XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

HIGH RESISTANCE COMPARISON AMONG KRISS, VNIIM AND NIM

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Abstract: In a high resistance comparison among KRISS, VNIIM and NIM, the relative resistance values of measurement results agreed well within 2 ppm in 10 megohm and 5 ppm in 1 gigohm. Also, relative combined standard uncertainties of the three institutes for the values is not beyond 4 ppm in 10 megohm and 8 ppm in 1 gigohm.

Keywords: high resistance comparison, 10 megohm and 1 gigohm, adapted Wheatstone bridge, binary voltage divider bridge

1 INTRODUCTION

Worldwide ascertainment on the equivalence of calibration laboratories' certificates is one of the most essential tasks for the present metrology. The results of measurements in calibrating laboratories depend on the size of the unit used and the latter are set by national metrology institutes (NMI) of the countries and by the quality systems used, which provide and control the use and dissemination if this values and their link with primary standards. It means that the equivalence of national standards is the initial point for the ascertainment of equivalence of calibrating laboratories' certificates. The present conception provides the determination of degree of NMI standards' equivalence by the system of multilevel key comparisons. Only the limited number of participants (usually not more than 20) take part in key comparisons of the highest level which are organized by BIPM or Consultative Committees for the different measurement types. These NMIs claim to have achieved the highest level of accuracy and they represent the regional metrology organizations (RMO). Reference values of these comparisons connect the corresponding values of RMO key comparisons. RMO key comparisons together with bilateral comparisons let all NMIs join this system of evaluation of equivalence of standards. CPEM have organized the key comparisons (CCEM-K2a) to test the principal technique of measurement of high value resistance standards. This comparisons started in September 1996 and are going to finish in 2000. On the stage of preparation to this comparisons three NMIs – of Russia, South Korea and China, which are the members of two RMOs – COOMET and APMP – have organized the preliminary trilateral comparisons of the standards of the same nominal values.

2 TRAVELLING STANDARDS

As 10 megohm and 1 gigohm tavelling standards were used the wire wound resistors (provided by Russia) made of molten microwire in glass tegument. This resistors have the superb stability(typical value is 1-3 ppm/year for 1-100 megohm resistors and 3-6 ppm/year for 1 gigohm resistors). Their deviation from nominal value does not exceed 100 ppm and their dependence on temperature is small (typical values of linear and quadratic terms of temperature formula are á= +(3-7) ppm/K and â=-(0.1-0.3) ppm/K^2 accordingly. The usage of cast amber for insulation provides the resistance of leakage not less than 10^{14} ohm, which allows to ignore the influence of leakage currents while measuring using the voltages less than 2 kV. The transportability is less than 3 ppm if hand carried. Basing on the preliminary study of stability and reliability of microwire resistors two standards were used in the comparisons: 10 megohm(serial no.: N901) and 1 gigohm(serial no.: N952) with stability of 1 ppm/year.

3 ORGANIZATION AND CONDITIONS OF COMPARISONS

Standards were delivered from one NMI to another with the accompanying person in following order: VNIIM (St.-Petersburg) – KRISS (Taejon) – NIM (Beijing) – KRISS (Taejon). Central dates of measurements are October, 1998 – November, 1998 – March, 1999 – April, 1999 accordingly. Time of measurement was about 1-2 weeks, total time spent by standards in each laboratory was mainly set by organizational reasons. Conditions of measurements: voltage is 50 V and temperature is 20 °C 23 °C. To compare the results of measurements done at different temperatures the results were reduced to the temperature of 20.00 °C using the coefficient a=+6.1 ppm/K, b= -0.01 ppm/K^2 for 10 megohm standard, a=+4.2 ppm/K, b= -0.01 ppm/K^2 for 1 gigohm standard.

4 SYSTEM DESCRIPTIONS AND MEASUREMENT METHODS

4.1 KRISS

1) Equipment

The system is a adapted Wheatstone bridge similar to that of NPL in U.K [1], which is totally electrostatic-shielded by triaxial connection and traxial cable including two comparing high resistors, two voltage sources and a detector as shown in figure 1. Guard potential is not used in this comparison. At balance, the system becomes typical Wheatstone bridge. We used HP VEE as GUI (Graphical User Interface) language controlled by PID tunning routine in order to determine Vx by automatic balancing [2].

