Interim **Profiler Operator's Manual**

- **TP/WVP-3000A**
- **TP-2500A**
- **WVP-1500A**

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Release Notes

Manual Version MetRI

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IMPORTANT: This revised operator's manual, **Version MetRI,** is an ***interim manual*** for the MetRI TP/WVP-3000A. Much of the content herein is applicable to the TP/WVP-3000A, but there are some differences. The infrared thermometer (IRT) is now mounted inside the cabinet. This new generation instrument is much more capable than the previous radiometer family described in this manual. The final manual is currently being written and will be furnished to the customer as soon as completed and final proof reading is performed.

The operation of the new Graphical User Interface software is described in a separate document entitled "TP/WVP-3000A Graphic User Interface Presentations." This interim manual in combination with the Graphic User Interface document will furnish sufficient information to operate the radiometer.

Examples of Procedure file commands are given on the 1-page document entitled "procedure examples.doc."

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1 General Description

1.1 Introduction

This manual provides information on the operation of Radiometrics' family of portable, profiling microwave radiometers. Information on the following models is included:

- **TP/WVP-3000A** Dual Band for Temperature, Water Vapor & Liquid Water Profiles
- **TP-2500A** 51-59 GHz for Temperature Profiles
- **WVP-1500A** 22-30 GHz for Water Vapor Profiles

All three models share the same basic hardware platform and use the same software. Operation of the three models is the same except as noted in this manual. Throughout this manual, the term "Profiling Radiometer" is used to refer to all models of the Radiometrics family of portable profiling radiometers.

Radiometrics Profiling Radiometers produce vertical profiles from the surface to 10 km in height. The TP/WVP-3000A produces temperature and water vapor profiles, and low-resolution liquid profiles. The TP-2500A produces temperature profiles only, and the WVP-1500A produces water vapor profiles only.

Figure 1. TP/WVP-3000A without optional Azimuth Positioner.

The TP/WVP-3000A includes two radio frequency (RF) subsystems in the same cabinet that share the same antenna and antenna pointing system. The temperature profiling (TP) subsystem utilizes sky observations at selected frequencies between 51 and 59 GHz. The water vapor profiling (WVP) subsystem receives at selected frequencies between 22 and 30 GHz. The TP-2500A uses only the 51-59 GHz subsystem, and the WVP-1500A uses only the 22-30 GHz subsystem. Surface meteorological sensors (Met Sensors) measure air temperature, relative humidity and barometric pressure. To improve the measurement of water vapor and cloud liquid water density profiles, the TP/WVP-3000A also measures cloud base temperature using a zenith-pointed infrared thermometer (IRT). All Profiling Radiometers have been designed for ease of use, accuracy, reliability, portability, and operation on a minimum of power. They only use passive technology, thus they do not emit any detectable radiation. The TP/WVP-3000A is shown in Figure 1 with the optional Azimuth Positioner mounted on the Radiometrics model TP-2000 Telescoping Tripod.

Profiling Radiometers are installed outdoors, normally on the TP-2000 Tripod. However, the user may supply an alternative compatible mounting platform. The instrument must be located where primary power is available (normally 115VAC or 230VAC), and the antenna system must have a clear view of the sky, from horizon to horizon, in at least one vertical plane. If the optional Azimuth Positioner is installed, a clear view of the sky is required for all azimuth and elevation angles of interest. Detailed installation requirements are provided in Section 3, Installation.

The Profiling Radiometers are controlled by Radiometrics proprietary software, referred to herein as the "Operating Code".[1] The Operating Code may be installed on any computer fitted with either a Microsoft Windows 2000 or XP operating system. The computer may be connected directly to the Profiling Radiometer via an RS232 cable, or it may be connected over a local area network (LAN) using a serial port server.[2] Four or more Profiling Radiometers can be operated using a single Windows computer. Operation of multiple Profiling Radiometers from a single Windows computer ensures precise time synchronization of all data. With appropriate configuration of the user's LAN Firewall, one or more Profiling Radiometers may be operated remotely via a serial port server and the Internet.

A laptop computer with all required software preloaded and configured is normally supplied. The user may specify the "no computer option", in which case the software is supplied on a CD with instructions for installation by the user on a user supplied Windows 2000 or XP computer.

