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Systematic Error Analysis in a Josephson Impedance Bridge

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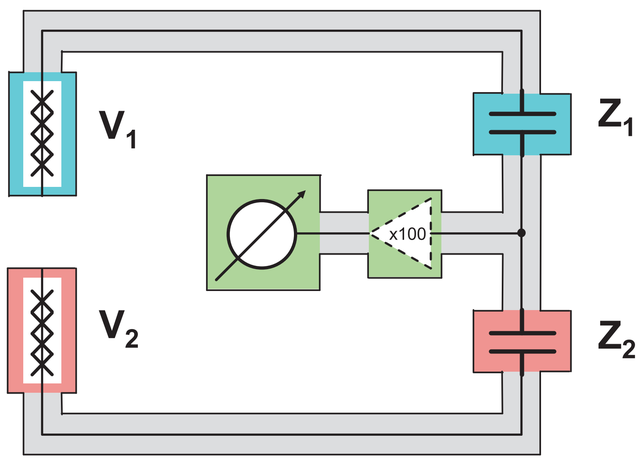
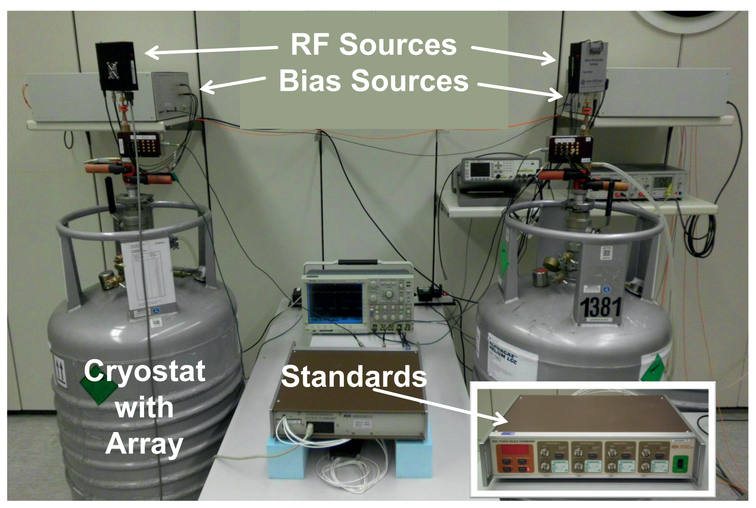
Josephson impedance bridges are under development by four European metrology institutes: SP (Sweden), VTT (Finland), CEM (Spain) and PTB. All four bridges are based on programmable Josephson arrays, but each bridge has slight variations in the setup, number of samples, degree of automation and adjustment procedures. The Josephson impedance bridge from PTB uses two individual Josephson systems, connected directly to the impedance standards, as shown below. Each system consists of a Josephson array driven at 70 GHz and biased with NPL designed bias sources. The bridge voltage is measured by a Lock-In amplifier (LIA) in combination with a pre-amplifier (PA). The number of samples is limited to two, resulting in the smallest error of ac voltage. A computer runs a frequency sweep from 25 Hz up to 10 kHz in typically 40 min. Reversing of the impedance standards is still manual, since no suitable change over switch has been implemented. The bridge is automatically balanced in amplitude by changing the rf frequency and in phase by a dual channel function generator controlling the timing of the bias sources.

