A simplified procedure for the calibration of CTs for PQ using a wideband comparator.

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About VSL

- National Metrology Institute of the Netherlands

- Company with a public task

- 100 fte, 40 % MSc or PhD

- Calibrations, reference materials, R&D, consultancy, training

- Focus on energy and industry
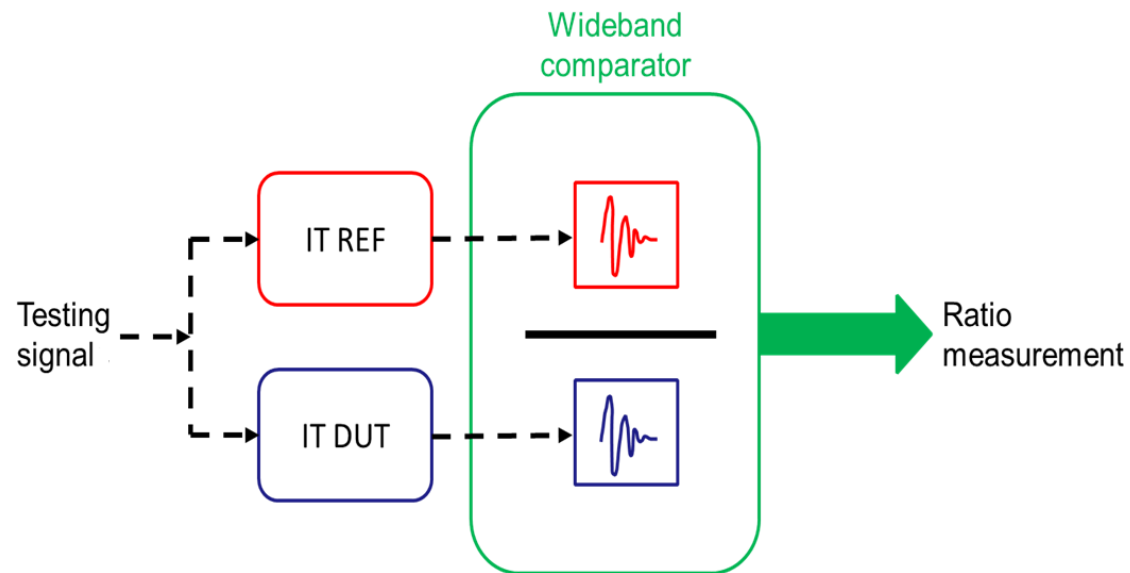
- Located in Delft, the Netherlands

Introduction.

Design and development of a simplified wideband comparator
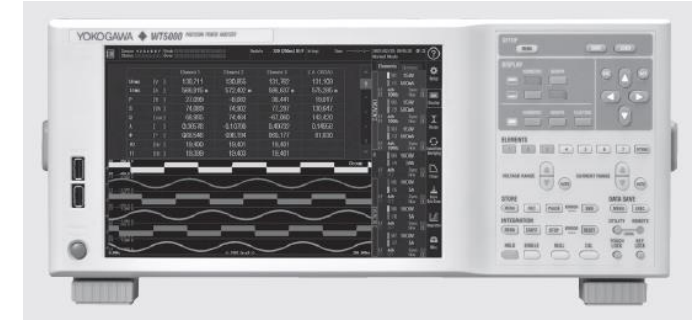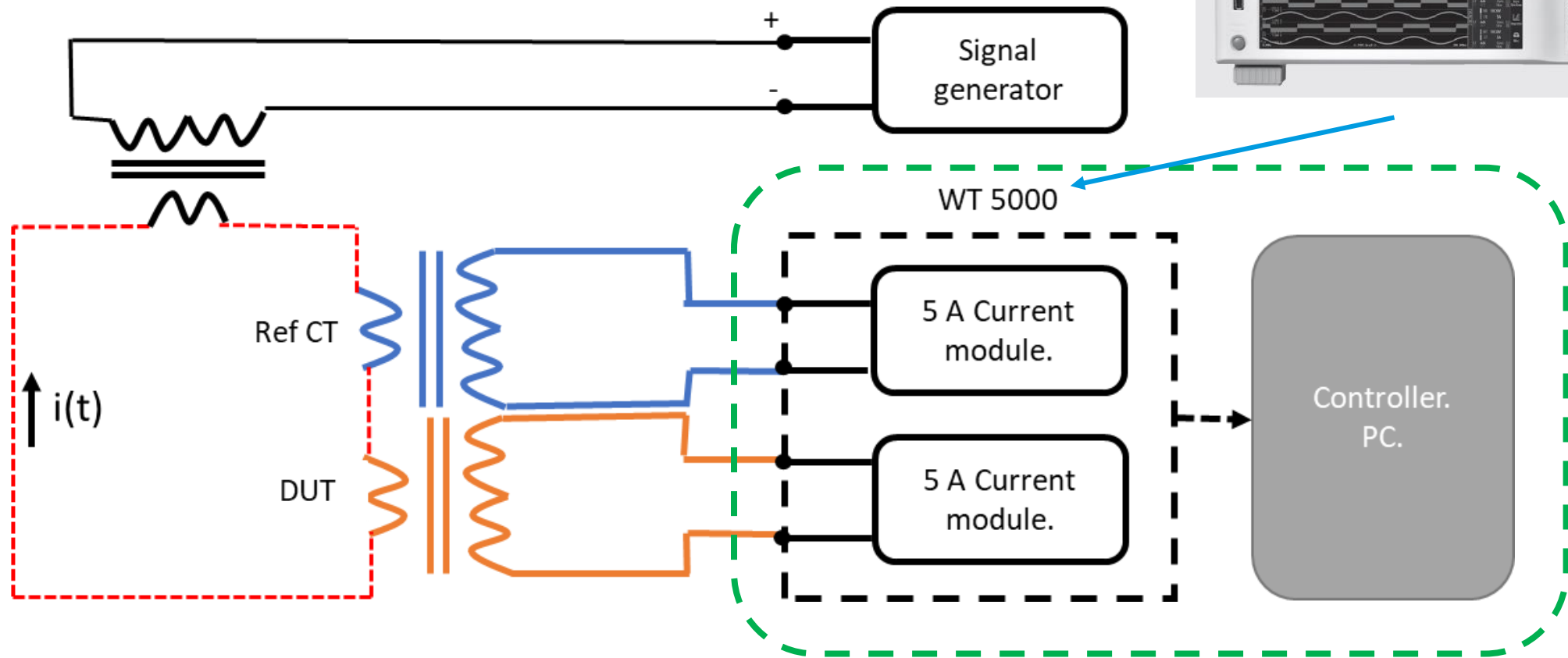
For industrial calibrations