When first started in Manual Mode[3], the Operating Code performs an automated power-on self-test, and then presents a menu of options. The user may choose to begin automatic operations immediately using: (1) one of several factory-supplied "Procedure Files", (2) a previously saved user-defined Procedure File, or (3) an automated liquid nitrogen (LN2) calibration may be selected.[4] Procedure Files contain a list of high-level commands that can be scheduled to execute at specific *absolute* times, or executed sequentially without any delay between commands (*relative* times).

[1] As of 22 August, the latest release of the Operating Code is V3.24. This manual describes the operation of the instruments with V3.24. V3.24 is functionally equivalent to V3.21 except for the addition of the gps command. Later releases may have slightly different features.

[2] For compatible serial port servers, contact Radiometrics Sales and Marketing

[4] As discussed in detail in later sections, liquid nitrogen is used seasonally with an external target to calibrate the internal *Noise Diodes* used operationally for continuous system gain measurements.

Once an option is selected from the menu, the Operating Code begins logging data to *level0* files (raw sensor data in volts), *level1* files (brightness temperatures), *level2* files (profile retrievals), and *TIP*[5] calibration data files. Real-time graphics of the *level1* and *level2* products, related to the specific option selected, are displayed. Real-time graphics for the TP/WVP-3000A include:

- Met Sensor time series (*level1* data)
- Brightness Temperature time series (*level1* data)
- Temperature, Water Vapor, Liquid Water, and Relative Humidity (RH) Profiles and column integrated vapor and liquid (*level2* data)
- TIP calibration derived values of Noise Diode Temperatures (Tnd_TIP)
- LN2 calibration derived values of Noise Diode Temperatures (Tnd_LN2)

The Operating Code can also be programmed to run automatically under the Windows Operating System Task Scheduler ("Scheduler"). Typically, Procedure Files used with the Scheduler contain all the commands required for a 24 hour observing period, and the Scheduler is used to schedule automated re-launch of the Operating Code every day at 00:00 GMT using a specified Procedure File. Scheduled this way, the Profiling Radiometer Operating Code will produce continuous 24-hour data sets indefinitely, without user intervention.

The Operating Code translates the high-level commands contained in the selected Procedure File into a series of detailed commands that are sent to the Profiling Radiometer. The Profiling Radiometer performs the requested command and responds with a message containing the data or status requested. The Operating Code then processes and logs the raw data to *level0*, *level1* and *level2* files as described in Section 6, Data Collection and Processing.

[5] The term "TIP" is used herein to refer to the TIP calibration method widely described in the literature, where in the radiometer antenna is tipped to several elevation angles to calibrate the radiometer gain standards (Noise Diodes).

