AVN Training Program – 2019

Calibration of a microwave low noise amplifier.

A. Objective:

To calibrate the noise temperature of a low noise amplifier using thermal reference terminations and to measure the system temperature when the amplifier is connected to a horn antenna pointed at the sky.

B. Equipment supplied:

The following equipment will be supplied:

1. A 7 GHz low noise amplifier attached to a test plate and connected to two waveguide switches which can connect to either of two reference thermal terminations or a horn antenna pointing at the sky.
2. A room temperature termination (Hot load).
3. A liquid nitrogen cooled termination (Cold load).
4. A microwave absorber that can be placed in front of the feed horn.
5. A total power radiometer incorporating a square law detector to measure noise powers
6. A microwave synthesiser to provide a local oscillator to convert from 7 GHz to baseband, or 0-10 MHz in this case.
7. An infrared thermometer for measuring the temperature of thermal loads.
8. A microwave noise diode which provides a secondary calibration source.
9. A computer monitoring system to record the radiometer output signals.
10. Necessary cables to connect the various modules together.
11. DC power supply to power the radiometer.

C. Basic theory

1. As explained in the Microwave Receiver lecture, a **hot** and a **cold** load are connected alternately to the amplifier input.
2. The respective power that is transferred to the **Square Law Detector** is given by:

   $P_{out} = Gk(T_{load} + T_{LNA})B$

   The ratio of P_{hot}/P_{cold}, which is denoted by Y, reduces to:

   $Y = (T_{hot} + T_{LNA})/ (T_{cold} + T_{LNA})$

   i.e.
   $T_{LNA} = (T_{hot} – YT_{cold})/(Y-1)$

D. Method:

1. The equipment should be connected as shown in the attached diagram.
2. Set the synthesiser frequency to 7.0 GHz, 10 dBM power level and note these values on the data sheet.
3. Using the waveguide switch, select the room temperature, i.e. **Hot,** load.
4. Set the attenuators on the **Radiometer** to give a reading of about -500 mV.
5. Record the attenuator value on the data sheet.
6. Using the waveguide switch, select the liquid nitrogen, i.e. **Cold,** load. Note that the meter reading should remain about 500 mV. (Why?)
7. The instructor will start running the computer monitoring system.
8. The Instructor will then assist in filling the cold load with liquid nitrogen, observing all necessary safety precautions, e.g. use of protective gloves and transparent face protector.
9. As the liquid nitrogen cools the cold load, the readings on the radiometer output meter and the computer monitor should decrease. (Why?)
10. Once the temperature of the nitrogen load has stabilised the calibration can begin.
11. Increase the 10 dB step attenuator to 100 db and record the radiometer output meter reading to get the correction bias.
12. Return to the original attenuator setting (the radiometer output meter should read ~500 mV)
13. Record the meter reading, $\mathbf{P_{cold}}$, averaging over the range of fluctuations, if necessary.
14. Switch to the **Hot Load.**
15. Record the meter reading, $\mathbf{P_{hot}}$**,** averaging over the range of fluctuations, if necessary.
16. Switch back to the hot load and change the attenuator by +1 dB, and repeat steps 15-16.
17. Switch back to the hot load and change the attenuator by -2 dB, and repeat steps 15-16.

Note that all this data will be recorded by computer.

E. **Analysis of results:**

18. Use the Y-factor formula to calculate the noise temperature. Note that the boiling point of liquid nitrogen has to be corrected for altitude, and frequency dependent correction made for which information will be supplied.

F. Measurements with Horn on Sky

1. Move the trolley with equipment outside onto the measurement platform.
2. Check that the cold load has sufficient liquid nitrogen, and top up if necessary.
3. Switch the waveguide switches so that the horn is connected to the sky.
4. Increase the 10 dB step attenuator to 100 db and record the radiometer output meter reading to get the correction bias.
5. Return to the original attenuator setting prior to step 4.
6. Record the meter reading, $\mathbf{P_{sky}}$**,** averaging over the range of fluctuations, if necessary.
7. Place the absorber foam over the feed.

8. Record the meter reading, **$P_{absorber}$,** averaging over the range of fluctuations, if necessary.
9. Use the infrared thermometer to measure the physical temperature of the absorber material and record.
   Remove the absorber from the feed and change the attenuator by +1 dB, and repeat steps 6-8.
   Remove the absorber from the feed and change the attenuator by -2 dB, and repeat steps 6-8.

G. Analysis of horn results:

There is a simple formula for calibrating these results:

$T_{Sys} = (T_{absorber} + T_{LNA})/Y$

Where $Y = T_{absorber}/T_{sky}$

For T_{LNA} use the average of the three measurements calculated in Section E above.

Notes on temperature of cold load.

The physical temperature of the cold load is determined by the boiling point of liquid nitrogen, 77.3 K at standard pressure.

At 5 GHz, the additional loss between the load and the output connector introduces additional noise, increasing T_{cold} to 82.5 K

At altitude the boiling point decreases by 0.3 K per 300 m altitude, or 1.4 K at HartRAO.

Corrected value for HartRAO: 81.1 K