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AN IMPROVEMENT OF DC VOLTAGE RATIO MEASURUREMENTS BY CHARACTERIZATION OF THE DC VOLTAGE DIVIDER AT UME

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Abstract: The accuracy of the DC voltage measurements higher than 10 V depends on the accuracy of DC voltage ratio measurements. Reference standards for DC voltage ratio measurements are resistive voltage dividers which are generally self calibrated by their own bridges.

Calibration of a absolute voltage divider with wide ratio range, such a Datron 4902S, using its bridge is difficult and time consuming calibration. Three different methods for the calibration have been investigated in order to make simpler divider calibration without losing from uncertainty. An extensive set of measurements were performed on Datron 4902S and its ratio drift for one year has been determined as less than $0.3\cdot10^{-6}$ for all ratios from 20V:10V to 1000 V:10 V. The measurement results of Datron 4902S are presented.

Keywords: DC voltage ratio**,** voltage divider, calibration

1. INTRODUCTION

Josephson Array Voltage Standards (JAVS) are used as a representation of the SI volt in many national metrology institutes (NMIs) for more than 20 years [1-3]. Unfortunately JAVS can reach around 10 V with an uncertainty that is typically smaller than 1 part in 10^9.

The uncertainty of the DC voltage measurements higher than 10 V depends on the accuracy of DC voltage ratio measurements. Reference standards for DC voltage ratio measurements are resistive voltage dividers which are generally self calibrated by their own bridges.

Calibrations of these dividers either using their bridges or comparing with a reference divider are time consuming calibrations and automation is difficult.

2. DC VOLTAGE RATIO MEASUREMENTS AT UME

Three different types of dividers are used at TÜBİTAK UME for the DC voltage calibrations up to 1000 V. These are Datron 4902S, Fluke 752A and Fluke 720A. Each of these dividers are self-calibrating and has own calibration bridge.

Calibration of Fluke 752A is easy. But it is valid for 8 hours and it has only two 100/10 and 1000/10 ratios which is sufficient for checking DC voltage performance of Multifunction Calibrators. Fluke 720A has a big amount of ratios but it has linearity and stability problems at full power [4]. Its calibration bridge is not stable and must be frequently characterized during calibration which is time consuming. Datron 4902S has 18 voltage ratios which is sufficient to characterize DC voltage performance of Multifunction Calibrators.

Datron 4902S consists of 10 kΩ resistive sections between 20V:10V, 30V:20V, …, 100V:90V terminals and 100 kΩ resistive sections between 200V:100V, 300V:200V, …, 1000V:900V terminals. Each of these resistors has four terminal connection at the front of the divider so can be measured independently. The typical relative uncertainty of the voltage ratio declared by its manufacturer is $0.2\cdot10^{-6}$ within 24 hour and $0.8\cdot10^{-6}$ with in 30 days from its self calibration [5].

A Datron 4902S DC Voltage Divider has been used as a transfer standard in EUROMET.EM-K8 and EUROMET.EM-K8-1 DC Voltage Ratio Comparisons [6-8]. As a result of experiences during the comparisons, it is decided to use 4902S of TÜBİTAK UME in daily calibrations and developed home-made software for its calibration using a MTS.

3. CALIBRATION METHODS

Calibration using Datron 4901 is time consuming and need to be experienced with the setup. Although 4901 Double Kelvin Bridge is recommended for the calibration of 4902S by its manufacturer [5] any resistance measuring system can be used. Automation of the measurement is simpler using MTS .

Firstly, 4902S was calibrated by substitution with a reference divider, Fluke 752A which was just self-calibrated before the calibration. The output of Fluke 5720A is measured firstly with FLUKE 752A and than with Datron 4902S using the same DCV reference standard and null detector.

Then, 4902S calibration was performed using MTS by measuring voltage drops on each resistive section of 4902S while it was powered from a Fluke 5720A. This method gives opportunity to perform calibration at rated power. Also error due to total heating effect is cancelled. The divider is constructed with active guard by another resistance chain which yields guarding each resistance connections and tracks in divider chain with its nominal voltage. The result of this construction is cancelling leakage current. The drawback in this method is the error coming from CMRR of the voltage measuring device?

Finally, the ratios of 4902S were determined by measuring resistance of each resistive section of 4902S by using MTS. During the measurements 4902S was not energized. Since this calibration is not performed at rated power, this method is meaningful only if power coefficient, leakage current and total heating effects are sufficiently small.

Measurement results of these three methods are presented in Table 1. Also as shown in Figure 1, the results are in a good agreement with in their uncertainties. So, it show us that Datron 4902S of UME has small leakage resistance and power coefficient.