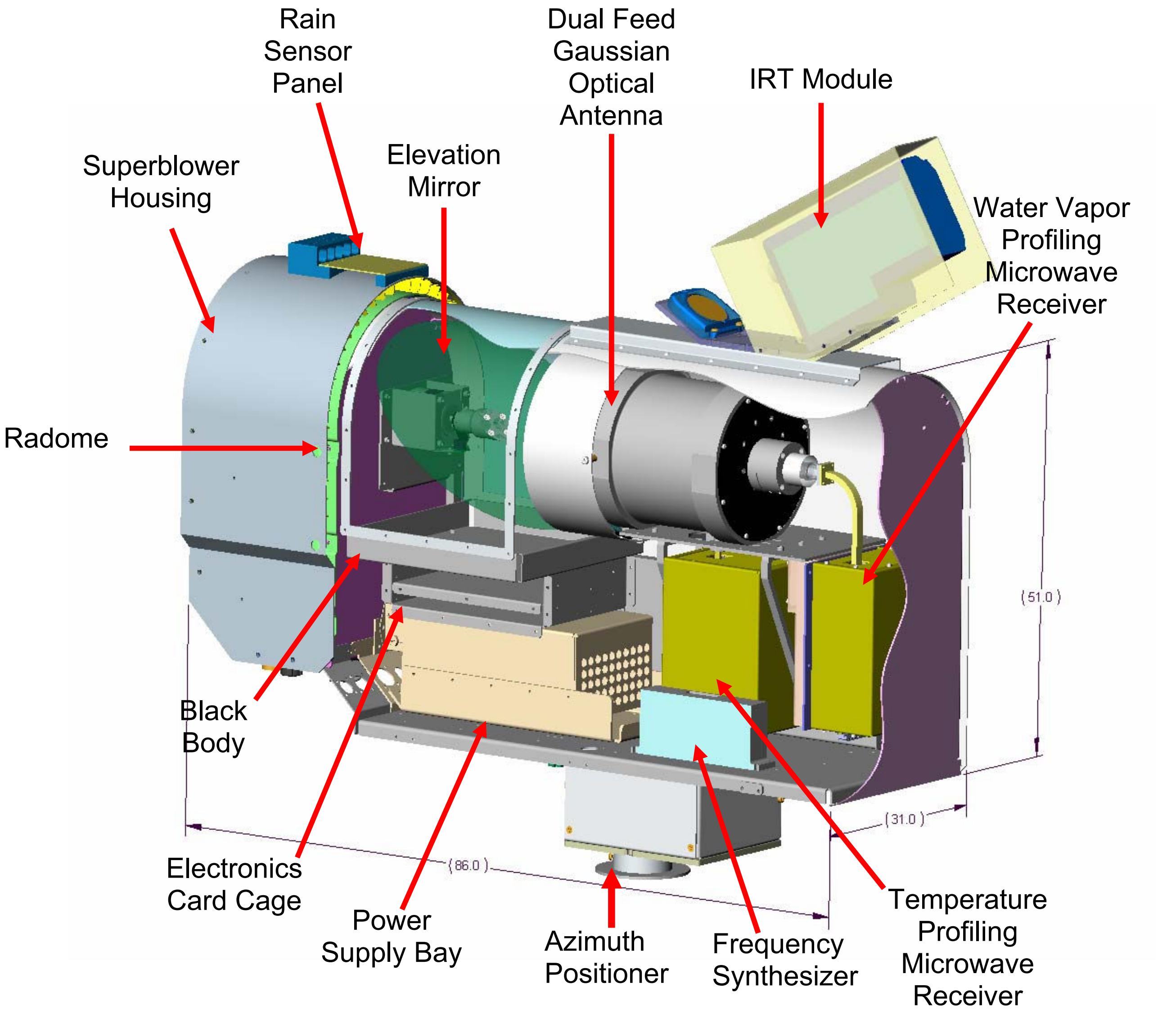

Figure 2. TP/WVP-3000A cut-away diagram.

A cut-away diagram of the Profiling Radiometer is shown in Figure 2. Liquid water on the antenna radome (also referred to as the "microwave window") can cause error in the observed brightness temperature. To minimize such error, the Profiling Radiometer radome is made hydrophobic to repel liquid water, and a special blower system (the Superblower) is used to sweep water beads and snow away from the radome. The ambient temperature and relative humidity sensors are integrated in the inlet of the blower system to ensure a steady flow of ambient air over the sensors. A rain sensor is mounted on the top of the blower system. The ambient barometric pressure sensor is located inside the cabinet to minimize the range of sensor ambient temperature. The IRT views the sky via a user replaceable low-loss mirror.

1.2 Instrument Specification

Function or Parameter	Specification
Calibrated Brightness Temperature Accuracy[6]	0.2 + 0.002*|TkBB-Tsky| [7]
Long Term Stability	<1.0 K / yr typical
Resolution (depends on integration time)[8]	0.1 to 1 K
Brightness Temperature Range[9]	0-400 K
Antenna System Optical Resolution and Side Lobes 22-30 GHz 51-59 GHz	 4.9 - 6.3° -24 dB 2.4 - 2.5° -27 dB
Integration Time (user selectable in 10 msec increments)	0.01 to 2.5 seconds
Frequency Agile Tuning Range Water Vapor Band Oxygen Band Minimum Frequency step size	 22-30 GHz 51-59 GHz 4.0 MHz
Standard channels used for profiles TP/WVP-3000A TP-2500A WVP-1500A	 26 7 14
Spectrum Analyzer Mode [10] (brightness temperatures only)	Up to 40 channels
Pre-detection channel bandwidth (effective double-sided)	300 MHz
Surface Sensor Accuracy Temperature (-50° to +50° C) Relative Humidity (0-100%) Barometric pressure (800 to 1060 mb) IRT[11] (Note: ΔT = Tambient - Tcloud)	 0.5° C @ 25° C 2 % 0.3 mb (0.5 + .007*ΔT)°, C
Brightness Temperature algorithm for *level1* products	4 point nonlinear model
Retrieval algorithms for *level2* products	Neural Networks

