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The cover design depicts the microwave planar near-field scanner being developed at NPL.

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National Physical Laboratory
Teddington, Middlesex, United Kingdom, TW11 0LW

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Improvements in the traceability of resistance measurements at NPL

J M Williams, A Hartland, N B Dupuy and C H Porter

National Physical Laboratory, Teddington, Middlesex, TW11 0LW, UK.

Introduction

The development of the automated cryogenic current comparator bridge^[1] (CCCB) at NPL has opened up new possibilities for the traceability route of resistance measurements. The majority of the routine resistance calibration work at NPL is in the range 1 Ω to 10 k Ω and the CCCB is used to measure these values in terms of a reference 100 Ω standard. This standard is in turn measured in terms of the quantised Hall resistance using a second CCCB.

Quantised Hall measurements

The first system to measure the quantised Hall resistance (R_H) in terms of room temperature resistors at NPL was manually operated and used a cryogenic current comparator with a turns ratio of 4001:62^[2]. The value of R_H for the $i=4$ plateau was related to a 100 Ω resistor and the value for the $i=2$ plateau to two 100 Ω resistors connected in series.

A fully automated system has now been developed and uses a cryogenic current comparator with turns ratios of 4130:32 and 4130:64. The ratios are constructed using combinations of individual windings based on a binary series and these individual windings can be checked for consistency using a binary build-up procedure. The availability of the two ratios means that the value of R_H for both plateaux can be directly related to a single 100 Ω resistor, R_{100} . The conventional value of the von Klitzing constant R_K is $R_{K-90}=25\,812.807\,\Omega$ and the above turns ratios on the cryogenic current comparator enable scaling of this value to 100 Ω with a value for N in the expression

$$R_H = \frac{R_K}{i} = NR_{100}$$

given by

$$N = \frac{258\,812\,807}{i} (1 + 11.893 \times 10^{-6})$$

A value of 100 Ω for the room temperature resistor is about optimum in terms of the total noise and the measurement power. The measurement current in the 100 Ω is 3.16 mA which corresponds to a power dissipation of 1 mW. At this power level, the effect of power dissipation is usually much less than 1 part in 10^8 . The corresponding current in the quantised Hall device is 49 μ A or 24.5 μ A depending on the ratio used. With this combination, the system noise is dominated by Johnson noise in the 100 Ω resistor and current noise from the null detector flowing in R_K . The contribution from the Johnson noise from R_K is small because it is at a low temperature.

The automated measurement system is still under development but a measurement accuracy of better than 1 part in 10^8 has already been demonstrated.

Room temperature resistor measurements

An automated CCCB with integer ratios between 1:1 and 1:25 has been developed to measure resistors in the range 1 Ω to 10 k Ω . Previously, resistors in this range were measured using a combination of substitution measurements and Hamon ratio devices. The accurate ratio of the CCCB, however, enables measurements to be made with fewer intermediate steps and hence a greater overall accuracy. For example, resistors submitted for calibration with values of 10 Ω , 25 Ω , 100 Ω and 1000 Ω can now be measured directly against a 100 Ω standard. Values of 1 Ω and 10 k Ω can be measured using intermediate standards at 10 Ω and 1000 Ω respectively.

The overall uncertainty of the measurements made using the CCCB now approaches 1 part in 10^9 . This represents the best performance which can currently be obtained for resistance measurements and the reproducibility of the results is normally dominated by the stability of the standards under test.

References

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