Table 1: Comparison of the results of the three methods

Voltage Ratios	Relative Deviation From Nominal Ratio (10^{-6})		
	Substitution with Fluke 752A	Measuring Voltage	Measuring Resistance
1000V:10V	-0,210	-0,096	-0,354
100V:10V	-0,250	-0,052	-0,108

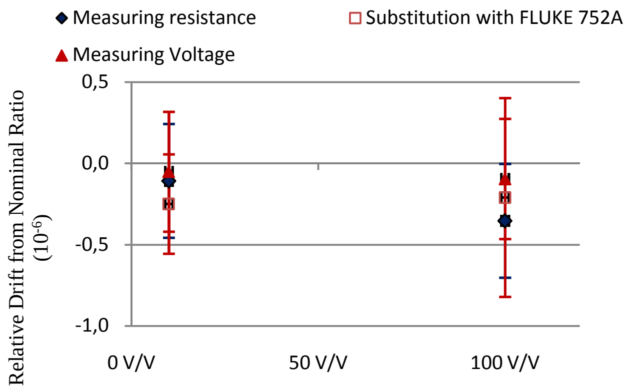

Figure 1. Graphical representation of Table 1

A Datron 4902S DC Voltage Divider has been used as a transfer standard in EUROMET.EM-K8 and EUROMET.EM-K8-1 DC Voltage Ratio Comparisons.

The travelling standard, Datron 4902S, was calibrated at TÜBİTAK UME by using the three different methods: Substitution with a reference divider FLUKE 752A, measurement of each individual resistive sections using MTS and measurement of voltage drops on the individual resistive sections using MTS. The results of these methods were in a good agreement. Also EURAMET comparison results show that three methods for the calibration of 4902S are in a good agreement [7].

For the calibration of 4902S, several precautions are taken in order to improve the reliability of the method.

1-The insulation resistance of the 4902S is measured annually in order to control if its leakage current is sufficiently small [9].

2-The calibrations of 4902S at rated power and at no power is repeated and the results are compared annually. if the differences for each ratio is well within $0.35.10^{-6}$, the power coefficient uncertainty of 4902S declared by its manufacturer combined with the measurement uncertainty Measurements at different voltages are presented in Figure 2 for 2V/V – 10 V/V ratios and in Figure 3 for 20 V/V – 100 V/V ratios.

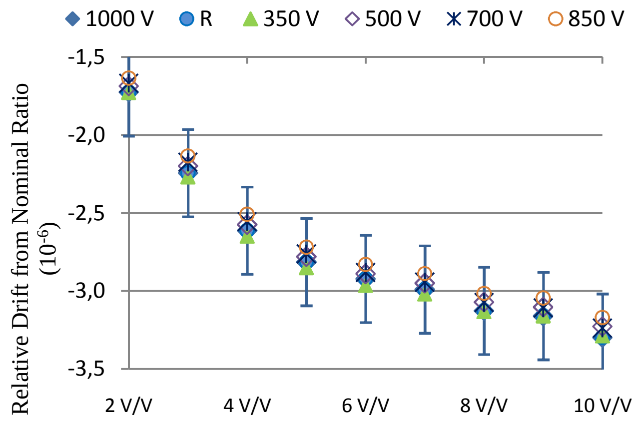

Figure 2. Voltage dependence of 4902S for 2V/V - 10V/V

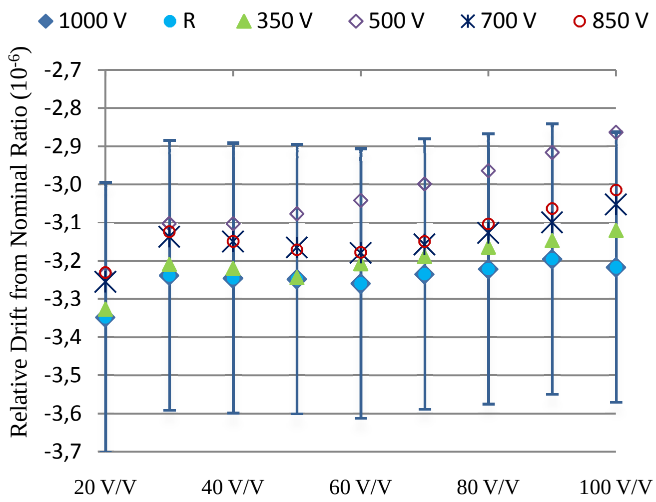

Figure 3. Voltage dependence of 4902S for 20V/V-100V/V

4. SOFTWARE

Software is developed for the calibration of 4902S using two methods; Measuring resistance of each individual sections of 4902S and measuring the voltage drops on the individual resistive sections by using MTS. It is written in LabWindows (National Instrument).

