Cryogenic LNA Characterization: GARD Experience

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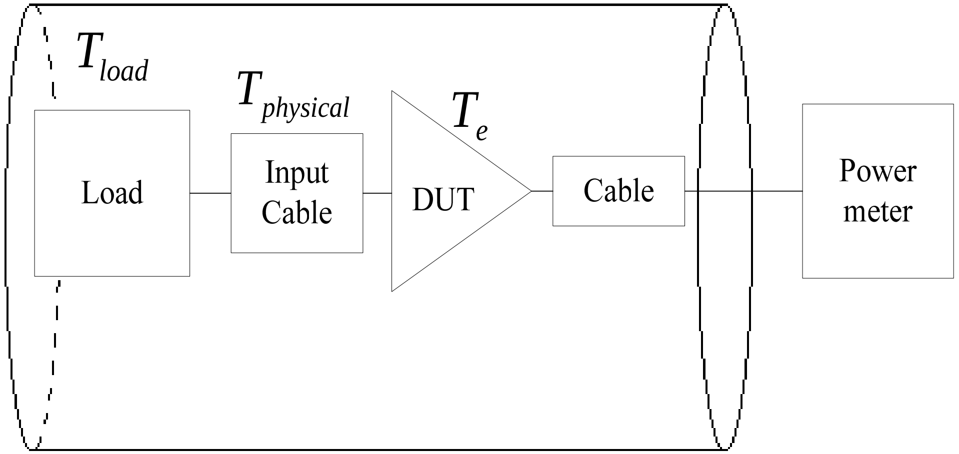
Outline

- Using a SIS junction as shot-noise source
  - Theory, design of the chip, hardware and measurements
- Our cryogenic setup
- Results
- Conclusions

Variable Temperature Load (VTL)

- Pros
  - "True" Y-factor method provides good accuracy
- Cons
  - Slow, change of physical temperature required
  - Temperature differences (load-DUT) requires cable, cause losses
  - Errors of actual physical temperature in load

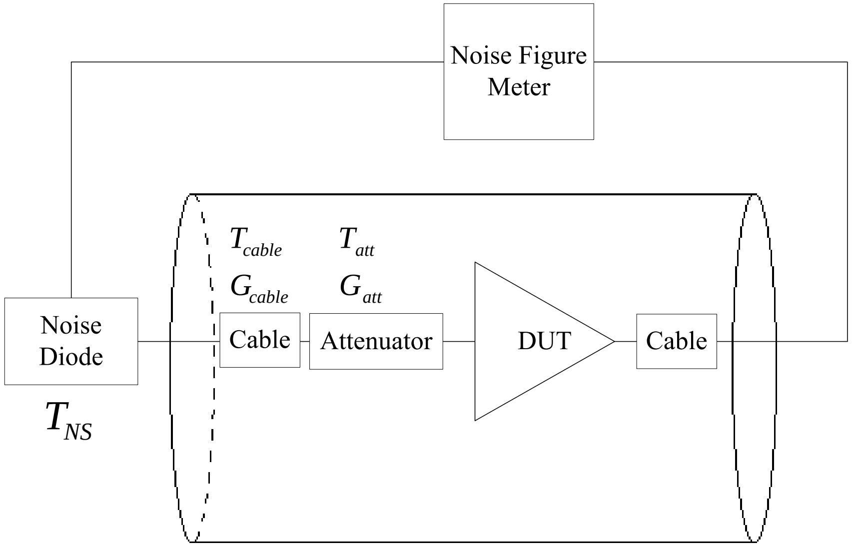
$$T_{source} = \frac{T_{load}}{L_{cable}} + T_{physical\_cable}\left(1 - \frac{1}{L_{cable}}\right)$$



Cold Attenuator (CA)