used to compare the outputs of ITs

For signals with a frequency range from DC up to 9 kHz

Wideband comparator

Testing signal

IT REF

IT DUT

Ratio measurement

Wideband comparator for CT4PQ.

Schematic

Wideband comparator.

precision power analyzer with 5 A modules (1000 V).

- Sampling rate up to 2 MS/s. (Streaming to a host computer)
- Use as a sampling unit.
- Broadband modules with 5 A or 30 A rated current can be added to the chassis.
- Resolution 18-bit.
- Additional circuits are not required.
- Synchronization among the modules.
- Bandwidth: DC, 0.1 Hz – 2 MHz.
- Up to 7 modules can be added (only 2 needed).
- Good EMI PROTECTION.
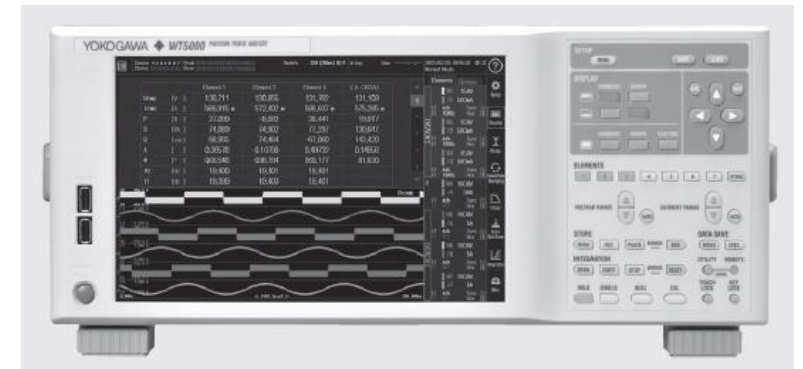
The readings of the two modules can be compared.
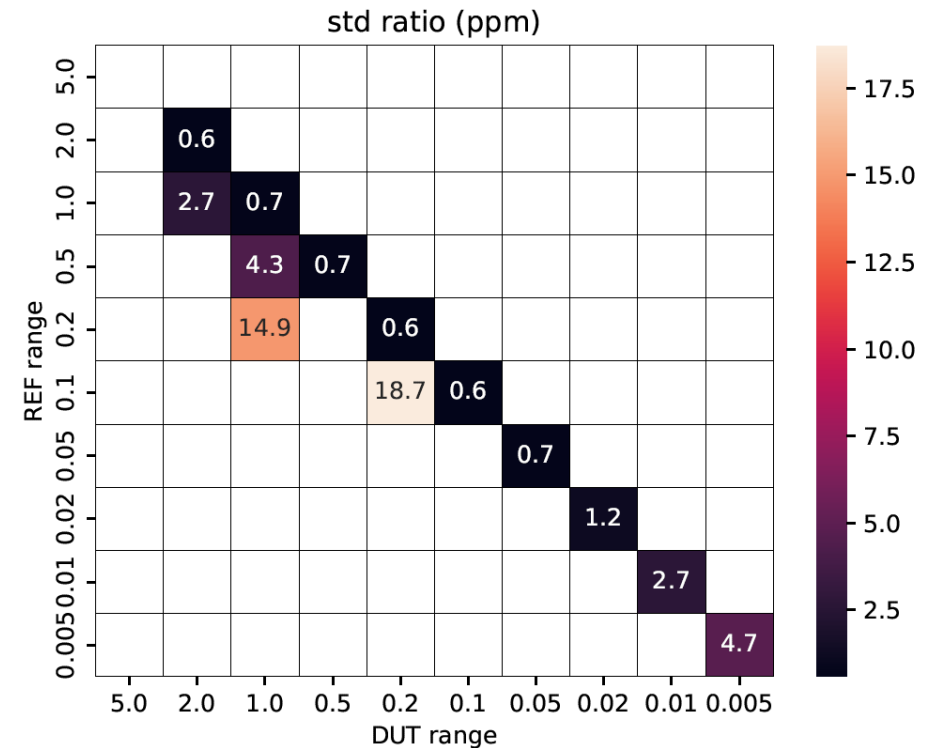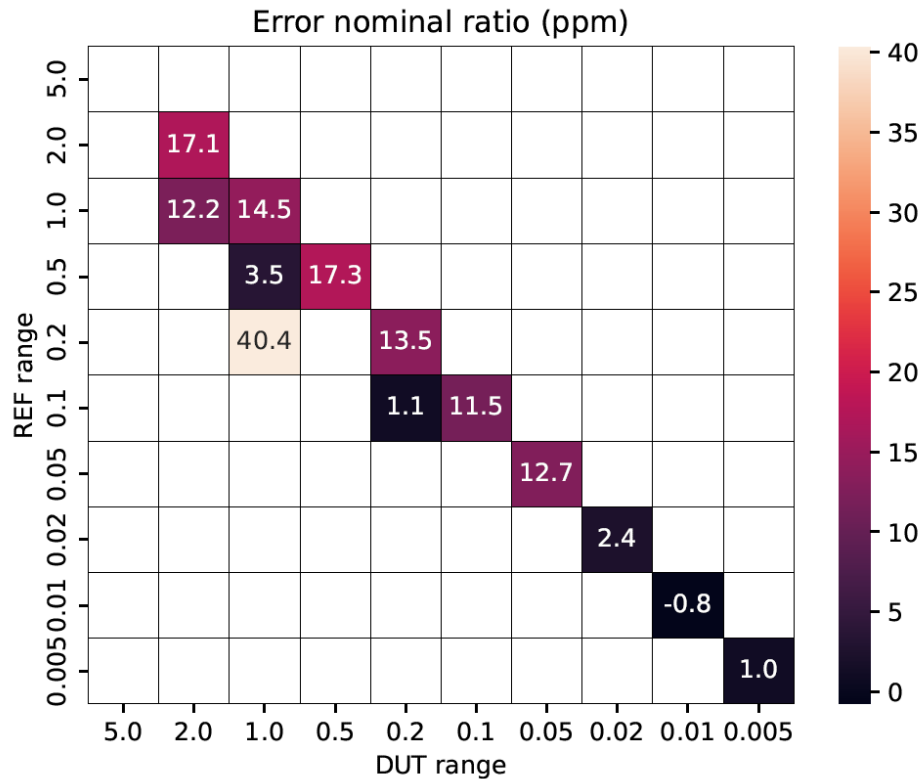
WT5000 characterization