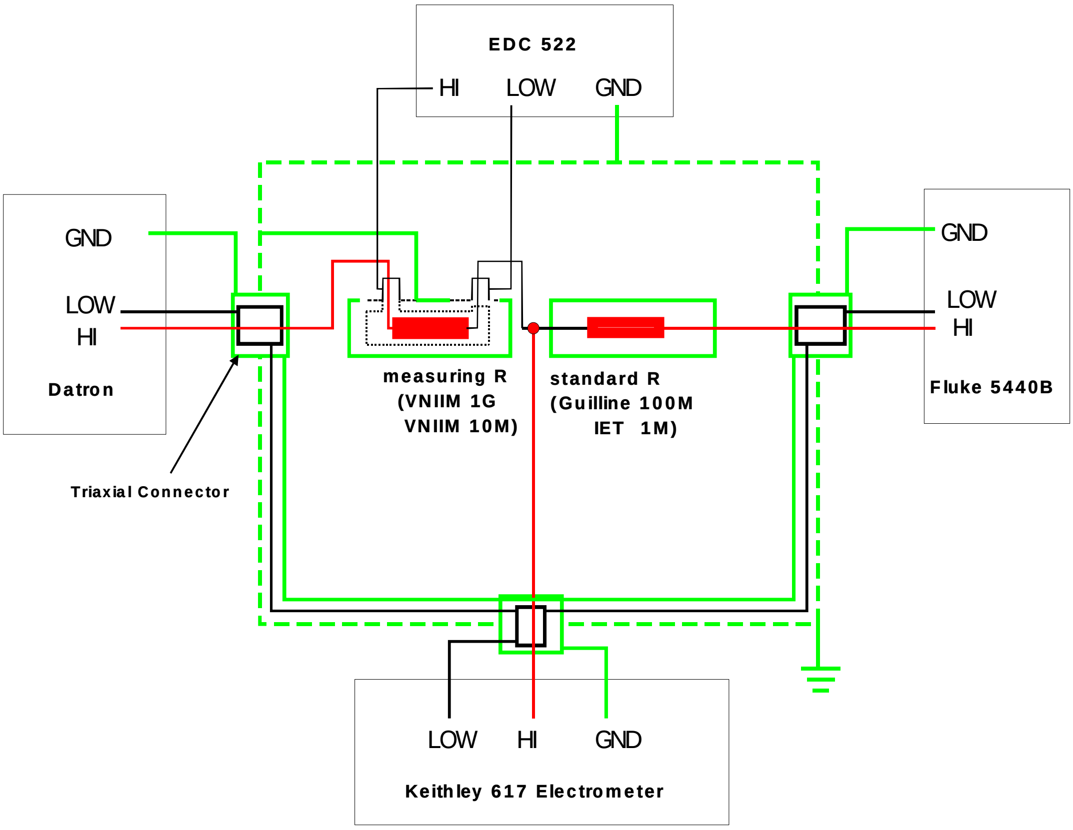

Figure 1. The KRISS high resistance bridge(Adapted Wheatstone bridge)

2) Method of measurement

The resistance standards scaled up by 10:1 bridge ratio measurements from 1 megohm to 1 gigohm successively and 1 megohm is traceable to quamtum Hall resistance using a current comparator bridge.

3) Uncertainty estimation

We used as reference standards of 1 megohm and 100 megohm IET and Guildline resistors traceable to Quantum Hall Resistance Standard. Ratio linearity is calibrated by a 7 digit digital voltmeter traceable to Josephson Voltage Standard. Detector linearity is determined by applying high voltage to high standard resistors and leakage current is measured by open circuit of comparing resistors and substituting more higher resistors for the comparing resistors. The results are as shown in table 1.