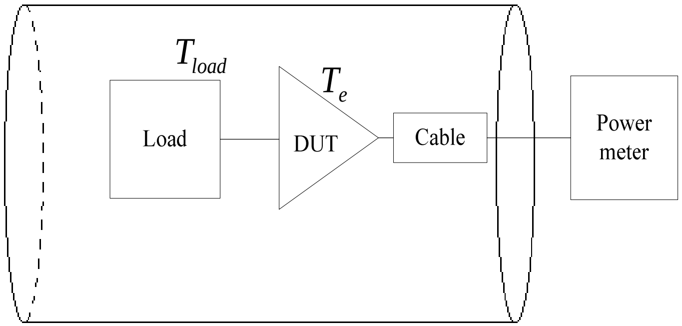
$$T_{source} = T_{NS} G_{cable} G_{att} + T_{cable} G_{att} + T_{att}$$
$$= \left(T_{NS} G_{cable} + T_{cable} \right) G_{att} + T_{att}$$
$$= \left[\frac{T_{NS}}{L_{cable}} + T_{cable} \left(1 - \frac{1}{L_{cable}} \right) \right] \frac{1}{L_{att}} + T_{att} \left(1 - \frac{1}{L_{att}} \right)$$

- Pros
  - Fast, noise diode
- Cons
  - Difficult to make loss estimation of input cable due to temperature gradient
  - Accuracy of temperature sensor
  - Errors of actual physical temperature in attenuator

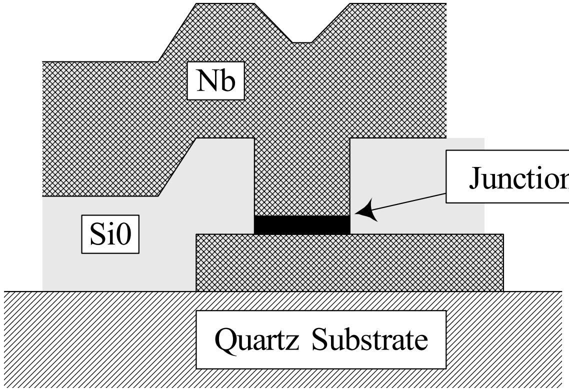


Using a SIS junction as shot-noise source?

- Advantages
  - Voltage controlled output power
  - No change in physical temperature
    - No temperature gradient
    - Directly connected to DUT
  - Based on fundamental constants



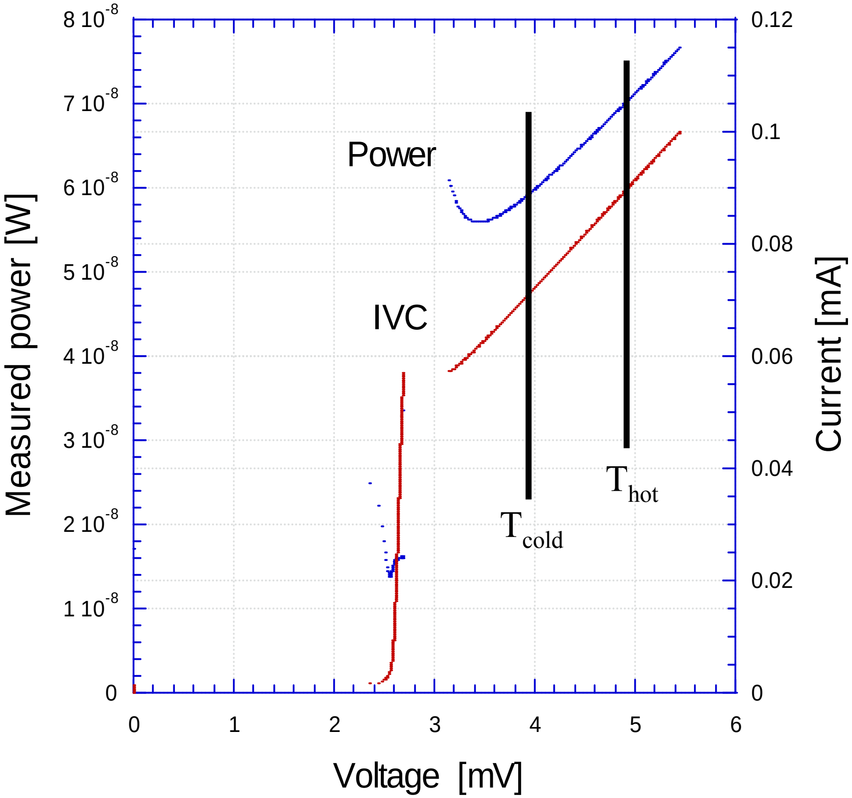
Superconductor-Insulator-Superconductor (SIS) tunnel junction



