# Primary Noise Calibration Systems (DC - 110GHz) – Accuracy and Advantages

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# Agenda

- Primary Noise Standards
- Design concept - Maury Hot and Cold Noise Calibration Standards
- Noise Calibration Systems – Dual and Tri Load systems
- Accurate computation of Effective Noise Temperature
- Applications

# Need for Primary Noise Standards

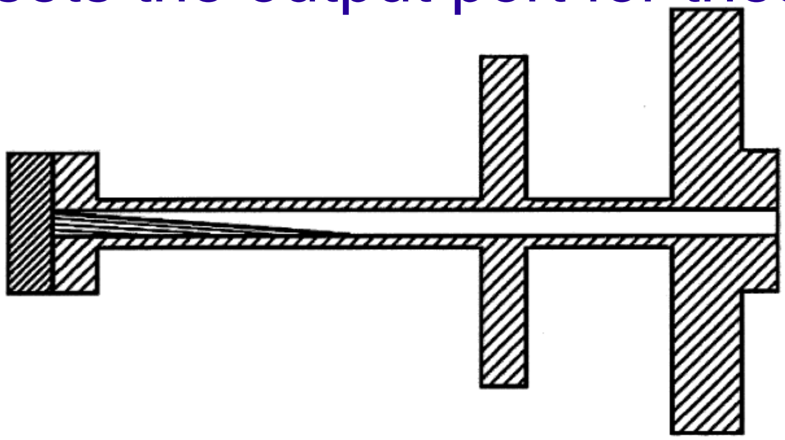
- The ability to characterize device noise is limited by the ability to separate system noise from noise generated by the device
- System noise performance needs to be known in radiometry applications, antenna noise temperatures, LNA performance evaluation, noise source calibrations, etc
- Primary noise standards help establish noise calibration by providing two known noise temperatures
- True thermal noise sources held at known physical temperatures

# Primary Noise Standards

- Standards can be designed using thermal termination sources or blackbody absorber to establish noise temperatures
- Thermal environments are 77K (LN2 boiling temp), 296K (ambient) and 373K (boiling water)
- Uncertainties much less than that of solid state generators
  - i.e., +/-1.5K vs. +/-30K @ 18GHz
- Maury Microwave offers -
  - Primary noise standards that are thermal termination standards and are calibrated for effective noise temperature at the measurement port
  - Designed with minimal system loss
  - DC to 110GHz

# Design Concept

- A hot or cold load standard consists of a thermal termination followed by a low loss airline section that sets the output port for these loads