Current channels (5 A modules)

1- A current range is set in each module (5 A, 2 A, 1 A, 0.5 A, 0.2 A, etc).
2- A single-tone current signal is provided to both modules.
3- For 60 s, the current signal is measured by both modules.
4 – Ratio and phase displac. computed for the recorded signals by applying the FFT to time periods of 1 s
5- Repeat 2, 3, and 4 for another frequency.
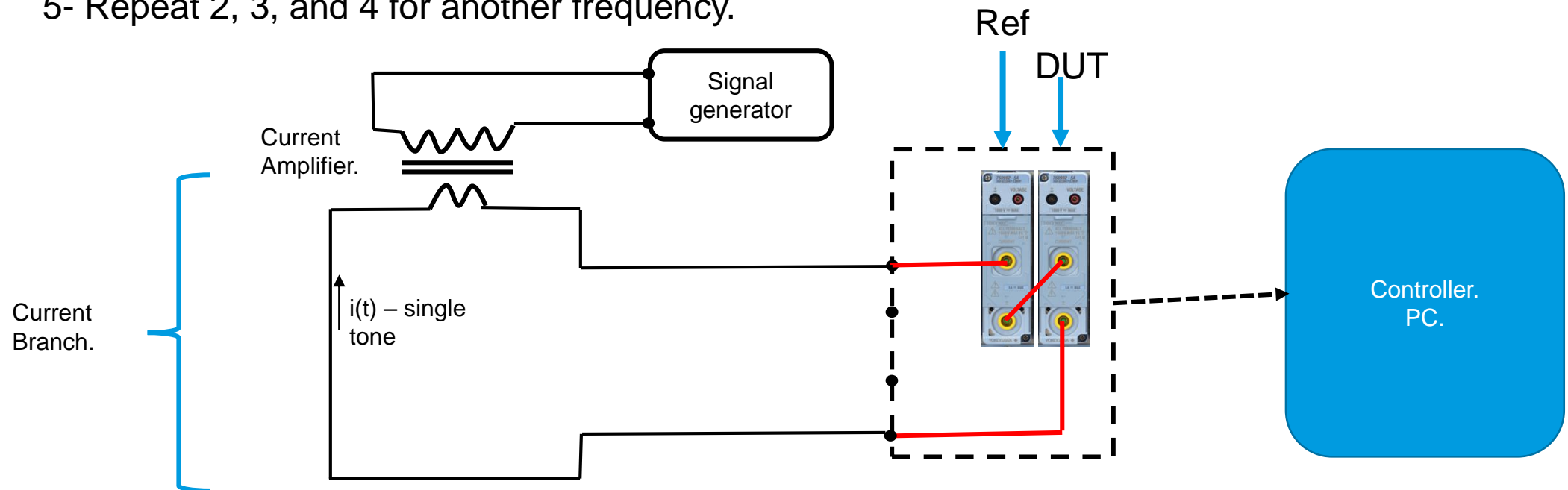
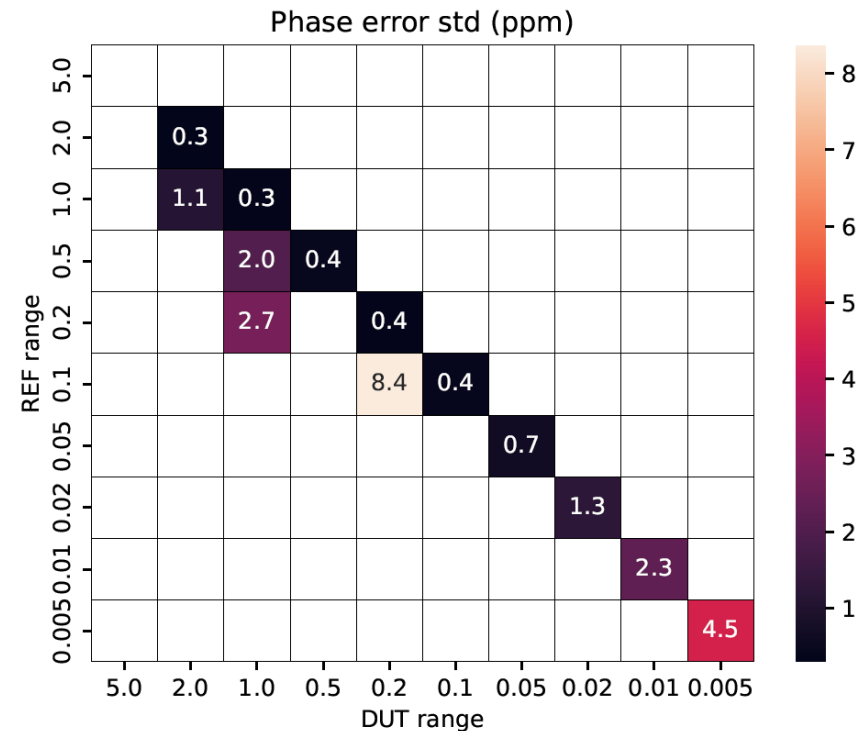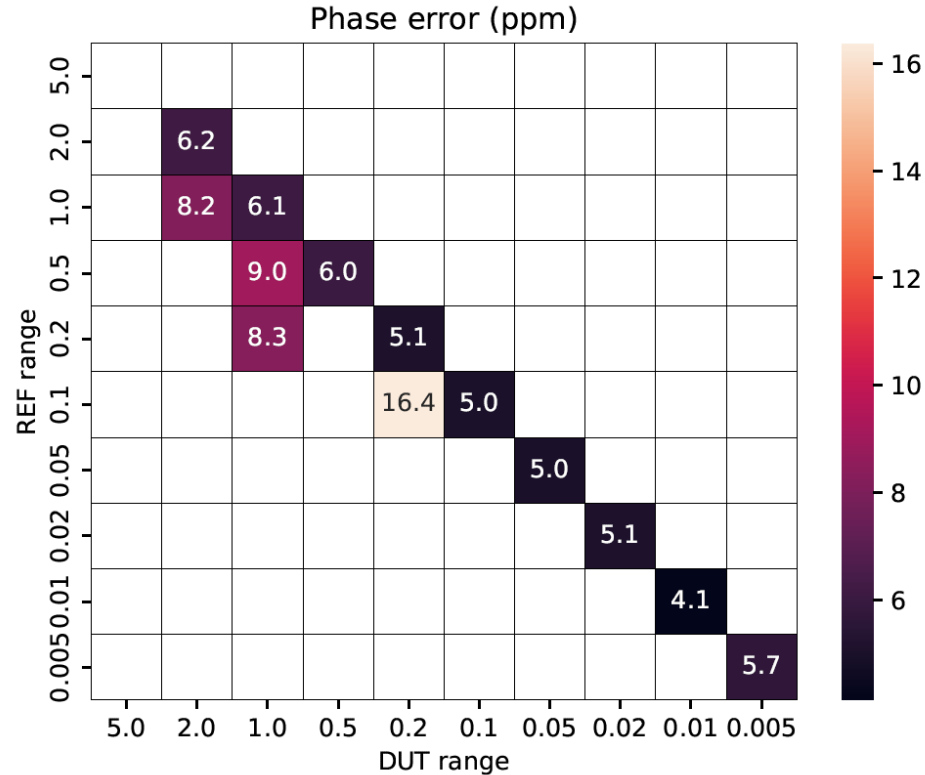# WT5000 characterization
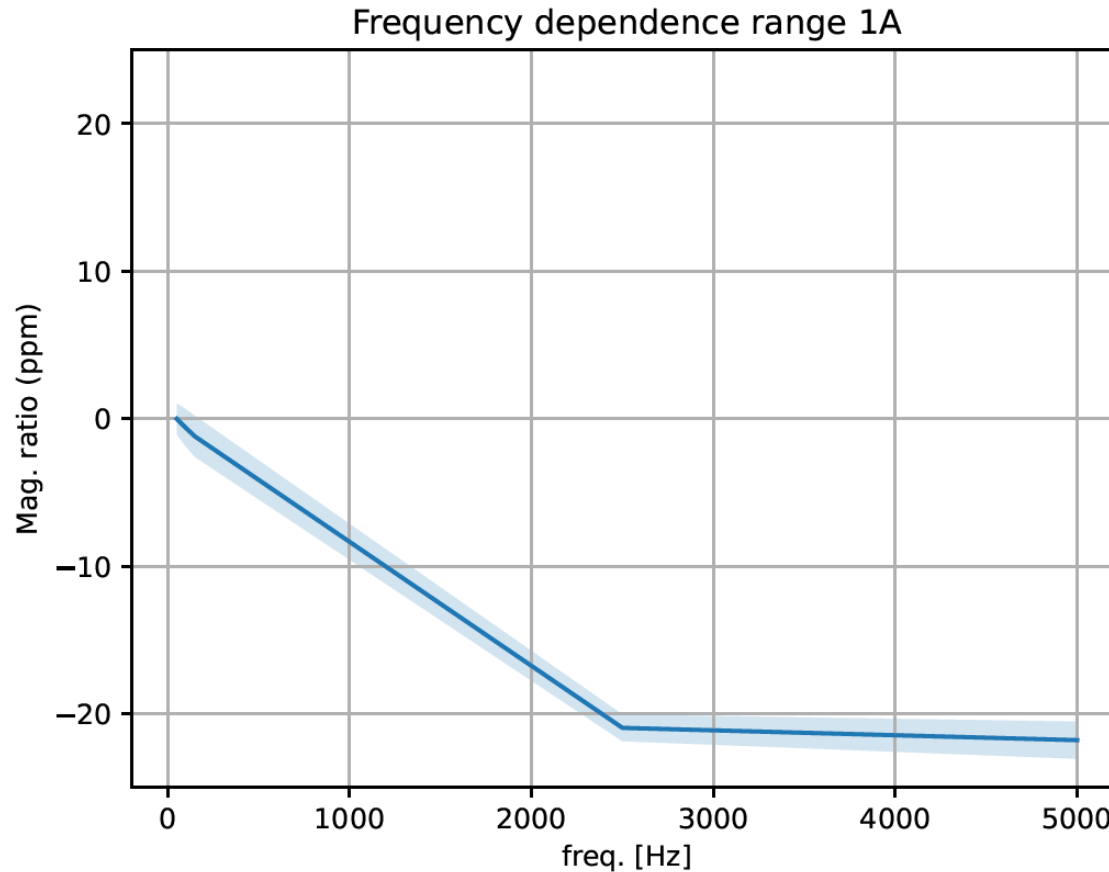
Ratio results for the current channels.
@ 50 Hz

