RADIOMETRIC MEASUREMENTS OF A NEAR-AMBIENT, VARIABLE-TEMPERATURE NOISE STANDARD*

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Abstract

A near-ambient, variable-temperature noise standard whose physical temperature can be accurately measured was constructed and then measured with the NIST total-power radiometer to test the accuracy of radiometer measurements in the temperature range of 263 K – 325 K over the frequency range 8 – 12 GHz .

Introduction

Remote sensing of the physical characteristics of the earth's oceans and land masses by use of satellite-based radiometers has been a common occurrence for many years. As weather forecasting models become more precise, and the issue of climate change becomes more urgent, it is necessary to understand the limitations of near-ambient radiometer temperature measurements. The uncertainty related to such measurements and the long-term stability of the standards are critical when the changes being measured are no more than a few kelvins.

One of the initial steps in the NIST remote-sensing project is to develop a variable-temperature standard whose noise temperature is determined by means other than the radiometer. The standard is used to determine the accuracy of radiometric noise temperature measurements at and near ambient temperature. This paper discusses the construction of the variable standard, the measurements made with NIST radiometers, and the results of these measurements.

Construction of the Standard

The variable-temperature noise standard is constructed of commercially available 7 mm and Type N components. Figure 1 shows the layout of the components. A 50 ohm Type N load is connected to one side of a dc block. An aluminum cylinder was machined to be the same outside diameter as the dc block, and a hole was bored in the center whose diameter and length are such that the cylinder fits snugly over the 50 ohm load and makes contact with the end of the dc block. The three components were glued together using a thermally conductive and electrically insulating epoxy cement. Copper tubing of 0.635 cm diameter was tightly coiled around the dc block and the aluminum cylinder and then glued in place with the same thermally conductive epoxy. A 0.159 cm diameter hole was bored in the end of the aluminum block for the temperature-sensing thermistor.

The hole was bored so that the thermistor rests against the outer surface of the 50 Ω load. The thermistor was also glued in place with the same epoxy. The copper tubing is connected to plastic tubing which runs to a water bath whose temperature range is –30 °C to 90 °C. A mixture of 50 % water to 50 % antifreeze is used in the water bath. The leads of the thermistor are connected to a digital voltmeter for making four wire resistance measurements. The variable standard is connected to the radiometer port using a 7 mm-barrel SMA-Type N adaptor which was characterized for its losses using the RT method discussed in [1].

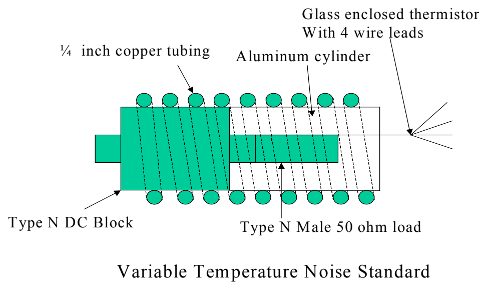

Fig.1 Near Ambient Standard Layout

The dc block is used to reduce heat flow either to or from the inner and outer conductors of the 50 ohm load to the radiometer head. An earlier model without the dc block functioned only within ± 5 K before large differences between the standard temperature and measurement temperature were noted. A disadvantage of using the dc block is that the reflection coefficient of the standard depends somewhat temperature. But the errors induced by the temperature dependence of the mismatch factors are less than 0.05 K.

The adaptor used to connect the standard to the radiometer was also designed to minimize heat flow between the standard and the radiometer head.

Calibration of the Standard

The electrical parameters of the variable standard with and without the adaptor connected were characterized using a network analyzer. The thermistor in the variable standard is calibrated against a thermistor probe with a total uncertainty of 0.01 K over the measured temperature range. In this calibration the calibrated thermistor was immersed in a well surrounded by the liquid from the variable-temperature bath, which then passes through the variable standard tubing and returns to the bath. The system was allowed to stabilize at a temperature and then readings was taken at 30 second intervals for a period of 20 minutes. This is done at 5 K increments between 263 K and 323 K. A least squares fit of the data was than applied to the Steinhart-Hart thermistor polynomial to correlate resistance and temperature readings. The maximum uncertainty of the variable standard physical temperature readings is less than 0.05 K .

Radiometer Measurements of the Variable Standard.