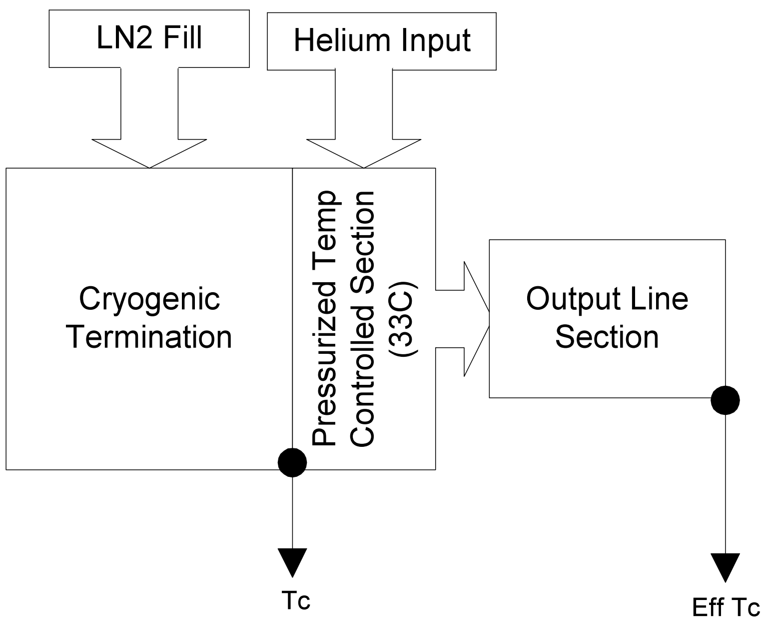


$$P' = \frac{2kB}{L}\int_0^l \alpha_x L_x T_x dx + \frac{P}{L}$$

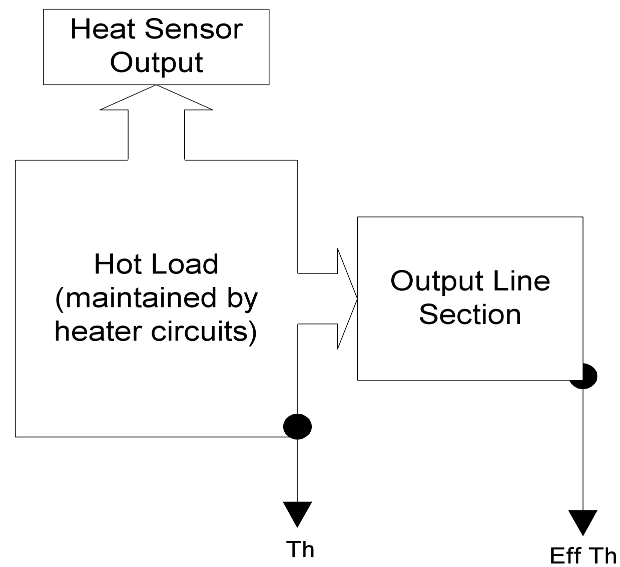
$$T' = \frac{2}{L}\int_0^l \alpha_x L_x T_x dx + \frac{T}{L}$$

- The noise power at the output reference plane is given by the noise power of the termination plus the contribution from the lossy transmission line [1].