WT5000 characterization

Phase displacement.
50 Hz

WT5000 characterization

Current channels - frequency dependency

Frequency dependence range 1A

Reference CT

- Primary standard.
- Zero-flux electronically compensated CT.
- Compact wideband multistage CT developed at NRC (Canada).
- Two high-current CTs and one summing CT
- Different and adjustable number of primary and secondary turns.
- Uncertainty $3 \cdot 10^{-6}$ in ratio and 3 μrad in phase at 50/60 Hz. For frequencies up to 5 kHz, the uncertainties are $5 \cdot 10^{-6}$ for the in-phase and $5 \cdot 10^{-6}$ for the quadrature errors.
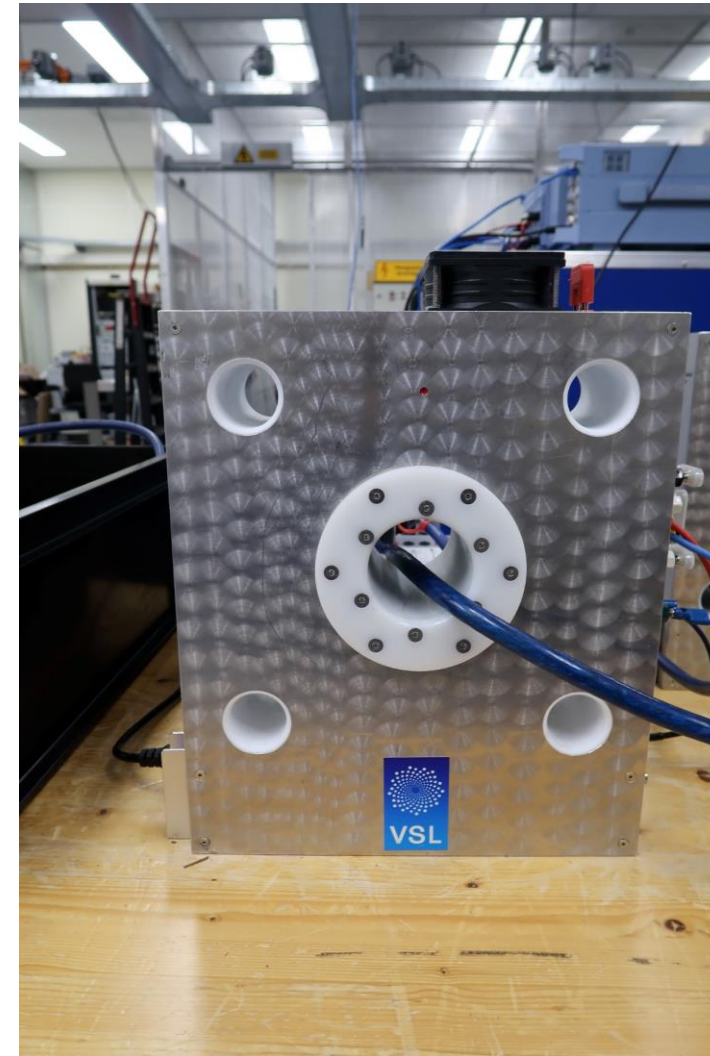
Current generation system

Allow us to apply two-tone signals, up to 2 kA @ 50 Hz

❖ PQ current signal is defined as a signal that consists of the fundamental tone, usually in the order of hundreds of A, and the harmonics or other PQ distortion, which are a fraction of the fundamental (below 10% and usually 1 % of the fundamental tone).

❖ The signal generator generates the PQ waveform, and subsequently, a broadband amplifier and a step-up transformer scale up the current signal to the desired primary level. Modulation is also available.
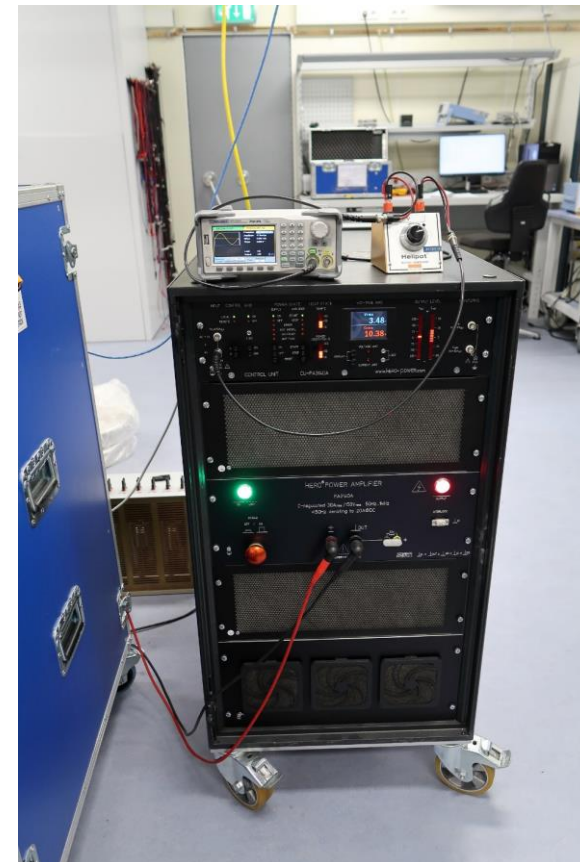
Software acquisition and processing.