Table 1. Estimation of standard uncertainties (for automatic measurements)

Nominal value	Type A STD uncertainty	Type B STD uncertainty						Combined STD uncertainty (RSS)
		STD Resistor	Temp. Correction	Ratio Accuracy &Linearity	Detector Linearity	Detector Stability	Leakage Current	
10 MÙ	1 ppm	1 ppm (1 **MÙ)**	<0.5 ppm	2 ppm	2 ppm	2 ppm	1 ppm	3.9 ppm
1 GÙ	0.5 ppm	5.3 ppm (100**MÙ)**	1 ppm	6.8 ppm	2 ppm	2 ppm	1 ppm	9.2 ppm

4.2 VNIIM

1) Equipment

Wheatstone bridge as shown in Fig. 2 measures with ratio 1 : 1 with grounded point of ratio arms which are formed by two microwire 100 kilohm resistors. Resistance of one of them can be changed gradually by 0.01 ohm(resolution 0.1 ppm). Three another points of the bridge are insulated by massive cast amber insulators, which provides the resistance not less than 10^{14} ohm between this points and grounded shield which surrounds the bridge. Measured and standard resistors are situated in air thermostat with the temperature 20 °C ± 0.05 °C. 5 and 1/2 digit voltmeter with input resistance of 1 gigohm serves as null detector. It provides the relative sensitivity 0.1-0.3 ppm when 100 V battery of dry elements is used as the bridge power supply.

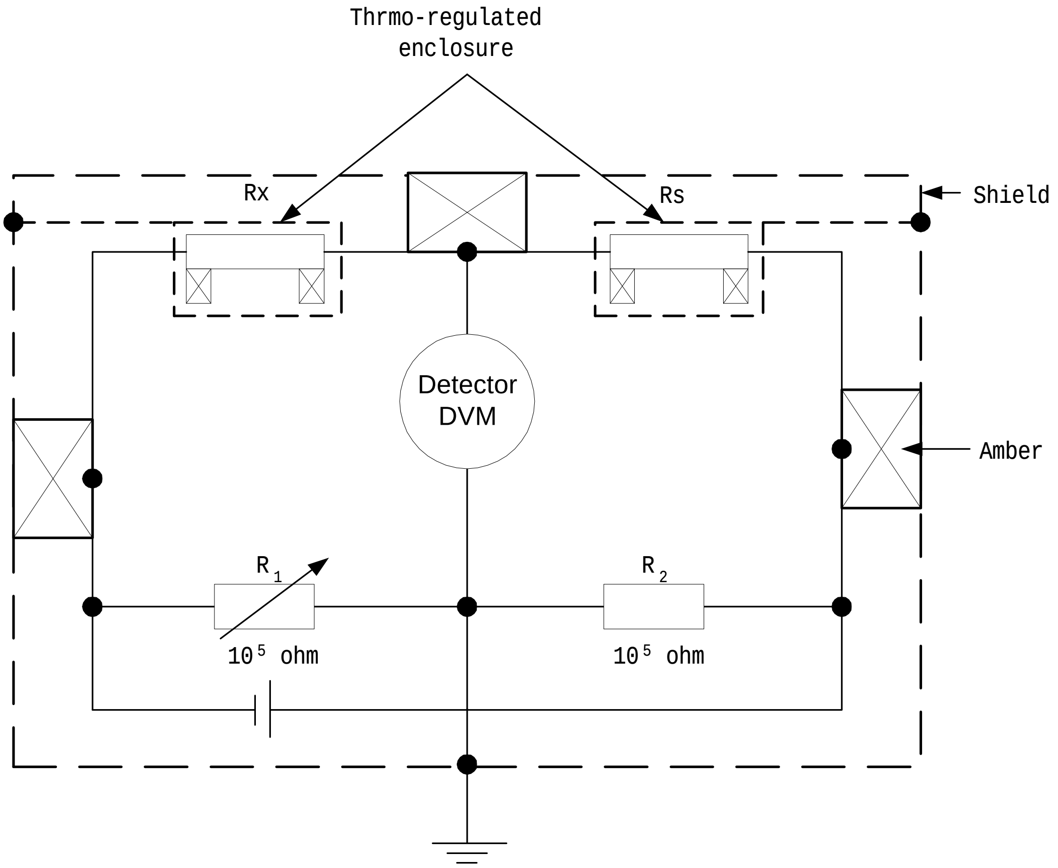

Figure 2. The VNIIM high resistance bridge (Wheatstone bridge)

2) Method of measurement

Comparison performed by means of permutation method using one unknown and two known resistance standards. The value of the resistance unit is scaled up by the chain of measurements including the comparison of resistance of transfer resistors (Hamon type) 10 X 1 kilohm, 10 X 10 kilohm (both based on thick foil resistors), 10 X 1megohm and 10 X 100 megohm (both based on microwire-wound resistors).