[6] Specified accuracy for instrument calibrated with an external target with no error.
[7] Absolute accuracy is best for sky brightness temperatures close to ambient, such as for the highest V band channels, and degrades as the absolute difference between the black body reference and sky temperatures increases.
[8] Typical resolution for 250 msec integration time is 0.25 K.
[9] Wider ranges are available. 0-400K is optimum for meteorological applications.
[10] Use of the Spectrum Analyzer Mode requires optional factory calibration for the specific frequencies of interest. Up to 40 evenly spaced frequencies can be scanned in one band (all models), or split between both bands (TP/WVP-3000). For example, 17 evenly spaced channels from 22-30 GHz and 17 evenly spaced channels from 51-59 GHz could be specified for use with the TP/WVP-3000, resulting in 17 channels in each band, evenly spaced 500 MHz.
[11] The standard Field of View (FOV) = 5°. Other lenses are available.

Function or Parameter	Specification
Calibration Systems Primary standards Operational standards	 LN2 and TIP methods Noise Diodes + ambient Black Body Target
Environmental Operating Range Temperature Relative Humidity Altitude Wind (operational/survival)	 -40° to +40° C 0-100 % -300 to 3000 m 100 km/hr / 200 km/hr
Physical Properties Size (H X W X L) Mass	 50 X 28 X 76 cm (add 17 cm to height for IRT) 29 kg
Power requirements Radiometer (100 to 250 VAC / 50 – 60 Hz) Superblower (100 to 125 VAC / 50 – 60 Hz)[12]	 200 watts max 100 watts max
Data Interface Primary computer port Auxiliary port Standard cable length[13]	 RS232 38.4 Kbaud RS232 1.2 to 38.4 Kbaud 30 m
Data File Formats	ASCII CSV (comma separated variables)

Table 1 Instrument Specifications.

1.3 Radiometer Theory of Operation

This section describes the theory of operation for the TP/WVP-3000A model. The theory of operation also applies to the TP-2500A and WVP-1500A models, within the bands observed by those instruments.

Microwave profiling methods make use of atmospheric radiation measurements in the 22 to 60 GHz region. The zenith path atmospheric absorption spectrum at sea level for a typical mid latitude atmosphere with a 1 km thick, 0.5 g/m^3 cloud in this frequency band is shown in Figure 3. Two altitudes and two water vapor densities are shown as well as radiometer

[12] The Superblower is supplied with an auto transformer for operation from 230 VAC. A special order 230 VAC Superblower is also available.
[13] For cable lengths longer than 30 m, optional RS422 converters are available for cable lengths up to 1000 m.

tuning bands, marked by bold lines. The feature at 22.2 GHz is a water vapor resonance that is pressure broadened according to the pressure altitude of the water vapor distribution, while the feature at 60 GHz is an assemblage of atmospheric oxygen resonances. The cloud liquid water emission spectrum increases approximately with the second power of frequency in this region.

