Conference Digest

Conference on Precision Electromagnetic Measurements

16-21 June 2002

Conference Digest

2002 Conference on Precision Electromagnetic Measurements

Ottawa, Ontario
Canada
16-21, June 2002

Conference Secretariat:
CPEM 2002
Management Office
National Research Council Canada
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IEEE Catalog Number	02CH37279
ISBN	0-7803-7243-5
Library of Congress	2001095315

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A 10 TΩ PER STEP HAMON TRANSFER STANDARD

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Abstract

To evaluate high-resistance measurements and scaling in the range 1 TΩ to 100 TΩ, a 10 TΩ/step Hamon transfer standard is being developed. The design uses fabrication techniques developed in recent years at NIST to construct high-resistance standards.

Introduction

In recent years, much work has been done at NIST to support calibration services in the high-resistance range of 10 MΩ to 100 TΩ such as the implementation and development of new measurement systems and standards. There have also been high-resistance comparisons between NIST and other metrology labs. Several NIST customer labs have needs for improved calibrations at the 1 TΩ level and above. Some of the driving applications of high-resistance measurements in this range, in addition to instrumentation and standards, are measurements to support the calibration of jet fuel quality test sets, photographic film processing, measurement of ceramic parts, and the evaluation of the quality of processes for applying coatings to ceramic parts.

Ratio Methods

Several ratio methods are available for calibrating resistance standards in the range 1 TΩ to 100 TΩ. The two techniques presently available at NIST are the use of a digital teraohmmeter system [1] and a guarded dual-voltage-source bridge system [2].

The teraohmmeter system has been used for routine calibrations to 1 TΩ for many years, in 1998 during a comparison at 1 TΩ and 10 TΩ between NIST and Sandia [3], and recently as a check method before and after a 10 TΩ special test for a NIST customer. This technique relies on the internal ratio of the teraohmmeter to scale to these high-resistance values from a lower valued standard resistor. The expanded relative uncertainties ($k = 2$) for this system are 1400×10^{-6} and 2000×10^{-6} for 1 TΩ and 10 TΩ, respectively.

The second technique available at NIST is the guarded dual-voltage-source bridge. This system has used 100:1 and 1000:1 bridge ratios to scale to the 10 TΩ level of resistance. Guarded Hamon transfer standards have been used to check the scaling of the dual-voltage-source bridge at resistance levels up to 100 GΩ. Over this range, the two techniques have agreed within 10×10^{-6}, thus providing confidence in scaling to the 100 GΩ decade of resistance.

Presently at NIST, only the teraohmmeter system is available to evaluate the dual-voltage-source bridge. This evaluation has shown agreement between the two systems within the relative expanded uncertainty of the teraohmmeter system. However, the uncertainties associated with the teraohmmeter system are several orders of magnitude larger than those associated with the guarded Hamon transfer standards. Therefore, construction of a 10 TΩ/step transfer standard has begun to further evaluate bridge ratios in the 1 TΩ to 100 TΩ range. Work is also proceeding on the construction of a 100 GΩ/step transfer standard to extend scaling with Hamon transfer standards to the 1 TΩ decade of resistance.

Design

The transfer standards will use precious metal oxide (PMO) resistance elements that are hermetically sealed in metal-insulator-metal containers as 1 TΩ and 10 TΩ resistors have been constructed at NIST in recent years [4]. This will allow guarding of both terminations of the hermetically sealed resistor thus reducing leakages to ground. Earlier designs of guarded transfer standards [5] have used all-metal containers for hermetically sealing the resistance elements. Figure 1 shows a schematic of several sections of the guarded transfer standard using the metal-insulator-metal canisters and the connected guard networks.

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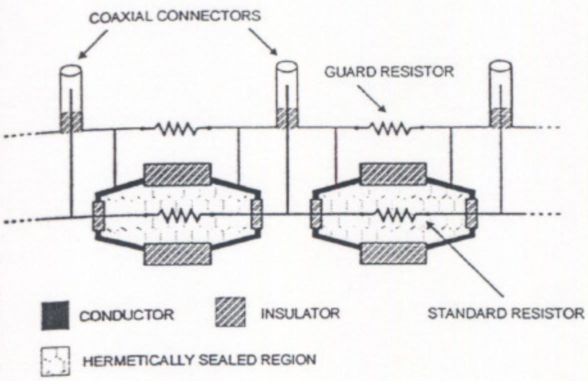

Figure 1. Schematic of the guarded transfer standard using metal-insulator-metal canisters to hermetically seal the resistance elements. Guard resistors are connected across the insulators to drive guard voltages at the container ends, thus suppressing leakage currents between the main and guard resistors.

Challenges

There are several known challenges that have made the construction of a transfer standard in the 1 TΩ to 100 TΩ range difficult in the past. In the past, one challenge has been the large voltage coefficients of film-type resistors. Measurements made on several of the PMO resistors at NIST has shown voltage coefficients less than 0.5×10^{-6} per volt, which are significantly less than the voltage coefficients of previous thin-film resistance elements.

Another challenge will be the selection of guard resistors that mimic the main resistors' voltage and temperature dependence. The selection of guard resistors is important because if it is poorly done, leakage currents could be increased instead of suppressed by the guard circuit. The current levels are very low, so increased noise may be a problem along with stray capacitance and large time constants in this resistance range.

Summary

To provide a better evaluation of uncertainties in the range 1 TΩ to 100 TΩ, a 10 TΩ/step transfer standard has been designed and is being assembled. Results of the testing of the device will be reported at the conference.

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