Measurements of the variable standard were made on the NIST coaxial total-power radiometer described in [2]. The variable standard and a check standard were measured over the frequency range 2 – 12 GHz. The radiometer is designed so that a check standard can be tested simultaneously with the variable standard to insure that the radiometer is functioning properly. Measurements were done in 5 K increments over the same 263 – 323 K interval. At this time the full range of temperatures has been completed only for 8 – 12 GHz.

Measurement Results

The Type B uncertainty of radiometer measurements over the frequency range 2 – 12 GHz is approximately 0.11% of the noise temperature. Over the temperature range of interest this is roughly 0.3 K. For the measurements performed, the great majority fall within this limit. Type A uncertainties are negligible.
The difference between the measured noise temperature and the noise temperature computed from the measured physical temperature over the frequency range 8 – 12 GHz is shown in Figure 2. The ± 0.3 K uncertainty is indicated by the solid lines. If the outlier at 12 GHz is ignored the average absolute difference between the measured temperature and the standard temperature is 0.078 K. Figure 2 shows a large difference between measured and predicted noise temperatures for 312 K at 12 GHz. We believe this is caused by thermal loading by the ambient source on the radiometer's switch head; variations in the ambient temperature at the radiometer switch port directly affect the adaptor correction for the ambient noise standard. Further measurements are in progress to verify this.

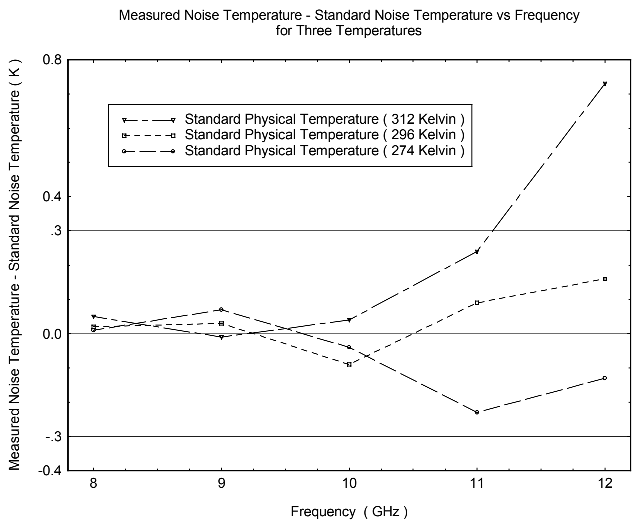

Fig. 2 Noise Measurements from 8-12 GHz

Figure 3 shows measurements in the temperature range 263 K – 323 K at a frequency of 8 GHz. The boxes for the data points are sized to indicate ± 0.3 K uncertainty. The straight line corresponds to equality between measured and predicted values. The average absolute deviation over the temperature range is 0.054 K, much smaller than the 0.3 K uncertainty.

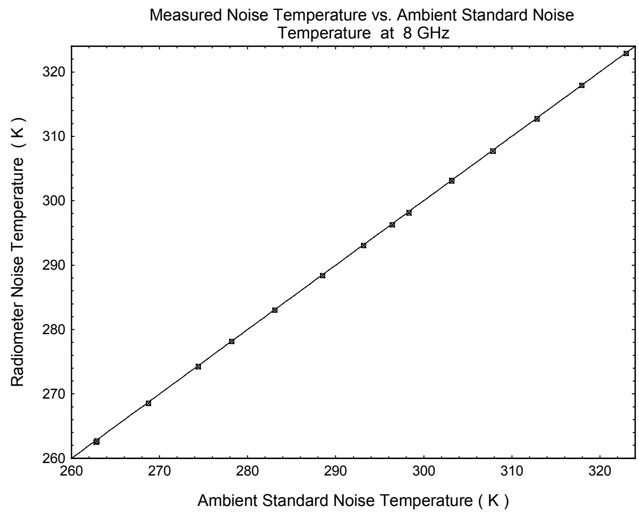

Fig. 3 Noise Measurements at 8 GHz.

Some measurements have been done in the 2 – 8 GHz range, but not enough to be included in the present analysis. The final report will include data over the full frequency range of 2 – 12 GHz with a slightly expanded temperature range.

References

[1] J. Randa,W. Wiatr, and R.L. Billinger, "Comparison of Adaptor Characterization Methods," IEEE Transactions on Microwave Theory and Techniques, Vol. 47,No. 12, pp. 2613 – 2620, December 1999.
[2] C.A. Grosvenor, J. Randa, and R.L. Billinger, "Design and Testing of NFRad- A New Noise Measurement System," NIST Technical Note 1518, March 2000.