Cryogenic System and Receiver Maintenance

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<u>Receivers and Cryogenics</u>

The purpose of this discussion is to provide VLBI personnel with an overview of the maintenance and testing of low-noise receivers using relevant measurements. This discussion will also impart relevant information concerning the cryogenics associated with low-noise receivers.

The following topics will be discussed:

- **Why accurate measurement of receiver noise temperatures are so important.**
- **Noise diodes and calibration the receiver system.**
- **Techniques used to calibrate receiver noise temperature.**
- **Techniques used to measure the calibration values of noise diodes.**
- **The importance of Cryogenics in receiver systems**
- **An overview of the Cryogenic system**
- **Sources of Cryogenic parts**
- **Basic maintenance, repair and replacement of Cryogenic parts**
- **Resulting benefits from this presentation**

Why receiver noise temperatures are so important

The typical receiver used in VLBI and Radio Astronomy detects thermal energy emitted by distant sources such as quasars, nebula and stars such as our sun. This energy arrives at the antenna at extremely low power levels, a small percentage of total system power. Each radio source emits energy, which is quantified by the unit of measure Flux Unit (FU) and is described as detected rise in system noise power. In a calibrated system the energy is rise in system temperature or Tsys expressed in Kelvin (K). The Tsys is compared to a noise standard such as a noise diode to give relevance. .

Noise diodes and the receiver system

Noise diodes (ND) provide the standard by which the received flux value is compared. This calibrated noise from the ND is added to the system's overall detectable power to allow measurement by substitution of the Antenna and receiver noise to provide the accurate measurement and calibration of system temperatures.

Techniques used to measure receiver noise temperature

There are many methods for measuring receiver noise temperatures. The following technique is both practical and accurate. This measurement will use a cold sky (a sky with as few noise sources as possible) and an absorber (such as Echosorb ®). The sky will provide the cold reference ~3k while the absorber acts as a hot termination of about 290K. The procedure for calibrating the receiver is as follows.

1. Point the receiver feed straight up at the sky (zenith angle) or use an aluminum reflector about 1 meter square at a 45 degree angle to reflect noise from the cold sky into the feed. (The angle should be adjusted to give the lowest possible power output from the receiver IF). Figure 1 shows the cold sky-ambient aperture load noise measurement system.

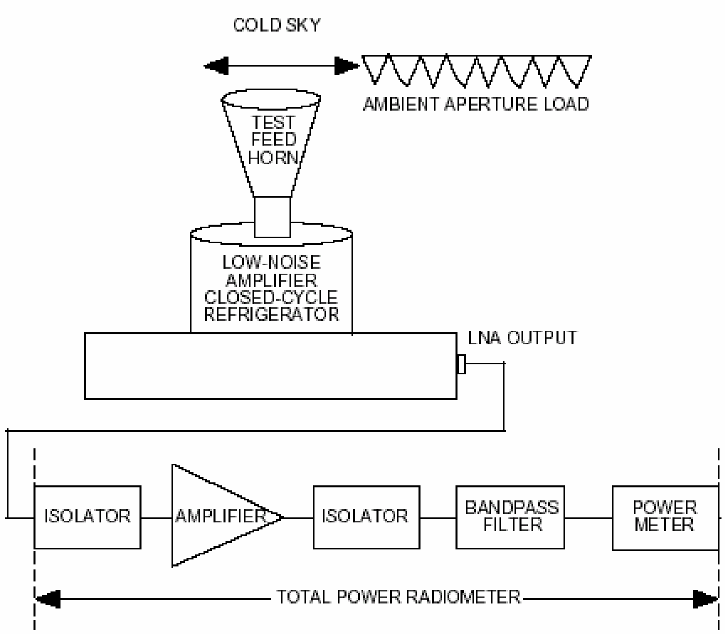


Figure 1. Cold-sky-ambient aperture load noise measurement system.

1. Record the power output of the receiver with the feed looking at the cold sky. Read the IF power to the nearest 0.01 dB.

3. Cover the feed with the absorber and record the power output of the IF.

4. Subtract the power readings obtained in steps 2 and 3 to obtain the receiver's "Y" factor. ($Y = P_{Cold} - P_{Hot}$)

1. Calculate the receiver noise temperature from:

$$X = 10.0^{(Y/10.0)}$$

Where Y is the “Y” factor obtained in step 4.

TR = X * TC - TH / 1.0 – X

Where TR is the receiver noise temperature, X is the result from the previous equation; TC is the temperature in Kelvin of the cold sky, about 10 Kelvin for a clear sky and about 20 Kelvin for an overcast sky.

