

Ultra-pure sinewaves

Project Final Workshop

22RPT02 – *True8DIGIT*

Towards a true 8-digit digitiser

<https://true8digit.eu>

Rado Lapuh, Left Right s.p.

15th May 2026

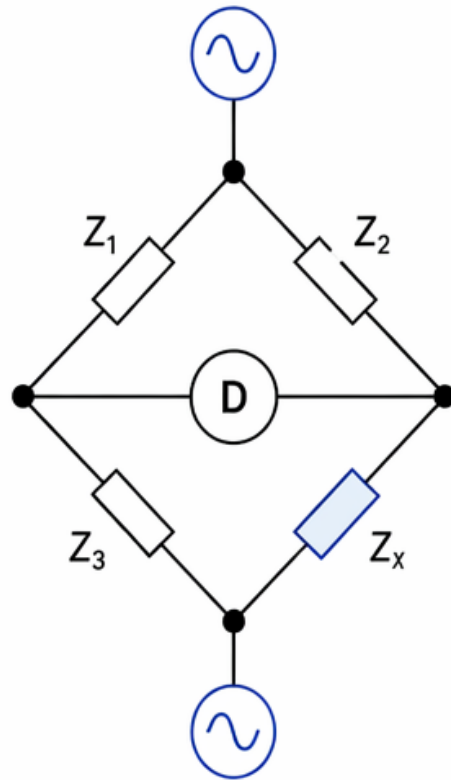


Why ultra-pure sine waves matter

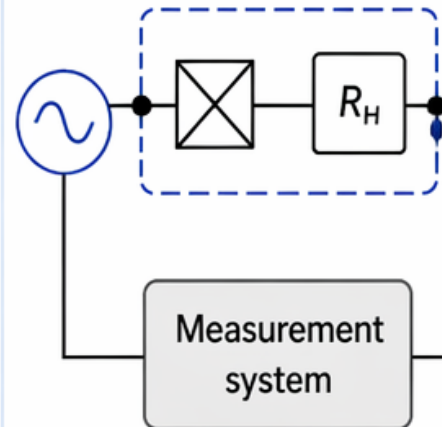
1. High-resolution ADC testing



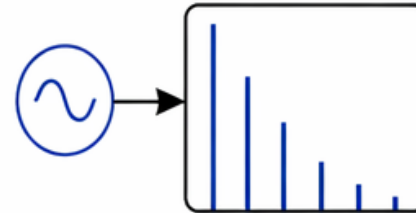
2. Impedance bridges



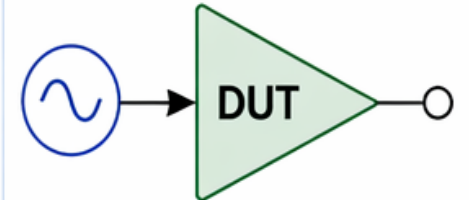
3. Quantum electrical standards



4. Spectral calibration



5. Low-distortion amplifier characterization



Traditional measurement limitation



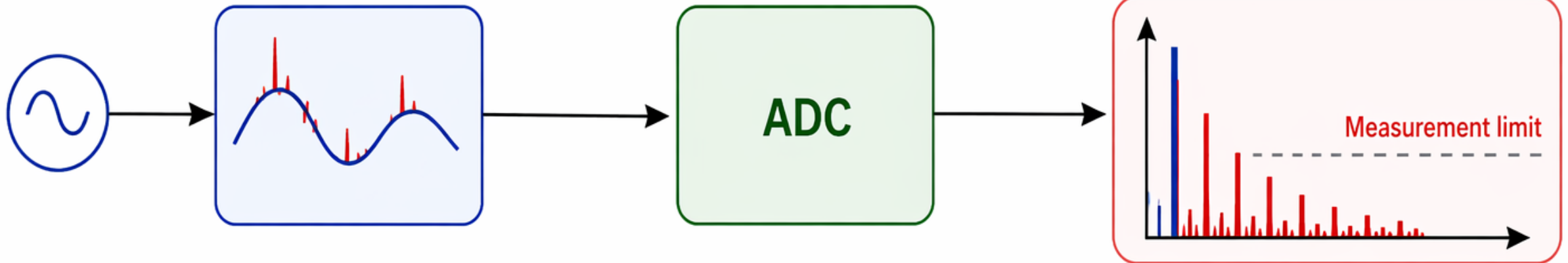
Generator distortion

+

ADC distortion

=

Measurement limit

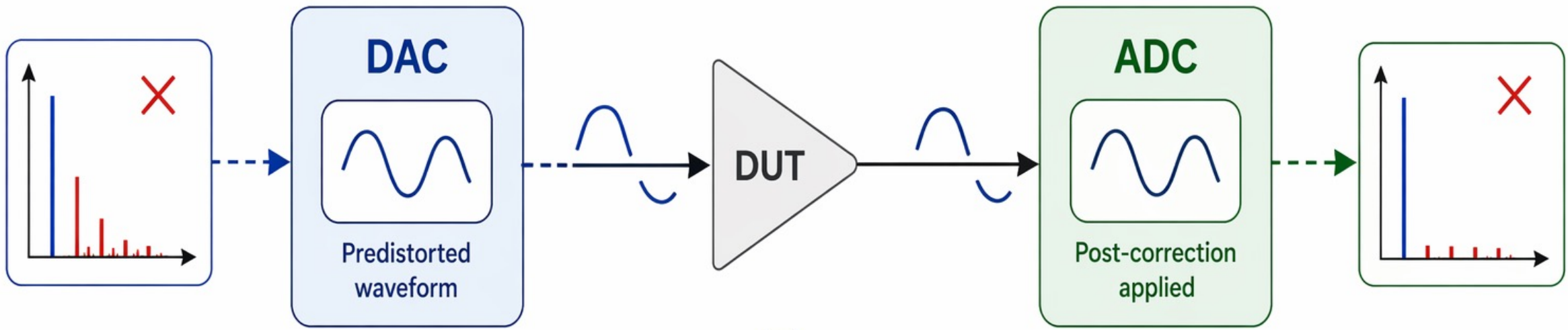


Typical workaround: analog notch filters

Key idea of this work




1 DAC harmonic cancellation (predistortion)

2 ADC harmonic cancellation (post-correction)

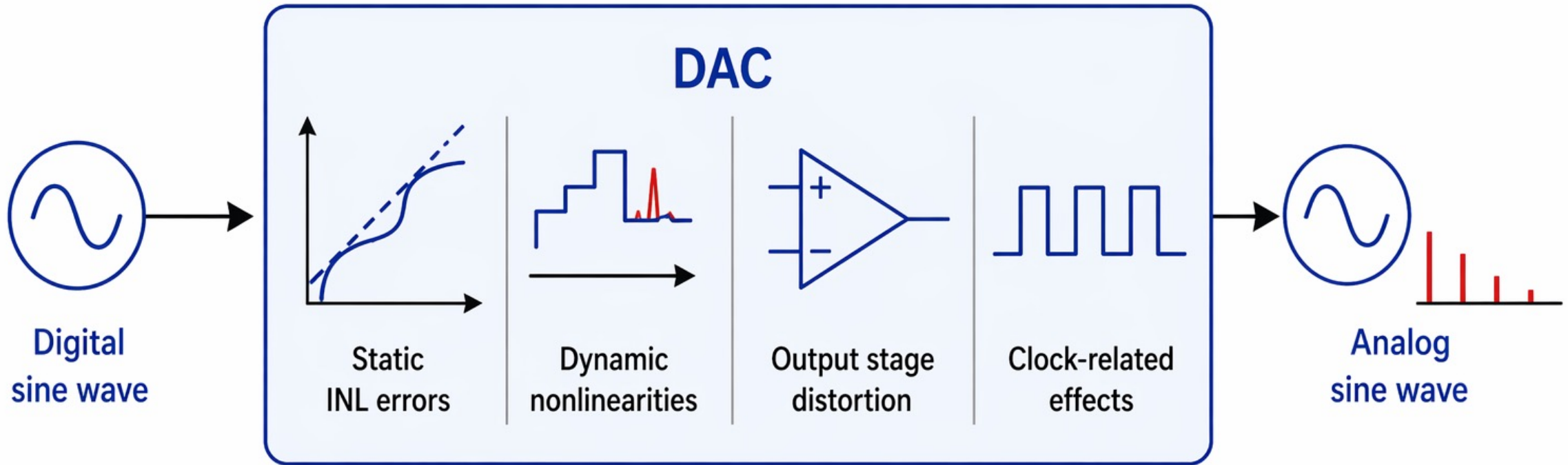


Result:

Digitally programmable ultra-pure sine wave metrology

 Sources |  Meters |  Transducers

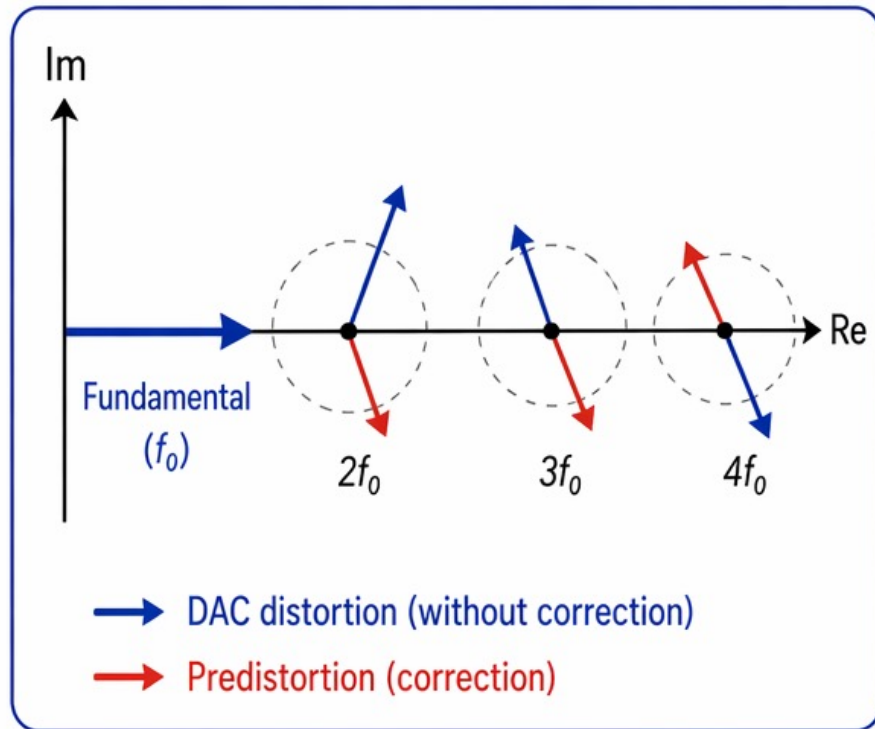
Why DAC sine waves are not perfectly clean