# Maury Thermal Noise Standards




Cold Noise Standard




Hot Noise Standard

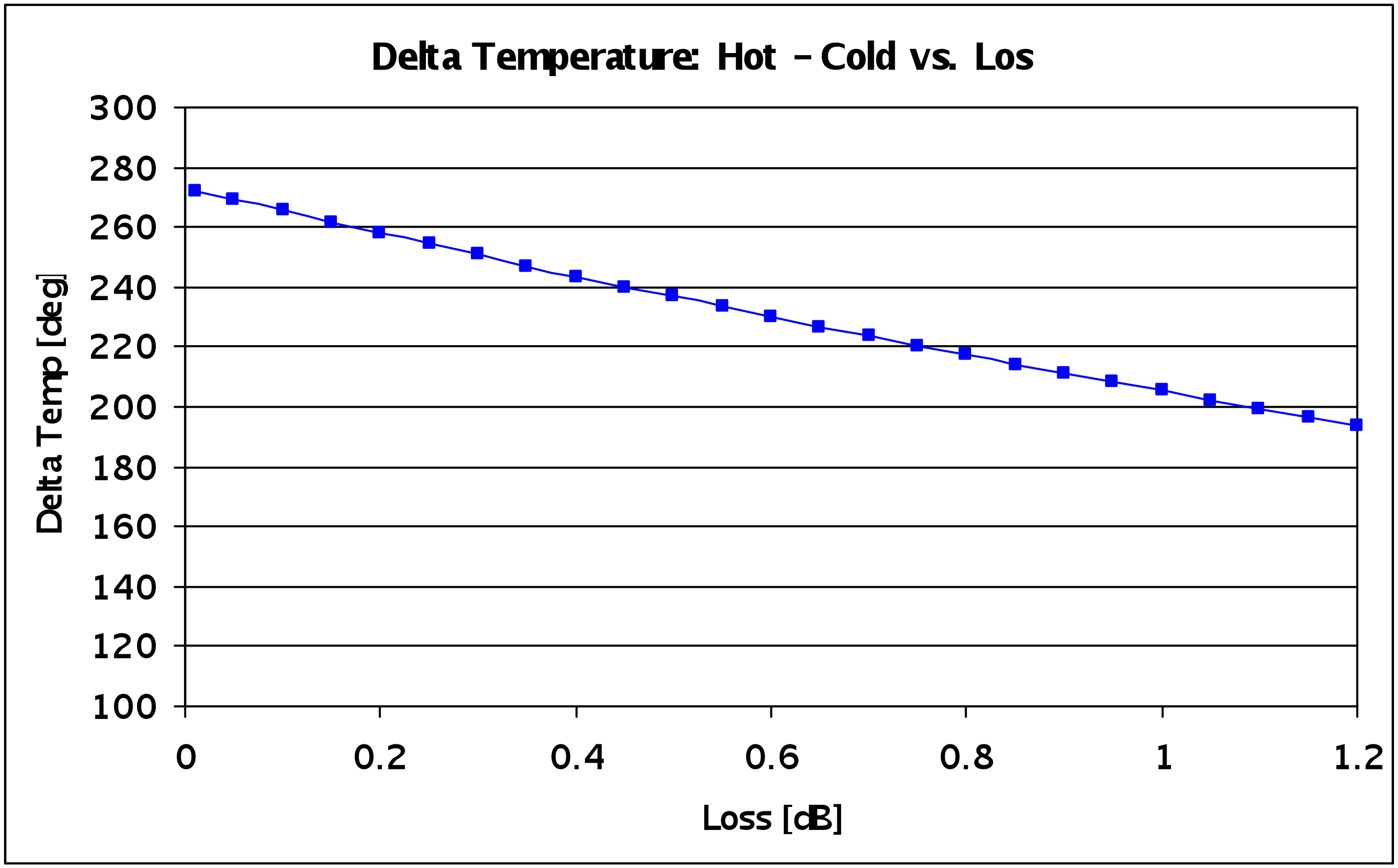
# Maury Thermal Noise Standards

- Available in coax up to 18GHz and waveguide up to 110GHz
- Cold standards operated at 77K using liquid nitrogen
- Hot load standards operated at 350K/ 373K with heater circuits
- Automated LN2 fill system that monitors LN2 levels in dewar
- Raised temperature section (33C) at output of cold load to prevent frosting
- Controlled temperature environment for hot loads (accuracy to within ±0.2K)
- Effective noise temperature accounts for termination temperature, atmospheric pressure and system loss

# Noise Calibration Systems

- Temperature separation between hot and cold states is crucial for noise source calibrations and other applications (shown on next slide)
- Maury offers dual load (cold/ hot) or tri load (cold/ ambient/ hot) noise calibration systems
- These establish two or three thermal noise references (power vs. temperature plot) which increases accuracy
- Convenient to switch between hot, cold or ambient states - better repeatability
- Effective noise temperature at system output includes effects of thermal noise standard, switch and interconnecting line sections

# Noise Calibration Systems



# Effective Noise Temperature

- Based on the paper by C. Stelzreid [1], the noise temperature at the output of the thermal standard depends on
  - temperature of the thermal load
  - insertion losses and temperature distribution through the transmission line segments
- Well matched terminations (minimizes hot/cold mismatch errors)
- Temperature of thermal loads are tightly controlled
- Accurate measurement of insertion loss of line sections

# Noise Temperature Uncertainty

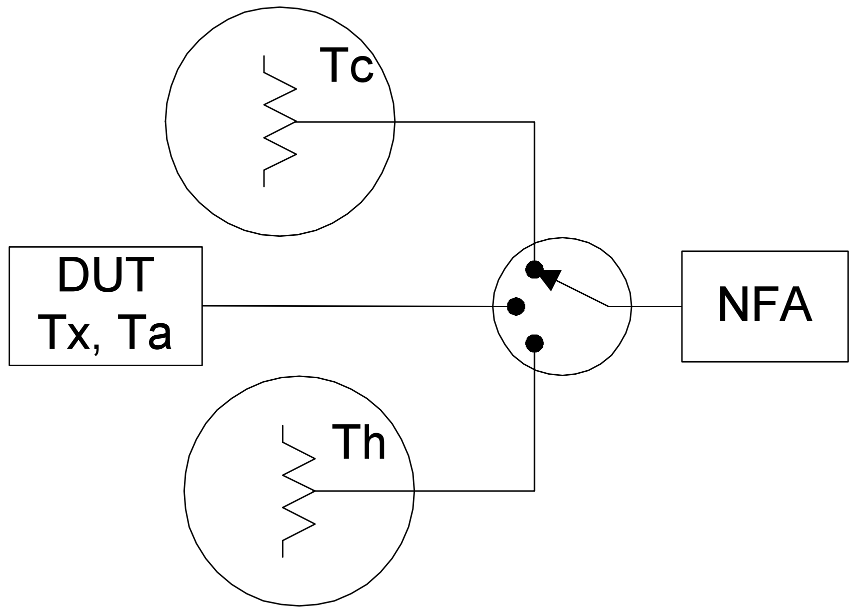
| Frequency | Connector Choices | Uncertainty |
|---|---|---|
| DC - 18GHz | 7mm/Waveguide | ±1.5K |
| 18 - 40GHz | WR28, WR42 | ±1.5K |
| 33 - 50GHz | WR22 | ±1.7K |
| 40 - 110GHz | WR15, WR10 | ±3K |