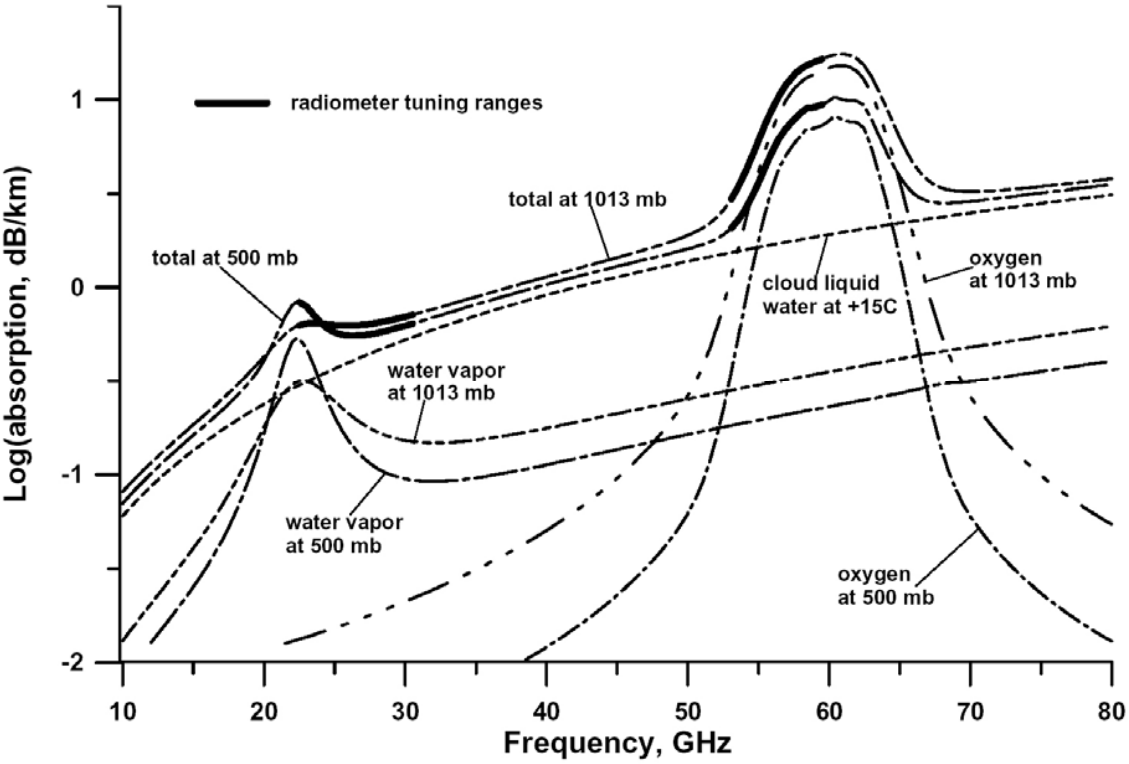

Figure 3. Absorption spectrum for two altitudes and water vapor densities.

Temperature profiles can be obtained by measuring the radiation intensity, or brightness temperature, at points along the side of the oxygen feature at 60 GHz. By scanning downward from line center, where the opacity is so great that all signal originates from just above the antenna, onto the wing of the line, where the radiometer “sees” deeper into the atmosphere, the instrument can obtain altitude information. Emission at any altitude is proportional to local temperature and density of oxygen; thus the temperature profile can be retrieved.

Water vapor profiles can be obtained by observing the intensity and shape of emission from pressure broadened water vapor lines. The water vapor line at 183 GHz is used for vapor profiling from satellites. The high opacity of this line hides the unknown emission emanating from the earth’s surface, eliminating this error source, but precluding profiling to low altitudes. The 183 GHz line is too opaque for observations from the ground, except in extremely arid environments. The line at 22 GHz is too transparent for effective profiling from satellites, but is suitable for ground based profiling in most areas. The emission from water vapor is in a narrow line at high altitudes and is pressure broadened at low altitudes. The intensity of emission is proportional to vapor density and temperature. Scanning the spectral profile and mathematically inverting the observed data can therefore provide water vapor profiles.

Limited resolution cloud liquid water profiles can be obtained by measuring the contribution of cloud liquid water to atmospheric spectral features of varying opacity. There is cloud liquid profile information in the combined 22 to 30 GHz and 51 to 59 GHz tuning bands utilized by the TP/WVP-3000A radiometer. Cloud base altitude information from a ceilometer or IRT improves the water vapor and liquid water profile retrievals.

Pressure broadening of the water vapor line near 22 GHz and the zenith absorption of the atmosphere in the vicinity of the assemblage of oxygen lines centered at 60 GHz at sea level and at 200 mb are shown in Figure 4. Pressure broadening smears the numerous oxygen lines into one feature. The TP/WVP-3000A radiometer tunes from 22 to 30 and 51 to 59 GHz.