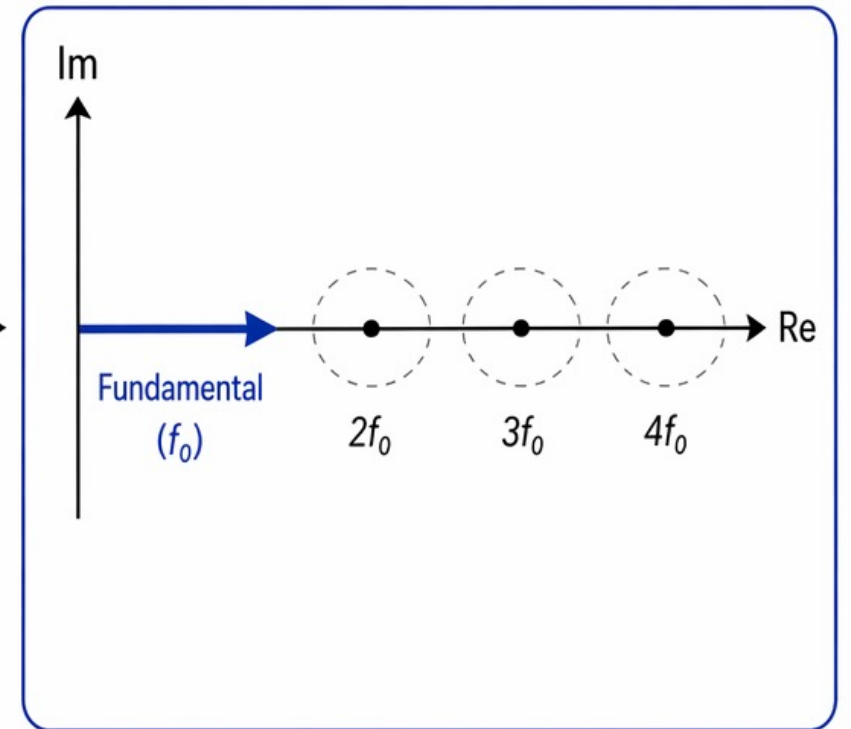
! Typical performance: -110 to -130 dBc

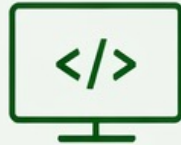
Principle of DAC harmonic cancellation

Add small correction harmonics

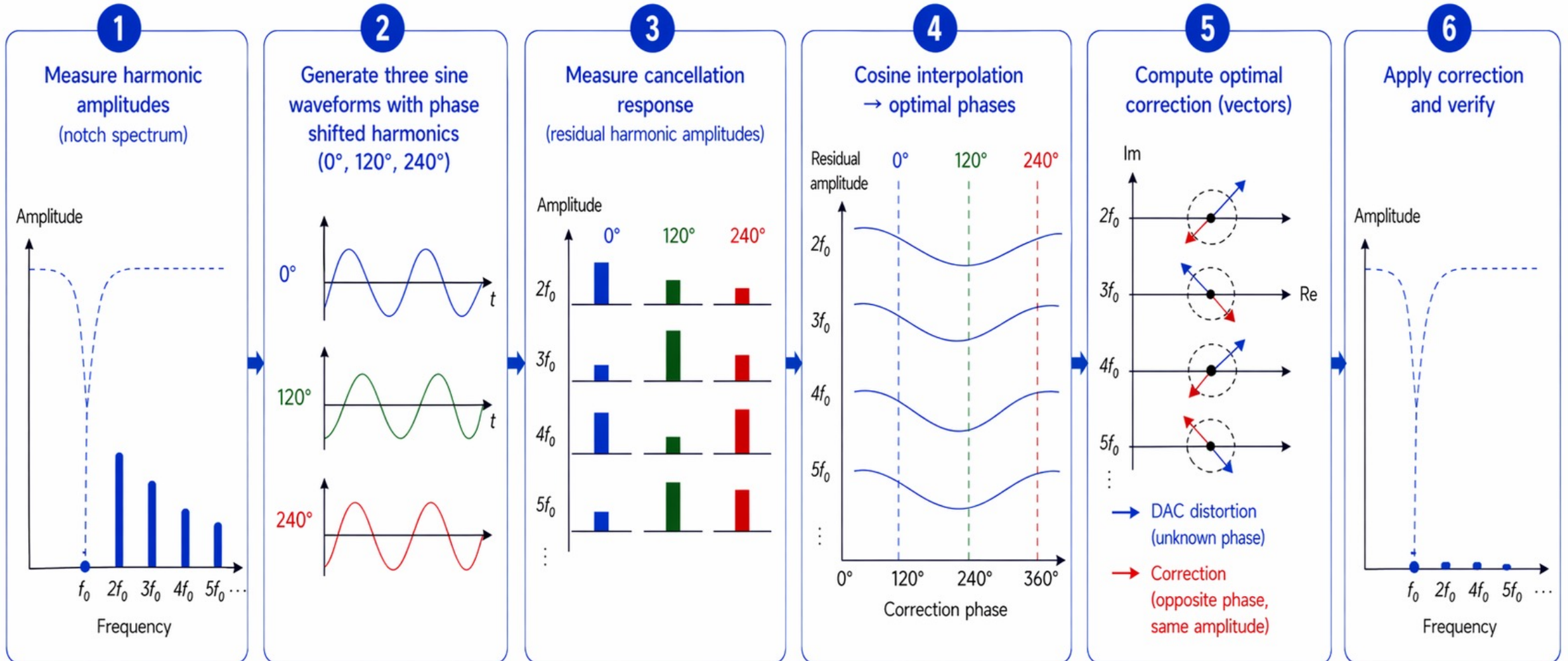


Fundamental + correction → clean output



 Digital predistortion

Automated optimization workflow

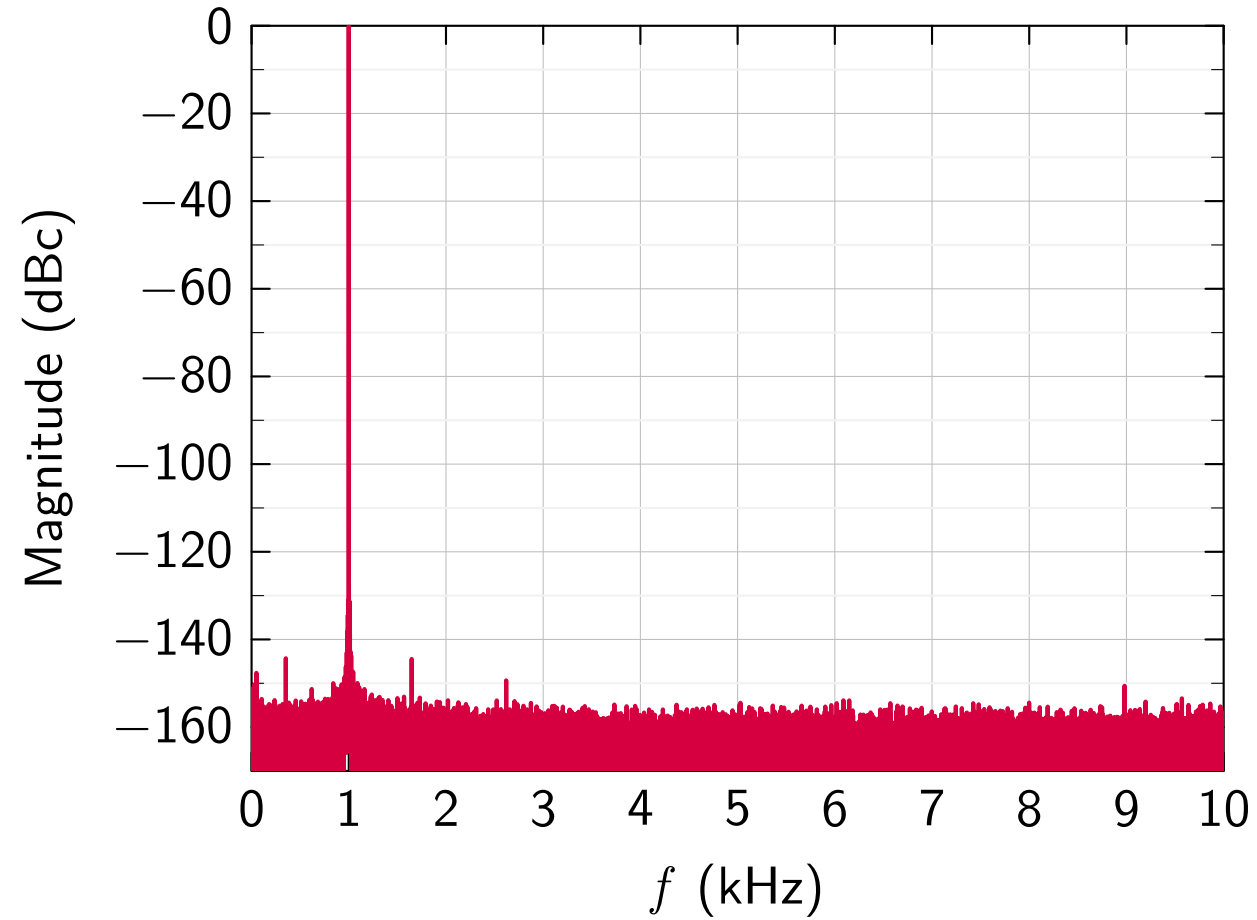