1. Steps 1 through 5 should be performed with the noise diodes turned Off.

An alternate method for calculating Tsys can be found in the Field System documentation.

An excellent discussion of Noise Temperature Measurements may be found in the IPN Progress Report 42-154. Authored by C. T. Stelzried, R. C. Clauss and S. M Petty.

http://ipnpr.jpl.nasa.gov/tmo/progress_report/42-154/154G.pdf

Techniques used to measure the calibration value of noise diodes

Following steps 1 through 5 with the noise diodes turned on may accomplish calibration of the noise diodes. Subtract the results with the noise diodes turned off from the results obtained with the noise diodes turned on.

It is recommended that these procedures be repeated several times and the results of several trials be averaged.

The importance of Cryogenics in receiver systems

Since the VLBI system is receiving what is essentially a very weak noise signal from a distant source (Quasar), it is very important to be able to differentiate this low level signal from other noise sources. Noise sources that can enter into the system are electronic or white noise, noise reflected from the ground, noise from the sky as well as noise from the antenna dish. These are external sources and are difficult to manage. Noise contributed by internal noise of the Low-Noise-Amplifier (LNA) can be greatly reduced by cooling the LNA to an low physical temperatures. Thermal-Electric cooling can obtain –50C. To make real gains in performance the use of cryogenics coolers will lower the operational temperature of the LNA to 20K. The overall effect of the cryogenic cooling is a >10 fold improvement in system temperature and thus system sensitivity.

An overview of the Cryogenic system

The basic cryogenic system is comprised of a helium compressor, interconnecting high-pressure hoses, cold head / refrigerator, vacuum Dewar and related interconnecting cables. The compressor cools the helium gas and raises the operating pressure of the helium supply to the refrigerator. The helium moves from the compressor (high pressure or supply side) through the hoses to the cold head. The cold head extracts the heat from the Dewar cooling the contents of the Dewar to 20K. The standard VLBI Dewar contains the X and S-band LNA's. The helium is circulated through the Dewar via cylinder displacers. The heated helium returns to the compressor (low pressure or return side) through lines of the same type as the high-pressure side.

Sources of Cryogenic parts

www.duniway.com This Company is a supplier of bellow valves, oils and other lubricants, vacuum gauges, leak detectors and other supplies.

www.oxford-instruments.com This Company is now the owner of Austin Scientific, manufactures and repairs cryopumps, cryogenic coolers and helium compressors of the type we use.

www.helixtechnology.com This company provides another source of compressors, pumps and other cryogenic parts.

