INTERCOMPARISON OF THERMAL CONVERTERS AT NIM, NIST, PTB, SIRI, AND VSL FROM 1 TO 100 MHZ

J.R. Kinard* Natl. Inst. of Stds. & Tech. Gaithersburg, MD USA

G. Rebuldela* Natl. Inst. of Stds. & Tech. Boulder, CO USA

Z. Zhen Natl. Inst. of Metrology Beijing, China

D. Janik Phys. Techn. Bund. Anst. Braunschweig, Germany

D.-X. Huang+ Shaoxing Indust. Res. Inst. Shaoxing, China

J. de Vreede Van Swinden Laboratory Delft, Netherlands

Abstract

Coaxial, thermal voltage converters(TVC's) have been intercompared between NIM, NIST, PTB, SIRI, and VSL in the frequency range from 1 to 100 MHz. This paper briefly describes the methods and underlying principles on which RF-dc difference determinations are based in each laboratory and gives the results of the intercomparisons.

Introduction

Coaxial TVC's are commonly used for the measurement of voltage in the frequency range from 1 to 100 MHz. An intercomparison of RF-dc differences in this frequency range between the participating laboratories is particularly informative because the methods and hardware differ significantly. The agreement between methods adds considerable additional confidence to the process. In these inter-comparisons, NIST-Gaithersburg was the pilot laboratory.

Methods of Individual Laboratories

National Institute of Metrology(NIM). At NIM, TVC's have been constructed in a special way in order to achieve flat frequency response without component compensation. In these special TVC's the thermoelement is placed near the input connector, to measure the input current approximately, and the range resistor is connected to the shield[1]. The RF-dc differences of the TVC's have been determined from 30 MHz up to 1 GHz by reference to a bolometer bridge with dual, thin-film thermistors . The uncertainty of this bolometer bridge at NIM is <±1% from 10 MHz to 3 GHz[2]. The special TVC's have also been compared to conventional TVC's at lower frequencies.

Natl. Inst. of Stand. and Tech. (NIST-Boulder). Two techniques have been used to establish the RF-dc difference of the NIST-Boulder working standard set of TVC's. The first of these involves the use of the bolometer bridge [3]. Although the bridge is no longer used, the RF-dc differences and uncertainties derived have been confirmed by comparison with voltages assigned from impedance measurements based on impedance bridges and power measurements based on a microcalorimeter from 100 MHz to 1000 MHz. The second technique establishes the frequency response below 100 MHz experimentally and theoretically as described in [4] and [5]. These results derived at low-frequency agree with the characterization of a 1-V TVC based on the bolometer bridge from 1 to 400 MHz. On the basis of the derivation of voltage from power and impedance measurements and the agreement with theoretical predictions for TVC's directly, working standard TVC's for determination of RF-dc difference from <1 to 1000 MHz have been characterized.

*Electronic and Elec. Eng. Lab., U.S. Dept. of Comm., Technology Admin.
+Currently working for Ballantine Labs, Inc. and is a Research Associate at NIST. U.S. Government work not protected by U.S. copyright.

Natl. Inst. of Stand. and Tech. (NIST-Gaithersburg). Using low frequency standards and nearly frequency-independent structures, the RF-dc differences of coaxial TVC's have been determined at 1 MHz [5]. To extend the frequency range, TVC's having cylindrical, carbon film range resistors of 1 to 5 kΩ were constructed using designs and materials chosen to permit detailed modeling and analysis. For these TVC's, the major contributions to RF-dc difference which are range independent are the voltage standing wave in the input connector structure and the current standing wave in the thermoelement section. Major range dependent contributions are the transimpedance of the range resistor and skin effect of the overall structure.

Physikalisch-Technische Bundesanstalt(PTB).

At PTB transfer difference measurements in the RF range are made in two steps. Because there is a separate set-up at PTB for measuring the ac-dc transfer difference up to 1 MHz with very small uncertainties, the RF-dc transfer difference is calculated from the RF--ac difference and the ac-dc difference measured at 100 kHz. The RF voltage in the device under test is compared to an ac voltage of 100 kHz. For frequencies above 1 MHz, a commercial coaxial calorimeter of the dual-load type is used as the primary voltage standard. With this standard containing two nearly identical resistance mounts the RF voltage is compared with an equivalent adjustable DC voltage. The effective efficiency and the input conductance of the calorimeter has been determined as a function of frequency up to 1 GHz, thereby the RF voltage can be derived from power and impedance standards. The automated primary voltage standard for voltages between 0.2 V and 1 V is described in [5].

For the RF-ac transfer difference calibration of thermal converters in the range between 0.5 V and 10 V and the frequency range up to 100 MHz an automated measuring set-up is used [6]. The set of working standards between 0.5 V and 10 V is calibrated with a step-up procedure starting with the 1 V converter which was calibrated referred to the primary voltage standard.

Shaoxing Industry Research Institute(SIRI). At SIRI, the RF-dc differences of TVC's have been determined by experimental analysis and theoretical calculations [8]. TVC's ranging from 0.5 V to 5 V have been measured by thin-film bolometers [3] from 30 MHz up to 300 MHz. An empirical equation, $d=d_0+A\sqrt{f}+Bf^2$ where d_0 is the ac-dc difference at audio frequency and A and B are constants to be determined, was used to make a non-linear fit employing the least squares method. Thus, the RF-dc differences from 100 kHz to 100 MHz for individual TVCs were determined. Direct comparisons between adjacent ranges confirmed this modelling [9]. Additional confirmation of these primary TVC's was obtained by comparison with UHF, thin-film multijunction thermal converters having RF-dc differences <0.5% from 10 Hz to 1 GHz, and by comparison with TVCs having multifilar ground-lead compensation and also having RF-dc differences <0.5% from 10 Hz to 300 MHz.

Van Swinden Laboratory(VSL). In VSL the RF-dc difference standards above 1 MHz have been established in terms of a set of calculable standards and can be used up to 30 MHz [10]. Recently a new set of 4-V standards, with smaller but not necessarily negligible RF-dc differences, was constructed for use up to 100 MHz [11]. All standards are provided with type-N male connectors and the symmetry plane of a type-N tee is taken as the plane of reference. In the automated measurement system, each thermoelement output is amplified and then the difference between the outputs is amplified. The RF-dc differences of each converter have been calculated and intercomparisons between TVC's yield good agreement within the combined uncertainties.

Transfer Standards and Results

This intercomparison was performed using two types of TVC's. The first type was commercially manufactured with 1-, 5-, and 10-V ranges containing UHF-pattern thermoelements, internal shield structures, and conventional series resistors. The second type was a VSL-constructed, coaxial, 5-V TVC containing a thin, straight wire for a series resistor.

The results reported by each laboratory were averaged to produce a representative value for that laboratory at each frequency. The representative values, or deviations, for all the laboratories at each frequency, were averaged and the data are plotted (see Fig. 1) relative to that overall average which is indicated as 0% RF-dc difference.

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