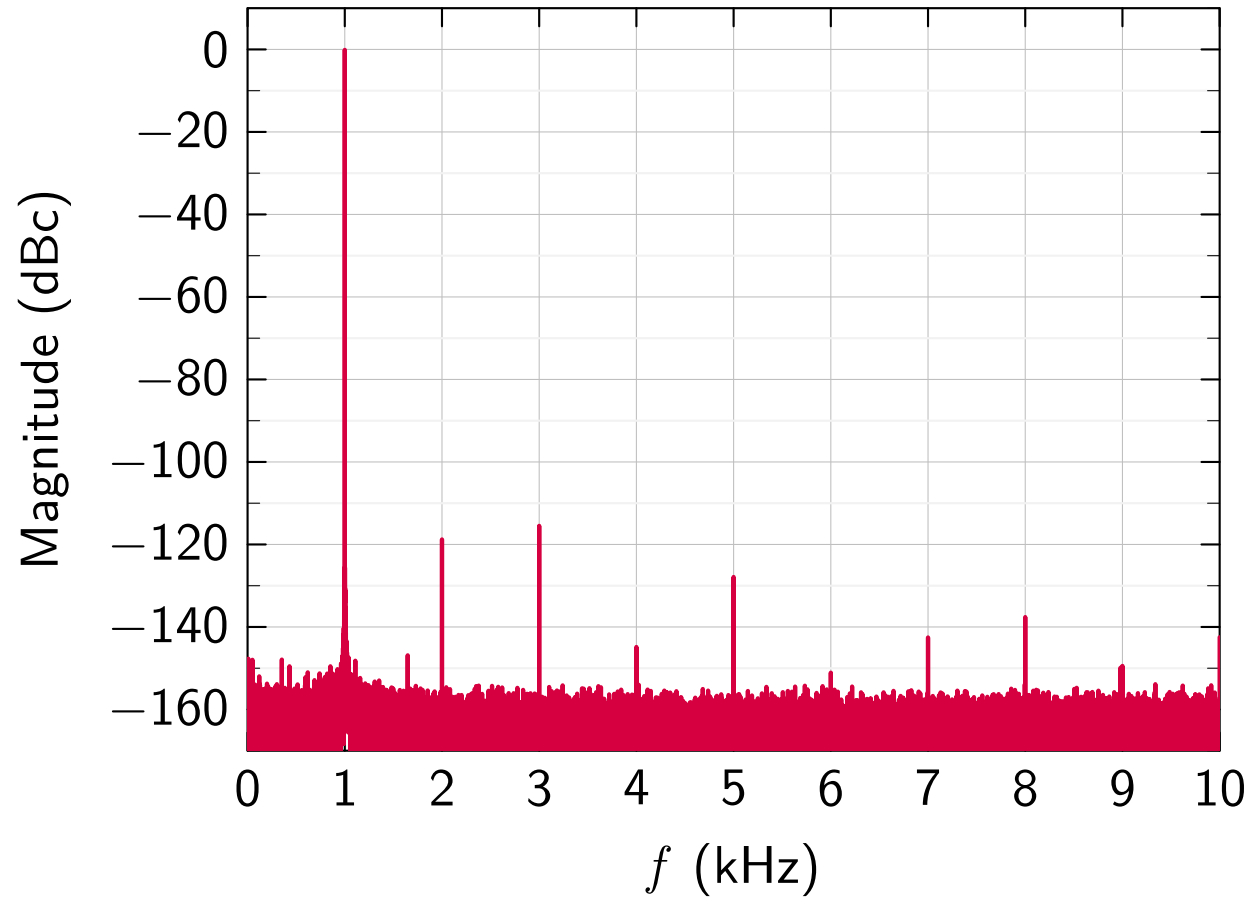


Execution time \approx 30 seconds



For our results we used Audio Precision APx555 (notch filter technique). Other instrumentation can be used if it provides a notch filter technique.

Spectrum before/after DAC correction

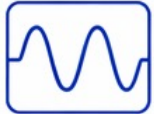


Practical properties of the DAC method

Advantages