Schematic

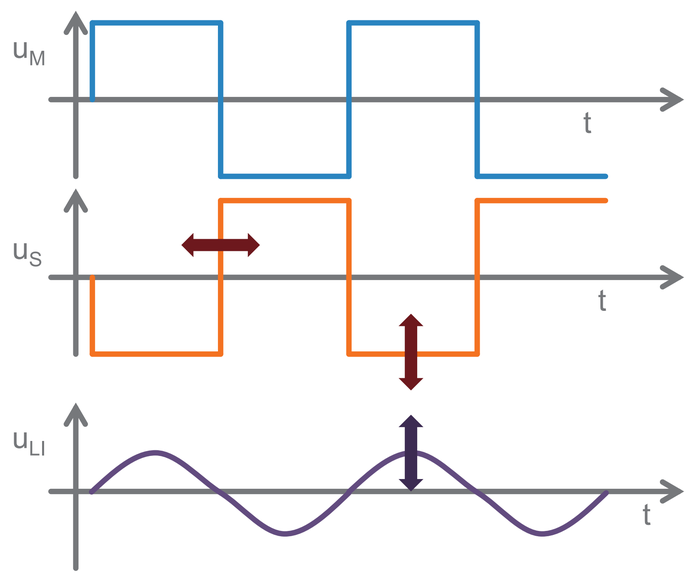


$$\frac{V_1}{V_2} = \frac{Z_1}{Z_2}$$

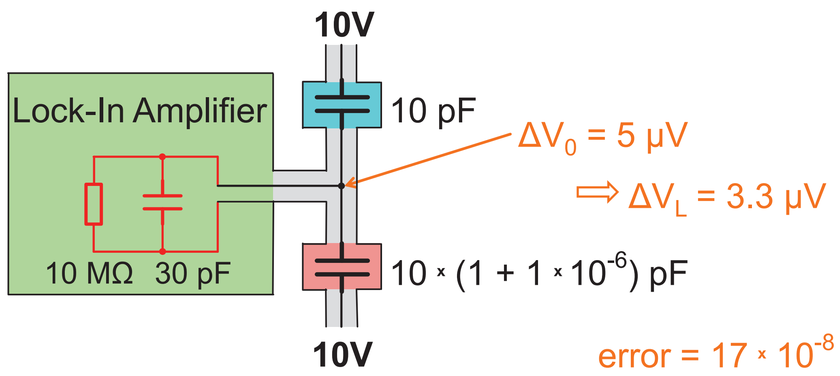
Setup



Waveform

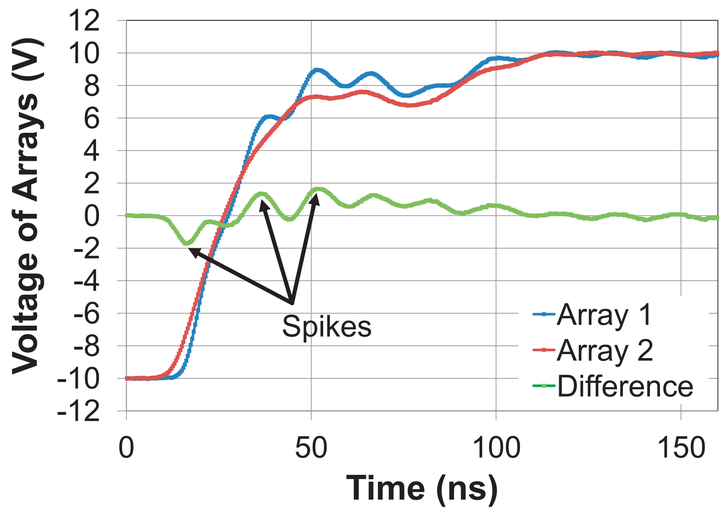


Loading



Adjusting the voltage within **100 nV** reduces the error to **3.5×10^{-9}**

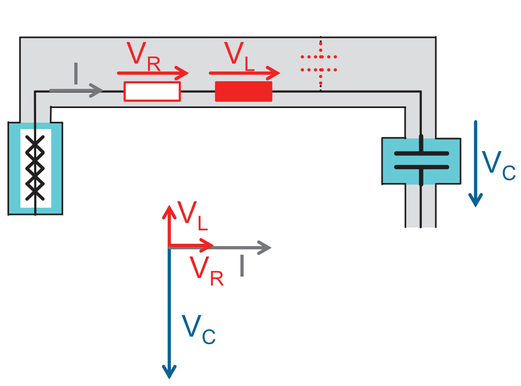
Asymmetries of Transients

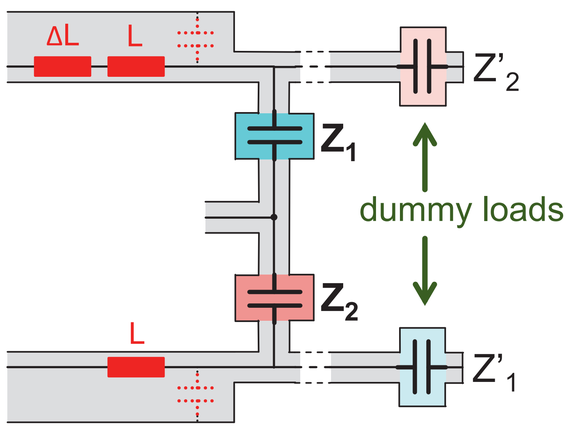


During transition the voltages differ in magnitude by more than 1 V. These spikes overload the PA input for tens of nanoseconds, affecting the reading slightly.

