SAND2022-16173C

Sandia National Laboratories

A comparison of AC-DC difference measurements between Sandia's JAWS and conventional measurements

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Motivation

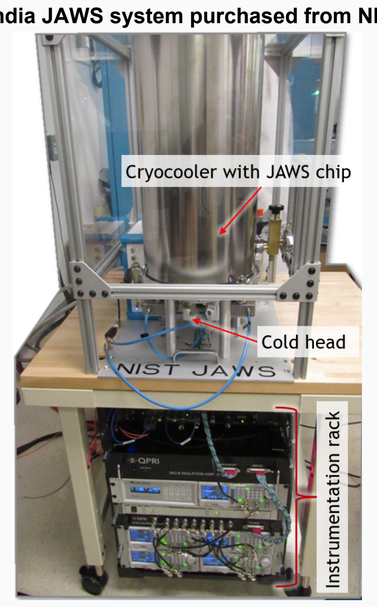
Problem: AC voltage calibrations are dependent on artifacts through the use of a transfer standard

Goal: Procure and optimize a **Josephson Arbitrary Waveform Synthesizer** (JAWS) – an intrinsic, quantum-based AC-voltage standard that may be able to eliminate artifacts and their associated problems

Approach:

- Purchase a NIST standard reference instrument (SRI) JAWS system (this was accomplished in 2019).
- Optimize the JAWS AC and DC voltage output over a range of frequencies and voltages.
- Source a voltage to a Fluke 792A (the device under test (DUT)) using JAWS and compare to conventional AC-DC difference measurements on the Fluke 792A.

Sandia JAWS system purchased from NIST



JAWS AC-DC Difference Experimental Setup

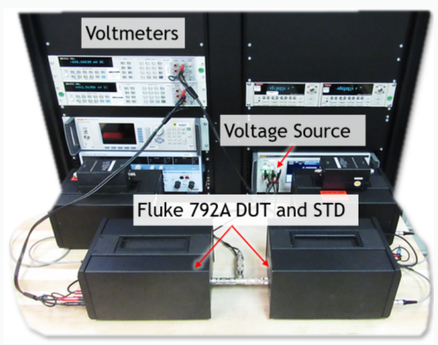
- JAWS outputs alternating AC and DC voltage signals into Fluke 792A.
- Fluke 792A outputs DC voltage proportional to rms potential of input.
- NIST-developed LabVIEW software controls measurement and performs calculations.
- Voltage sequence V_{+DC}, V_{AC}, and V_{-DC} repeated 6 times.

$$\delta = \frac{(AC_{DUT} - DC_{DUT})}{DC_{DUT}}$$

δ = AC-DC difference
AC_{DUT} = DUT output voltage with AC input
DC_{DUT} = DUT output voltage with DC input

Conventional AC-DC Difference Experimental Setup

- DUT measured in parallel with standard (another Fluke 792A)
- AC and DC voltages applied to each device
- Requires correction factor to account for any difference between measured value and calibrated value of standard



$$\delta_{DUT} = \left(\frac{(AC_{DUT} - DC_{DUT})}{n_{DUT} DC_{DUT}}\right) - \left(\frac{(AC_{STD} - DC_{STD})}{n_{STD} DC_{STD}}\right) + \delta_{STD}$$

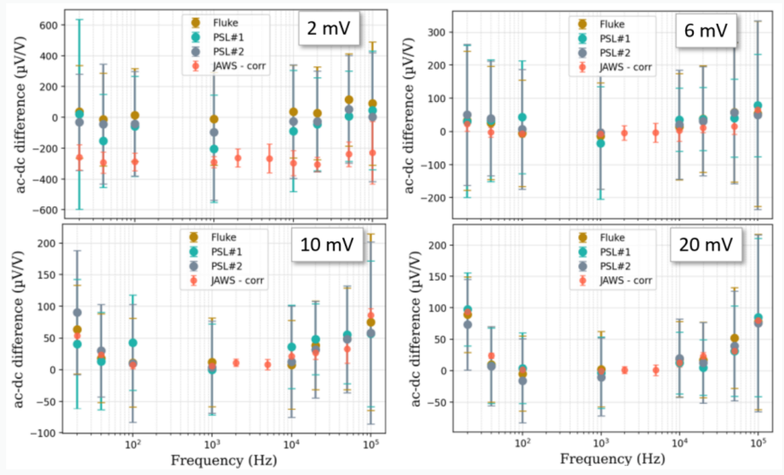
δ_{DUT} = AC-DC difference of the DUT
AC_{DUT} = DUT output voltage with AC input (DUT and standard (STD))
DC_{DUT} = DUT output voltage with DC input (DUT and STD)
δ_{STD} = AC-DC difference of the STD
$n_{DUT,STD}$ = sensitivity coefficient for DUT and STD

Results

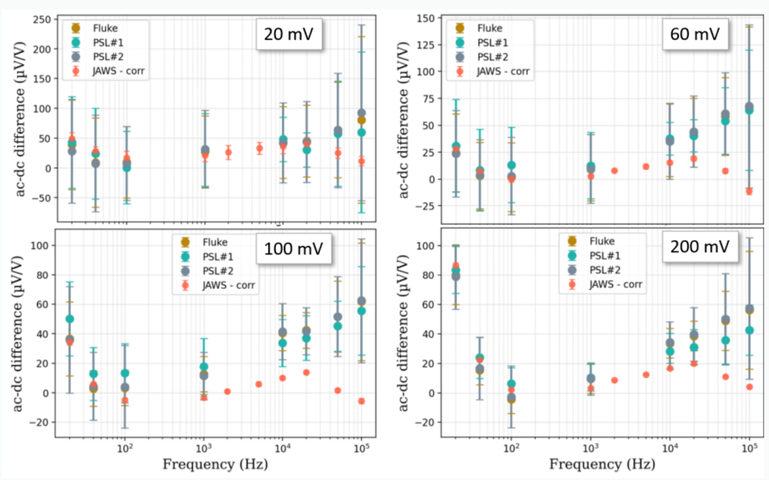
- **Used same device (Fluke 792A) for conventional AC-DC difference and JAWS AC-DC difference measurements**