3) Uncertainty estimation

Evaluation of uncertainty of measurements on different stages of the process of scaling is given in the table 2.

Table 2. Estimation of standard uncertainties

Step	10 kohm – 100 kohm	100 kohm – 10 Mohm	10 Mohm – 1 Gohm
Type A STD uncertainty	0.03 ppm	0.3 ppm	0.5 ppm
Type B STD uncertainty	0.1 ppm	0.5 ppm	ppm

4.3 NIM

1) Equipment

NIM system is a commercial potentiometric ratio bridge based on binary resistive voltage divider [3] but this bridge as the most recent model supply to DC 100 V.

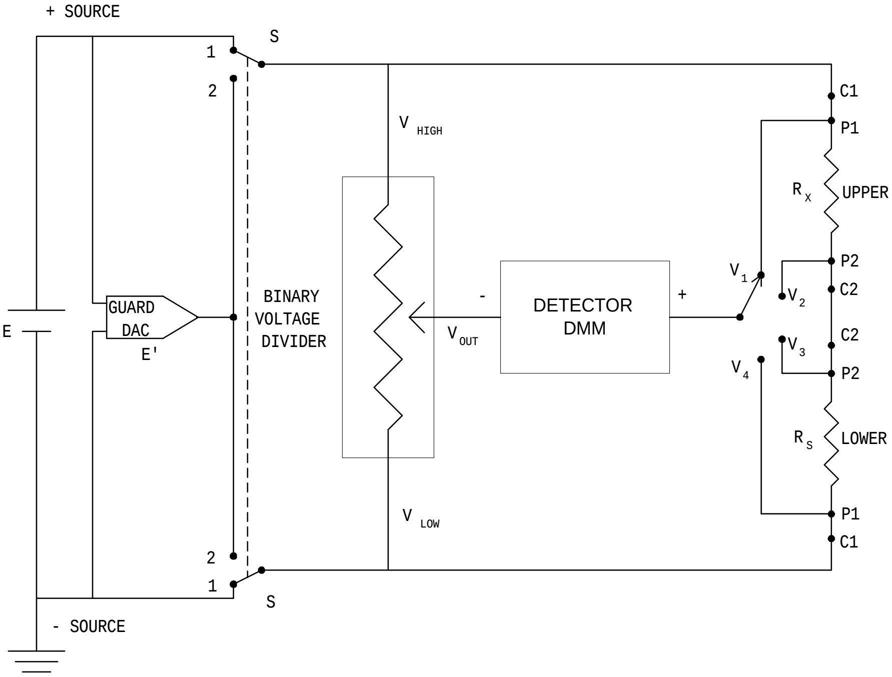

Figure 3. NIM high resistance bridge (automatic BVD bridge)

2) Method of measurement

100 kilohm resistance is transferred from NIM' 1 ohm secondary standard by a set of Hamon resistors in an oil bath. Then the 1 megohm : 100 kilohm is tested on the high resistance bridge at ratio 10 : 1. Other high resistors is determined by the same way. That means 10 megohm : 1 megohm / 100 megohm : 10 megohm / 1 gigohm : 100 megohm are measured respectively.

3) Uncertainty estimation

The high resistance bridge have a linearity better than 0.1 ppm after self-calibrated though 1 gigohm measurement uncertainty is described as less than 20 ppm in the manufacture's specification. So the ratio 10 : 1 is directly used to extend the resistance with good accuracy. The estimated uncertainties are shown in table 3.