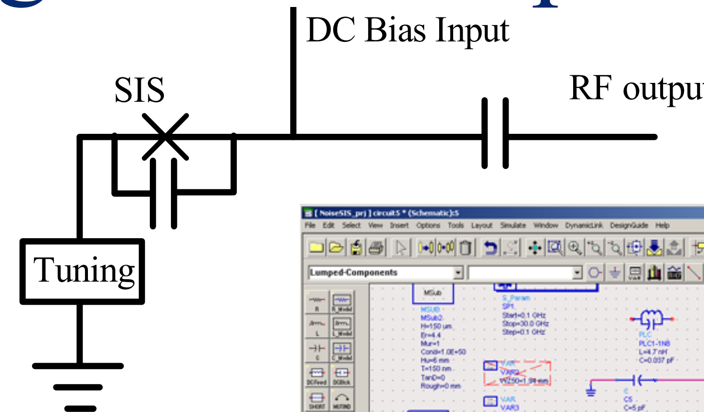
$$P_{shot} = \frac{1}{2} \cdot e \cdot I_{bias} \cdot B \cdot \coth\left(\frac{eV_0}{2kT}\right) \cdot R_{dyn}$$

$$T_{load} = \frac{e \cdot I_{bias}}{2k} \cdot \frac{dV}{dI} \cdot \coth\left(\frac{eV_0}{2kT}\right)$$

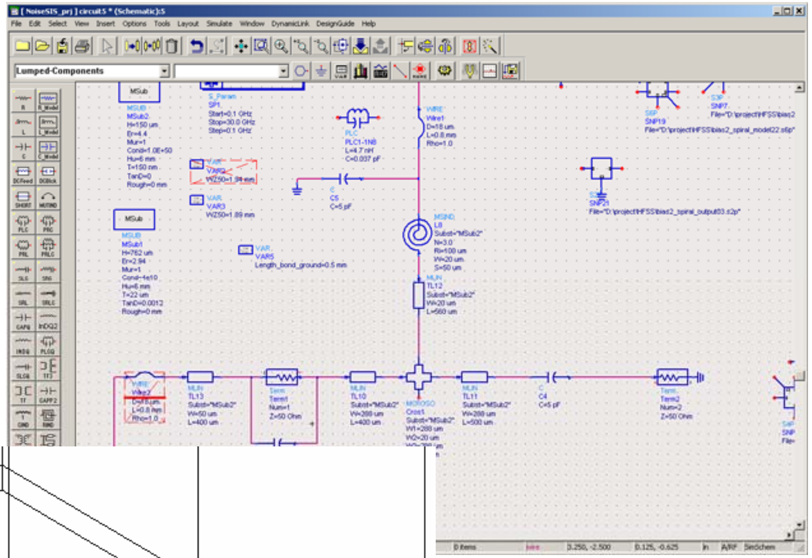
$$T_{load} = \frac{e \cdot V_{bias}}{2 \cdot k} \approx 5.8\text{K/mV}$$