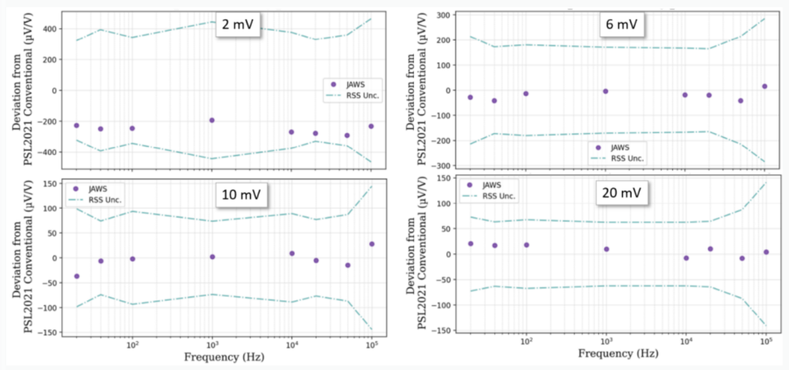
Comparisons:
Fluke conventional AC-DC difference calibration 2017
PSL conventional AC-DC difference calibration 2020
PSL conventional AC-DC difference calibration 2021
JAWS AC-DC difference measurements 2022

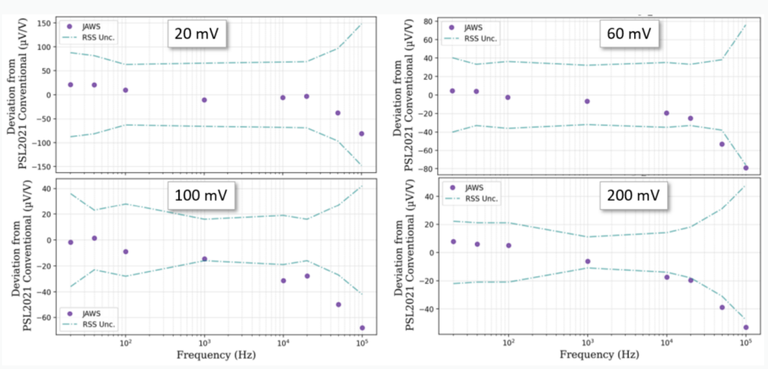
22 mV Range



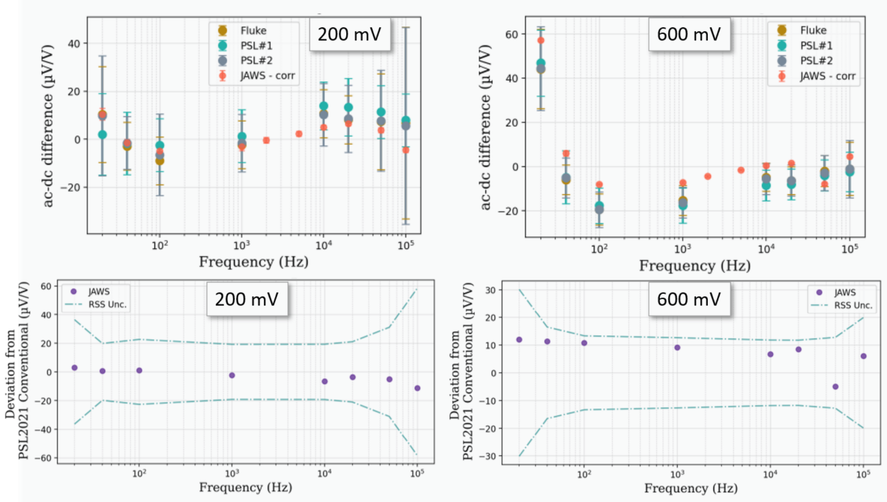
220 mV Range







700 mV Range



Discussion

- The JAWS data suffers from transmission line effects above 10 kHz. These effects need to be corrected using a weighted quadratic fit (data shown here includes high-frequency correction).
- Overall, the JAWS data shows good agreement with conventional AC-DC difference measurements, especially at modest frequencies.
- The JAWS data typically falls well within the combined uncertainties of the conventional and JAWS data.

Conclusions

- Sandia procured one of the first NIST SRI JAWS systems.
- System setup and optimization are complete and AC-DC difference measurements have been performed.
- Conventional AC-DC difference measurement results were compared to AC-DC difference measurements using the JAWS as a source (use Fluke 792A as DUT).
  - Overall, data shows excellent agreement.
  - The PSL is working to finalize the data on all voltages, frequencies, and ranges.
- The PSL is working with NIST-Gaithersburg on a JAWS system-to-system comparison using a Fluke 792A as a transfer device (inter-laboratory comparison).

Acknowledgements/References

- NIST – Nathan Flowers-Jacobs, Alain Rufenacht, Paul Dresselhaus, Jason Underwood

- J.Underwood, Metrologia, **56**, 2019

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