Appendix C: Radiometer Calibrations

C.1 Calibrating Radiometrics MP-xx00A Radiometers with Liquid Nitrogen (LN2)

Safety Considerations

Liquid Nitrogen (LN2) is extremely cold. It can cause severe burns to the human body, particularly to the skin and eyes. To avoid the risk of a cryogenic burn, LN2 should always be handled with care and respect. Handlers should wear appropriate protective clothing, gloves and goggles.

Handlers must also take precautions to ensure adequate ventilation. The gas is not toxic, but at high concentrations, it reduces the available oxygen in the air.

Disconnect the Azimuth drive (if installed) prior to placing the Cryogenic Target on the radiometer to avoid potential LN2 spills resulting from the azimuth drive moving.

To calibrate the profiling radiometer, use two “microwave targets” (microwave loads) of known temperature:

- A built-in ambient-temperature Black Body Target
- An external Cryogenic Target filled with 15 liters of liquid nitrogen (LN2)

C.1.1 Using the Cryogenic Target

When LN2 is placed in a Cryogenic Target containing microwave absorber Figure C-1, the target brightness temperature will be that of boiling LN2 (-195° C).

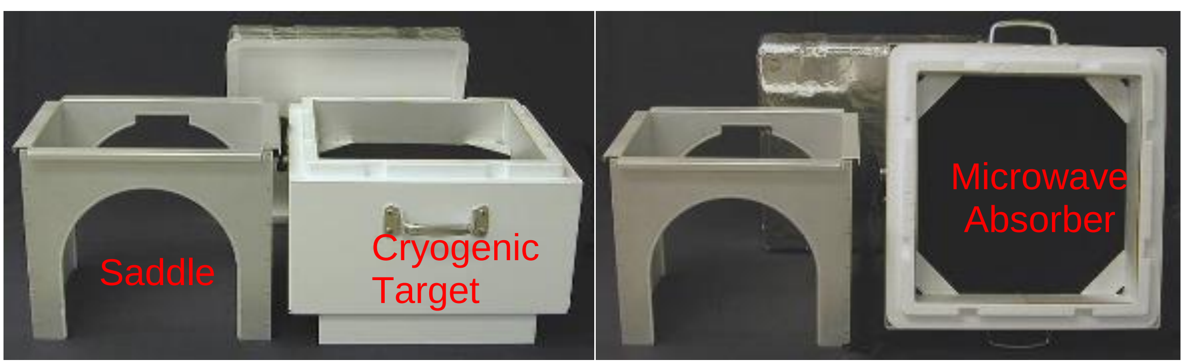

Figure C-1. Cryogenic Target for calibrating microwave-profiling radiometers

The LN2 calibration procedure points the radiometer internal mirror to alternately view the ambient temperature Black Body Target and the Cryogenic Target (refer to Section 2 of the **Operator’s Manual** for additional information on the radiometer antenna pointing mechanism).

When a calibration is performed, the Cryogenic Target is placed on top of the radiometer, above the Radome as shown in Figure C-2. Instructions for proper placement of the Saddle and Cryogenic Target are given below.

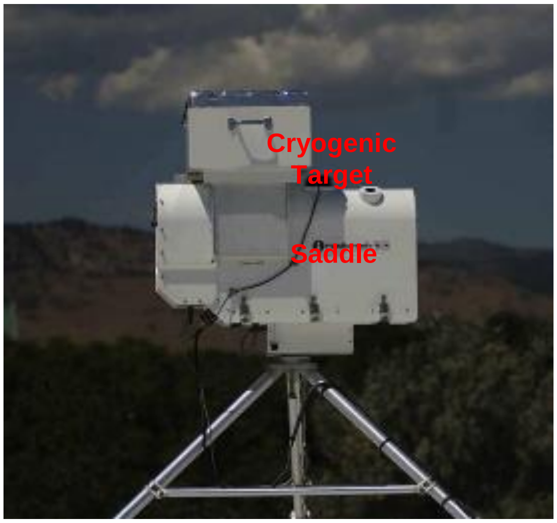

Figure C-2. Radiometer with Saddle and Cryogenic Target in place

The Saddle is used to position the Cryogenic Target above the radiometer Radome. It also forms a wave guide that serves to minimize extraneous microwave emissions (warm bias) reaching the antenna. The radiometer “views the target” through a Radiometrics-patented microwave transparent window in the bottom of the target.

Note that one end of the Saddle has a notch that fits over the rain sense board on the Superblower, when properly installed. The Saddle is designed so that the front cut out fits over the Superblower and the rear cut out fits against the hood immediately behind the Radome. When properly installed, the Saddle fits securely to the radiometer with no gaps between the Saddle and the hood (except at the bottom of the Saddle) as shown below in Figure C-3.

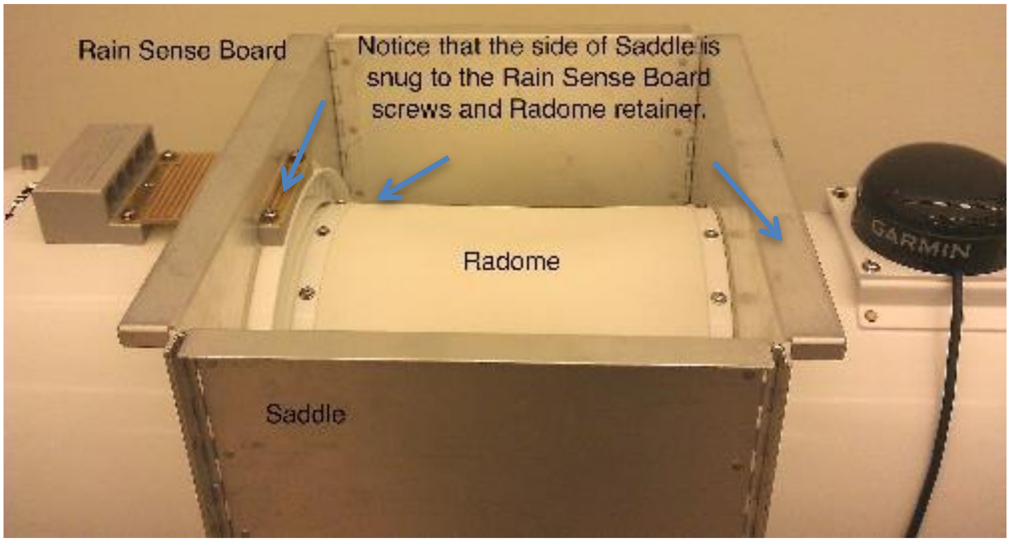

Figure C-3. Saddle for Cryogenic Target, properly seated

Safety Considerations

Ensure proper LN2 handling safety by filling the Cryogenic Target while it is sitting on the ground, as shown Figure C-4. Use the safety strap to secure the lid to the target before placing the target on the Saddle.