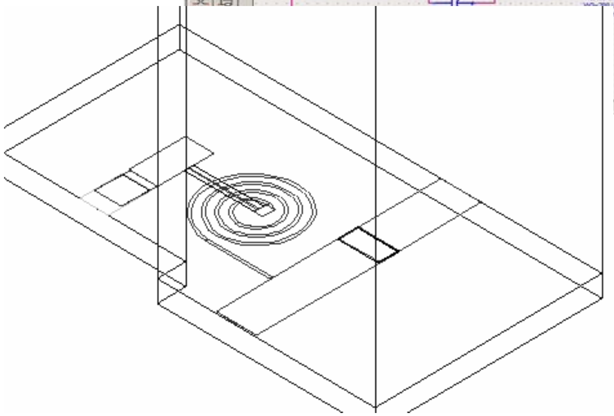


Design of the chip



- Equivalent circuit
  - Perfect coupling between junction and output
  - Bias-T
- Simulation of different bias/matching networks
- Detailed simulation of chosen approach
- Production of chip





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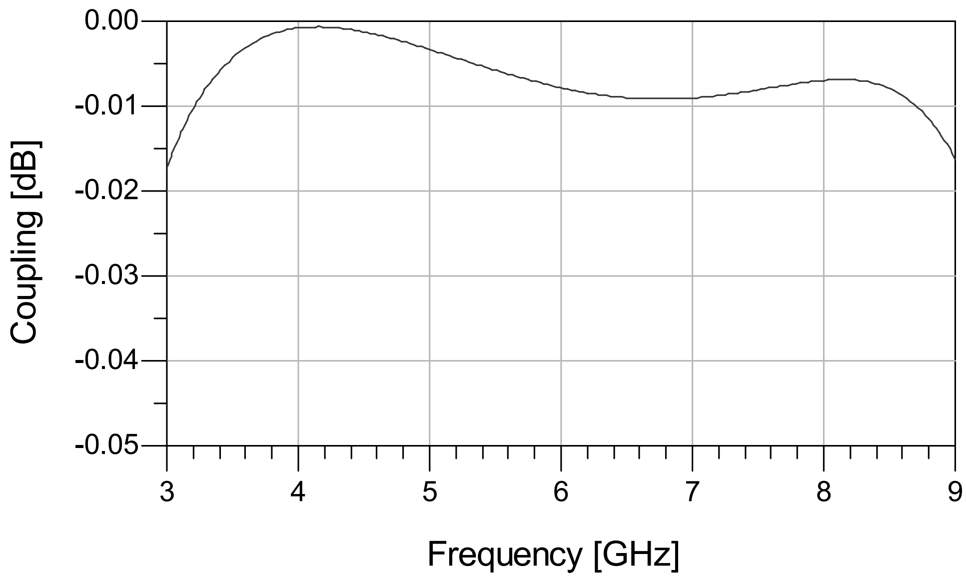
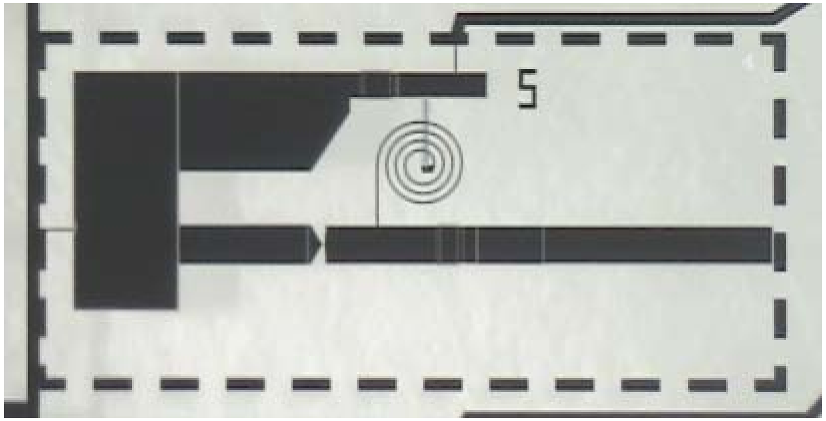
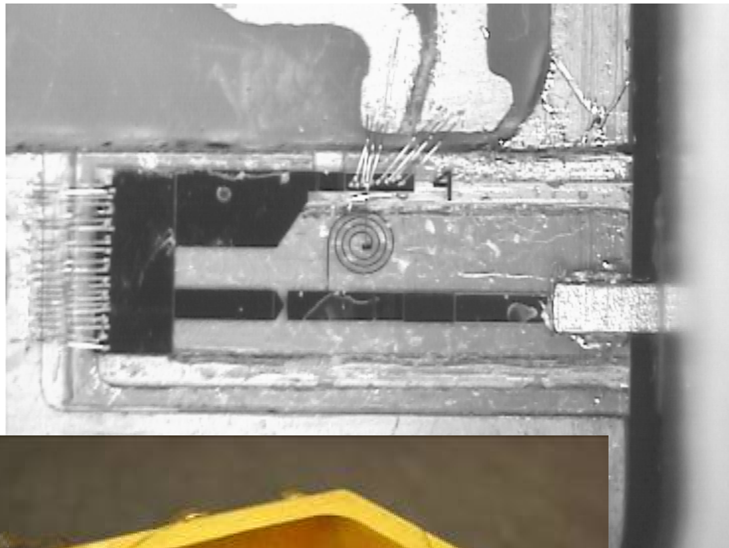