Fast automated optimisation



Programmable waveform correction



Stable results



Synchronisable to reference clock



Scalable across frequency range



Turns a very good DAC into a precision sine-wave source



Stable over time (drift typically < 0.1 dB)

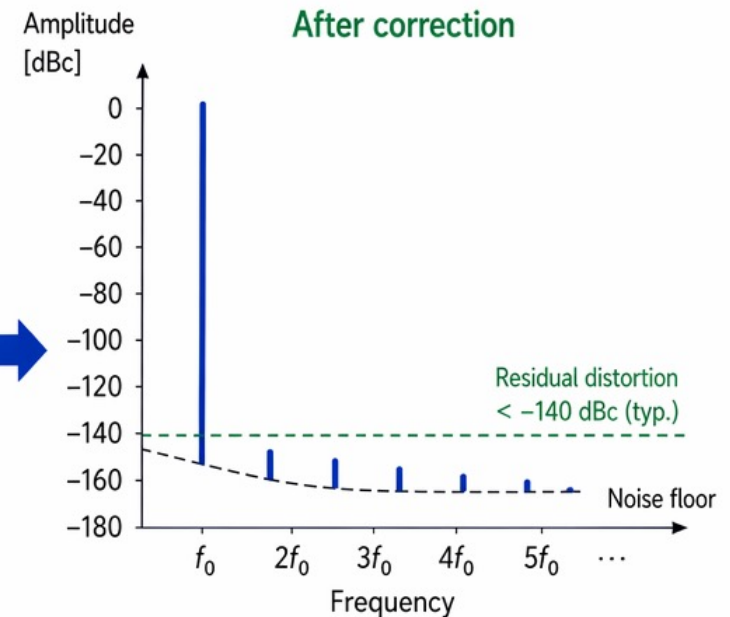
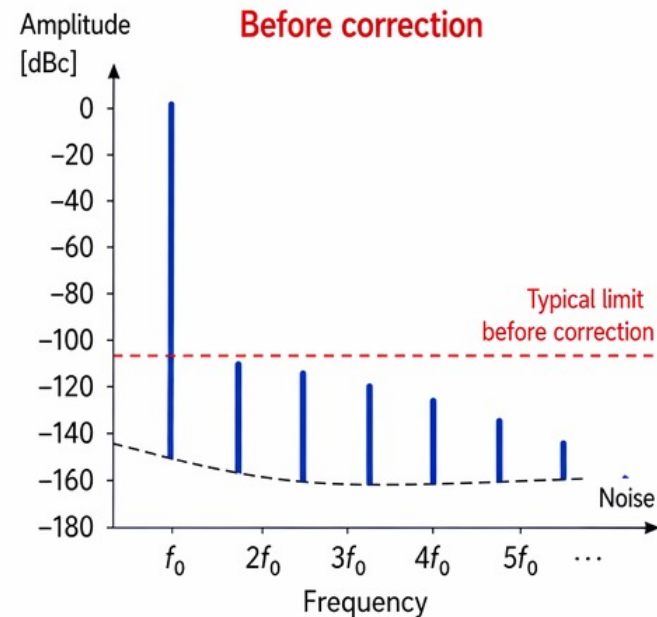
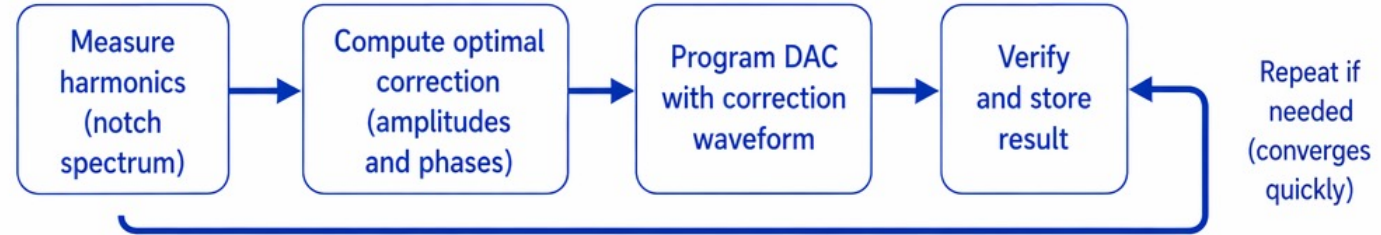


