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INTERNATIONAL COMPARISON OF NOISE-TEMPERATURE MEASUREMENTS AT 2, 4, AND 12 GHZ

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Abstract

We report results of a recent international comparison of thermal noise-power measurements, performed under the auspices of CIPM/CCE. The noise temperatures of two solid-state sources with GPC-7 connectors were measured at 2, 4, and 12 GHz. All results agreed within the expanded uncertainties. The comparison was performed in accordance with the guidelines recently adopted by the CCE.

Background

An international thermal noise comparison has been performed, comparing measurements of noise temperature made at 2 GHz, 4 GHz, and 12 GHz. The participating laboratories were the Laboratoire Central des Industries Electriques (LCIE) in France, Physikalisch-Technische Bundesanstalt (PTB) in Germany, the National Physical Laboratory (NPL) in the United Kingdom, and the National Institute of Standards and Technology (NIST) in the United States, which served as the pilot laboratory. The comparison was initially approved by the CCE in 1992 and was assigned the number GTRF-92-2. It was dormant until August, 1995, shortly after the CCE had adopted a set of guidelines for conducting such international comparisons. At that time it was revived, with an intention to follow the guidelines, and a schedule was adopted which did so (approximately). Thus, in addition to comparing noise measurements, this comparison also serves as a test case for the new guidelines. The schedule adopted for the comparison called for an initial period of organization and protocol development, lasting through the end of 1995. The measurement phase commenced in January, 1996, with initial measurements at NIST. The artifacts were then circulated to LCIE, NPL, PTB, and finally back to NIST for repeat measurements to verify that the noise temperatures of the artifacts had not changed during the course of the comparison. The timetable for the circulation and mea-surement of the standards at the participating laboratories (including twice at the pilot laboratory) allowed a total of 60 weeks for the five sets of measurements.

The travelling standards were two commercial broadband noise sources with GPC-7 connectors. In the interlaboratory transfers, the two sources were shipped on different days so that a single mishap could not damage or lose both at once. Each laboratory measured the noise temperature of each source at 2 GHz, 4 GHz, and 12 GHz. The laboratories used their own power supplies, operating the sources according to the manufacturer's specifications. The laboratory temperature was kept at 23 ± 1 °C. In accordance with the CCE guidelines, the measurements were performed using the state of the art in the laboratory at the time of the comparison, without additional research or development.

There is sufficient diversity among the standards and radiometers at the participating laboratories to provide a meaningful comparison [1-9]. Two entirely different types of primary standards (cryogenic and oven) and two different types of radiometers (switching and total power) are used. The combinations represented by the participating laboratories are oven standards with switching radiometers at two laboratories, oven standards with a total-power radiometer at one laboratory, and a cryogenic standard with total-power radiometers at one laboratory.

Results

Results of the measurements of the noise temperature of one of the devices are given in fig. 1. Results on the other device are qualitatively the same. The uncertainties are the expanded (k = 2) uncertainties, corresponding to a 95% coverage probability. The order of the laboratories in the figure corresponds to the chronology of the measurements, beginning and ending at NIST. The agreement between NIST-1 and NIST-2 demonstrates the stability of the two travelling standards over the course of the comparison. The maximum difference between before and after measurements is 15 K, or about 0.15%, and the average difference is 10 K, about 0.10%.

The salient feature of the results is the good agreement among the participating laboratories. At each frequency, all the results agree within the expanded

uncertainties. The same is true of the results on the second device, which are not shown. Considering the fact that the expanded uncertainties are quite small, ranging from approximately 0.5% to 2.9%, this represents a significant achievement. The agreement is also evident in graphs of the results, presented in fig. 1. In the graphs, the results at each frequency (2.0 GHz, 4.0 GHz, and 12.0 GHz) have been grouped near the respective frequency to separate the individual data points.

Conclusion

Two principal conclusions may be drawn from this comparison, one technical and the other procedural. The technical conclusion is that measurements at the participating laboratories, made with differing primary standards and different radiometer designs, are all in very good agreement. This agreement suggests that both the measurement techniques and the associated uncertainty analyses at the participating laboratories are correct – to the extent tested here.

The procedural issues are related to the CCE guidelines for conducting international comparisons. After its revival in 1995, this comparison was conducted according to the CCE guidelines. The biggest challenge posed by the guidelines was the timetable. At the start of the comparison a schedule which (essentially) met the CCE guidelines was adopted, and this original schedule was actually followed for the full course of the comparison. Meeting the schedule was facilitated by the CCE stipulation that the measurements should be done according to the state of the art at the laboratories at the time of the comparison. Additional research or development was not to be done. Consequently, the measurements were treated as (almost) routine calibrations. Typical complications arose and were overcome during the course of the comparison: personnel turnover, measurements at one laboratory performed at only one time during the year, an intramural relocation of one laboratory, delays in customs, temporary closure of one laboratory. In summary, we found it possible, though not easy, to follow the CCE guidelines for international comparisons. It required some effort, the cooperation and support of *all* participating laboratories, and perhaps a little good fortune.

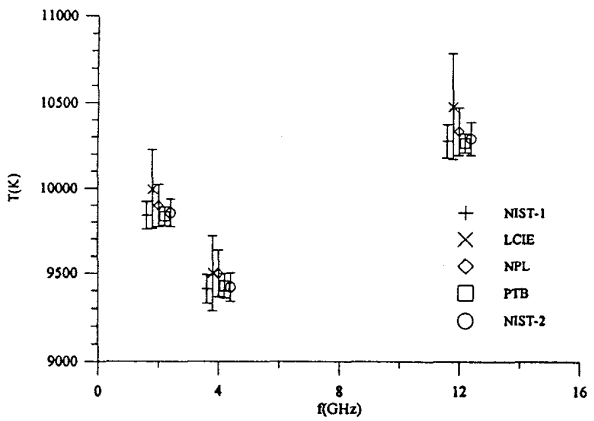

Figure 1 Measured noise temperatures for source 12136.

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