The measurement program

The measurement program controls the WT 5000, sets the acquisition parameters, acquires the current signals, and sends them to the host PC, where the signals are stored.

Computation of results

The signal is split into an integer number of time windows. Then, the magnitude ratio and phase difference of the two output signals is computed for each time window by applying Fast Fourier Transform (FFT).
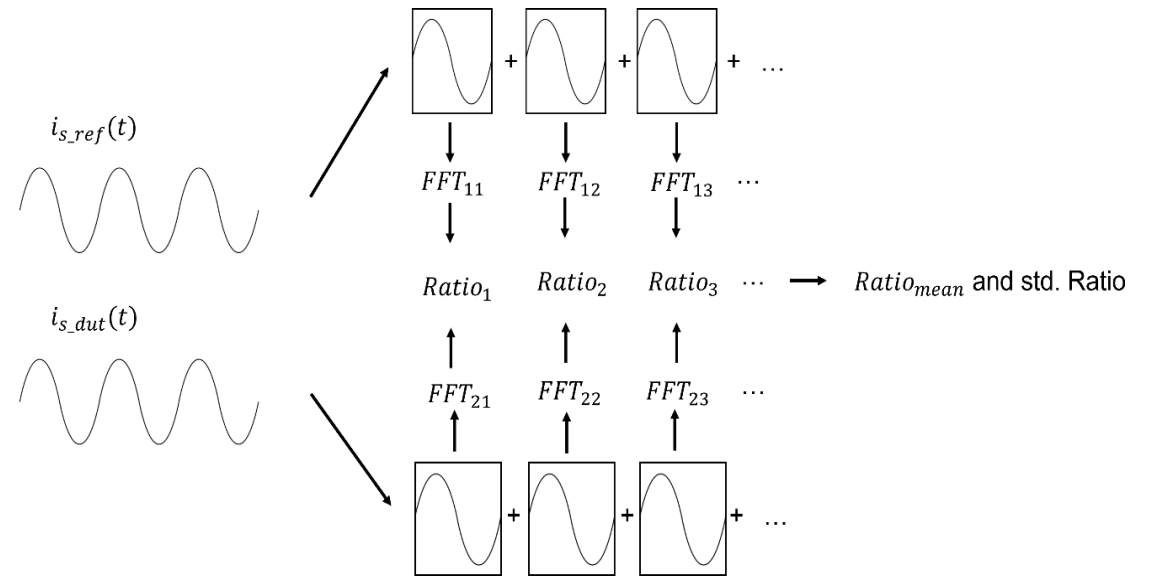
Simplified measurement system
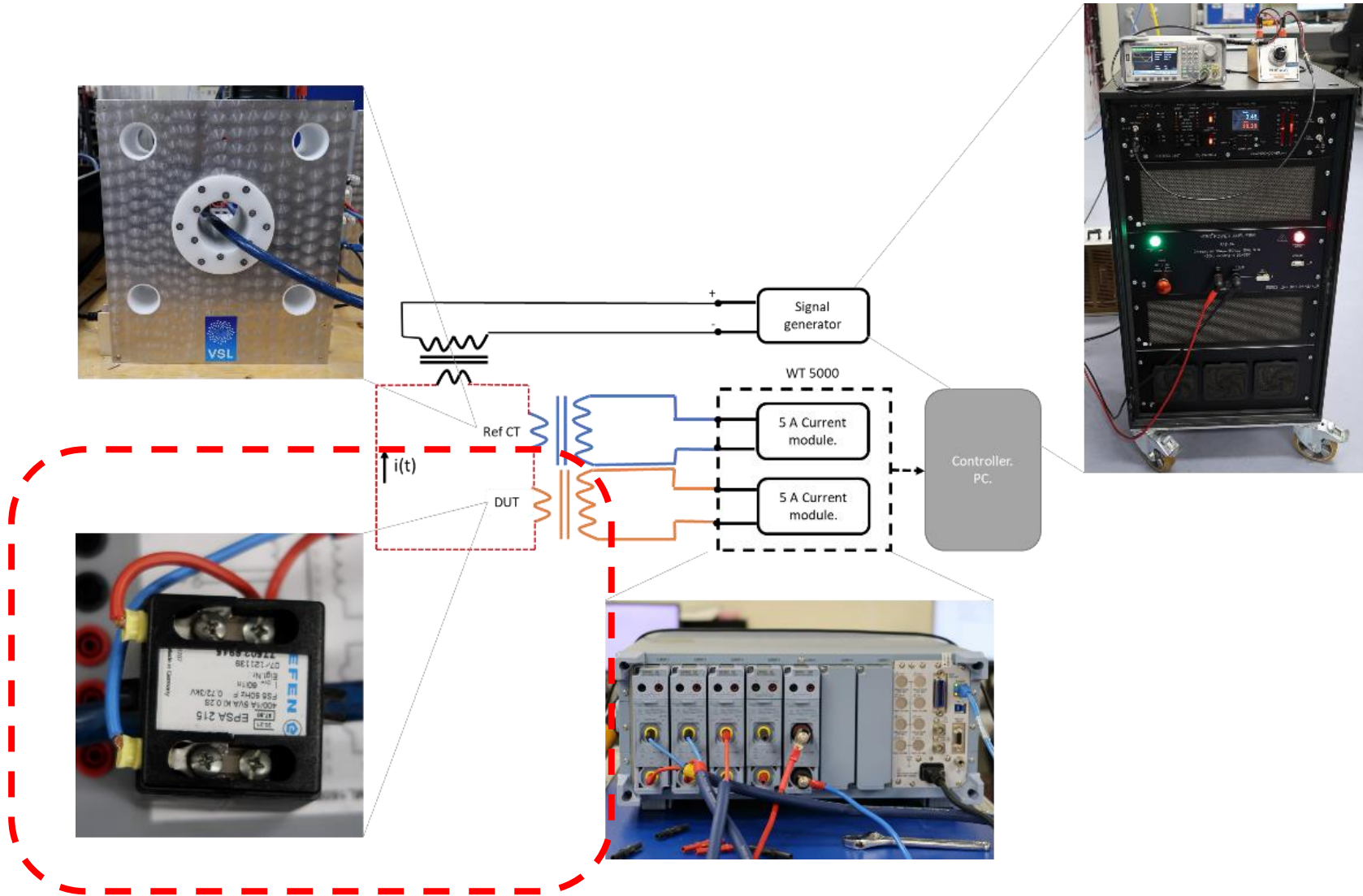
Calibration of an Inductive CT.