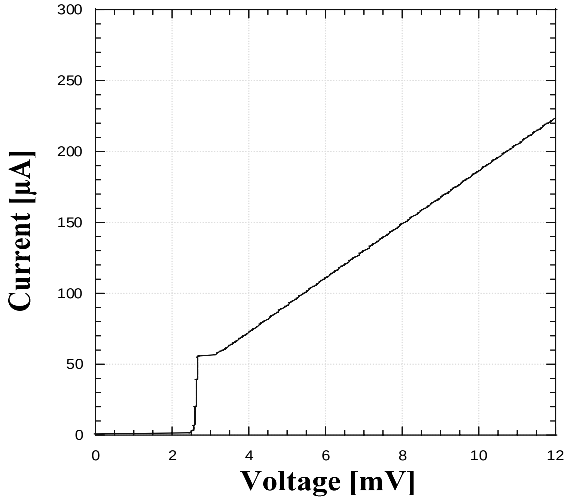


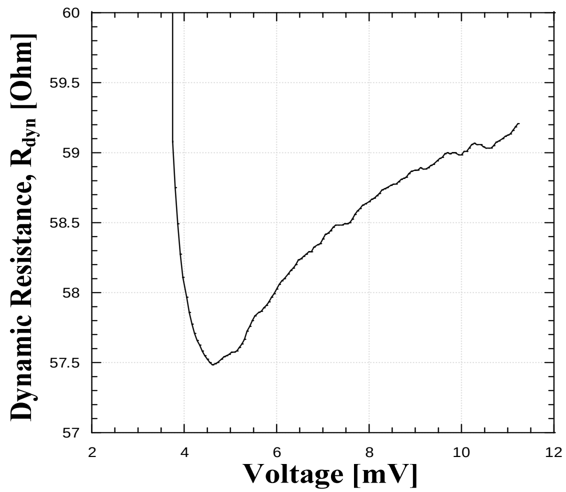
Measurement setup



Considerations and sources of errors

- Considerations
  - Chain of components
  - Dynamic resistance ≠ Rn
  - Complex formula (Tn≈5.8 K/mV)
  - Mismatch, Rn≠50Ω
  - Coth-term - bias voltage and junction temperature