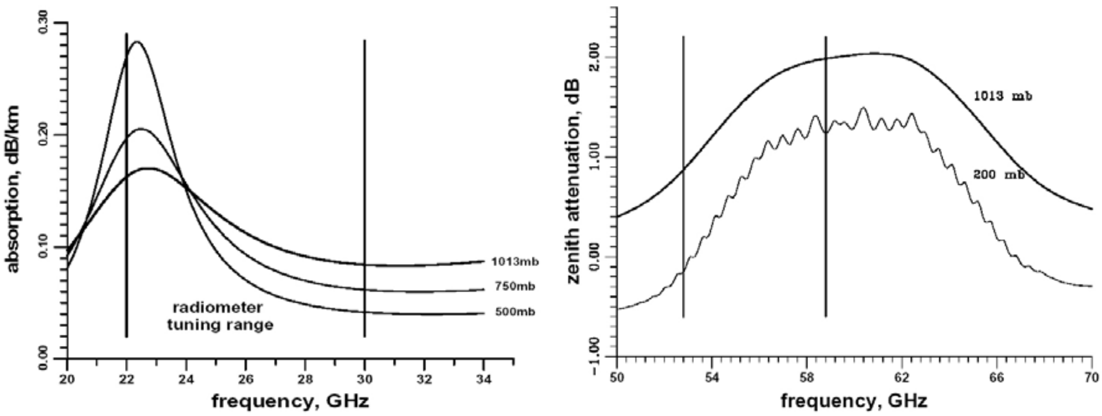

Figure 4. Atmospheric absorption spectra near 22 and 60 GHz.

Surface relative humidity, temperature, and barometric pressure are measured by the Profiling Radiometer and used in the determination of profiles. Additionally, a vertically pointed infrared thermometer (IRT) indicates the presence of cloud, and measures cloud base temperature if clouds are present. Knowing cloud base temperature yields the vapor density at cloud base (at saturation), and combined with the retrieved temperature profile, yields cloud base altitude. These physical measurements are important constraints for profile retrieval.

1.4 Brightness Temperature Transfer Function

All Profiling Radiometers use a state-of-the-art algorithm and calibration system to derive sky brightness temperature from the *level0* observations (receiver detector output voltage). This algorithm makes use of factory measured calibration coefficients to compensate for the small but finite effects of ambient temperature and system non-linearity. The algorithm and calibration system also include proprietary methods for the elimination of “1/f” noise in observations, thereby significantly reducing the overall noise compared to competing technologies. The transfer function is as follows:

$$\mathbf{Tsky = (Vsky/gain\_sky)^{\wedge}(1/\alpha) - Trcv\_sky}$$

Where measured values are:

Vsky = **integrated receiver output from a sky observation with Noise Diode off**

Vsky_nd = **integrated receiver output from a sky observation with Noise Diode on**

Vbb = **integrated receiver output from an ambient Black Body target observation with Noise Diode off**

Vbb_nd = **integrated receiver output from an ambient Black Body target observation with Noise Diode on**

TkBB = **Black Body target effective radiation temperature**[14]

Where calibrated parameters are:

α = **non-linearity correction exponent**

Tnd290 = **Noise Diode temperature @ TkBB = 290K**

K1 - K4 = **factory calibrated temperature coefficients**

dTdG = **receiver hardware specific parameter**

Where calculated values are:

gain_sky = **gain during sky observation = [(Vsky_nd^(1/α) – Vsky^(1/α))/(Tnd290 + TC)]^α**

Trcv_sky = **Receiver temperature during sky observation = Trcv_bb + dTdG*(gain_sky – gain_bb)**

gain_bb = **gain during ambient Black Body Target observation = [(Vbb_nd^(1/α) – Vbb^(1/α))/(Tnd290 + TC)]^α**

Trcv_bb = **Receiver temperature during ambient Black Body Target observation = (Vbb/gain_bb)^(1/α) – TkBB**

TC = **K1 + K2*TkBB + K3*TkBB^2 + K4*TkBB^3**

1.5 Profile Retrievals from Observations

Extensive analysis indicates that artificial neural networks outperform other methods for retrieving water vapor, cloud liquid water, and temperature profiles from radiometric data. The Profiling Radiometers therefore use this mathematical inversion method for profile determination. The neural networks are derived using the *Stuttgart Neural Network Simulator* and a history of radiosonde profiles. A standard back-propagation algorithm is used for training, and a standard feed-forward network is used for profile determination. Profiles are output in 100 meter altitudes up to 1 km and 0.25 km from 1 to 10 km.[15] Although the number of independent measurements (eigenvalues) is less than the 47 retrieved layers output, the finer "resolution" provides better displays and easier processing in subsequent data processing steps. Above approximately 7 km, the atmospheric water vapor density and temperature approach the climatological mean values.

[14] TkBB is the measured physical temperature of the ambient Black Body target adjusted for implementation bias.
[15] Output at 50m or other altitude increments is available by special order.