5 COMPARISON RESULTS AND DISCUSSION

Measurement results of three metrology institute having different measurement systems is shown in table 3. In the table large difference of type A standard uncertainty between manually and automatically-measured values mainly results from differences of measurement sensitivity and determination of response time at balancing. To minimize leakage problems in high resistance measurements, KRISS used two voltages having low output impedances and VNIIM used cast amber insulators for isolating and insulating bridge junction parts from grounded shield. NIM reduced the effect by connecting ground to battery side instead of typical detector side and by using a special switching technique(so called “virtual null”). For scaling up KRISS and NIM used 10 : 1 bridge ratio up to 1 gigohm and transfer errors are more increased than VNIIM which used Hamon transfer method with 100 : 1 ratio and permutation method. Also, in 10 : 1 measurements from 10 megohm to 1 gigohm voltage coefficients were determined and then corrections applied to the measured resistance values, while the effect is not appeared in 1 : 1 permutation method. The difference of measured values (automatic measurements in case of KRISS) relative to a mean value of measured values among three institutes agreed well within 1 ppm in 10 megohm and 2.7 ppm in 1 gigohm relative to the mean value of three measured values. The degree of equivalence relative to the mean value at the 95% confidence level at 10 megohm is calculated using the following equations.[4],[5]

Table 3. Comparison results among KRISS, VNIIM and NIM.

	Metrology Institute	10 MÙ	1 GÙ
Measured values	KRISS	9.999 61(manual)	1.000 034(manual)
		9.99965(automatic)	1.000 033(automatic)
	VNIIM	9.999 67	1.000 035
	NIM	9.999 66	1.000 038
Type A Standard uncertainties (ppm)	KRISS	3	20
		1	0.5
	VNIIM	0.5	1.0
	NIM	0.1	1.2
Type B Standard uncertainties (ppm)	KRISS	7.9	11.3
		3.6	9.2
	VNIIM	1.0	2.0
	NIM	2.4	7.4
Combined standard uncertainties (ppm)	KRISS	8.5	23
		3.9	9.2
	VNIIM	1.2	2.4
	NIM	2.4	7.5

$$\Delta = \left| m_{lab} - m_{mean} \right| + \left\{ 1.645 + 0.3295 \left[\exp\left(-4.05 \left| m_{lab} - m_{mean} \right| / u_p \right) \right] \right\} u_p \qquad (1)$$

$$u_p = \sqrt{u_{lab}^2 + u_{mean}^2} \qquad (2)$$

$$u_{mean}^2 = u_{trans}^2 + u_{stabiliy}^2 + u_{S.D}^2 \qquad (3)$$

where subscript ‘lab’ is one of KRISS, VNIIM, NIM and subscript ‘mean’ is the average value of three measured values, and also u_{mean} is uncertainty of the average value, u_{trans} is transportability of the high resistors, $u_{stability}$ is resistance stability of the high resistors per year as described in section 2, $u_{S.D}$ is standard deviation of the average value. According to those equations, $u_{S.D}^2$ is calculated as 0.6 ppm for 10 MΩ and 1.5 ppm for 1 GΩ and the degree of equivalence is estimated as 10.0 ppm, 6.7 ppm and 7.7 ppm for KRISS, VNIIM and NIM, and at 1 gigohm 19.7 ppm, 8.2 ppm and 16.9 ppm for KRISS, VNIIM and NIM, respectively.

6 CONCLUSION

Using micro wire-wound transportable standards of one 10 megohm and one 1 gigohm a high resistance comparison had been carried out among KRISS, VNIIM and NIM. The difference of measured values relative to a mean value of measured values among three institutes has been agreed well within 1 ppm in 10 megohm and 2.7 ppm in 1 gigohm and the degree of equivalence relative to the mean value at the 95% confidence level at 10 megohm has been 10.0 ppm, 6.7 ppm and 7.7 ppm for KRISS, VNIIM and NIM and at 1 gigohm 19.7 ppm, 8.2 ppm and 16.9 ppm for KRISS, VNIIM and NIM, respectively. It is considered in respects of international compatibility that a good agreement among three national metrology institutes has been obtained in spite of different systems.

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