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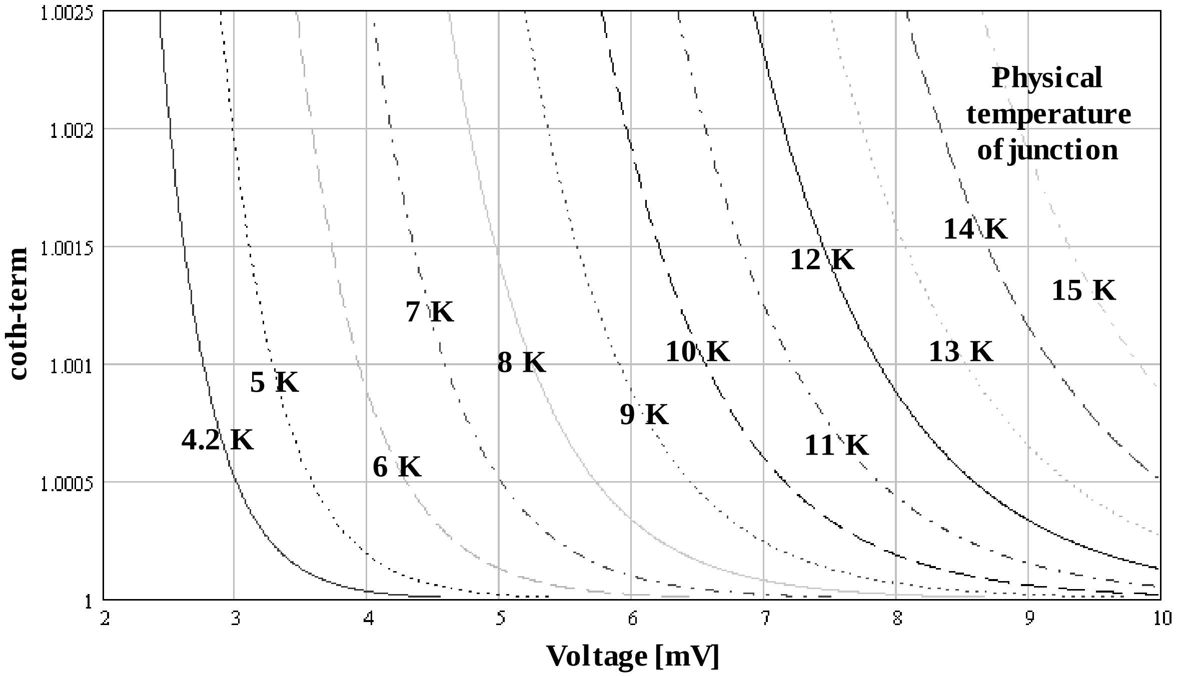
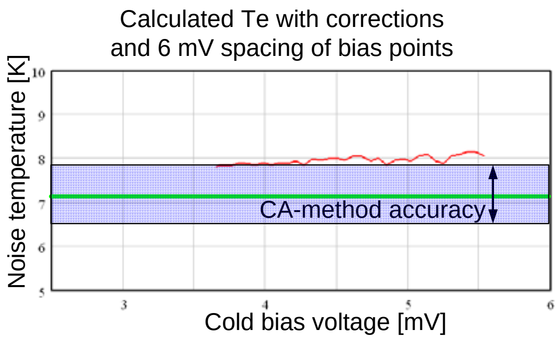
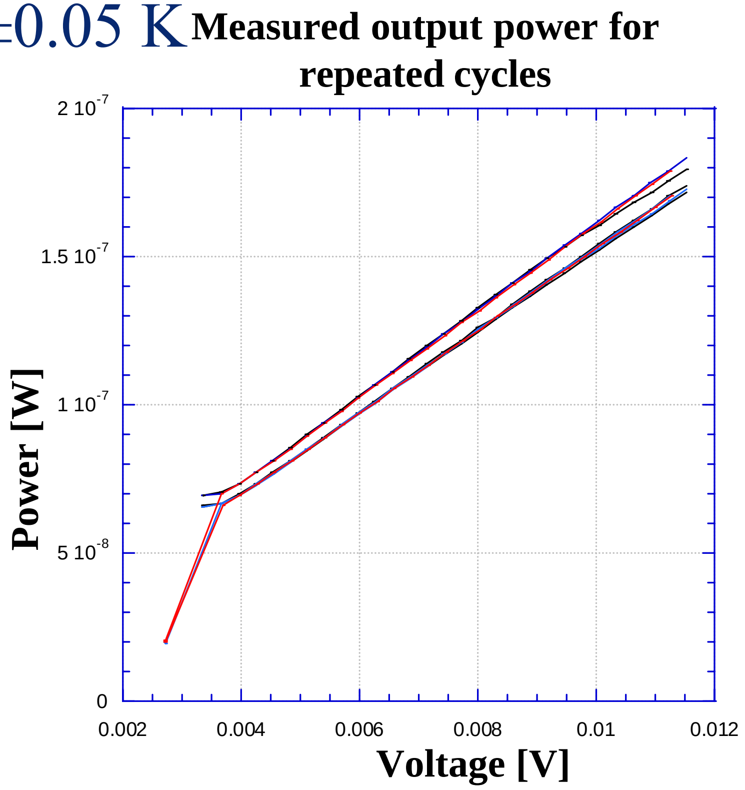