1.6 Radiometer Error Sources

The operator should be aware of the following error sources:

- The Sun is a 6,000 K Black Body radiator. The angular area of the sun is ~ 1% that of the antenna, so pointing the Profiling Radiometer at the Sun will increase the signal by ~ 60 K. If the Sun is in the first antenna sidelobe (~ 10 degrees off the antenna pointing axis), it will cause an increase in brightness temperature of ~ 1 K. Observations should therefore be avoided in directions within ~15 degrees of the Sun position.

- Neural network retrieval algorithms are somewhat site dependent, especially for retrieval of water vapor and liquid water. The operator should ensure that the retrieval coefficients are representative for the observation site. Such retrieval coefficients are generated from a history of radiosonde (RAOB) data from the same or a representative site.

- Liquid water on the Profiling Radiometer radome can result in artificially high radiometer brightness temperature measurements. However, the Rain Effect Mitigation (REM) system, which includes the hydrophobic radome and Superblower (patent pending), minimizes the accumulation of liquid water on the radome and provides measurement capability during precipitation.

- Radio frequency interference (RFI) can cause “spikes” in the data. Although Radiometrics has implemented RFI protection throughout the systems, strong transmitters, especially in the 40 to 200 MHz, 22 to 30 GHz, and 51 to 59 GHz regions can interfere with the Profiling Radiometer receivers. Observations are averaged to minimize this effect. However, spikes with a magnitude greater than several Kelvins can affect the accuracy of the retrieved profiles. The Profiling Radiometer should be installed in a location that is isolated or shielded from strong radio transmitters.[16]

- Calibration error will degrade the inherent instrument accuracy. Noise Diodes provide an accurate, high stability operational gain reference, but they are only as accurate as the accuracy of the primary standards used to calibrate them. Care should be taken when calibrating the Noise Diodes using either of the methods described herein. The internal ambient Black Body target provides a means to calibrate the system temperature, from which the receiver temperature is derived. The receiver temperature is very stable, so observations of the Black Body target can be relatively infrequent. To minimize Trcv error during periods of rapidly changing ambient temperature, Black Body calibrations should be performed every 5 minutes or more often.

- In all radiometers, the system gain fluctuates with “1/f noise”, resulting in added random noise in the observations. For typical integration times (~1 sec), 1/f noise can be dominant. All Profiling Radiometers use Radiometrics’ proprietary calibration methods and transfer function to virtually eliminate 1/f noise contributions.

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[16] Note that Radiometrics patented frequency agile architecture uniquely provides the means to select RFI-free channels within each band to mitigate RFI problems, should they develop. If the user suspects RFI problems, contact Radiometrics for assistance in programming alternative frequencies.

2 Profiler Components

2.1 Overview of Microwave Receivers

The Profiling Radiometers utilize a single heterodyne, direct double sideband down conversion receiver architecture. Both receivers are similar in architecture and construction, except for the frequency ranges covered. Microwave channels are selected using a high stability frequency synthesizer to tune any of the 2000 channels in each band (4 MHz step size). The resulting frequency agility is a patented feature of Radiometrics Profiling Radiometers, making them unique in their ability to scan many channels without the high cost and complexity of filter-bank technology. For standard profiling, 5 pre-selected channels are used in the 22-30 GHz band, and 7 channels are used in the 51-59 GHz band.

The ability to tune any in-band frequency also enables these Profiling Radiometers to emulate other microwave profilers for comparative measurements, or to transfer the calibration to other radiometers. Sky noise can also be measured at any in-band frequency of interest for microwave communications link studies.