- Noise temperature uncertainty driven mainly by insertion loss measurement uncertainty and by the ability to maintained a controlled temperature

- Output noise temperatures are calculated and provided in calibration reports with formula provided to compensate for ambient temperature and pressure

# Applications - Noise Source Calibration

- ENR of noise source can be calibrated by measuring noise performance at hot and cold states of the noise standards system and then repeating measurements on the noise source

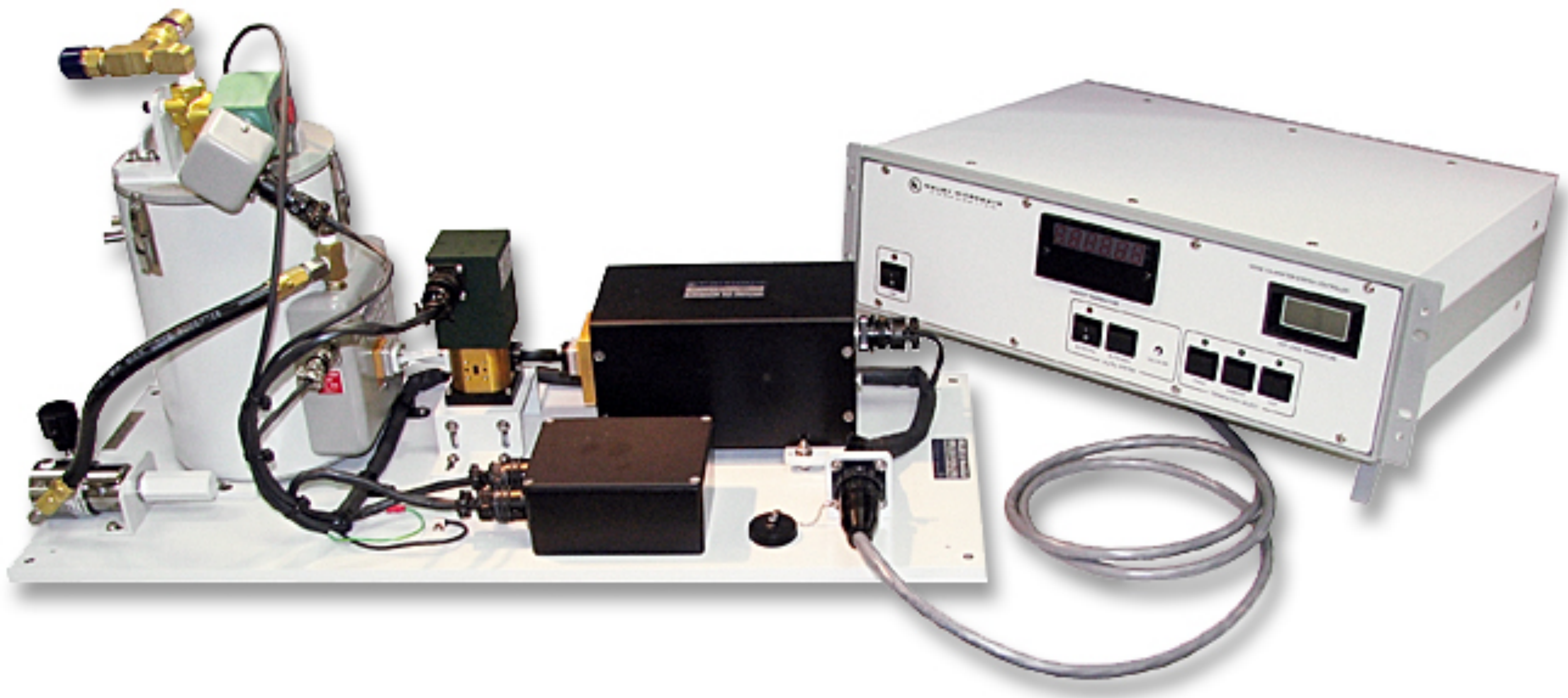



$$Tx = (Yx-1)\left[(Ta-Tc)+\left(\frac{Th-Tc}{Ys-1}\right)\right]+Ta$$

$$ENR = \frac{Tx}{To} - 1$$

- Tx, Ta - Hot and cold temp of noise source being calibrated
- Yx - Y factor of noise source being calibrated
- Th, Tc - Hot and cold temperatures of noise standards system
- Ys - Y factor of noise standard