- In Activity A2.2.4 a comparison among the simplified and primary procedures/setups/methods was launch.

- VSL participated in the comparison for the calibration of an inductive CT. Participants: PTB lead and TUBITAK.

- **PTB provided a travelling standard: I_P = 400 A, I_S = 1 A, and Cl. 0.2S**

- Measured quantities: ratio error ε and phase displacement δ at different frequencies f (from 50 Hz to 5 kHz)

Tests performed

Harmonics. Two-tone signals = fundamental (100 A @ 50 Hz) + harmonic.
> **Test point 1: f_n = 2nd, amplitude: 5 % of fundamental**
> **Test point 2: f_n = 3rd, amplitude: 10 % of fundamental**
> **Test point 3: f_n = 50th, amplitude: 1 % of fundamental**
> **Test point 4: Harmonics at 1% of the fundamental from the 2nd   to the 50th order**
> **Test point 5: f_n = 100th, amplitude: 1 % of fundamental**

Interharmonics.
> Test point 1: f_{ih} = 75 Hz, amplitude: 5 % of fundamental
> Test point 2: f_{ih} = 375 Hz, amplitude: 10 % of fundamental
> Test point 3: f_{ih} = 2475 Hz, amplitude: 1 % of fundamental
> Test point 4: 1% of the fundamental at 7 Hz, 149 Hz, 951 Hz, 2048 Hz
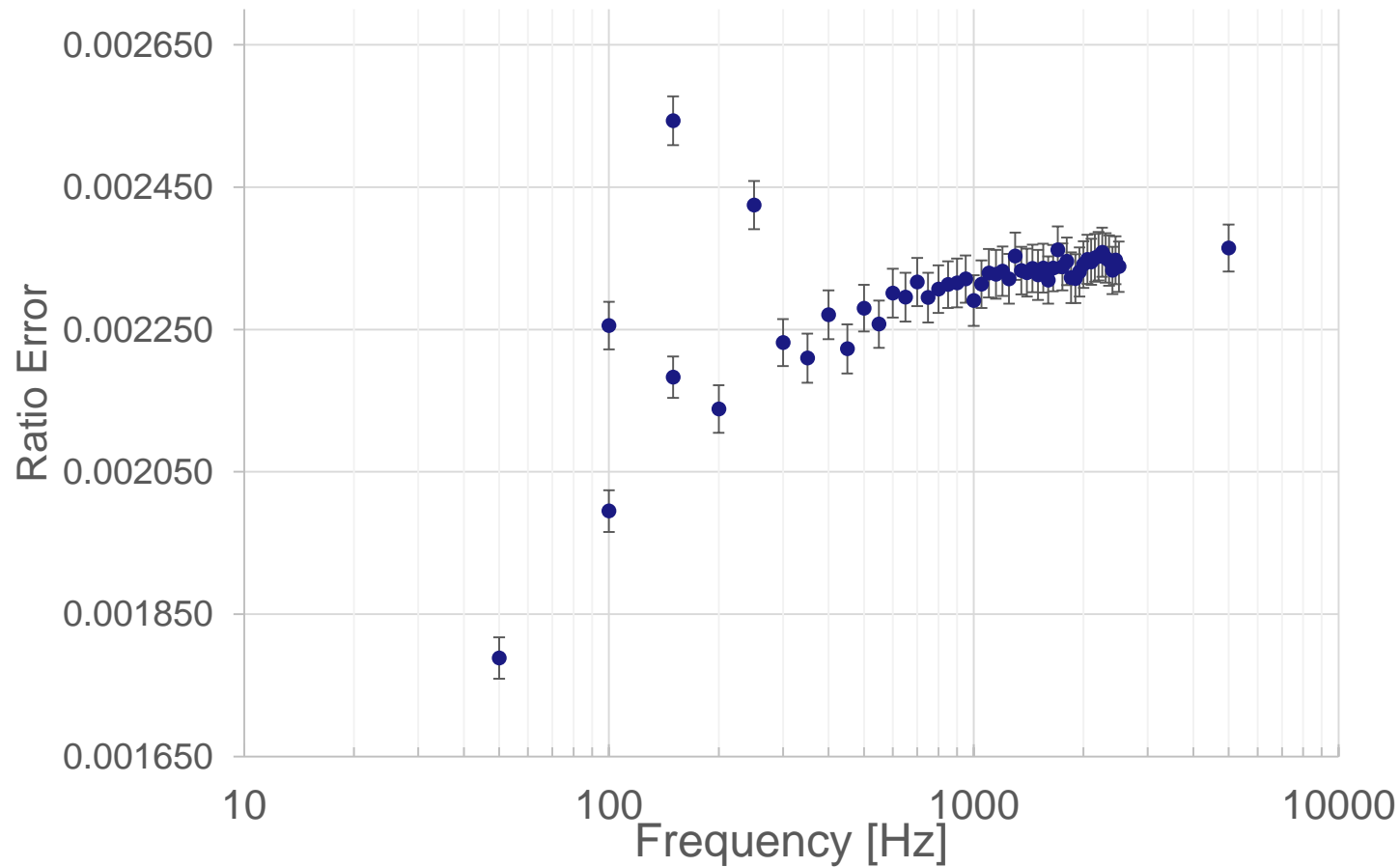> Test point 5: f_{ih} =4975 Hz, amplitude: 1 % of fundamental

