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DC & AC RESISTANCE MEASUREMENTS AT CENTER FOR MEASUREMENT STANDARDS

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Abstract – Electrical unit of resistance maintained at the Center for Measurement Standards (CMS, Republic of China) is based on the second plateau of quantized Hall resistance, $R_H(2)$. Resistors are directly or indirectly compared with the $R_H(2)$. We report the procedure of the dc and ac resistance measurements at the CMS. Uncertainties associated to the measurements are also briefly reported.

Keywords: ac & dc resistance measurements, quantum Hall effect standard of resistance, CCC bridge, ac resistance ratio bridge

1. INTRODUCTION

Resistance standard maintained at the CMS is based on the $R_H(2)$ since 1996 [1][2]. Resistors are directly or indirectly compared with the $R_H(2)$ using a laboratory-made CCC bridge (resistance ratio bridge using a cryogenic current comparator), a commercially available DCC bridge (resistance ratio bridge using a direct current comparator, Measurement International, model 6010B, serial no. 93103), a laboratory-made AC bridge (ac resistance ratio bridge) and calculable ac/dc resistors (laboratory-made and commercially available quadrifilar 1 kΩ resistors).

We regularly calibrate the 1 Ω working standard resistor (Leed&Northrop, model 4210, serial no. 1915092) by comparing it with the $R_H(2)$ using the laboratory-made CCC bridge. Typical combined standard uncertainty of calibrating a 1 Ω resistor was evaluated to be about $1.2 \cdot 10^{-8}$ [2]. We use the 1 Ω working standard and the commercially available DCC bridge to calibrate the customers' resistors. Typical combined standard uncertainty of the calibration was evaluated to be about $2 \cdot 10^{-7}$ [2]. The calculable ac/dc 1 kΩ resistors are used to enhance the frequency range of the resistance measurements from dc to several 10 kHz. Their frequency dependences were calculated using the Gibbing's theory [3]. Resistances of the ac resistors are measured using the laboratory-made AC bridge. Typical combined standard uncertainty of each ac ratio measurement was evaluated to be less than $1 \cdot 10^{-7}$ [4][5].

Table 1 Evaluated uncertainties of resistance ratio measurements of $R_H(2)$:100Ω, 100Ω:1Ω and 10kΩ:100Ω. All parameters are listed in 10^9.[2].

Source of uncertainty	A/B	$R_H(2)$: 100Ω	100Ω: 1Ω	100Ω: 10kΩ
temperature fluctuation	B	–	4.3	4.3
current dependence of 100Ω resistor	B	–	negligible	–
instability of 100 Ω resistor	A	–	8.8	8.8
Coil balance	B	0.02	0.02	0.02
total flux noise	A	0.07	0.01	1.1
resistance divider	B	0.08	0.08	0.008
contact resistance	B	3.3	3.3	3.3
voltage measurement by DMM		0.03	0.03	0.03
voltage measurement by nan voltmeter	B	3	3	3
isolation resistance	B	1.29	0.01	1
combined standard uncertainty		4.76	10.79	10.89

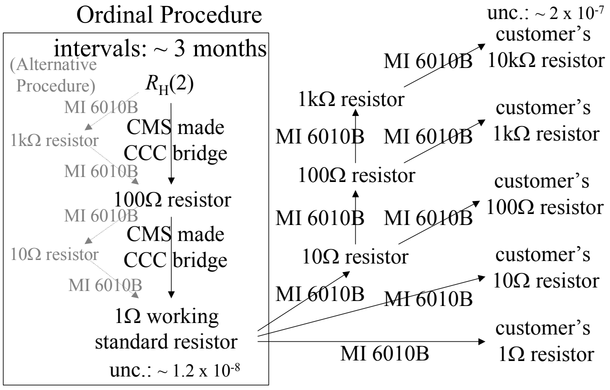

Fig. 1 Procedure of dc resistance measurements at CMS. The laboratory-made CCC bridge is usually used for measuring the 1 Ω working standard resistor. The commercially available DCC bridge (MI 6010B) is used for calibrating the customers' resistors and for calibrating the 1 Ω working standard resistor till the CCC bridge was developed.

2. DC RESISTANCE MEASUREMENTS

Figure 1 shows the procedure of the dc resistance measurement. Table 1 shows the evaluated standard uncertainties of the resistance ratio measurement [2].

