NOISE-PARAMETER MEASUREMENT WITH AUTOMATED VARIABLE TERMINATIONS*

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Abstract

NIST has upgraded its measurement capability of noise parameters on low-noise amplifiers with a variable termination unit in the 1 to 12.4 GHz range. Such a unit allows improved time efficiency in the noise-temperature measurements used to de-embed noise parameters of amplifiers. We present measured results for noise parameters of a low noise amplifier in the frequency range of 8 to 12 GHz.

Introduction

Accurate measurements of noise parameters on amplifiers, especially low noise amplifiers (LNAs), are of great importance to the microwave community. The National Institute of Standards and Technology (NIST) has successfully demonstrated the capability to measure the noise parameters of both packaged [1] and on-wafer [2] LNAs. Extraction of noise parameter involves a source-pull approach that varies the impedance seen by the input of the amplifier. Previous measurements of noise parameters at NIST were very time-consuming, owing mainly to the manual connection and disconnection of different terminations at the input of the LNA. In order to expedite the measurement, we have designed and built a variable termination unit (VTU), allowing automated switching to various input sources for the amplifier.

In this paper, we first describe the design and characterization of the VTU and briefly outline the measurement method. Next, measured noise data, including uncertainties, for a packaged amplifier with the VTU are presented. Future improvements are discussed at the end.

Noise-Parameter Measurement Method

The VTU is an aluminum box housing two coaxial switches, as shown in Fig. 1. A six-way rotary switch is cascaded with a five-way in-line switch, resulting in a total of 10 terminations to the LNA input. All the connectors of the switches are either SMA or PC-3.5. The common port of the first switch is connected with a PC-7-to-PC-3.5 adapter as the output of the VTU, mated with the input connector of the packaged amplifier and the radiometer. The ten termination connectors of the VTU are two PC-7 connectors (linked to the switch through adapters) for noise diodes or other external terminations, and eight PC-3.5 and SMA connectors for internal ambient terminations. An unbiased noise diode is used as a matched ambient source on one of the PC-7 connectors. A biased noise diode in connection with a 10 dB attenuator, exhibiting a noise temperature of about 1000 K, consumes the other PC-7 connector. During the characterization of the LNA, we also swapped the hot source with a cold source (the input of an amplifier with its output terminated by a matched load) for additional redundancy checking. Each of the PC-3.5 and SMA ports is terminated with an ambient mismatch, so that the impedance gives a good coverage (at least 3 quadrants) on the Smith chart in the frequency range of 1 to 12 GHz. The VTU switches are controlled by a switch controller as a part of the automated measurement system. It is important to keep the temperature of the entire VTU at a fixed value, preferably room temperature. In our current design, only the first switch is thermally stabilized by a regulated water bath at 23 ˚C. The second switch is placed in close proximity to the first switch and presumably has a temperature close to 23 ˚C.

The repeatability of the VTU was checked by use of a vector network analyzer (VNA). The VTU was switched to each port 50 times, and the complex reflection coefficients for each port at the reference plane (the output of the VTU) were measured with a

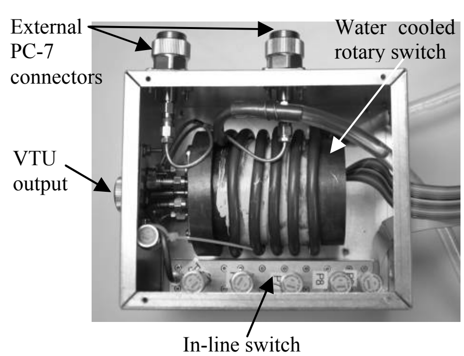

Fig.1 Inside view of the VTU.

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VNA. Measured reflection coefficients showed variations of magnitude and phase below 0.3 % (1σ), indicating a repeatable performance of the VTU.

Noise-parameter measurement of an LNA was performed on the NIST coaxial radiometer system (NFRad) in the manner outlined in [3]. A 20 dB attenuator was inserted between the LNA and the radiometer to ensure that the radiometer operated in its linear region. The measurement setup is illustrated in Fig. 2. Prior to the noise-parameter measurement, reflection coefficients at plane 1, plane 2 and plane 2' for each termination of the VTU were measured on the VNA, and all the data were transferred to the computer, which controls the radiometer. The input noise temperature at plane 1 for all non-ambient terminations was measured. The output noise temperature at plane 2' was read 50 times consecutively for all VTU terminations connected to plane 1. The noise temperature at plane 2 can be inferred from the output noise available at plane 2' by the knowledge of the available gain of the attenuator. In addition to the forward configuration, the LNA's input was connected to the NFRad with its output terminated with an ambient load in order to measure the reverse radiation of the LNA input. A least-squares fit was then performed on the measured data to obtain the noise parameters of the LNA [3].

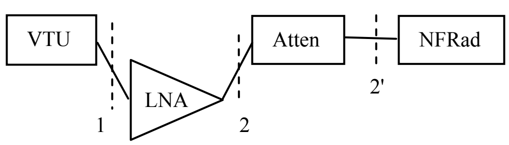

Fig. 2 Forward configuration of noise temperature measurements.

Measured Results and Uncertainty Analysis

We measured a packaged commercial LNA at integer frequencies from 8 to 12 GHz. A good fit was obtained at all frequencies. The minimum effective input noise temperature T_{min} and the magnitude of the optimal input reflection $|\Gamma_{opt}|$ are plotted in Fig. 3. The error bars indicate the standard uncertainty, which is a combination of type-A and type-B. Type-A uncertainties were determined directly from the fitting program. Type-B uncertainties were evaluated from a Monte Carlo simulation [3]. The uncertainties of T_{min} at all frequencies are below 3 %, indicating satisfactory measurement accuracy.

Discussion and Conclusion

There are a few improvements to be made on the design of the VTU. First, the temperature of the inside of the VTU box was found to be about 1 K above the ambient temperature. A better temperature regulated environment of the VTU is desirable. Second, we discovered a variation of reflection coefficients as high as 3 % on some of the terminations of the VTU in a two-week period. Switches of high repeatability as well as more rigid connections for the internal terminations are needed to provide more reliable reflection coefficients. Third, it is possible to produce a better coverage of the Smith chart from the VTU terminations in order to obtain a more rigorous redundancy check. This can be implemented by inserting adjustable offsets between the switch port and mismatch terminations.

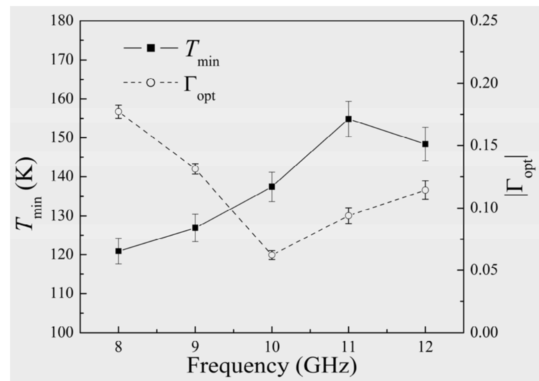

Fig. 3 Measured T_{min} and $|\Gamma_{opt}|$.

Nevertheless, the preliminary results have demonstrated the successful implementation of the VTU for noise-parameter measurements on packaged amplifiers. The time required for the entire measurement was reduced by at least a factor of five, compared to that of the manual method. We expect that the use of VTU will also improve the speed of bare transistor noise measurements [2] and minimize the variation arising from multiple connections of various inputs.

References

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