Measurements

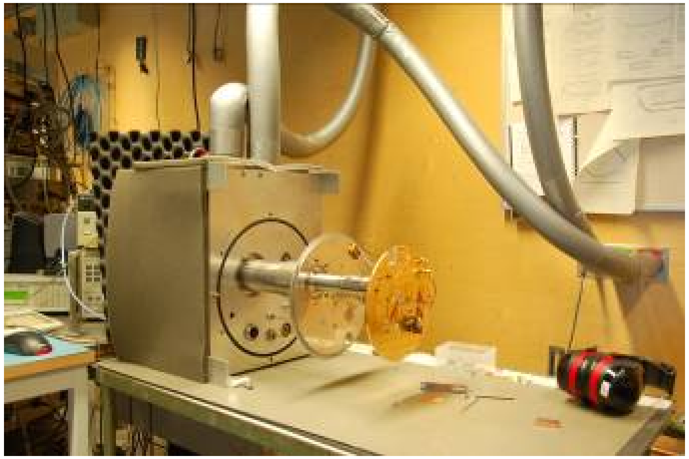
- Still room for improvements
  - Coupling, Microstrip-SMA
- Indication of repeatability better than ±0.05 K

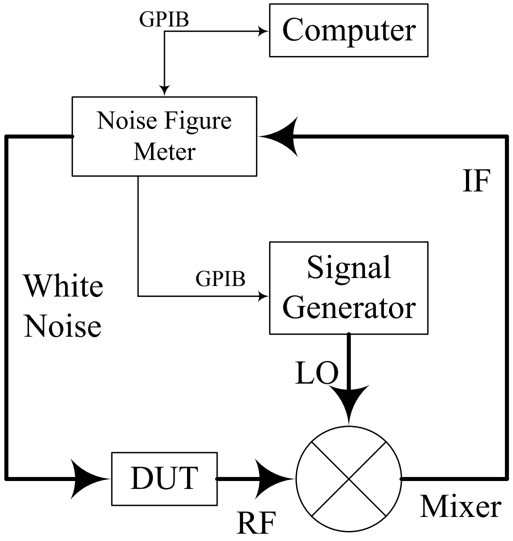




Cryogenic LNA measurement setup

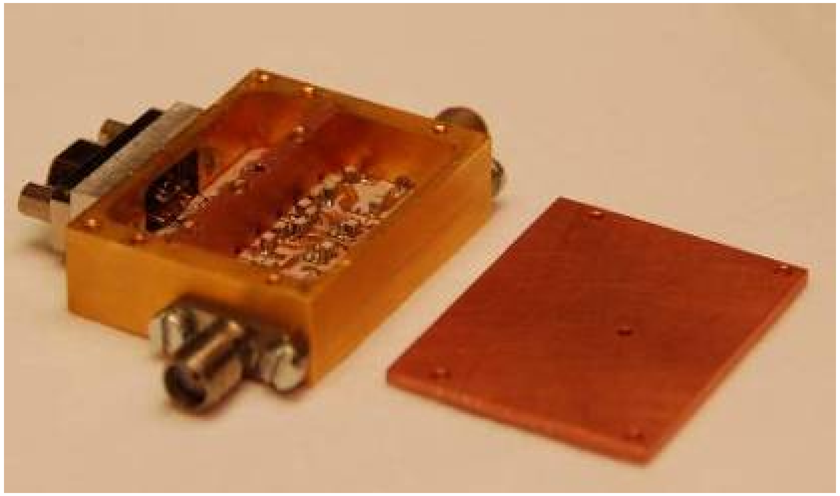
- Cold Attenuator method
- CTI 1020 closed cycle 12K
- Improved cold-plate
  - Required thermal decoupling to reduce temperature fluctuations
- Allan Variance measured with Agilent PNA
