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MEASUREMENT AND ESTIMATION OF ARBITRARY SIGNAL POWER USING A WINDOW TECHNIQUE

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Motivation

Sampling technique using a simultaneous and coherent sampling of sine wave voltage and current is a reference power measurement technique in calibration labs for decades. However, when coherent sampling is not possible and the signal is not pure sine wave, the signal power estimation from the sampled data becomes a complex problem. One possible solution, still achieving reasonably small uncertainties, is proposed here.
A time domain window technique is used on arbitrary signals where coherent sampling is not possible but the spectral components in the signal are well separated, at least for a few FFT bins. The actual performance of the method can be tuned by the selection of the appropriate time window (Hanning, Blackmann-Harris (BH92), ...).

Signal RMS value using window technique

Voltage of coherently sampled *V*

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} V(n)^2}$$

Voltage of non-coherently sampled *V*

$$V_{wrms} = \sqrt{\frac{1}{S_2}\sum_{n=1}^{N} \left(V(n)w(n)\right)^2}$$

where *w* is selected time domain window.

$$S_2 = \sum_{j=1}^{N} w^2(j)$$

Reference: M. Novotny and M. Sedlacek, ”RMS value measurement based on classical and modified digital signal processing algorithms,” Measurement, vol. 41, no. 3, April 2008

Active and apparent power using window technique

The same windowing technique can be applied for discrete power estimation, when the same window is applied to both voltage and current sampled series.

Active Power of simultaneously and coherently sampled *V* and *I* signal

$$P_s = \frac{1}{N}\sum_{n=1}^{N} V(n)I(n)$$

Active Power of simultaneously and non-coherently sampled *V* and *I* signal

$$P_{ws} = \frac{1}{S_2}\sum_{n=1}^{N} V(n)I(n)w^2(n)$$

Apparent Power of simultaneously and non-coherently sampled *V* and *I* signal

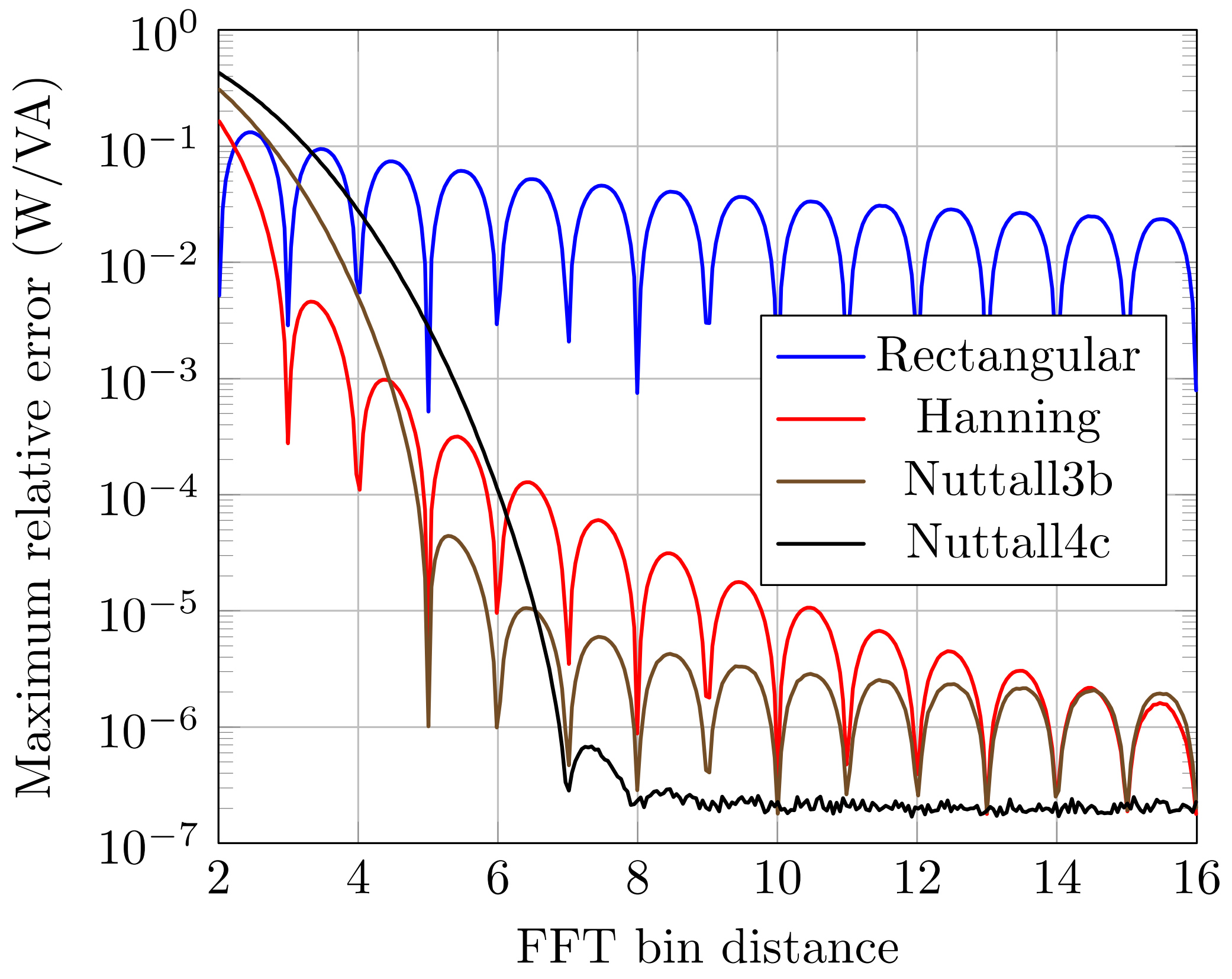
$$Q_{ws} = \frac{1}{S_2}\sqrt{\sum_{n=1}^{N} V_w(n)^2 \sum_{n=1}^{N} I_w(n)^2}$$

Discussion

- Possible windows are are all cosine windows like Hanning, Blackman, Blackman-Harris, as well as flat-top family of windows.
- The error of the proposed method depends on the window function used and the frequency distance of signal components.
- Windows with lower side lobes requires greater signal frequency distance, but provide faster settling (e.g. require less sampled signal cycles for a given maximum permissible estimation error).
- Windowing technique provides an accurate method to estimate active power of arbitrary (but repetitive) wave-shape, as long as spectral components are separated at least a few FFT bins apart.
- The actual performance can be tuned by the selection of the appropriate time window function.

Simulated and measured results

N = 1000, random phase, 0 rad phase difference, *SNR* = 120 dB
U = 100 V sine wave at 50 Hz
a) *I* = 5 A + 10 % interharmonic component, t_s = 1 ms



a) Maximum relative power error as a function of inter-harmonic frequency distance from the fundamental tone.

b) Harmonically distorted current and comparison to non-distorted current scenario using commercial power source and Agilent 3458A as sampler (T_s = 1 ms, T_a = 0.2 ms).