NEVER attempt to pour LN2 into the target when it is on the radiometer.

NOTE:
Do not fill the Cryogenic Target until the operator is ready to start calibration. Load Cryogenic Target onto the Saddle from the front **only**.

Before starting an LN2 calibration:

1. Ensure the radiometer has been powered on for more than one hour to allow the microwave components to reach stable operating temperatures.
2. Stop the current procedure file if one is running.
3. Disconnect the Azimuth Positioner cable (if installed) from the radiometer.
4. Place the Saddle on the radiometer as described above, and place the filled Cryogenic Target on top of the Saddle.

Carefully pour LN2 into the Cryogenic Target until the LN2 level is at least one cm above the microwave absorber. Do not overfill – there should be at least a 2.5 cm (1 inch) gap between the LN2 and the top of the target.

Figure C-4. Proper method for safely pouring LN2 into the Cryogenic Target

Note that when the Cryogenic Target is properly seated on the Saddle, the two handles are oriented as shown in Figure C-2, and the target is level on the Saddle.

Additional information on LN2 availability, transport and storage is provided at the end of this appendix.

C.1.2 MP-Series Calibration Target and Maintenance

Over time, the calibration target can accumulate moisture, especially in humid environments. Such accumulation of water can compromise LN2 calibration. This bulletin provides instructions for inspecting the calibration target and removing moisture from it.

Radiometrics recommends turning the cryogenic target upside down immediately after use to avoid moisture condensation and seepage downward into the Styrofoam-Mylar membrane interface.

Note:
Depending on environmental humidity, consider performing LN2 calibrations indoors or at a time of day when humidity is lowest.

Procedure

1. Remove the Styrofoam from the calibration target body (Figure C-5).

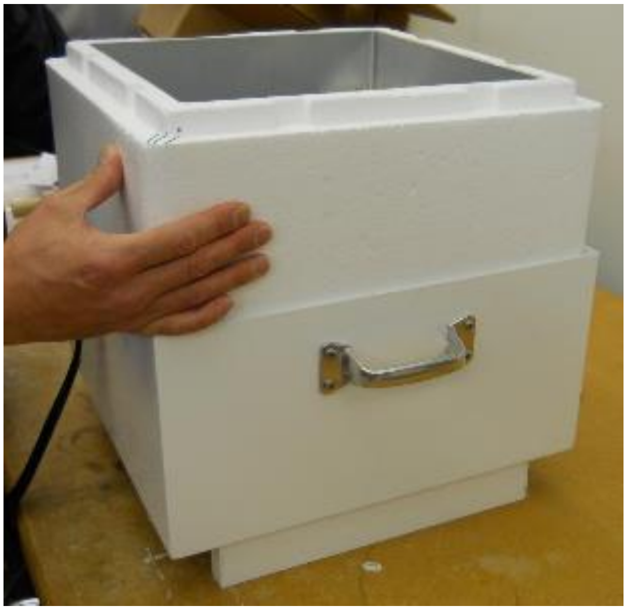

Figure C-5. Lifting Styrofoam box from the target body

2. Inspect the Styrofoam exterior for any cracks or damage, particularly the bottom side (Figure C-6).

Figure C-6. Inspecting Styrofoam

If Styrofoam is cracked or damaged, contact Radiometrics Corporation Customer Service, support@radiometrics.com or 303-449-9192.

3. Remove the metal frame and microwave-absorbing foam, being careful to not tear the protective liner (Figure C-7).

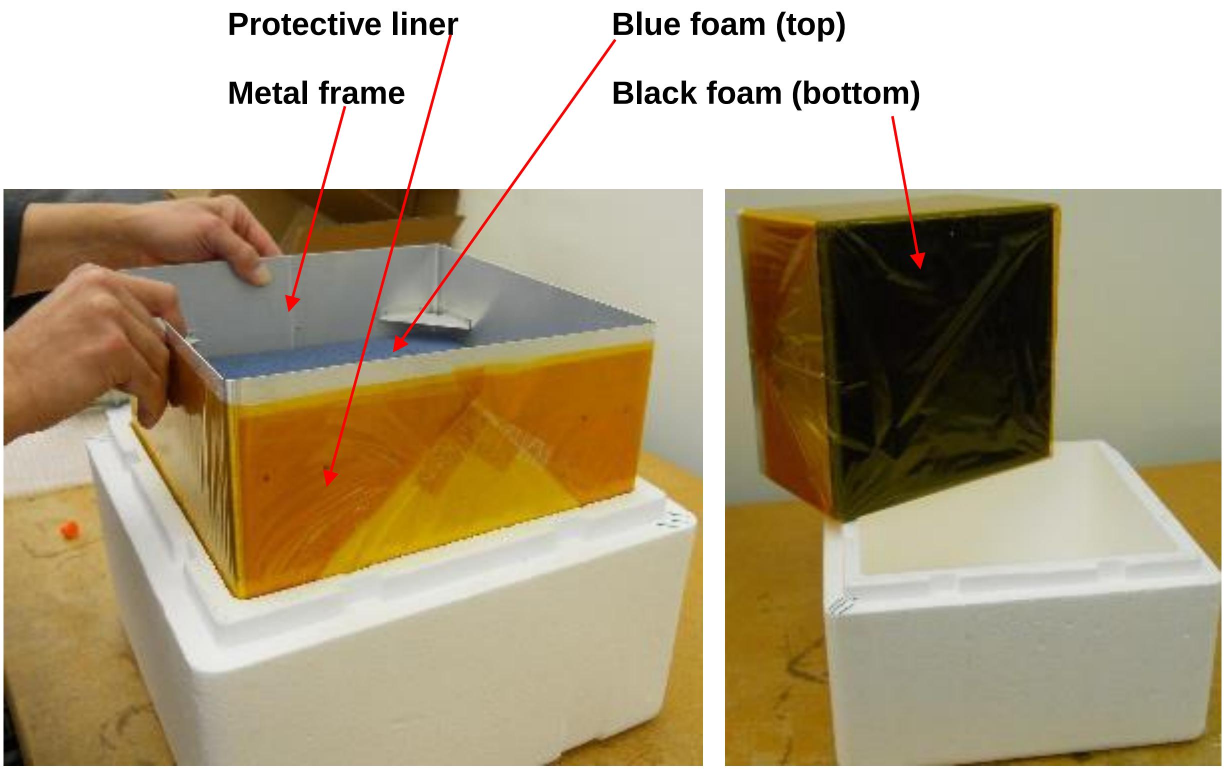

Figure C-7. Removing and inspecting microwave absorbing foam

If the protective liner is torn or damaged, contact Radiometrics Corporation Customer Service, support@radiometrics.com or 303-449-9192.

