NOISE-SOURCE STABILITY MEASUREMENTS

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Abstract

We report results of stability tests on several noise sources for selected frequencies between 12 and 26.5 GHz. Measurements covered intervals of about 1 week and about 1 year or more. Drifts in noise temperature were typically less than the uncertainty of the tests, about 0.03 % per day or about 0.05 % per year for hot sources.

Introduction

We have recently conducted tests to determine the stability of several different noise sources over time periods of about one week (intermediate-term) and about one year (long-term). In addition, we have noise sources that are used as check standards that have been in use for many years, and the histories of their measured noise temperatures provide a measurement of their stability over long time periods. The stability of the measurement system is also measured as a byproduct of the tests, and it is presented as well. Only a small, representative subset of the available data will be presented. More complete results, including graphs of the data, can be found in [1].

Sources and Tests

We have stability results for four different types of noise sources: common gas tubes and diodes, a FET-based variable-temperature source (VTS) [2,3], and an "ovenized" source, built by the Jet Propulsion Laboratory (JPL). The JPL source consists of a commercial WR-62 diode source housed in a temperature-controlled box to maintain stability under varying ambient conditions. The FET-based VTS achieves variable noise temperature by varying the gate and drain voltages. Its stability was measured for four different output temperatures, ranging from about 119 K to about 240 K. All the other sources had noise temperatures in the range 8500 K to 11 000 K.

All measurements were performed on NIST waveguide radiometers [4,5]. In a noise-temperature measurement, the delivered powers from the two standards and the device under test (DUT) are read in succession, and a noise temperature is calculated from the radiometer equation [4,5]. This cycle constitutes one "reading." It is repeated many times (20 for waveguide systems), and the noise temperatures are averaged for one "measurement." This procedure effectively recalibrates the radiometer gain and noise temperature for each reading. We are thus insensitive to drift in these system parameters except over the time interval of one reading cycle (one minute or less).

For the intermediate-term tests, measurements were made twice per day for four to seven days. A full system calibration was done only at the start, with the DUT left connected to the system throughout the tests. This method avoids effects of variations in system calibration and DUT connection, but it is susceptible to variations due to drift in the system calibration. This drift is less than the variations in connections and system calibration, and consequently we prefer to leave the DUT continuously connected. As a byproduct of measuring the stability of the noise sources, we also obtain a measure of the radiometer stability, from the measurement of the system gain and noise temperature in each measurement. For the long-term stability tests it is not practical to leave the DUT continuously connected, and so we performed a full system calibration before each measurement.

Results

We measured the intermediate-term stability of three noise sources. A commercial diode source (called 098) and the VTS were measured at 18 GHz, and the JPL source was measured at three frequencies around 13 GHz. Here we present results for only one frequency for the JPL source and for only one of the four bias settings for the VTS. The results at the other frequencies and bias settings are qualitatively the same. For the JPL source, we use 13.402 GHz, which is the middle of the three frequencies. For the VTS we use the results for $V_{ds} = 1$ V and $V_{gs} = 0.4$ V, corresponding to a noise temperature of about 127 K.

Due to space limitations, we forego graphs of the data; they can be found in [1]. Qualitatively, the data indicate that the three sources are all *very* stable. The stability can be quantified in many different ways, some of which are given in Table 1. The third column is the sample standard deviation (not the standard error or standard deviation of the mean) for the sets of data points. It reflects the spread of the random variations of the noise temperatures assuming no drift. The slopes are the results of weighted least-squares fits to the data. Uncertainties in the slopes are statistical (type-A) only, and correspond to

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1σ. To facilitate comparison of sources with very different noise temperatures, we have given the fractional (relative to the mean) values for the sample standard deviations and the slopes. The intermediate-term slopes are consistent with zero for all the noise sources tested. They are generally less than 0.04 % per day, and the uncertainty is less than 0.09 % per day. The standard deviations of the sets of measured noise temperatures are also small, on the order of 0.1 % of the noise temperatures.

The radiometer noise temperature and gain were recorded during the intermediate-term tests, and a weighted least-squares fit was performed on each set of data. At 13.402 GHz the resulting slopes were (0.12 ± 0.18) K/d for T_e and $(1.4 \pm 2.0)\times 10^{7}$/d for G. Thus the fractional drifts were (0.023% ± 0.035%) per day for system noise temperature and (0.019% ± 0.026%) per day for gain. Both are very small and consistent with zero.

For the long-term stability tests, 098 and the VTS were measured at 18 GHz at irregular intervals for a little over one year. These data were supplemented by historical data on check standards in order to check for trends and for dependence on frequency and type of source. Results are summarized in Table 2. The entry for 098 is the result of the measurements over one year. The 098′ entry is the result of a fit to 18 GHz data on 098 spanning just over three years. The mean noise temperature is essentially the same as for the smaller sample, but the slope has decreased by a factor of almost 2. We can also investigate whether the observed drift is frequency dependent, and for this purpose we include results of a fit to 6 years of data on 098 at 26 GHz, 098″. In this case there is no evidence for any drift. The final entry in Table 2 shows the 18 GHz results for a different check standard, a WR-62 gas tube (023), over a period of about 6 years. It shows no evidence of drift.

Table 1. Intermediate-Term Stability Test Results.

Source	Mean T (K)	σ (K)	σ (%)	Slope (K/day)	Slope (%/day)
098	8548	5.9	0.07	2.0±2.5	.023±.029
JPL	8446	2.7	0.03	1.4±2.0	.017±.024
VTS	127.2	0.18	0.14	.05±.11	.039±.086

Table 2. Summary of Long-Term Stability Tests

Source	Mean T (K)	σ (K)	σ (%)	Slope (K/year)	Slope (%/year)
VTS	126.1	1.0	0.8	2.0±0.2	1.6±0.1
098	8561	13	0.16	-17±4	-0.20±.05
098′	8562	13	0.15	-9.4±1.7	-0.11±.03
098″	10247	25	0.25	-1.1±4.5	-.01±.044
023	10962	14	0.13	1.4±1.7	.013±.015

Summary

The slopes of the linear fits measure the drift of the noise temperature. In the intermediate-term tests all were consistent with zero. The type-A uncertainties were about 0.1 K/d for the cold source (VTS) and about 2 K/d for the hot sources, or between 0.024 % per day and 0.9 % per day. The fact that the unmodified diode noise source exhibited stability comparable to the temperature-stabilized JPL source is presumably due to the fact that the measurements were performed in a temperature-controlled laboratory. Assuming no drift, the sample standard deviations measure the repeatability of the noise-temperature measurements. In the intermediate-term tests the sample standard deviations were all less than 0.2 % of the noise temperature, as low as 0.03 % for the JPL source. This corresponds to a few kelvin for the hot sources and about 0.2 K for the VTS. The effective noise temperature and nominal gain of the measurement system were also monitored during the intermediate-term tests. The fractional drifts in both were about 0.02 % per day ± 0.03 % per day.

In the long-term results, there is evidence of a small degree of drift at 18 GHz in both the VTS and in a diode source (098). The drift in 098 decreases by half when a longer time interval is considered, but it is still statistically significant. At 26.5 GHz, there is no evidence of drift in 098. The gas tube considered (023) shows no drift. Long-term standard deviations are around 0.2 % for the hot sources and about 0.8 % for the VTS.

References

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