INTERLABORATORY COMPARISON USING A TRANSPORT JOSEPHSON VOLTAGE STANDARD SYSTEM

Y.Tang*, S.L.Kupferman**, M.T.Salazar**
*National Institute of Standards and Technology, Gaithersburg, MD 20899, USA
**Sandia National Laboratories, Albuquerque, NM 87185, USA

Abstract[+]

A portable Josephson voltage standard (JVS) system has been used as a transfer standard to make an interlaboratory JVS comparison. The results are compared with an interlaboratory comparison between the same two JVS systems using transport Zeners made at about the same time. The portable JVS improves the uncertainty of the comparison by largely eliminating the problem associated with non-ideal Zener transportability, environmental dependence, and non-linear drift.

Introduction

This interlaboratory comparison was designed to compare JVS systems by two methods. In one case, the transfer standard was a set of four Zener voltage standards used in a conventional Measurement Assurance Program (MAP). In the other case, the transfer standard was a portable JVS.

The two JVS systems compared are laboratory systems at NIST in Gaithersburg, Maryland and at Sandia National Laboratories (SNL) in Albuquerque, New Mexico. Both the Zener and portable JVS transfers were completed within a period of about five weeks. The Zener transfer was also used to compare the SNL portable JVS and the NIST laboratory system. This same portable JVS was then used as a transfer standard to compare the NIST and SNL laboratory JVS systems. Portable JVS systems have been in use for several years for transferring the Volt to calibration laboratories in the NASA and Department of Energy (DOE) laboratory complexes.

In this experiment, we were interested in comparing the JVS systems as used in their normal working configurations for calibrating secondary Zener voltage standards. In this mode the systems are all computer controlled and are used with automated scanners.

Experimental Description

The BIPM has been performing JVS comparisons by shipping its JVS system to many national metrology institutes (NMI) around the world [1]. The successful development of more portable JVS system makes the JVS interlaboratory comparison much more accessible. The SNL portable JVS is a 10 V system. It was originally developed for replacing conventional traveling Zener voltage standards within several NASA and DOE standards laboratories [2]. The laboratory JVS systems at both NIST and SNL are conventional 10-volt systems. The uncertainties (k = 1) of the portable JVS, the NIST and the SNL laboratory JVS systems for 10 V measurements have been evaluated as 5 nV, 7 nV and 10 nV, respectively.

In preparation for the portable JVS transfer a low thermal switch box was designed and built for switching the Zeners between the two JVS systems without introducing excessive uncertainty due to contact thermals and other thermal voltages. The difference due to interchanging the JVS systems is less than 5 nV. The variation and repeatability among all channels and polarities is less than 10 nV. The stabilization time for transient thermal voltages to diminish is approximately 10 to 15 s when switching channels or polarities.

The same set of four Zener standards used in the MAP was also used in each laboratory to intercompare the laboratory system with the SNL portable JVS. The time for an intercomaprison sequence using the portable JVS was relatively short. Within an hour or so eight pairs of plus and minus polarity measurements to Zener voltage standards can be made resulting in four voltage differences between the two systems. In this case the environmental conditions for the Zener standards were identical for the portable and laboratory JVS systems and no corrections were required for pressure, temperature or humidity. In each laboratory, a total of eight intercomparison sequences were made between two JVS systems over a period of three days resulting in a total of 32 voltage differences. In this part of the experiment, the portable JVS was used as the transport standard *between* the two laboratories while the Zeners were used as a *within* laboratory short term transfer standard, thus eliminating the effect of the non-ideal behavior of the Zeners when they are transported. Use of the portable JVS as the transport standard resulted in a reduction in the uncertainty of the intercomparison by more than an order of magnitude.

A protocol of paired measurements using the low thermal switch box was applied to the comparisons using the SNL portable JVS as transfer standard. All measurements were made at 10 V. The mean time of the paired measurements made by the SNL portable and the NIST JVS systems using the protocol were very close to within a few minutes to avoid possible effect due to Zener drifting with time.

Prior to the comparison between the SNL portable JVS and the laboratory system at NIST, MAPs were performed using the same set of Zener references as transport standards [3]. The SNL also performed a comparison between its portable JVS system and laboratory JVS system so that the quantitative equivalence of the Volt represented by NIST and the SNL laboratory JVS systems could be obtained.

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Table 1. Results of MAPs and JVS transfers

Voltage Differences Measured	Dates Measured	Difference ± Uc (nV) (95% confidence)	Effective Degrees of Freedom
MAP SNL lab - NIST lab	10/3-11/9/01	33 ± 250	4.27
MAP SNL port - NIST lab	10/3-11/9/01	38 ± 255	4.34
SNL port - NIST lab JVS at NIST	11/13-11/15/01	4 ± 12	31
SNL port - SNL lab JVS at SNL	11/28-11/30/01	-6 ± 15	31
SNL lab - NIST lab JVS transfer	11/13/11/30/01	10 ± 19	31

Results and discussion

The results of the transfer experiments are shown in Table 1. All voltages are in nV. The columns indicate, respectively, the quantities measured, the dates of measurement, the voltage differences and their uncertainties Uc at 95% confidence, and their number of effective degrees of freedom associated with each experiment. The bottom row shows the voltage difference between the SNL and NIST laboratory systems and its uncertainty, as calculated from the results in the two rows above.

The Table shows that the uncertainty of the difference between the Volt represented by the NIST and SNL laboratory systems is a factor of 13 less when the transfer is made using the portable JVS system than when the Zener voltage standards are used in a conventional MAP. A comparison of data rows two and three indicates that the uncertainty of the difference between the Volt represented by the SNL portable system and the NIST laboratory system is a factor of 21 less when the two systems are compared in the same laboratory using Zener voltage standards than when the same Zeners are used to conduct a MAP between the two systems in their home laboratories.

In all cases the voltage differences between the systems being compared are significantly less than the uncertainties of the comparison. Effectively, the Volts represented by the three JVS systems are statistically identical, as would be expected.

The larger uncertainties observed in the MAPs using transport Zener voltage standards are due to the non-ideal behavior of these standards. Table 2 shows the uncertainty components in the MAP between the SNL portable JVS system and NIST JVS system. All units are in nV. The largest contributor to the combined uncertainty (transport Type B) is the small but significant random shifts in the values of the Zener standards when they are shipped.

Table 2. Uncertainty components of SNL - NIST MAP

NIST pooled Type A	23.7
SNL portable Type A	26.3
NIST and SNL JVS Type B	8.6
Pressure correction Type B	10.1
Transport Type B	83.8
Effective Degrees of Freedom	4.34
Student t factor (95% confidence)	2.78
Combined uncertainty (95% confidence)	255

Conclusion

We have used a portable JVS system and Zener voltage standards as transport standards to make interlaboratory comparisons. Because of the convenient transportability of the portable JVS system we were able to make an *in situ* JVS interlaboratory comparison between NIST and SNL. Unlike the array-to-array direct comparison which checks Josephson array performance, this method provides a thorough verification of a JVS system including all the components of the system, such as switches, DVM and software as it is used for most of its workload – to calibrate a secondary voltage standard. The advantage of using a portable JVS system for such a comparison is to improve the accuracy and uncertainty. We have achieved factors of 13 and 21 reduction in uncertainty by using the SNL portable JVS system compared to the uncertainty using a conventional Zener MAP procedure. This improvement is largely due to the elimination of uncertainty associated with the environmental and transportability effects of Zener standards. Using a portable JVS system for interlaboratory JVS comparison also improves the efficiency by shortening the time to two or three days compared to several weeks in a conventional MAP procedure.

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