4. Inspect the bottom of the target for any moisture or condensation.
5. Carefully remove the protective liner and inspect the foam for moisture (Figure C-8).

Figure C-8. Untaping and removing protective liner

Both sides of the foam should be dry, not even moist. If the foam is not dry, drying may be achieved by the following:

- Placing the target foam in direct sunlight
- Using a hairdryer to dry the foam
- Placing the target foam in a warm, dry environment (not to exceed 45° C)

6. When finished examining or drying the foam, replace the protective liner around the metal frame and insert it back into the Styrofoam (Figure C-9).

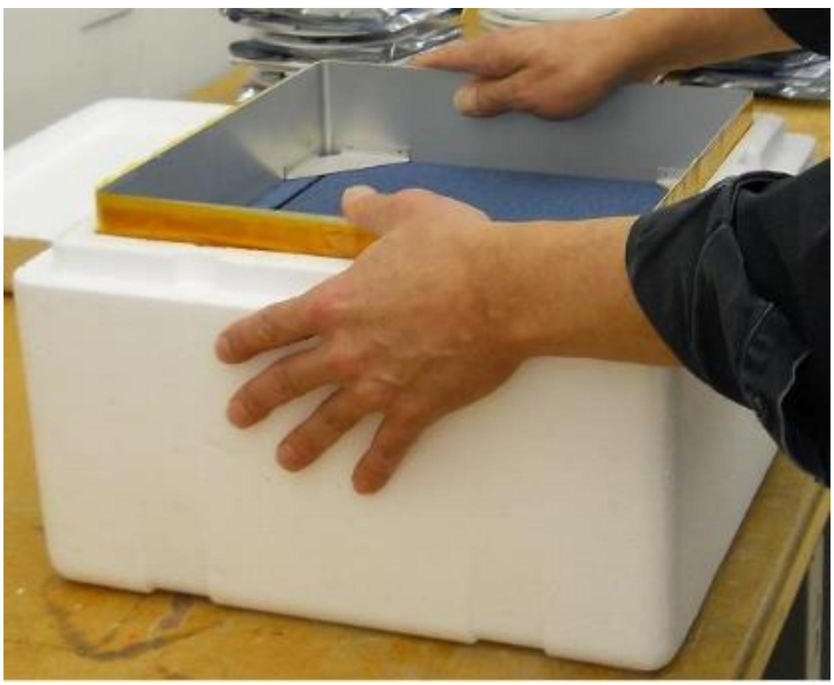

Figure C-9. Replacing the metal frame, target foam, and protective liner

C.1.3 Calibration procedure using the Single-User Interface:

Start the Operating Code in Manual Mode. Check the Tknd0 and Tknd1 temperatures for stability (323.15 K ± 0.1 K typical). When the instrument is ready, press **3** to start the LN2 Calibration. The calibration will begin automatically and continue until the user terminates it with a "**Q**" command (Quit).

Allow the calibration to continue for 1-2 hours, provided that dry conditions prevail, and condensation on the target is not observed or expected. If condensation on the bottom of the target is likely to form, due to high humidity (RH > 70%), then shorten the calibration to ~30 minutes.

During the calibration, the Operating Code will display the calibration elapsed time, and a graph of Tnd for each channel as shown in Figure C-10. LN2 calibration observations are logged in a file named **yyyy-mm-dd_hh-mm-ss_ln2.csv** where yyyy-mm-dd_hh-mm-ss is the start time of the calibration.

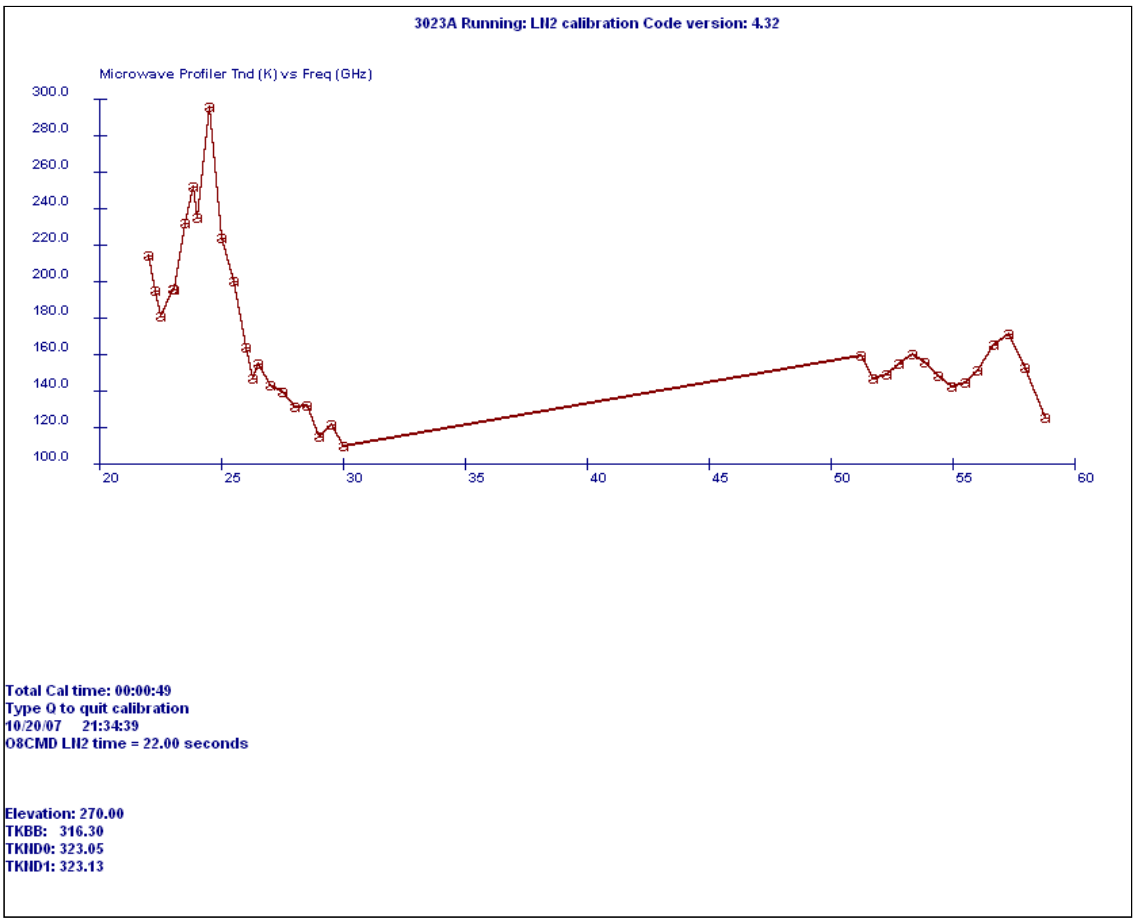

Figure C-10. LN2 calibration display

When the user presses the **Q** key to end the calibration, the Operating Code automatically computes new Tnd calibration values for all channels, and then terminates execution. The Operating Code writes these values to the operational configuration file (mp.cfg) and archives the previous configuration file with a file name indicating the date/time corresponding to the time of the calibration (i.e., 2007-01-10_18-29-16.cfg). The Operating Code logs the date of the user LN2 calibration in the new configuration file in the Channel Calibration Block.