The software algorithm for measuring resistances of each resistive section of 4902S is given below:

1. Measure the resistance of individual ten 10 kΩs, R_i^{10k}.
2. Measure the resistance of individual ten 100 kΩs, R_i^{*100k}.
3. Determine correction using equation (1).

$$\text{Correction} = \sum_{i=1}^{10} R_i^{10k} - R_1^{*100k} \qquad (1)$$

4. Apply corrections to R_i^{*100k} using equation (2).

$$R_i^{100k} = R_i^{*100k} + \text{Correction} \qquad (2)$$

5. Compute the ratios for 2 V/V ,…,10 V/V and for 20 V/V, 30 V/V,…, 100 V/V using equation (3) and equation (4) respectively.

$$\frac{V_{in}}{V_{out}} = \frac{\sum_{i=1}^{N} R_i^{10k}}{R_1^{10k}} \quad ; \quad N = 2, 3, ..., 10 \qquad (3)$$

$$\frac{V_{in}}{V_{out}} = \frac{\sum_{i=1}^{N} R_i^{100k}}{R_1^{10k}} \quad ; \quad N = 2, 3, ..., 10 \qquad (4)$$

Algorithm for measuring voltage drops on the individual resistive sections is similar to algorithm given above.

5. LONG TERM DRIFT OF THE 4902S

Since Datron 4902S divider consist of resistive elements and these elements have non negligible temperature and humidity coefficients, 4902S is maintained temperature and humidity controlled laboratory which has ambient conditions (23 ± 0.5) °C and (45 ± 5) % RH.

4902S was adjusted at the end of 2003 at UME. Then behaviour of the each individual resistive section (ratio) was monitored.

Calibration of 4902S is very simple by measuring resistance using MTS. Long term drift of 4902S has been investigated by using this method.

Each resistive sections are measured by using a MTS and the ratios 20V/10V, 30V/10V,…, 100V/10V, and 200V/10V, 300V/10 V,…, 1000V/10V are determined by means of home-made software. Calibration of 4902S has been performed more than twice in a year. The calibration results only for 100V:10V and 1000V:10V are presented in Figure 4 and Figure 5 respectively.

As can be seen easily from the Figure 4 and Figure 5, 4902S has been drifting quite smoothly after three years of the adjustment. Its drift for one year is less than $0.3 \cdot 10^{-6}$ for all ratios. This is better than the ratio drift declared by its manufacturer for one month (0.8 ppm/month) [5].

6. CONCLUSION

A simpler method for the calibration of 4902S can be used for its all ratios without any significant difference in uncertainty.

Long term drift of 4902S of TÜBİTAK UME has been investigated using home-made software. It is found out that drift of 4902S is better than the drift declared by the manufacturer. With the aid of this work TÜBİTAK UME can deliver uncertainty for ratios less than 0.55 ppm/year which is much better than the accuracy 0.8 ppm/month declared by manufacturer. [5] This uncertainty is sufficient to characterize DC voltage performance of Multifunction Calibrators.

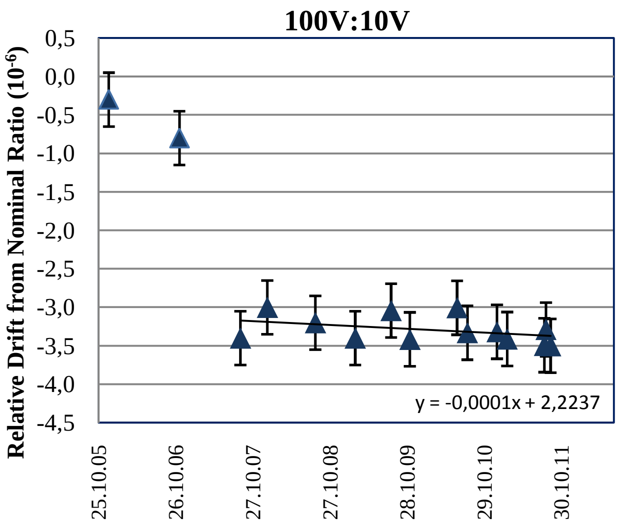

Figure 4: Long term stability of 10 V/V

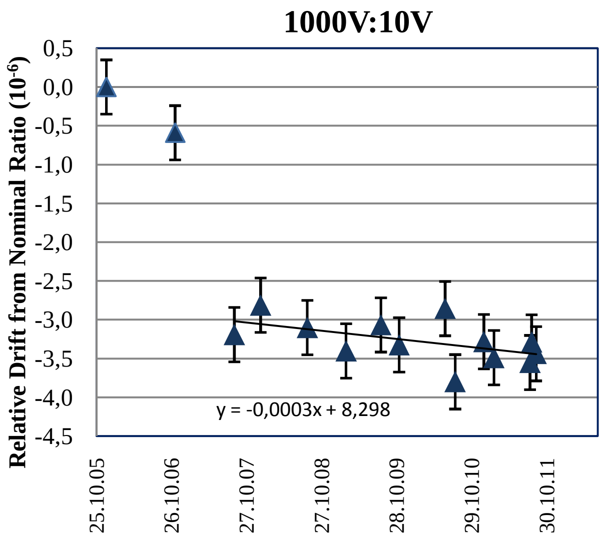

Figure 5: Long term stability of 100 V/V

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