It also shows that the rms values of both Josephson systems are not exactly equal. A reversing method can eliminate this error for 1:1 measurements, but not for 1:10 measurements, because of different voltage levels with different transients on each array.

Inductance of Connecting Leads



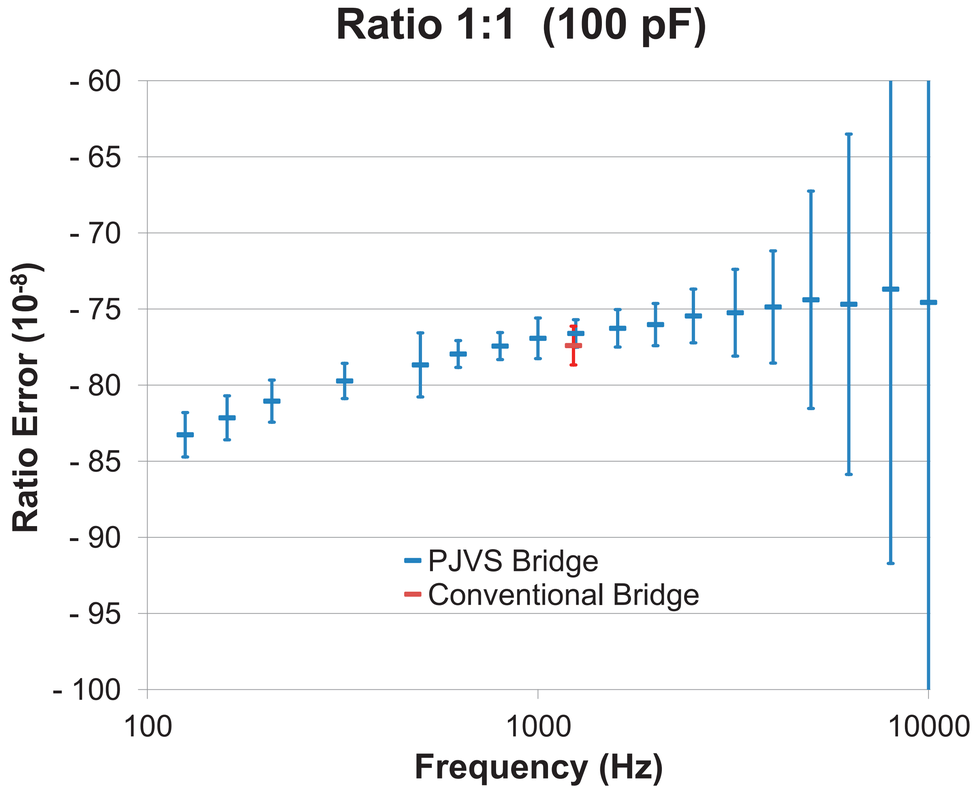


Frequency (kHz)	0.1	1	10
X_L (mΩ) [1.7 µH]	1.1	10.7	106.8
X_C (MΩ) [100 pF]	15.9	1.6	0.2
error (10^{-8})	**0.007**	**0.7**	**67.1**

Frequency (kHz)	1	5	10
ΔX_L (mΩ) [50 nH]	0.31	1.57	3.14
X_C (MΩ) [100 pF]	1.59	0.32	0.16
error 10^{-8}	**0.0**	**0.5**	**2.0**

Reversing the standards reduces this error. Only a contribution from ΔL remains. Additional ‘dummy loads’ eliminate this problem entirely.

Comparison with Conventional Bridge Ratio 1:1 (100 pF)



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