There are two methods to verify that the calibration completed correctly. First, the new and previous configuration files can be opened and inspected using the text editor **Notepad**. When closing these files, be sure **not** to “save changes.” Unless the calibration follows repairs or changes to the hardware, the new values of alpha, dTdG and Tnd should be close to the previous values. Typically, alpha will be in the range of 0.9 to 1.1, dTdG will be in the range of -100,000 to -5,000,000, and Tnd will be within 1-2% of the value computed in the previous known good calibration. Departure from these guidelines may indicate a poor calibration.

Second, to verify that moisture did not corrupt the calibration, open and plot the values of Tnd in the LN2 calibration file (**yyyy-mm-dd_hh-mm-ss_ln2.csv).** If the values of Tnd are reasonably constant over time (only a small amount of random noise, but no long-term drift up or down), then the calibration is good. Figure C-11 shows a plot of the data in a typical MP-3000A LN2 calibration file. Notice that all channels remain constant over the duration of the calibration and the noise level is very low. These checks provide high confidence that a successful, accurate calibration has been achieved.

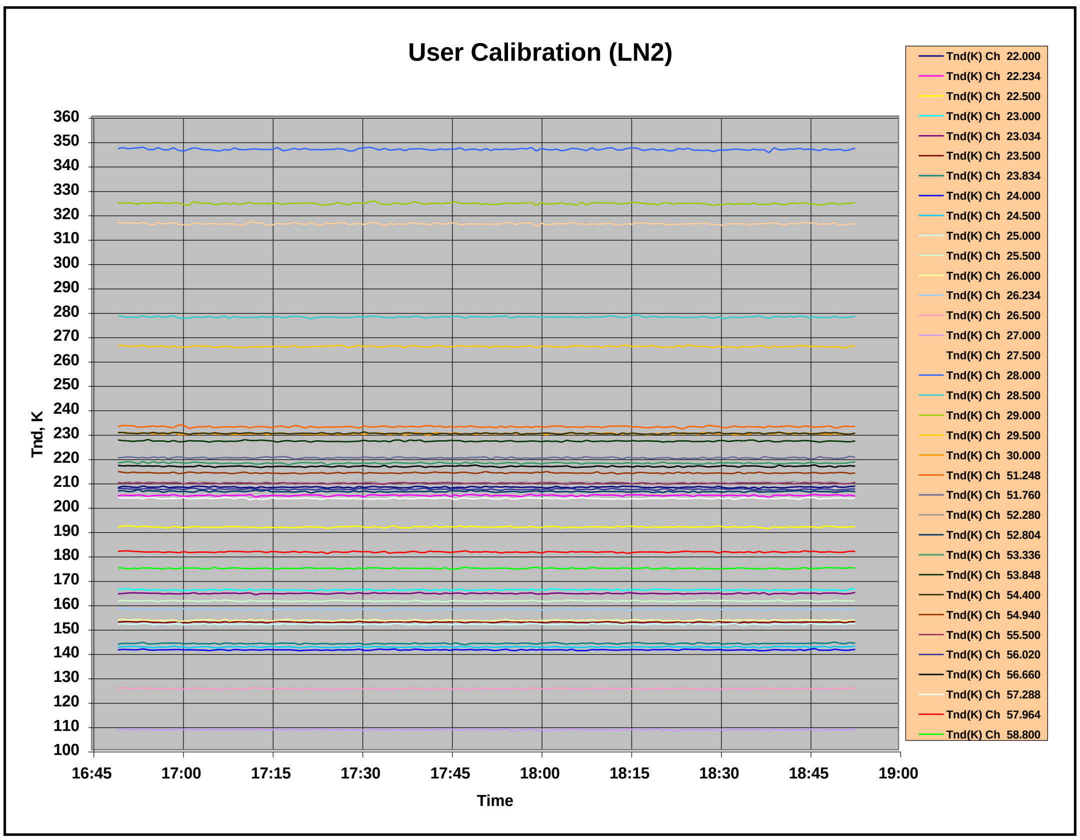

Figure C-11. Tnd values from user LN2 calibration (Excel plot)

C.1.4 LN2 Calibration Verification Test

While the target is still on the Saddle, the new calibration can be further verified by running a special procedure that alternates between views of the internal Black Body Target (elevation angle = 270 degrees) and the external cryogenic target (elevation angle = 90 degrees). It is best to start this verification immediately after the calibration completes, while the target still has sufficient LN2, and moisture has not started to build up on the bottom surface. A test Procedure File is included in the standard procedure list to do this. To run this procedure, restart the Operating Code (double click on the radiometer icon on the desk top), then select option **1** (Standard Procedure), then scroll to the Procedure File named B&L35.prc. Press **Return** to begin the verification procedure. Press **1** to select the Brightness Temperature Display. After a few observation cycles have completed, the display will begin showing the sky brightness temperature for all channels, switching back and forth between the internal ambient and external Cryogenic Targets.

If the calibration was successful, then the brightness temperatures for all channels should closely match the calculated values of the effective target temperature (typically, 77-80 K, depending on barometric pressure). If the target has not been moved on the Saddle, and the LN2 level has not dropped below the black absorbing foam in the target, then the average of the cryogenic target observation errors (observations minus effective target temperature) should be < 0.5 K. The average of the ambient target observation errors (target observation minus TkBB) should be < 0.5 K.

It is sufficient to observe the Brightness Temperature Display for a few cycles of the procedure to verify that all channels were calibrated reasonably well. However, to calculate the errors more precisely, allow the B&L35.prc procedure to run for approximately 1-2 hours, and then press **Q** to Quit. Open the new *level1* file in a spreadsheet or data analysis application to calculate the brightness temperature error (T_observed – T_target) for each record, and the average of the errors for each channel. Figure C-12, Figure C-13 and Figure C-14 show examples of the data from a post user cal B&L test. See Section 5 of the **Operator's Manual** for additional information on data files and data processing techniques.