  - CW sweep, 20001 points, 10Hz IF BW

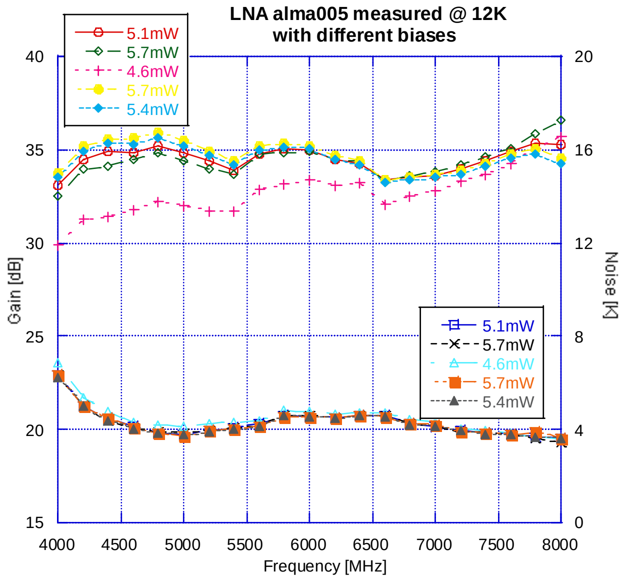


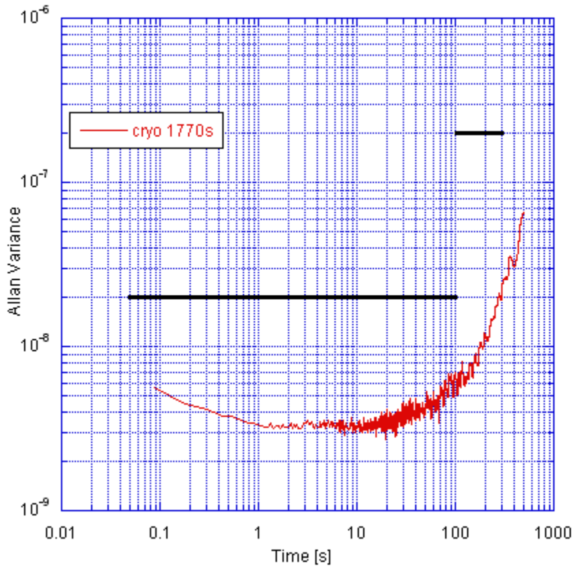


LNAs

- Low power budget







Conclusion

- A different approach to a noise source for NF measurements has been evaluated
  - Estimated potential accuracy is ±0.2 K compared with ±0.7 K for our CA-method
  - Further work is needed
- Measurement setup
  - Operation temperature 10.5-11K
  - Pessimistic setup, DUT is better than we measure