A GaAs/AlGaAs heterostructure device made by LEP (Laboratoires d'Electronique Philips) was used as the QHE sample. It was installed in the 14 T superconducting magnet system with a ^{3}He insert whose lowest temperature is 0.3 K. A 100 Ω transfer resistor (Tinsley, model 5685A, serial no. 260932) is directly compared with the $R_H(2)$ using the laboratory-made CCC bridge Typical combined standard uncertainty of the comparison is evaluated to be $4.8 \cdot 10^{-9}$ [2]. The 1 Ω working standard resistor is directly compared with the 100 Ω transfer resistor using the same CCC bridge with different settings. Typical combined standard uncertainty is evaluated to be $11 \cdot 10^{-9}$, including the instability of the 100 Ω transfer resistor [2]. Typical combined standard uncertainty of calibrating the 1 Ω working standard resistor was given as their root sum squares, $12 \cdot 10^{-9}$, since these two comparisons were independent of each other.

The customers' resistors are directly or indirectly compared with the 1 Ω working standard resistor using the DCC bridge (MI, 6010B). Uncertainty of the resistance ratio measurement using the DCC bridge was experimentally evaluated to be about $2 \cdot 10^{-7}$ by comparing it with the CCC bridge [2].

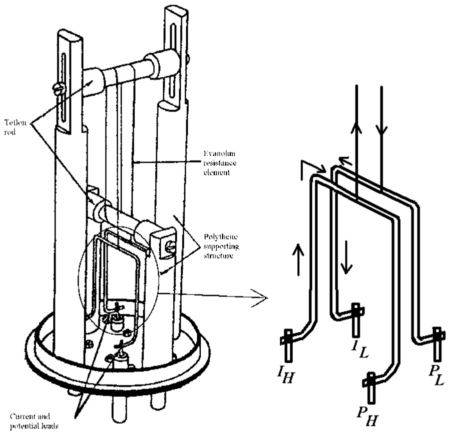

Fig.2 Bifilar-type ac/dc calculable 1 kΩ resistor.

3. AC RESISTANCE MEASUREMENTS

Figure 2 shows the schematics of the laboratory-made quadrifilar type ac/dc calculable 1 kΩ resistor [4][5]. We also use the commercially available ac/dc calculable 1 kΩ resistor (NL Engineering). Their resistances are determined by comparing them with the 1 Ω working standard resistor using the DCC bridge. Their frequency dependences were calculated using the Gibbing's theory [3]. They are used for enhancing the frequency range of from dc to several 10 kHz.

We developed an AC bridge [4][5], whose operation was based on the coaxial AC bridge [6]. Ac resistance of the 10 kΩ and 100 kΩ resistors are determined by comparing them with the ac/dc calculable 1 kΩ resistor using the AC bridge.

Figure 3 shows the procedure of the ac resistance measurements and the evaluated uncertainties associated to each procedure.

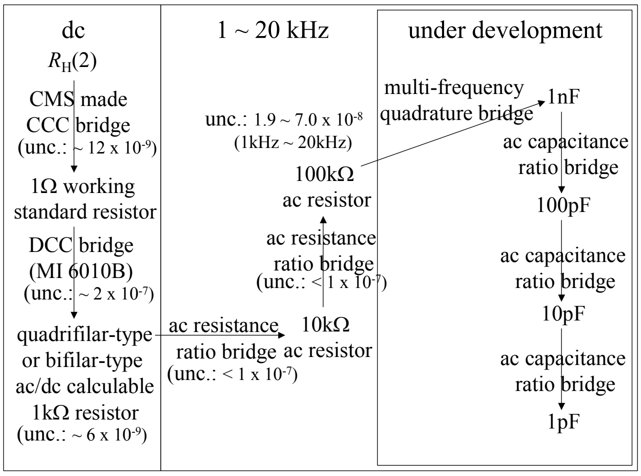

Fig. 3 Procedure of the ac resistance measurements and uncertainties associated to each procedure.

4. DISCUSSIONS AND CONCLUSION

We developed dc and ac resistance measurements systems, based on the $R_H(2)$, at CMS. We measure dc resistances of from 1Ω to 10 kΩ resistors with uncertainties of about $12 \cdot 10^{-9}$ when we use the CCC bridge, and with uncertainties of about $2 \cdot 10^{-7}$ when we use the DCC bridge. We measure the ac resistances of the 1kΩ, 10kΩ and 100 kΩ resistors with uncertainty of a few parts in 10^7.

We are developing a multi-frequency quadrature bridge, which is modified from that developed by Nakamura [7]. We are also developing an ac capacitance ratio bridge [6]. We will use these bridges to measure capacitors of from 1 pF to 1 nF.

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