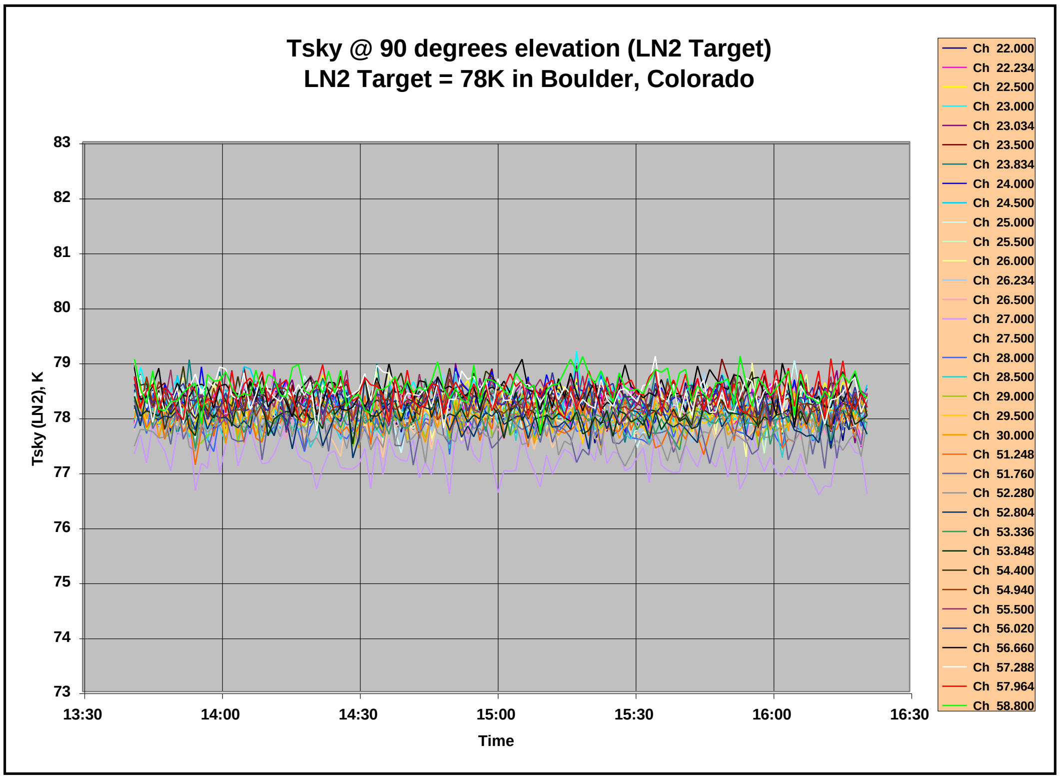

Figure C-12. Example of B&L Cryogenic Target for MP-3000A (Excel plot)

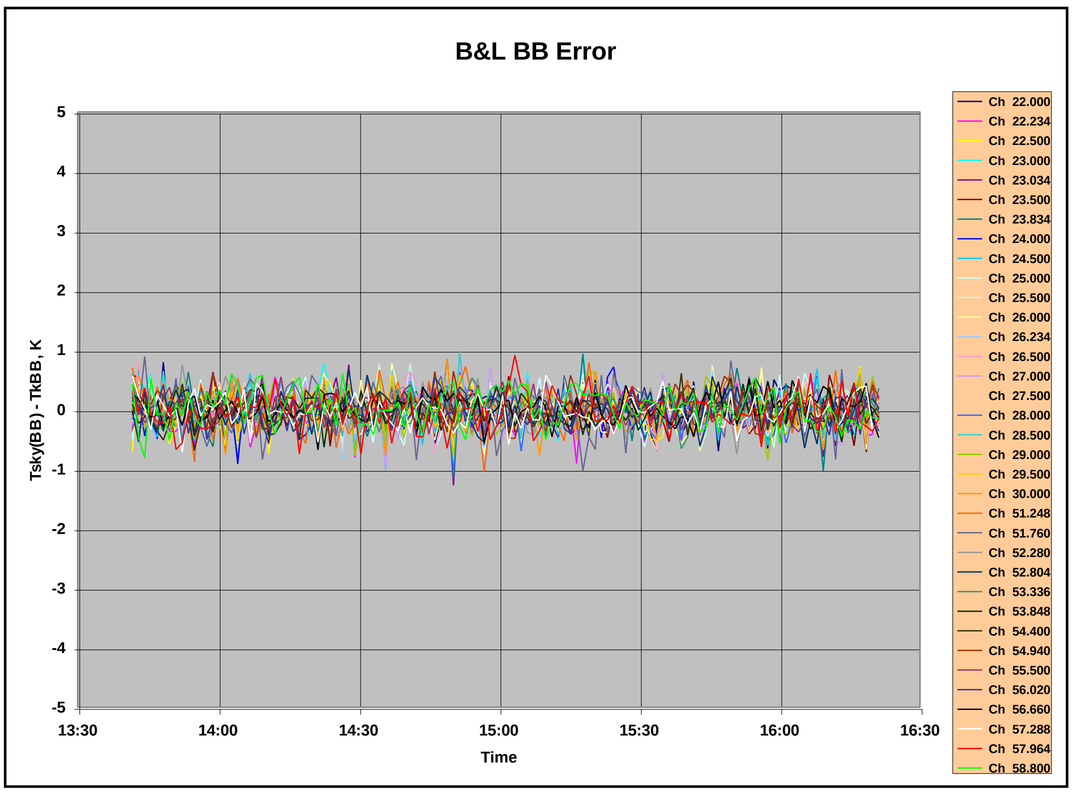

Figure C-13. Example of B&L temperature error for MP-3000A (Excel plot)