Fully digital – no hardware modifications

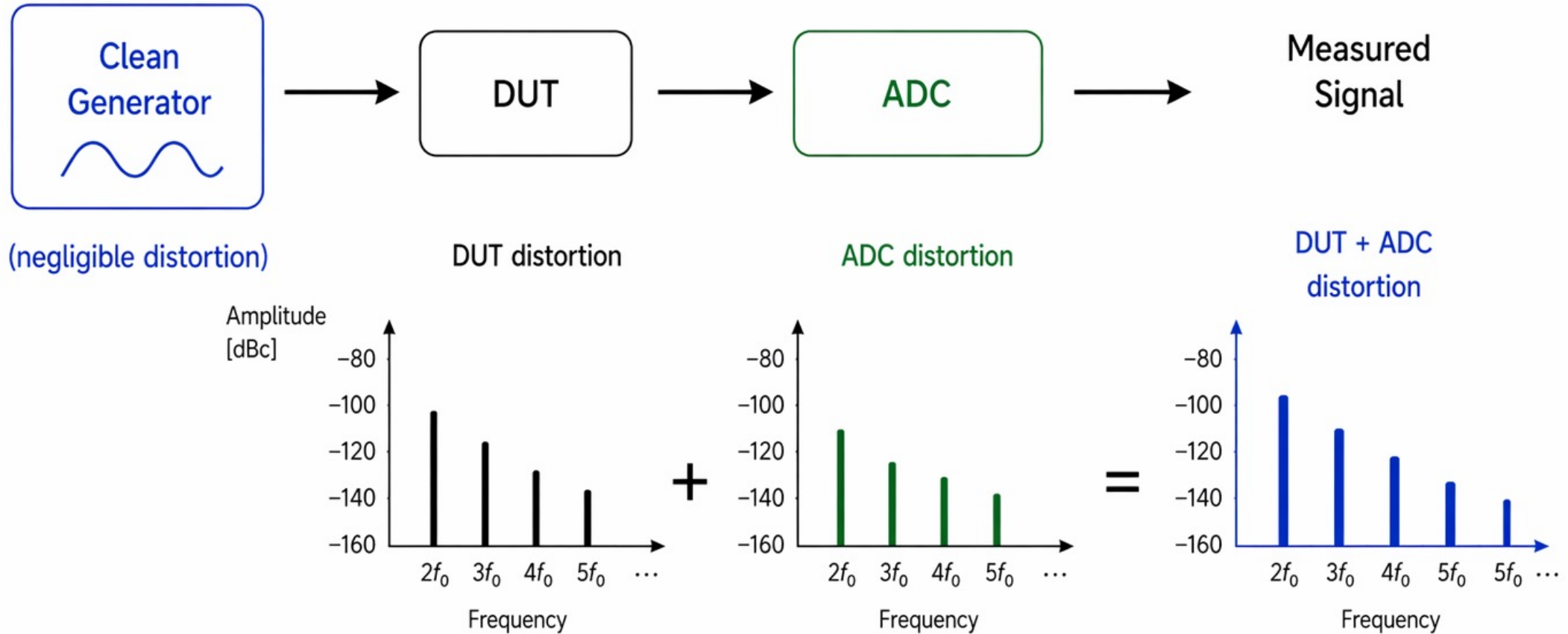


Broadband capability – improvement across the measurement band

Automated correction workflow (~30 s)