Amplitude modulation.
> Test point 1: k_{AM} = 10 %, f_{AM} = 2 Hz
> Test point 2: k_{AM} = 10 %, f_{AM} = 5 Hz
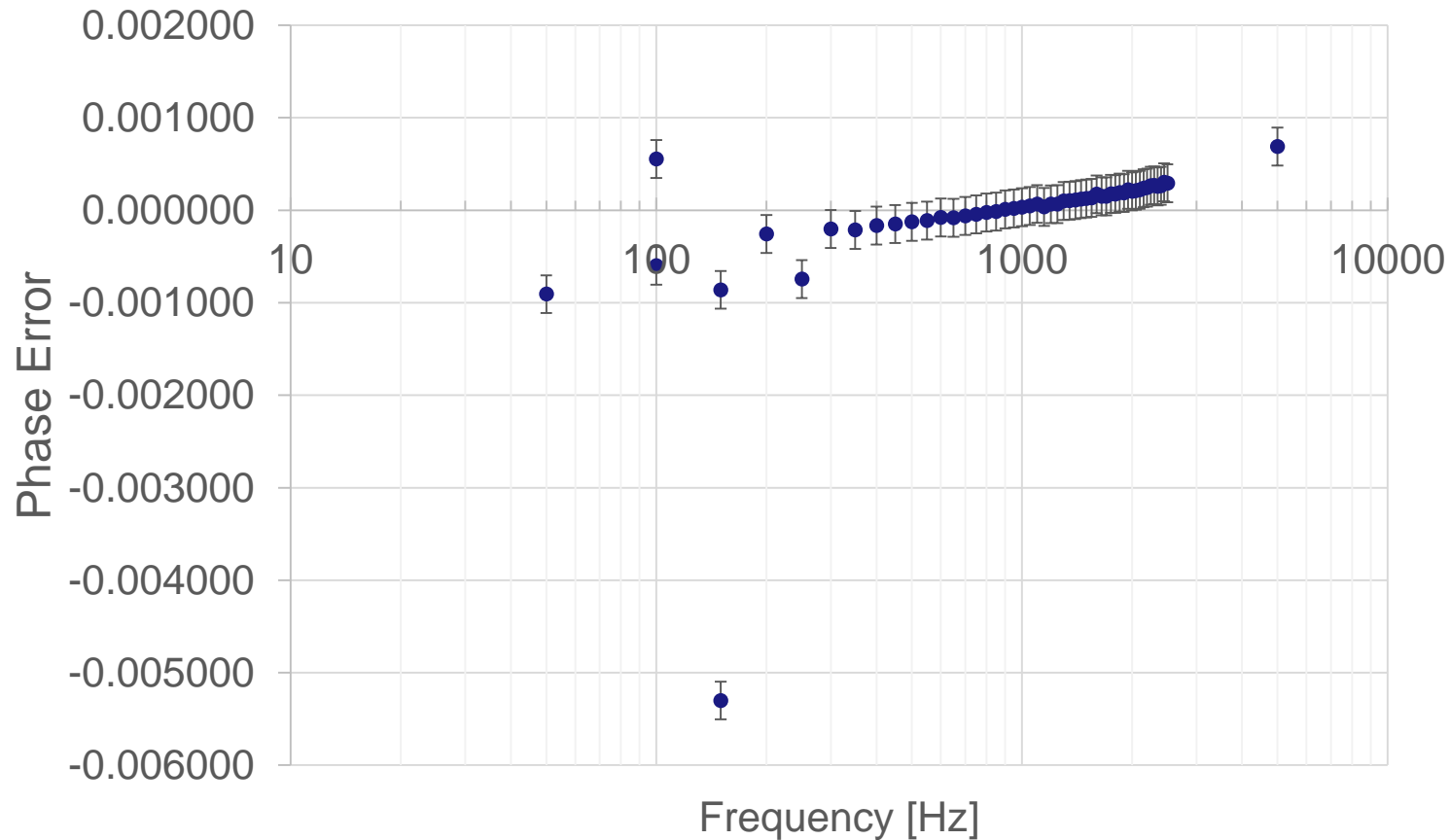
Preliminary results

Harmonics: Two tone signal. Ratio error.

Frequency [Hz]	Unc (k=2)
50	29 ppm
5000	33 ppm

Preliminary results

Harmonics: Two tone signal. Phase error.

Frequency [Hz]	Unc (k=2)
50	0.2 mrad
5000	0.2 mrad

Conclusions and future work.

- The WT 5000 is a suitable option to be used as a simplified wideband comparator.
- The generation of two-signals, and modulated signals was achieved by using a current amplifier and a step-up transformer.
- EMI could have caused some additional errors.

- Calibration CT in a fundamental freq. different than network.
- Characterize the effect of EMI, position, stability.

Thanks for your attention!

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