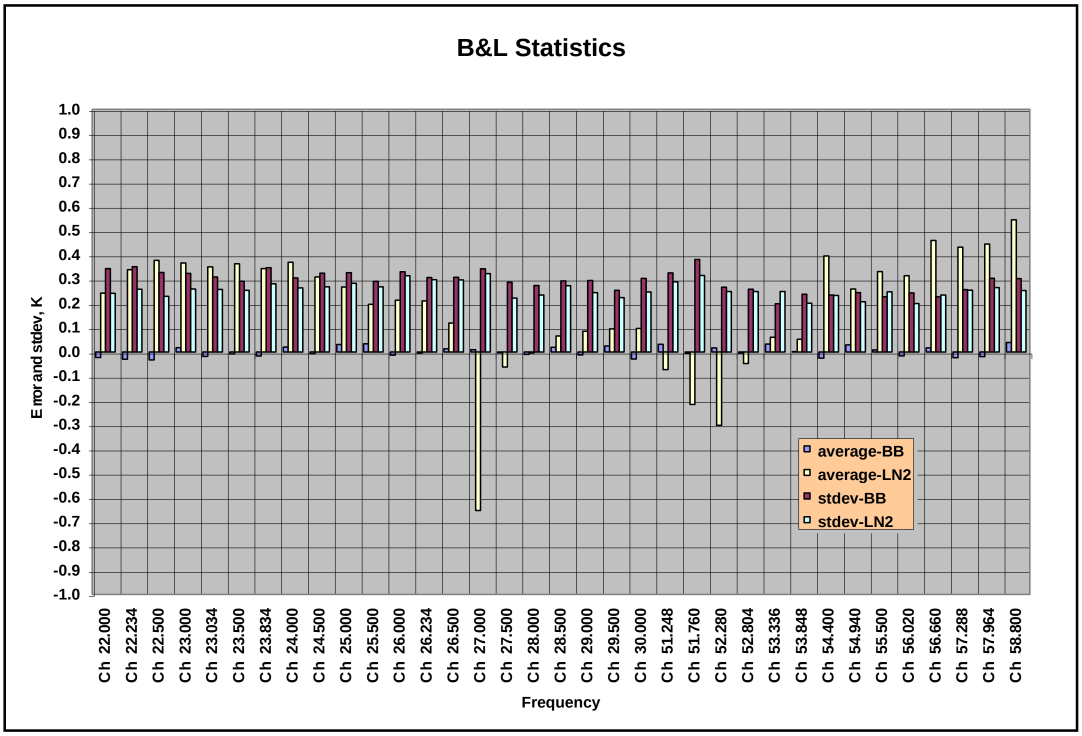

Figure C-14. Example of B&L statistics for MP-3000A (Excel plot)

C.1.5 LN2 availability, transport and storage

Nitrogen is the most abundant naturally occurring gas in the earth's atmosphere (78%). When we breathe, we breathe mostly nitrogen into our lungs. It is not toxic in normal concentrations. LN2 is used for many industrial and medical purposes. Because it is so abundant and nontoxic, it is relatively easy to manufacture and use. It is readily available from any industrial gas supplier. It is often available in limited quantities from local hospitals if there is no industrial gas supplier nearby.

LN2 is typically delivered from suppliers in large (160 liter) Dewars, as shown in Figure C-15. It can also be purchased in smaller quantities.

Figure C-15. Dewars used for storing and handling LN2

For short-term use, Dewars can be rented from many industrial gas suppliers. Dewars are also available for sale from Radiometrics. Dewars can be used to transport and short-term storage (typically less than 24 hours).

Figure C-16. Handling LN2: Filling Cryogenic Target (left)
Pouring residual LN2 into Dewar after calibration is finished (right)

Contact Radiometrics Customer Support for additional information on radiometer LN2 calibration.

C.2 Radiometer Calibration

There are seven parameters associated with every microwave channel that are individually calibrated to provide the highest level of accuracy overall operating conditions. The surface met sensors also contribute to the accuracy of level2 data products. Most of the Profiling Radiometer parameters that require calibration remain stable for many years. All these parameters are calibrated at the factory, *over the full operating temperature range*, and normally require no user adjustment. The seven factory-calibrated parameters associated with each microwave channel are:

- alpha linearity correction exponent
- dTdG 1/f noise suppression coefficient
- K1 zero order coefficient of Tnd temperature dependent correction
- K2 1st order coefficient of Tnd temperature dependent correction
- K3 2nd order coefficient of Tnd temperature dependent correction
- K4 3rd order coefficient of Tnd temperature dependent correction
- Tnd@290 effective Noise Diode Temperature at TkBB = 290K

These seven parameters are used to compute brightness temperature in accordance with the transfer function described in the Brightness Temperature Transfer Function section of **Appendix B**: Section 0.

The *effective* Noise Diode Temperature (Tnd) is very stable, but it should be recalibrated after transport of the instrument, and once every 3-6 months to ensure the highest accuracy. Two methods are available to calibrate the Noise Diode “secondary gain standards” using “primary standards.” The “LN2 calibration method” is applicable to all microwave channels in all models. The “TIP calibration method” is only applicable to the relatively transparent K band channels MP-3000A model. Each method has strengths and weaknesses described below.

The instrument configuration file (mp.cfg) contains all the settings and parameters associated with the operation of an instrument. The Channel Calibration Block in the configuration file contains the factory calibration data unique to each instrument RF subsystem. It contains data for each channel in each receiver (22-30 and 51-59 GHz as applicable). Figure C-17 shows an example of a typical Channel Calibration Block for the 35-channel MP-3000A.

CALIBRATION BLOCK:
2006/08/11 22:22:39 Date of last factory LN2 calibration
2007/03/02 18:03:04 Date of last user LN2 calibration
.90 :target tolerance for ln2 cal
35 :number of frequencies