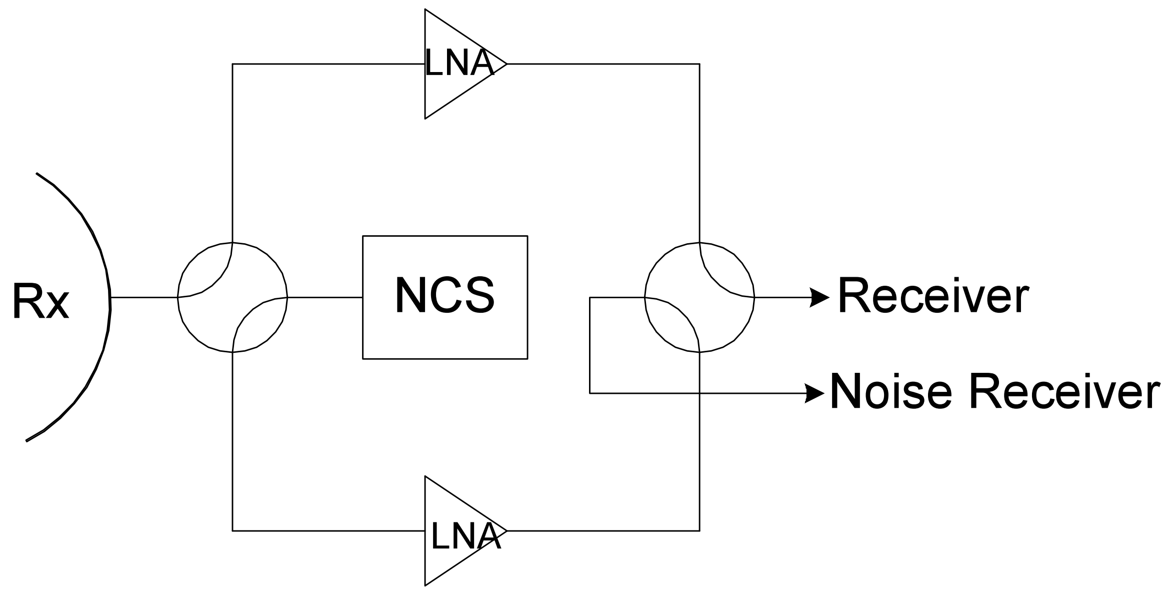
# Applications - Noise Source Calibration



Example of WR28 hot/cold noise calibration system

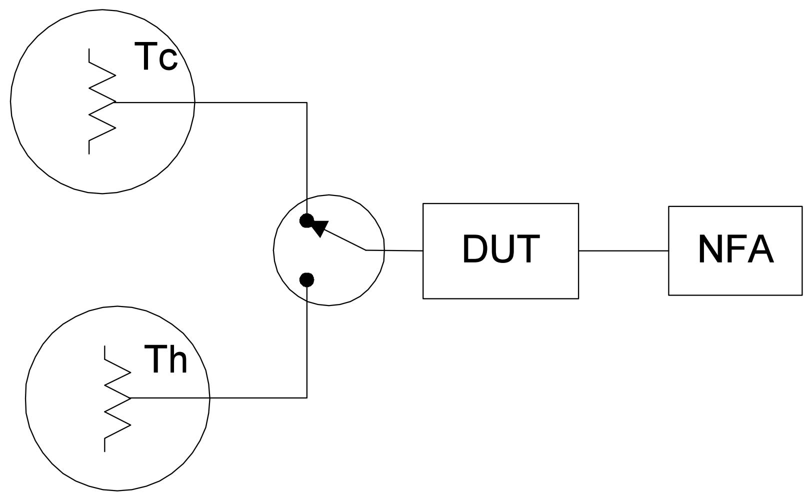
# Applications - Earth Station Receiver Verification

- Monitor LNA noise performance used in earth station receivers (Redundant LNA System)



# Applications - Noise Figure Measurements

- Measure noise figure of LNA or other DUT using Y factor method
- Eliminates additional uncertainty by using the primary noise standards for ON and OFF states



# Additional Information

Available upon request from our web site

- http://www.maurymw.com/literature_request/lit_form.php
- Technical notes TN-009, TN-011, TN-015, TN-019 & TN-021
- Product data sheets

# Reference

1. "Microwave Thermal Noise Standards", C.T. Stelzreid, IEEE Transactions on Microwave Theory and Techniques, Vol MTT-16, No. 9, September 1968