Cryogenic Noise Parameter Measurements

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Introduction to Noise Figure and Noise Parameters

Noise Figure

Noise Figure is a measure of how much noise a device (like an amplifier, mixer, or receiver) adds to a signal, relative to an ideal, noiseless device. It quantifies the degradation in the signal-to-noise ratio (SNR) as a signal passes through a system.

- **Definition:** Noise figure (NF) is defined as the ratio of the input signal-to-noise ratio (SNR) to the output SNR:

$$NF = \frac{\text{SNR}_{\text{in}}}{\text{SNR}_{\text{out}}}$$

Since noise figure is usually expressed in decibels (dB), it is calculated as:

$$NF\,(\text{dB}) = 10\log_{10}\left(\frac{\text{SNR}_{\text{in}}}{\text{SNR}_{\text{out}}}\right)$$

- **Explanation:** A lower noise figure means the device adds less noise to the signal, while a higher noise figure means the device introduces more noise.

Noise Parameters

Noise parameters are a set of values that describe the noise performance of a device, typically for different operating conditions such as frequency, input impedance, and temperature. The four key noise parameters often used are:

1. **Fmin:** The minimum noise figure (minimum NF a device can achieve under optimal conditions).
2. **Rn:** The equivalent noise resistance, which describes how the noise figure degrades as the input impedance deviates from the optimal source impedance.
3. **|Γopt|:** The magnitude of the reflection coefficient of the optimal source impedance for minimum noise
4. **Γopt<:** The phase of the reflection coefficient of the optimal source impedance for minimum noise

Together, these parameters describe how the noise figure of a device changes with varying source impedance.

Cryogenic Impedance Tuner

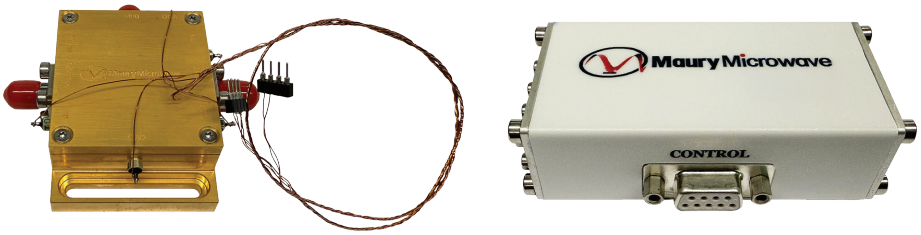
An impedance tuner is a critical component in a noise parameter measurement setup, as it allows a user to vary the source impedance presented to a device under test and measure the resulting noise power, from which the noise parameters are extracted.

Impedance tuners can take many forms, the most common being electro-mechanical, based on a slabline and RF probe/slug. While offering many advantages, electro-mechanical tuners are not suited for cryogenic measurements as they cannot function within a cryogenic environment (i.e, cryostat, cryogenic probe station) due to their large size, mechanical operation, and the amount of heat created.

Solid-state tuners provide a good alternative when purpose-designed for cryogenic impedance tuning. The CT-series cryogenic automated tuners, shown in **Figure 1**, use electronic components rated for use at cryogenic temperatures below 4K* to present electronically varied impedance states to a DUT. At under 80 grams, 60mm x40mm, and consuming less than 0.2mW, is ideally suited for operation inside a cryogenic environment. An integrated temperature sensor ensures the precise temperature inside the tuner is known. An integrated bias tee allows for the optional biasing of the DUT source, while external biasing can be used to bias the load of the DUT.

**Operating temperatures below 4K are possible given sufficient cooling in cryogenic environment*

Figure 1



Cryogenic Noise Parameter Measurement System

A cryogenic noise parameter measurement system is shown in **Figure 2**, and comprises of the following components:

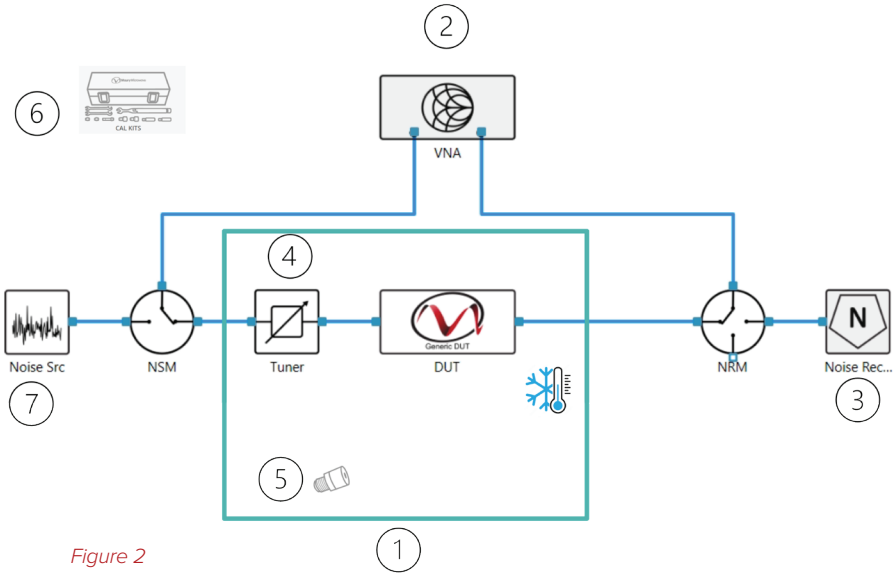


Figure 2

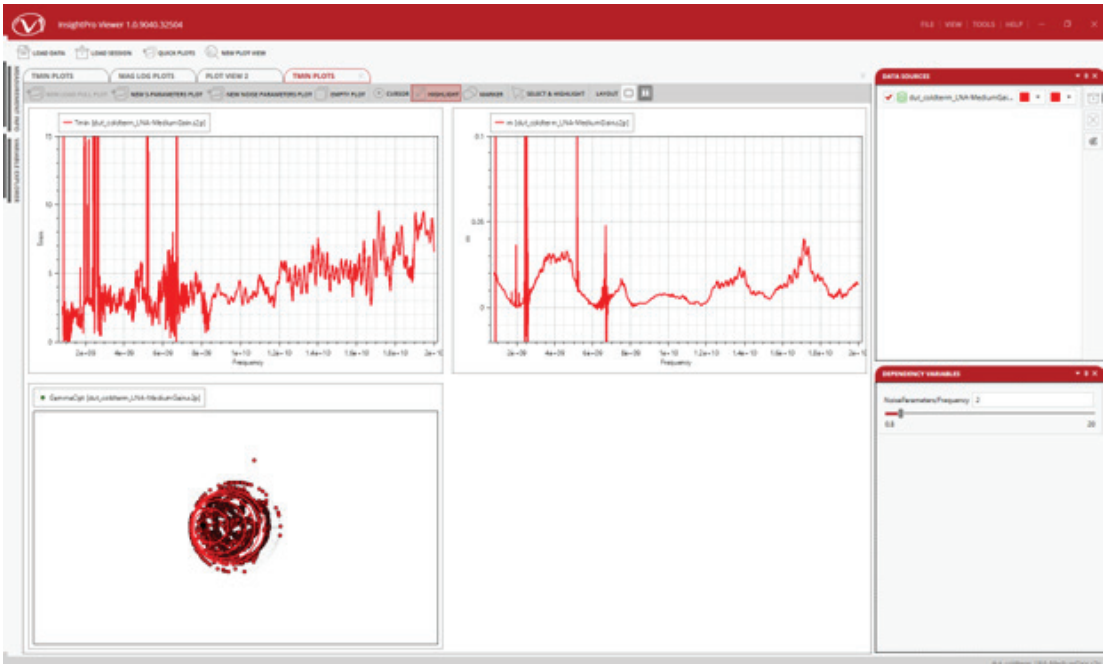
1. Cryostat or cryogenic probe station able to reach the desired temperature
2. Vector network analyzer (VNA) to measure S-parameters
3. Noise figure analyzer (NFA) to measure noise power (can be a standalone NFA or spectrum analyzer with noise personality, or integrated into the VNA)
4. Cryogenic impedance tuner able to set at least four impedance states
5. Cryogenic termination
6. Cryogenic VNA calibration kit
7. Noise source with sufficient ENR for noise power calibration
8. Cryogenic and room-temperature cables and adapters

Cryogenic Noise Parameter Measurement Results

Exemplary noise parameter measurements were taken on a Cosmic Microwave low noise amplifier (LNA) model CITCRYO1-18, using the following components:

1. Cryostat - Montana Instruments CryoStation S200,
2. Vector network analyzer (VNA) – Keysight Technologies N5245B PNA-X with integrated 029 noise receiver
3. Noise figure analyzer (NFA) – integrated in VNA
4. Cryogenic impedance tuner – Maury Microwave CT-2G-18G
5. Cryogenic termination – Quantum Microwave QMC-CRYOTERM-DC18NM
6. Cryogenic VNA calibration kit – Maury Microwave MODEL
7. Noise source – Maury Noisecom NC346D
8. Cryogenic and room-temperature cables and adapters - Miscellaneous

In addition, a Maury Microwave noise switching module (NSM) was used to simplify the input and switch between the noise source and the VNA. A Maury Microwave noise receiver module (NRM) was used between the output of the DUT and the PNA-X to lower the receiver noise figure and improve measurement sensitivity.



Note: spikes shown above are caused by interference as measurements were not taken in a Faraday cage

For more information on the CT-2G-18G cryogenic impedance tuner, please visit maurymw.com.
For more information on cryogenic noise parameter measurements, please contact sales@maurymw.com.

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