Frequency	MRT	Window Coef	ND drive	IF Atten	alpha	dtdg	k1	k2	k3	k4	Tnd
22.000	275.0	0.000140	22000	18.5	1.0564	-8.89E+05	-7.51E+00	3.85E-02	-6.53E-05	7.53E-08	173.250
22.234	275.0	0.000140	22000	18.5	1.0437	-7.98E+05	-7.01E+00	1.01E-01	-5.24E-04	8.98E-07	155.140
22.500	275.0	0.000140	22000	18.5	1.0360	-7.91E+05	-2.16E+02	2.24E+00	-7.80E-03	9.12E-06	151.090
23.000	275.7	0.000140	22000	18.5	1.0218	-6.50E+05	-5.21E+01	4.92E-01	-1.61E-03	1.84E-06	144.360
23.034	275.7	0.000140	22000	18.5	1.0238	-6.53E+05	3.69E+01	-4.37E-01	1.61E-03	-1.87E-06	143.920
23.500	275.7	0.000140	22000	18.5	1.0181	-6.02E+05	-5.47E+01	5.40E-01	-1.85E-03	2.19E-06	159.320
23.834	276.0	0.000150	22000	18.5	1.0154	-6.53E+05	6.07E+00	-6.93E-02	1.81E-04	-4.79E-08	151.430
24.000	275.7	0.000140	22000	18.5	1.0184	-6.73E+05	-2.47E+01	2.18E-01	-6.54E-04	6.73E-07	145.060
24.500	275.7	0.000140	22000	18.5	1.0394	-7.63E+05	-3.68E+01	3.33E-01	-1.03E-03	1.11E-06	184.940
25.000	275.4	0.000164	22000	18.5	1.0519	-9.40E+05	1.33E+01	-1.59E-01	5.32E-04	-4.93E-07	141.490
25.500	275.4	0.000164	22000	18.5	1.0592	-9.36E+05	-1.28E+01	9.46E-02	-3.20E-04	5.06E-07	158.860
26.000	275.4	0.000164	22000	18.5	1.0712	-8.00E+05	3.20E+01	-3.60E-01	1.27E-03	-1.43E-06	137.290
26.234	275.4	0.000164	22000	18.5	1.0723	-7.10E+05	5.81E+01	-6.20E-01	2.13E-03	-2.34E-06	143.860
26.500	275.4	0.000164	22000	18.5	1.0685	-6.58E+05	-2.13E+01	2.44E-01	-1.02E-03	1.47E-06	168.390
27.000	275.4	0.000164	22000	18.5	1.0629	-5.87E+05	3.20E+01	-3.88E-01	1.46E-03	-1.72E-06	160.490
27.500	275.4	0.000164	22000	18.5	1.0537	-5.80E+05	-8.01E+01	8.46E-01	-3.08E-03	3.85E-06	187.580
28.000	275.4	0.000164	22000	18.5	1.0444	-6.39E+05	-3.38E+01	2.80E-01	-7.93E-04	7.88E-07	210.880
28.500	274.1	0.000200	22000	18.5	1.0407	-7.84E+05	-1.29E+02	1.32E+00	-4.64E-03	5.55E-06	213.600
29.000	274.1	0.000200	22000	18.5	1.0397	-1.11E+06	-1.22E+02	1.28E+00	-4.54E-03	5.45E-06	234.990
29.500	274.1	0.000200	22000	18.5	1.0347	-9.59E+05	-1.94E+02	2.03E+00	-7.11E-03	8.37E-06	189.640
30.000	274.1	0.000200	22000	18.5	1.0315	-1.21E+06	-8.08E+01	8.77E-01	-3.26E-03	4.11E-06	184.890
51.248	274.1	0.000200	45000	20.5	1.0500	-8.56E+05	2.01E+01	-1.14E-01	-2.95E-05	6.37E-07	181.500
51.760	274.1	0.000200	45000	20.5	1.0570	-1.28E+06	-4.52E+01	4.90E-01	-1.86E-03	2.46E-06	192.020
52.280	274.1	0.000200	45000	20.5	1.0590	-7.56E+05	-1.90E+01	2.16E-01	-9.93E-04	1.64E-06	226.450
52.804	274.1	0.000200	45000	20.5	1.0566	-7.62E+05	-4.76E+01	4.01E-01	-1.25E-03	1.50E-06	218.580
53.336	274.1	0.000200	45000	20.5	1.0512	-7.13E+05	-8.90E+01	9.01E-01	-3.22E-03	4.04E-06	165.690
53.848	274.1	0.000200	45000	20.5	1.0507	-7.36E+05	-1.06E+02	1.07E+00	-3.63E-03	4.20E-06	136.590
54.400	274.1	0.000200	45000	20.5	1.0547	-7.46E+05	-6.54E+00	3.19E-02	-8.58E-05	1.84E-07	138.260
54.940	274.1	0.000200	45000	20.5	1.0634	-9.87E+05	7.78E+01	-7.68E-01	2.40E-03	-2.32E-06	158.610
55.500	274.1	0.000200	45000	20.5	1.0600	-9.65E+05	-2.63E+01	2.35E-01	-8.44E-04	1.20E-06	168.490
56.020	274.1	0.000200	45000	20.5	1.0504	-7.68E+05	1.76E+01	-2.27E-01	8.05E-04	-8.00E-07	143.740
56.660	274.1	0.000200	45000	20.5	1.0603	-8.32E+05	-2.10E+01	2.05E-01	-7.54E-04	1.02E-06	118.280
57.288	274.1	0.000200	45000	20.5	1.0680	-1.06E+06	-4.07E+01	4.01E-01	-1.39E-03	1.70E-06	124.880
57.964	274.1	0.000200	45000	20.5	1.0545	-8.97E+05	9.25E+00	-8.72E-02	1.71E-04	6.80E-08	146.690
58.800	274.1	0.000200	45000	20.5	1.0574	-1.28E+06	-3.17E+01	2.92E-01	-9.91E-04	1.25E-06	138.380

Figure C-17. Example of Channel Block Configuration File

C.3 LN2 Calibration

The Noise Diodes in Profiling Radiometers are used as the “secondary standard” to measure *system gain* in each channel for each observation. When enabled, they add a calibrated increase to the brightness temperature. When the value of Tnd is not known, it can be determined by observing two targets of known temperature. In the fully automated method used by Radiometrics, the built in ambient Black Body target provides one target of known temperature for the calibration, and an external Cryogenic Target, filled with LN2, provides the second. The ambient target physical temperature (TkBB) is measured by the instrument each time a **Trcvcal** command is executed. The effective target temperature of the Cryogenic Target is calculated automatically by the Operating Code.

Contributions to Cold Target Temperature

Temperature contributions to the patented cryogenic calibration target developed by Radiometrics include:

- insertion loss of the polystyrene insulation that contains the target and absorbing foam (the insertion loss contributes to temperature by re-radiating to the same extent as the absorption)
- reflection from the polystyrene-LN2 interface
- reflection from the surface of the absorbing foam that is immersed in LN2
- elevation in boiling point of the LN2 due to the hydrostatic pressure associated with the depth

These contributions are automatically taken into account by the automated calibration through coefficients held in the configuration file (mp.cfg).

The boiling point of LN2 (TLN2) is a weak function of ambient barometric pressure P:

TLN2(K) = 68.23+0.009037*P(mb)

The physical temperature of the LN2 target is determined by the local LN2 temperature. The hydrostatic load must therefore be added to the atmospheric pressure at the surface of the LN2. This hydrostatic pressure enhancement is about 1.2 mb/cm of depth. At a 20 cm depth of LN2, the temperature increase is about 0.22° K. The various components contributing to the effective Black Body temperature are summarized in Table C-1. An ambient temperature of 300° K and a target temperature of 77° K are assumed.