Why ADC distortion still matters



Measured signal
= DUT distortion + ADC distortion

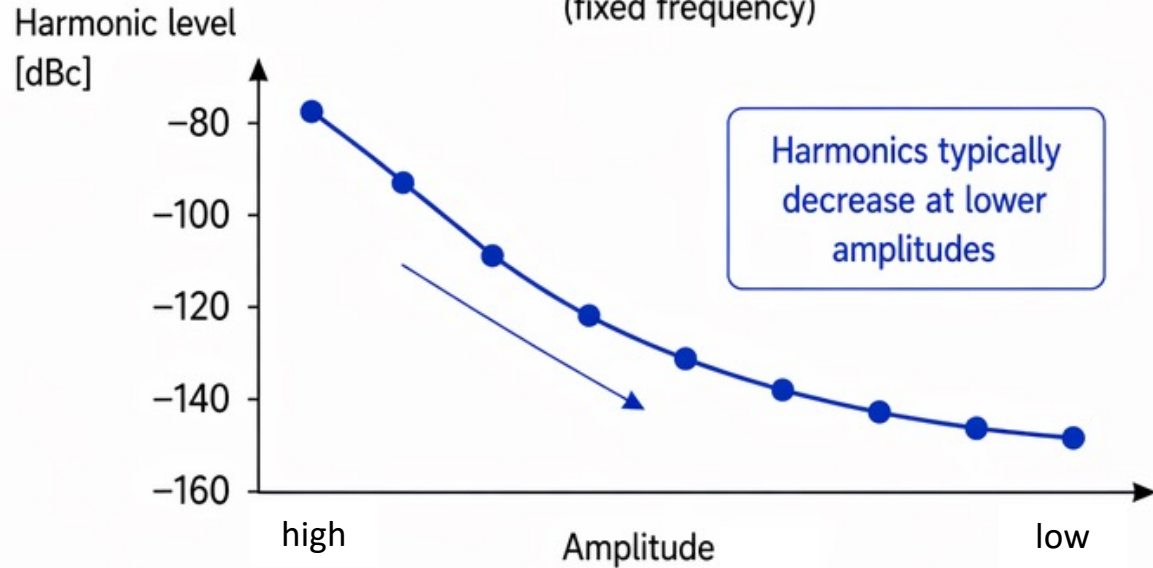
Typical ADC THD:
-117 to -130 dB

Principle of ADC harmonic correction



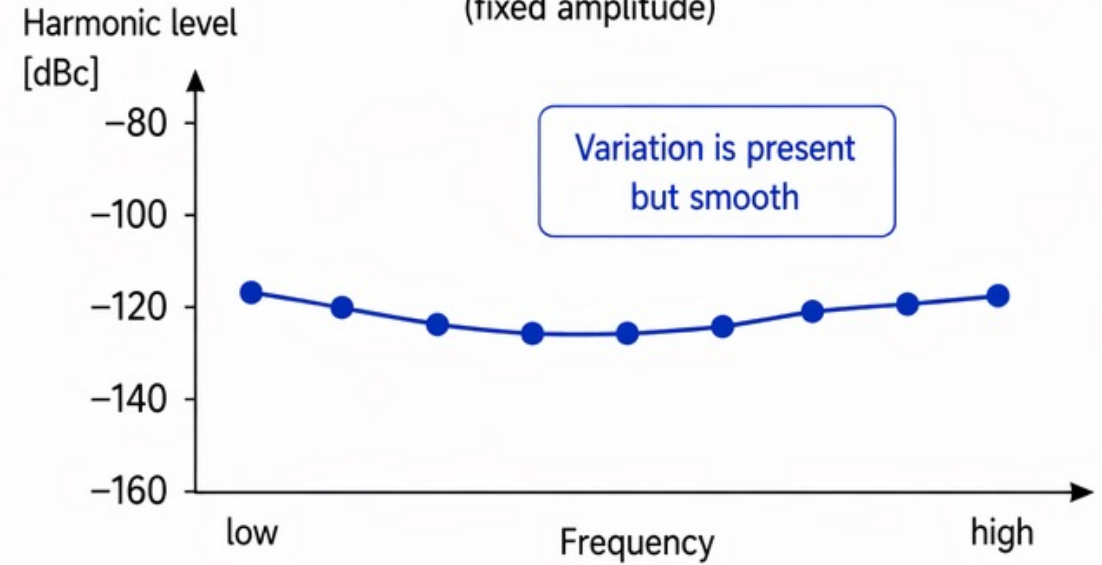
Harmonic level vs. amplitude

(fixed frequency)

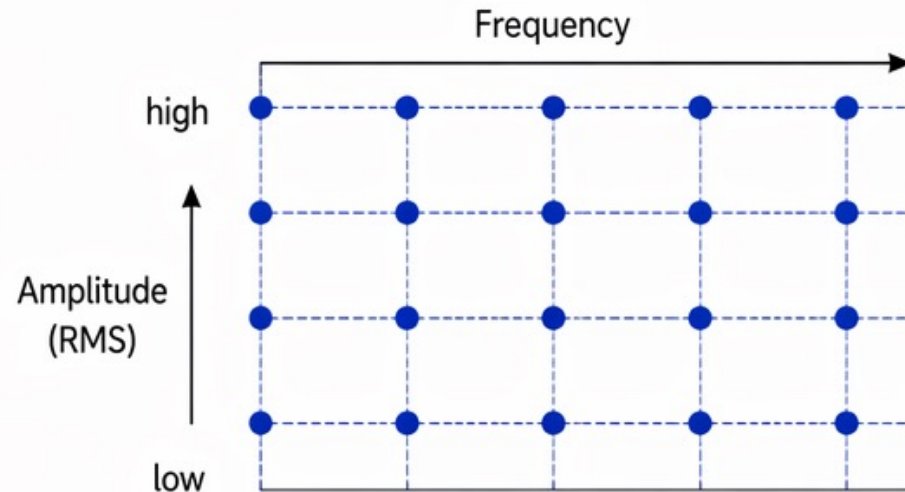


Harmonic level vs. frequency

(fixed amplitude)



Record the local distortion fingerprint
(on an amplitude × frequency grid)

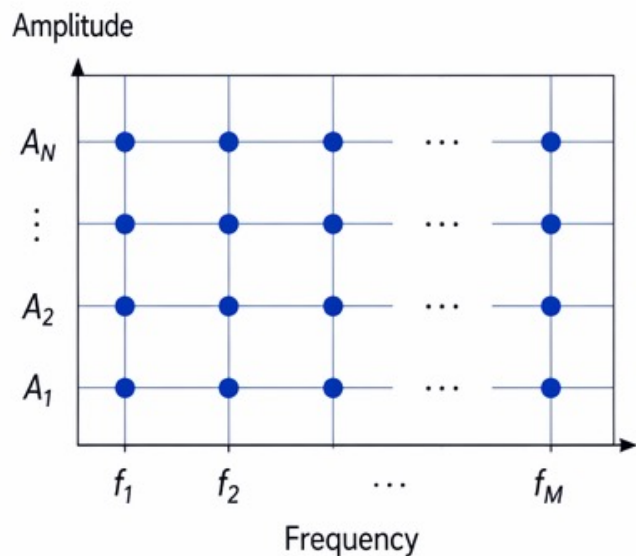


Use adequate grid granularity to capture the behavior where it changes fastest.

