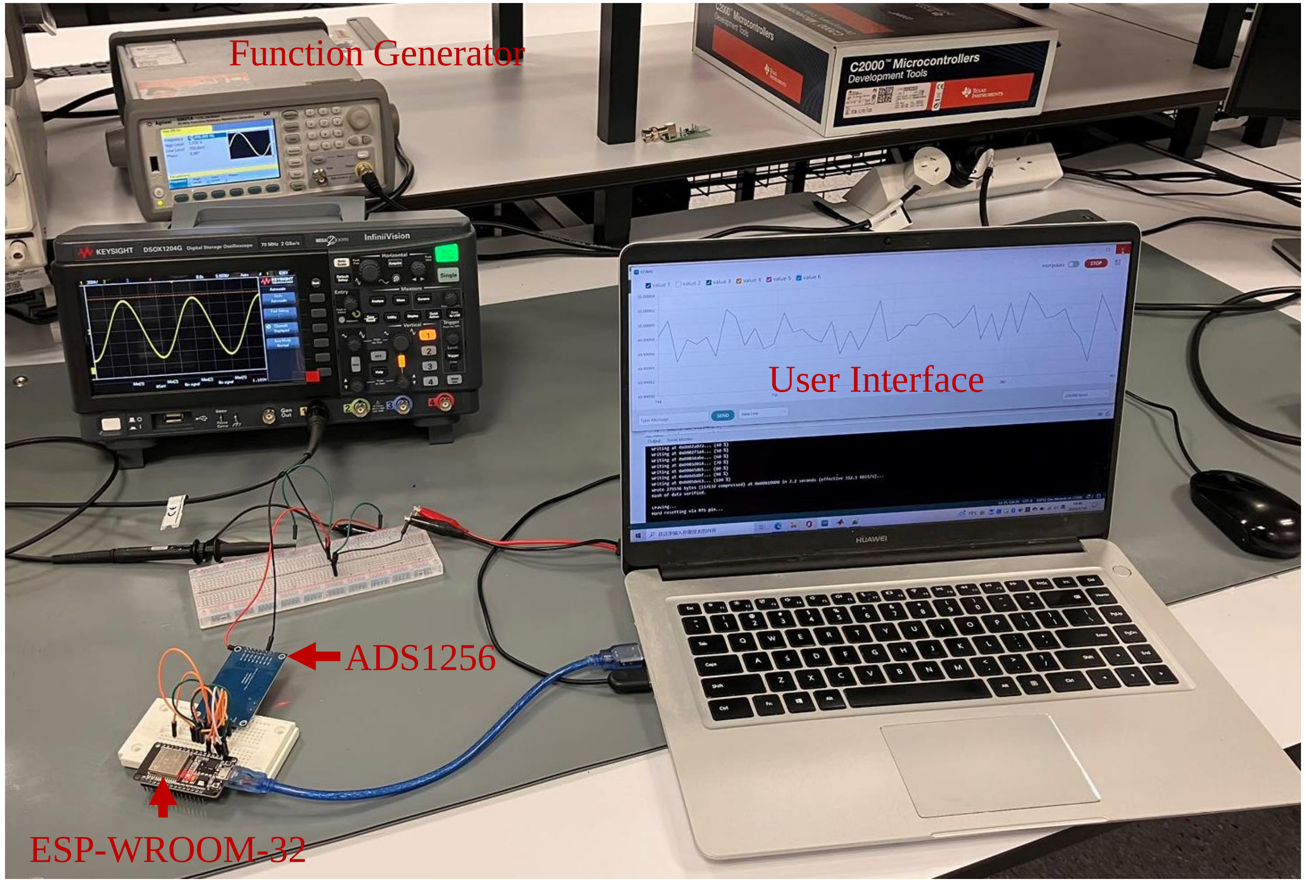
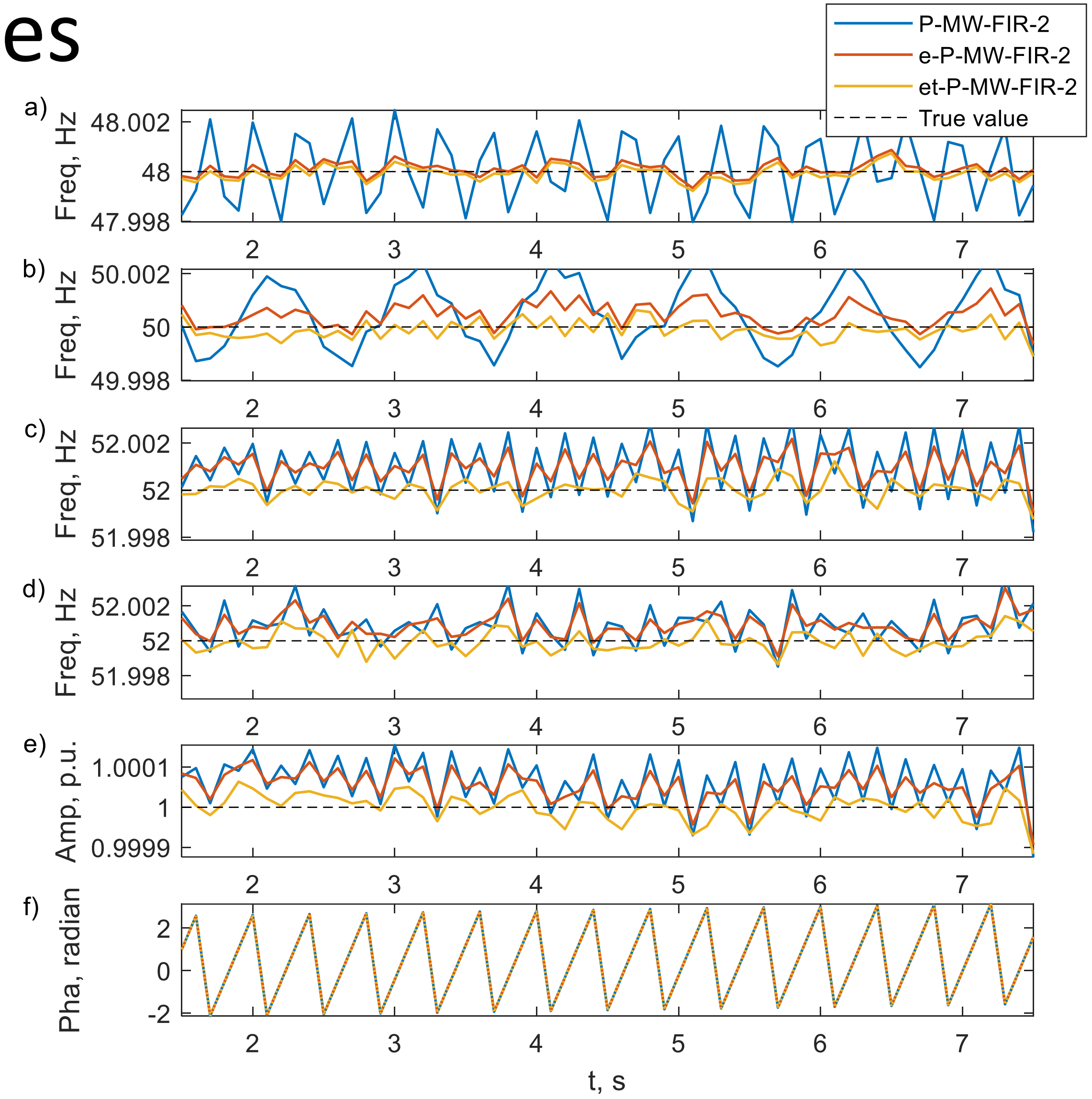
Extended MW-FIR using Fake Samples



Hardware implementation.



Fragments of reported estimates from hardware implementation. d) simulated input signal $f_0 = 52$ Hz and SNR = 80 dB.

Source: X. Liu, K. I. -K. Wang and N. K. C. Nair, "Extended Morlet Wavelet-Based FIR Phasor Estimation Using Fake Samples," in IEEE Transactions on Industrial Informatics, 2023.