Table C-1. Typical contributions to Cryogenic Target Black Body temperature

Contribution	Amount
Insertion loss at 55 GHz of polystyrene containing LN2	0.26° K
Air-polystyrene interface reflection	0.002° K
Polystyrene-LN2 interface reflection	1.74° K
LN2-absorbing foam interface reflection	0.00° K
Increase in boiling point due to 20 cm hydrostatic column of LN2	0.22° K
Total contribution at 300° K ambient temperature	2.22° K

LN2 Calibration Precautions

When performing the LN2 calibration, a number of precautions must be observed:

- To achieve the best possible calibration accuracy, the bottom of the target must be clean and dry. The Profiling Radiometer “looks” through the target bottom. Any dirt, debris, or moisture on the bottom of the target will contribute an error to the effective target temperature. If necessary, the target should be cleaned with mild soap and water, and allowed to thoroughly dry before use.
- The Profiling Radiometer must be at its stable operating temperature. Thus, the Profiling Radiometer should be turned on for a period of at least 30 minutes before the calibration begins. It is always best if the instrument has been on for several hours. (It is not necessary for the software to be running.)
- When LN2 is in the target, the outside will eventually cool, and may reach the atmospheric dew point temperature. This may cause condensation on the outside bottom surface of the target, which causes error. Therefore, the target should not be filled until shortly before calibration begins. The Superblower will help to minimize condensation, as will performing the calibration on days when the humidity is low (dew point is depressed). The user LN2 calibration may not produce accurate results if the ambient RH > 70%.
- The calibration procedure should be allowed to continue for 1-2 hours to obtain a large number of observations, thereby reducing measurement noise.

WARNING!
Contact with LN2 can cause burns and skin damage — handle with care!

LN2 User Calibration Procedure

NOTE:
Be sure to disconnect the Azimuth drive prior to calibrating the radiometer with LN2. LN2’s cold temperature could damage components of the Azimuth drive, if spillage were to occur.

TIP Calibrations

The use of an external Cryogenic Target is required to calibrate the Noise Diodes in 51-59 GHz receivers. The LN2 calibration process described above also calibrates the Noise Diode in the 22-30 GHz receiver. However, because the zenith brightness temperature in the 22-30 GHz band are typically less than 50 K under clear skies, the 22-30 GHz receiver Noise Diode can also be calibrated using a “TIP derived calibration.” In this method, the Profiling Radiometer uses the atmosphere itself as a “cold target.” By observing the brightness temperature of the sky at several elevation angles in rapid succession, the Profiling Radiometer can calculate an estimate of the 22-30 GHz Noise Diode temperatures. The 51-59 GHz Noise Diodes cannot be reliably calibrated using the TIP method due to the relatively small temperature difference observed between the built-in ambient Black Body target and some of the more opaque channels.

LN2 vs. TIP Calibrations: Strengths and Weaknesses

The LN2 and TIP calibration methods each have their own strengths and weaknesses. The following example will illustrate why the LN2 calibration method works best for the 51-59 GHz band, while the TIP method has certain advantages in the 22-30 GHz band.

Assume for the purpose of this cryogenic calibration example that the ambient Black Body target is at 278 K, and there is no ambient target error. Then assume a cryogenic LN2 target at 78 K, but with a 2 K error. This effective LN2 target temperature error will produce a sky brightness temperature with a 1% gain error [2/(278-78)]. This manifests as a 2 K error for Tsky = 78 K, a 1 K error for Tsky = 178 K, but only 0.2 K error for Tsky = 258 K. Since most 51-59 GHz channels produce sky brightness temperatures much closer to ambient than the Cryogenic Target (78 K), a relatively large target error does not impact the 51-59 GHz channels as much as it would a 22-30 GHz channel, where the sky brightness temperature is sometimes less than 10 K. Thus, for a given effective LN2 target temperature error, the impact is generally much less in the 51-59 GHz channels than it is in the 22-30 GHz channels. Fortuitously, the TIP calibration method works best on the coldest radiometer channels, where the Cryogenic Target is weakest, and the Cryogenic Target works best for the warmest channels, where the TIP method breaks down.

Of course, the TIP calibration method also has error sources, but for 22-30 GHz, these errors can be managed to a level lower than the typical Cryogenic Target induced error. To obtain a high quality TIP calibration, make sure the Profiling Radiometer is level, and use a spreadsheet to select only data from observation periods when the atmosphere is very stable. This process will be described in detail in Section 0.

TIP Calibration Procedure

To calibrate the 22-30 GHz channels with the TIP method, use the following procedure:

1. Specify the elevation angles to be used in the TIP Configuration section of the configuration file (mp.cfg), if necessary. The default values (30, 45, 90, 135, 150 degrees) usually provide excellent results. In most cases, the use of complementary angles (i.e., 30 and 150) will provide the best results since they tend to compensate for instrument leveling error and atmospheric gradients.

2. Collect TIP data for at least a few hours during a time when the atmosphere is generally stable. A full day or more may be necessary at times and in areas where the atmosphere is rarely stable. If necessary, collect TIP data for several days to make sure a stable period is included. Select a Procedure File that includes frequent periodic **cal21** commands. The **cal21** command collects TIP calibrations on all 21 K band channels. The standard Procedure File xxx_zen_ret_tip.prc (where xxx is the site code) will produce alternating TIP calibrations, zenith observations and 26 input zenith NN retrievals. New TIP data

and the current operational values of Tnd can be viewed graphically in real-time by pressing the T key to check for differences.

3. Use VizMet-B to select and transfer TIP calibrations.

Surface Met Sensor Calibration

The Surface Met Sensors include ambient air temperature, relative humidity, barometric pressure, IRT, and rain. All Profiling Radiometers are delivered with the Met Sensors pre-calibrated at the factory, ready to use. This Section provides general information about the Met Sensors. For detailed information on the maintenance and calibration of these sensors, refer to **Section 6** of the **Operator's Manual**.

Temperature and Relative Humidity Sensor

Radiometrics Profiling Radiometers are fitted with a Rain Mitigation System consisting of the Superblower and the hydrophobic radome. The Superblower uses increased airflow, but no heater (as used in previous models) to keep the radome dry.[2] The Superblower incorporates an ambient air temperature and RH sensor in the air-inlet where unbiased ambient air is constantly flowing over the sensor. The Superblower assembly also shades the sensor from direct sun. The sunshade and continuous airflow ensure negligible bias due to solar radiation.

Figure C-18. Superblower with End Cover removed; sensor and filter

The sensor is factory calibrated to a high standard, and normally requires no field calibration. If the user has access to very high accuracy field standards for Tamb and RH, and wishes to adjust the sensor calibrations in the field, linear offset values may be entered in the configuration file (mp.cfg) in place of the default values (0.0) as follows:

+0.00 :Tamb correction

+0.00 :Rh correction

Offset values for Tamb and RH are *added* to the measured values. For example, if the temperature observed with a high quality standard (placed close to the inlet of the

[2] Elimination of the heater eliminates one source of locally generated error in ambient temperature and RH measurements.