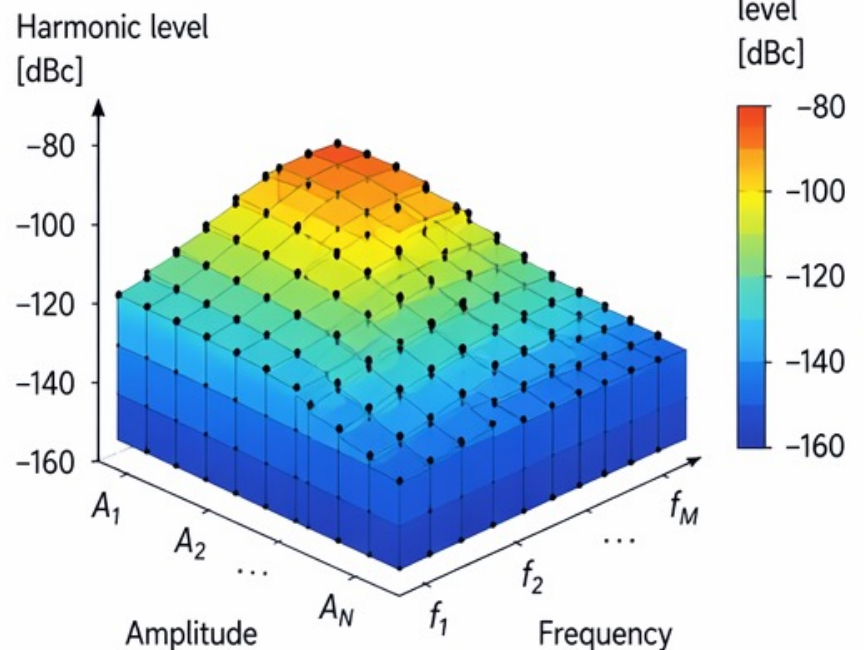
Building the ADC error surface

Scan by amplitudes and frequencies

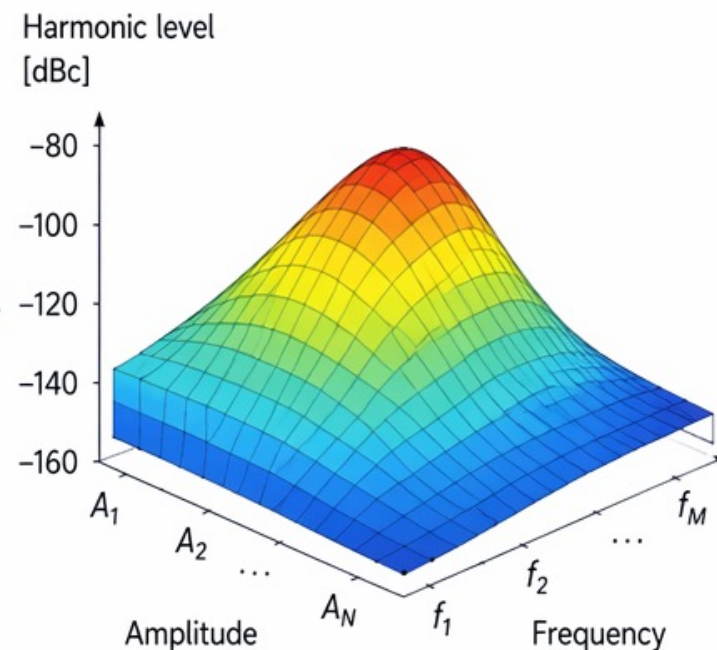
- ▶ Sine input at many amplitudes
- ▶ Repeat for many frequencies around the expected signal



Measured harmonic level at each (amplitude, frequency)

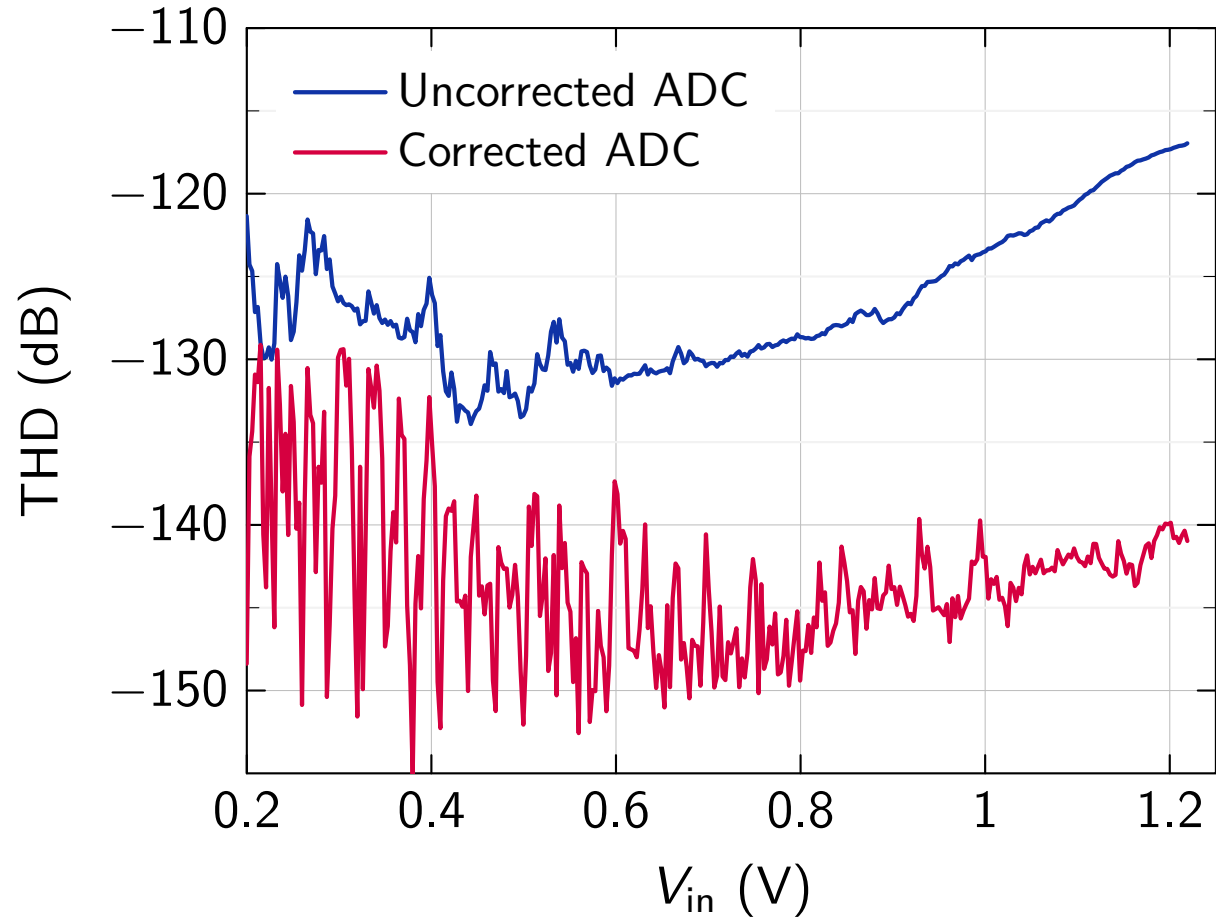


2D interpolation model (harmonic fingerprint)

