Cold-Source Noise Temperature Measurements with a Vector Network Analyzer Frequency Extender at WR-6.5

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The cold-source method is adapted to Vector Network Analyzer (VNA) frequency extenders to enable measurement of both noise temperature and S-parameters with the same test setup. With LNA MMICs steadily moving upward in frequency, a single testing solution for characterizing a device's sensitivity and s-parameters would accelerate on-wafer testing. Particularly for cryogenic measurements, such an approach could save many hours of cryo-cycling and improved measurement accuracy by capturing both characteristics within seconds of each other.

Noise temperature is typically measured at Terahertz frequencies with the Y-factor technique, which presents the DUT with noise power of two different, well known temperatures. While this technique is well-proven, it requires either free-space optics to a temperature controlled black-body or a noise source. Y-factor measurements only capture noise temperature and conversion loss, so if s-parameters are required, another test setup must be applied. To avoid this second setup, the cold-source technique relies on accurate knowledge of the s-parameters of the DUT to calculate the noise temperature from the noise power emitted by the device [1,2]. With proper characterization of the receiver's bandwidth and noise temperature beforehand, the noise temperature of the DUT can then be calculated as:

$$T_D = \frac{P_{out}^D}{kG_rB_rG_D} - \frac{T_r}{G_D} - T_0$$

Where P^D_{out} is the noise power of the DUT measured by the receiver, T_r is the noise temperature of the receiver, G_r is the gain of the receiver, B_r is the bandwidth of the receiver, G_D is the gain of the DUT, T_0 is the temperature of the load presented to the DUT and *k* is Boltzmann's constant.

With VNA frequency extenders now available, high accuracy s-parameters are relatively easy to measure up to 1 THz [3]. To accurately measure noise temperature with the cold-source technique, the receiver temperature must not dominate the total power measured. To achieve this, the frequency extender modules are modified to minimize the receiver's noise temperature at the expense of test-port power. In this study, the modification of VDI's WR-6.5 module achieves a noise temperature between 5000K and 8000K with a test-port power of 10uW.

Figure 1 compares the noise temperature measurements of a standard quasi-optical Y-factor to the cold-source technique for a WR-6.5 power amplifier. While the high noise of this device makes it easier to measure with the cold-source technique, an analysis will be presented that shows that noise temperatures down to 100K can be reliably measured is the DUT has gain over 10dB.

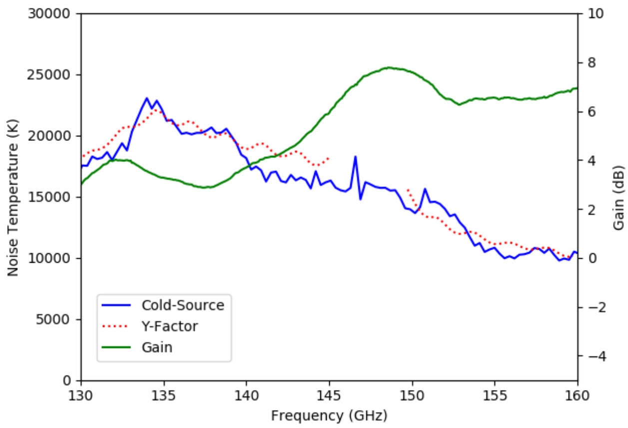

Fig. 1. A comparison between the noise temperatures measured with the cold-source and Y-factor techniques. The gap in the Y-factor measurement around 148GHz is due to the high gain creating an error in the software designed for mixer measurements.

References

[1] Keysight Technologies, "High-Accuracy Noise Figure Measurements Using the PNA-X Series Network Analyzer", Application Note 5990-5800EN.

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[3] T. W. Crowe, B. Foley, S. Durant, K. Hui, Y. Duan and J. L. Hesler, "VNA frequency extenders to 1.1 THz," 2011 International Conference on Infrared, Millimeter, and Terahertz Waves, Houston, TX, 2011, pp. 1-1.

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