Basic maintenance, repair and replacement of Cryogenic parts

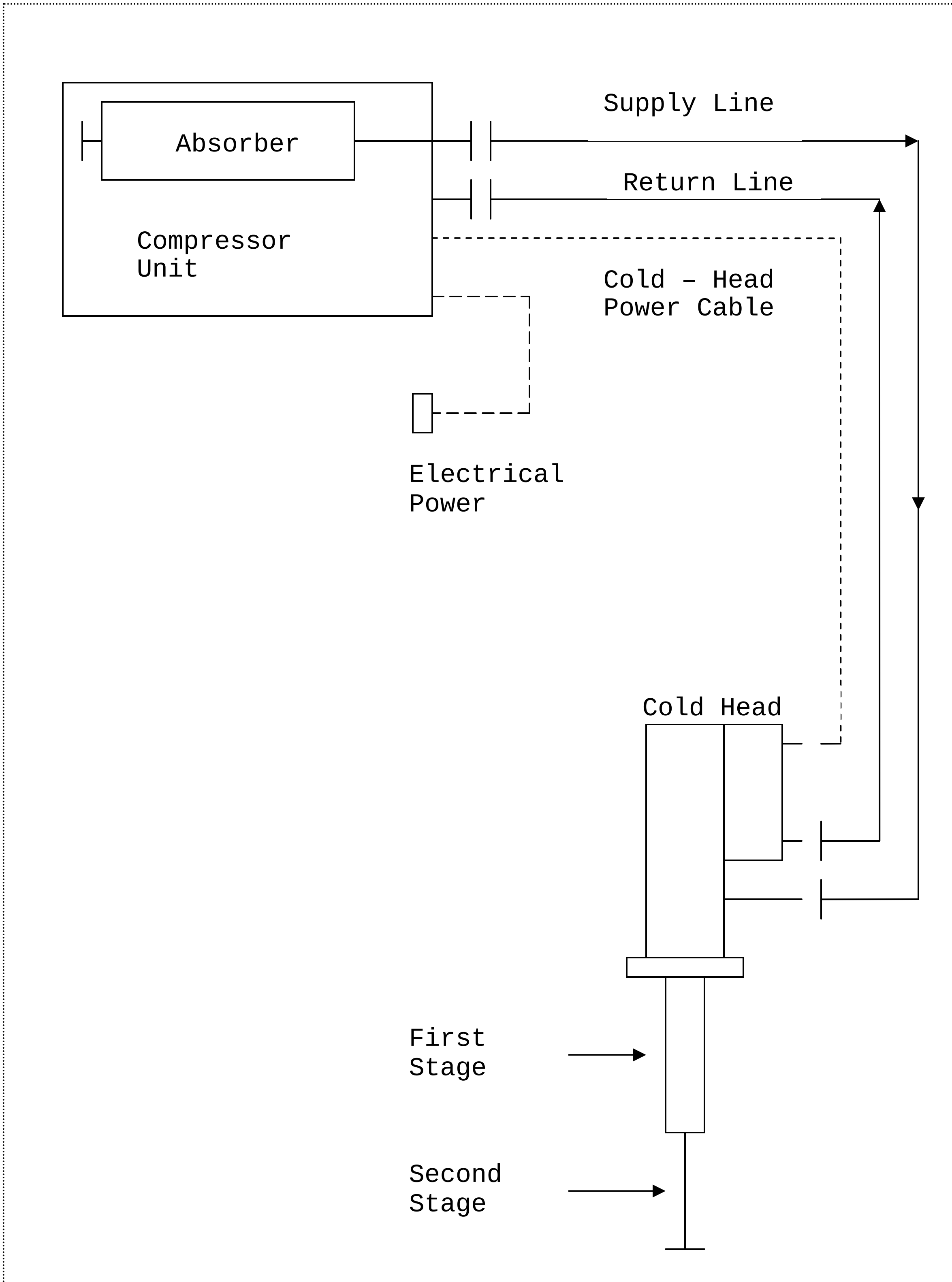
Refrigerator Replacement

1. Attach the charging adaptors to both helium ports,
2. Open both adaptor valves to discharge the pressure from the refrigerator. Remove charging cylinder.
3. Remove the four #10 Hex head screws securing the refrigerator to the cylinder and withdraw the refrigerator, thus removing the displacers from the cylinder.
4. Perform steps 1 through 3 on the replacement unit.
5. Carefully place the second stage seal suppressor over the seal on the replacement unit.
6. Clean the inside of the cylinder in the Dewar with a suitable solvent (petroleum ether is preferred, however, alcohol can be used). Make sure that the cylinder is completely clean and dry before proceeding.
7. Clean the "O" ring grove on top of the cylinder and install a new "O" ring coated very lightly with apiezon grease.
8. Carefully insert the displacers into the cylinder until the crosshead mates with the cylinder and bolt in place using a crossed pattern tightening procedure which insures that the bolts are tightened evenly.
9. Perform steps 1 through 6 of the system purging procedure.

Refrigerator Purging and Pressurization Procedure

Once this procedure is performed the helium gas contained in the compressor, hoses and refrigerator will be of the highest purity.

1. In order to get a successful purge of the system the helium lines must be removed from the refrigerator when the system is as cold as possible. Trapping the contamination in the refrigerator.
2. Allow the refrigerator to warm to room temperature before proceeding.
3. Attach purging and charging adaptors to both the supply and return helium lines on the refrigerator.
4. Attach a regulated supply of ultra pure helium to the charging adaptor on the supply side of the refrigerator and adjust the regulator pressure to 50 PSI.
5. Apply electrical power to the refrigerator by attaching the cable from the compressor and turning on both switches on compressor.
6. Open the valves on both charging adaptors and allow helium to flow through the refrigerator for at least one minute.
7. Close the exhaust valve on the return side of the refrigerator and allow the pressure in the refrigerator to equalize.
8. Close the valve on the supply side of the refrigerator, the supply valve on the helium tank and remove the charging adaptors.
9. Return the normal helium line connections to the refrigerator and begin a normal cool down cycle as the refrigerator is now ready for use.


Absorber
Compressor Unit
Supply Line
Return Line
Cold – Head Power Cable
Electrical Power
Cold Head
First Stage
Second Stage

Resulting benefits from this presentation

From this presentation you should have a better understanding of the following:

1. Noise temperature and it's relevance to the VLBI receiving system
2. Procedures for calibration of the noise diodes
3. Procedures for the calibration of the receiver
4. The use of cryogenics in the receiver system
5. Procedures for replacing the refrigerator
6. Procedures for purging the pressurizing the refrigerator