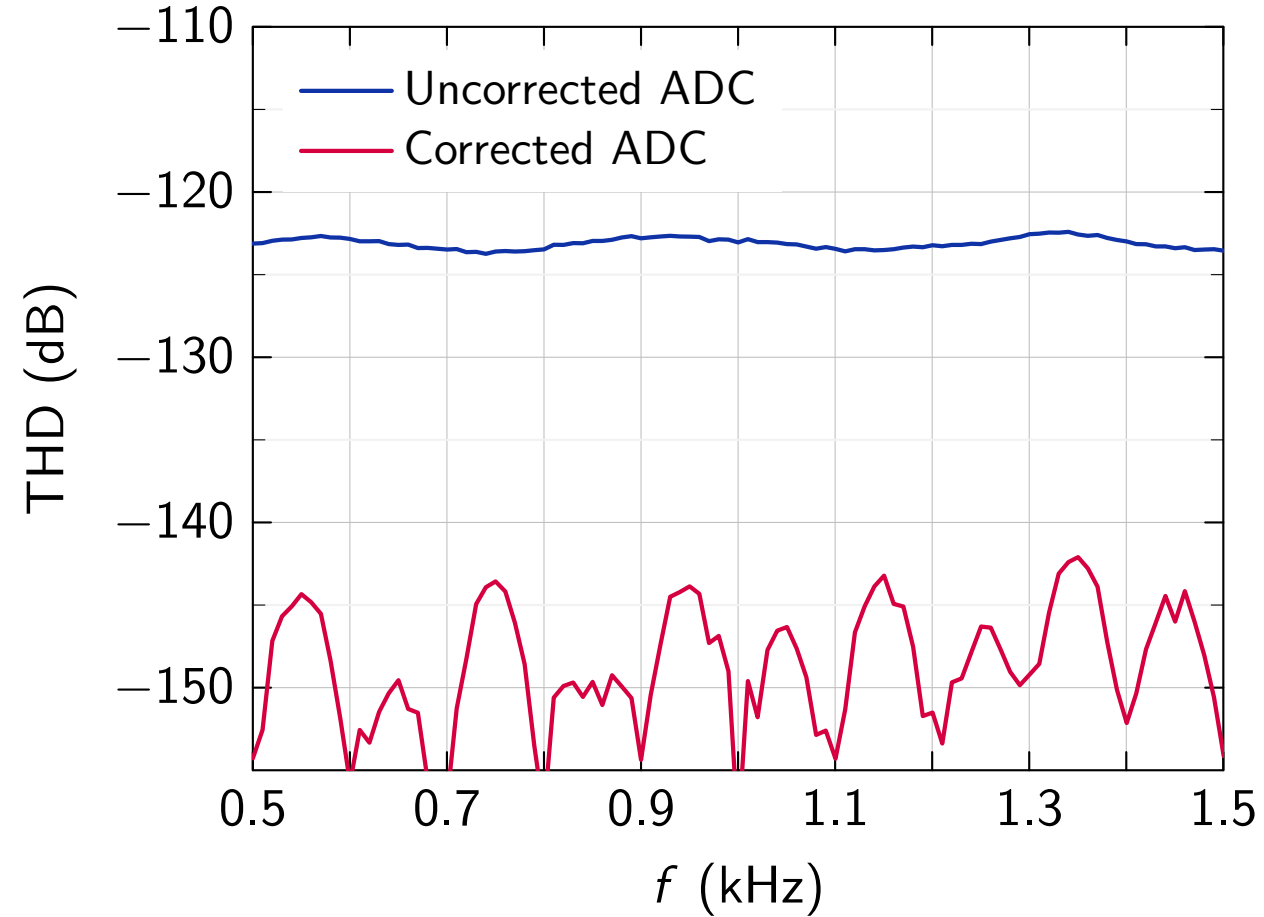


Interpolation used to predict ADC harmonics at any (amplitude, frequency)

ADC correction results



amplitude step: 30 mV (cal.); 3 mV (meas.)



frequency step: 100 Hz (cal.); 10 Hz (meas.)

Combined system capability



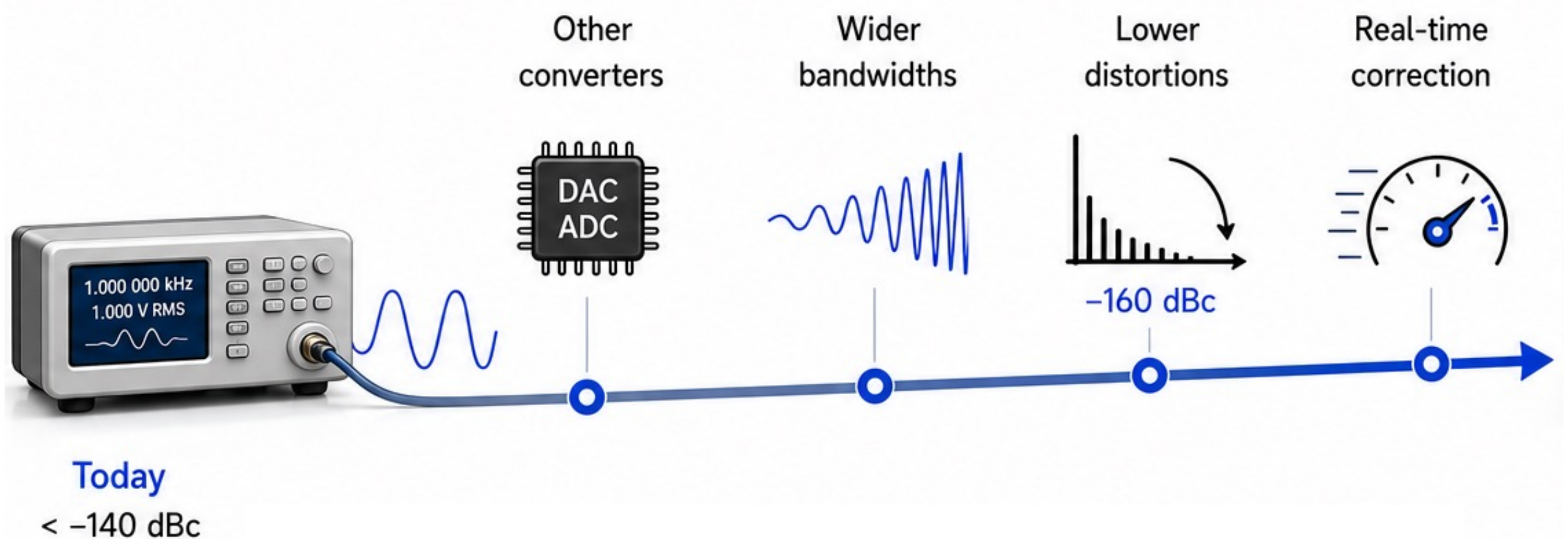
DAC

L. Palafox, R. Lapuh, „Ultra Low Distortion Sine Waves from Digital to Analog Converters,“ CPEM 2026

ADC

R. Lapuh, L. Palafox, „Ultra Low Distortion Sine Wave Sampling,“ CPEM 2026

Outlook and future developments



Thank you



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