NIST COMPARISON OF THE QUANTIZED HALL RESISTANCE AND THE REALIZATION OF THE SI OHM THROUGH THE CALCULABLE CAPACITOR

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Abstract

The latest NIST results from the comparison of the quantized Hall resistance (QHR), with the realization of the SI ohm obtained from the calculable capacitor measurement will be reported. Various systematic checks have been performed.

Introduction

The last reported comparison of the quantized Hall resistance (QHR) and the realization of the SI ohm from the NIST calculable capacitor was presented at CPEM 1988 [1-3]. From the results of the NIST ohm realization and QHR measurement, the NIST value for the von Klitzing constant was R_K = 25 812.807 23 (61) Ω, which agrees well with the value adopted internationally in 1990 [2]. However, recent comparisons of the QHR with the SI ohm realization show a small difference. To determine the cause of this difference, several checks on systematics in both the ac and dc parts of the measurement have been performed.

Measurements

The comparison of the QHR with the realization of the ohm through the calculable capacitor is made through the measurement of a 1000 Ω transportable resistor. The ac and dc part of this measurement sequence is shown in Fig. 1. The 1000 Ω resistor, R311, consists of nine 1000 Ω Evanohm resistors connected in series-parallel and mounted in a sealed metal can filled with oil [4]. The relative difference between the values of the 1000 Ω resistor from the calculable capacitor and the QHR measurement is approximately 5 in 10^{-8}, which is more than the expected uncertainty for this comparison. This difference, which has been consistent over a period of three years since 1993 implies that a value of R_K that is approximately 5×10^{-8} larger than the value reported in 1988.

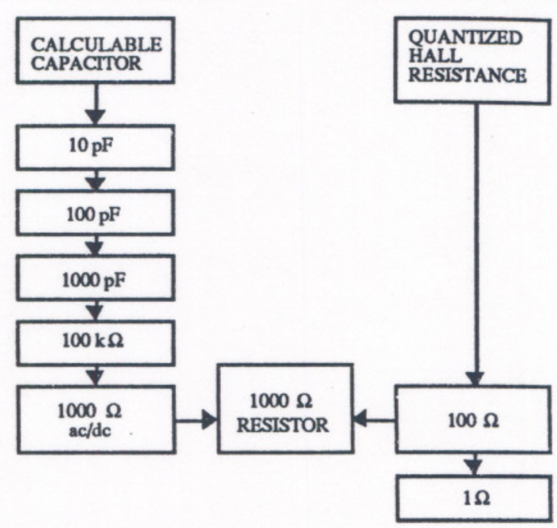

Figure 1. Measurement sequence for the comparison of the QHR and the realization of the SI ohm through the 1000 Ω transportable resistor.

AC measurements

The calculable capacitor system and the rest of the ac measurement sequence are the same as described in Ref. [1]. The following systematic checks have or will be performed and reported:

a) The electrode alignment of the calculable capacitor was checked and found not to have changed significantly since the last alignment in 1988 [1].

b) The optical system for the laser and the Fabry-Perot interferometer of the calculable capacitor were realigned. Measurements made following this alignment agreed well with previous measurements. The effect of changing the beam diameter of the laser beam will also be investigated.

c) The transformer ratio of the four-terminal-pair bridge used in the 10:1 step-ups from 10 pF to 100 pF and from 100 pF to 1000 pF was measured and found to agree with previous measurements to within 1 in 10^9. The transformer ratio for the calculable capacitor bridge and the 100:1 resistance bridge will also be checked.

d) The voltage dependence of the 10 pF capacitor which is used at 4 V and 14 V in the calculable capacitor bridge and then at 200 V for the 10:1 step-up, is measured during the time the SI ohm determination is performed. In addition, the voltage dependence of the 100 pF and 1000 pF capacitors between 20 V and 200 V are also required. Any correction due to voltage dependence is applied to the measurement values. The voltage dependence of the calculable capacitor will also be checked to make sure it is negligible.

e) The bridge linearity and phase adjustment of the calculable capacitor bridge, 10:1 four-terminal-pair bridge, and 100:1 bridge will be checked.

f) Coaxial chokes are used in the bridges in every step of the SI ohm determination. Choke corrections are

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measured for each choke and applied to the bridge measurements.

g) The relative uncertainty due to harmonics in the quadrature bridge (1000 pF to 100 kΩ) was measured and found to be less than 1 in 10^9.

h) A new four-terminal-pair bridge is being constructed at NIST. This bridge will be used as a check on the present four-terminal-pair bridge used in the SI determination.

DC Measurements

DC resistance scaling at NIST is based on both Hamon device and cryogenic current comparator (CCC) measurements [5]. Before 1992, Hamon scaling and potentiometric measurements at a one-to-one ratio were used with the QHR [3]. Beginning in 1992, the CCC technique has been used to compare 100 Ω reference resistors against the QHR.

There have been eight measurements of the 1000 Ω transportable resistor, R311, using CCC scaling since 1992. Scaling was done with 100 Ω references that were assigned values against the QHR on approximately the same mean dates as the groups of 1000 Ω measurements. The 100 Ω resistors are well characterized, with predictable drift rates, and require negligible temperature and pressure corrections. Based on a linear fit to the eight measurement values, R311 has drifted at a rate of 0.153×10^{-3} Ω/year and the residuals range from +0.005 to - 0.006×10^{-3} Ω.

The following list summarizes the systematic checks that have been made on the QHR and the dc scaling measurements.

a) The CCC current linkage (ratio) error has been determined to be negligible in the three CCC devices in use. The gain of the CCC bridge output is calibrated after each series of measurements. Integrating feedback keeps the nanovolt detector at null so that the detector gain need not be calibrated.

b) Leakage resistance has been measured for the measurement systems and resistance references. The level of certain leakage currents can also be checked using *in-situ* CCC measurements [6].

c) The 10:1 ratio of the CCC bridge used for the 1000 Ω measurements was compared to the same ratio of two other CCC systems in 1992 and 1994. The 10:1 ratios agreed to within the relative measurement resolution of 5×10^{-9}.

d) Between 1992 and 1996, three different QHR devices have been compared against the primary NIST standard GaAs-8. There has been no difference detected in the value of the QHR standard using CCC measurements. The same CCC system that was used for the 10:1 measurements was used for the 6453.2 Ω scaling. Since 1993, QHR measurements have also been made at 12 906.4 Ω using a second CCC system.

e) Loading effects in the reference resistors have been investigated [7].

f) In 1992, two QHR systems were operating at NIST, and potentiometric measurements were compared to CCC based QHR measurements using three 6453.2 Ω transfer standards. The two different QHR assignments agreed to within the measurement uncertainties of all three transfer standards.

g) Comparisons of the 10:1 and 64.532:1 ratios of one CCC bridge against Hamon devices are described in Ref. [5].

h) The CSIRO National Measurement Laboratory of Sydney, Australia and NIST participated in a comparison of dc resistance standards in August and September, 1995 using transportable 1 Ω and 100 Ω references. These comparisons indicated that the QHR assignments of the two laboratories are in good agreement.

Conclusions

Periodic comparisons of the QHR with the realization of the ohm through the calculable capacitor ensures that the ohm based on the quantum Hall effect is consistent with the SI ohm. Systematic errors are still being investigated and a final value for the von Klitzing constant will be reported. The results of this comparison will provide data for the least-squares adjustments of fundamental constants in 1997.

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