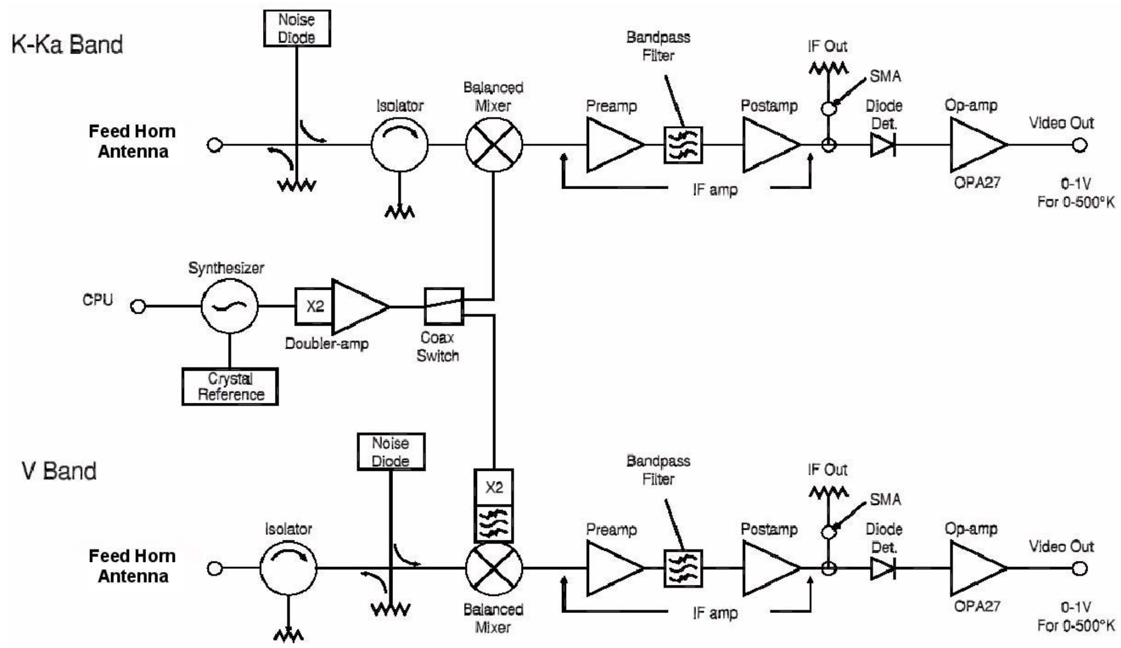

Figure 5. TP/WVP-3000A receiver block diagram.

A block diagram of the two receivers is shown in Figure 5. The receivers accept input power from the Gaussian Optical Antenna (GOA) and generate an output voltage nearly proportional to system temperature (combined antenna and receiver noise). The square law detector output is amplified and digitized using an integrating A to D converter. Receiver frequency selection is accomplished by commanding the synthesized local oscillator frequency. The noise source (Noise Diode), used for system gain measurement, is controlled by the software via the Profiling Radiometer "digital board". The physical temperature is stabilized by the Profiling Radiometer "analog board".

The receiver is very nearly linear with antenna power over the range of the sky and calibration observables. The residual non-linearity of the system is calibrated during an LN2 calibration, and removed by the transfer function. Noise injection from a Noise Diode allows the addition of a known added signal so that the Profiling Radiometer system gain may be calibrated continuously. In order to accomplish this for all channels in each receiver, a single broadband Noise Diode is coupled to the input by means of a broadband directional coupler.

The microwave receivers are thermally stabilized (held at a constant physical temperature) to within 0.5 C. Thermal stabilization ensures the stability of the Noise Diodes over the operating temperature range. All critical voltages are regulated on each printed circuit board, at the intermediate frequency (IF) amplifier, and at the synthesizer for low noise and high stability. Constant voltage standing wave ratio (VSWR) and insertion loss of the various receiver components are also ensured.

The sky brightness temperature is measured in the following manner. The small-angle receiving cone of the Gaussian lens microwave antenna is steered with a rotating flat mirror. A dual junction isolator isolates the receiver from the antenna VSWR and blocks mixer radio frequency (RF) port leakage from exiting and re-entering the antenna. The mixer converts the RF input to base band using a frequency agile local oscillator in the profiler receivers. The resultant IF signal is amplified, filtered to yield a dual sideband signal, detected, amplified again and then converted by an integrating analog to digital converter (ADC). Temperature, RH, water vapor, and liquid water profiles are calculated using artificial neural network algorithms.[17]

2.2 Microwave Receiver Components

2.2.1 Gaussian Optical Antenna

The GOA consists of a 15 cm aperture optical lens focused into a pair of corrugated feed horns via a wire grid beam splitter. The lens acts as a phase correcting device that converges plane wave fronts into the phase center of the corrugated feed horns. Special baffles and absorbing collars are included to minimize errors due to side lobes and reflections. The result is higher gain and lower side lobes than can be obtained with a horn alone, while maintaining small size. Antenna characteristics are summarized in Table 2.

Antenna Characteristic	22 GHz	30 GHz	51 GHz	59 GHz
Full width half power beam width	6.3	4.9	2.5	2.4
Gain, dBi	30	32	36	37
Side lobes, dB	<-23	<-24	<-26	<-27

Table 2 Gaussian Optical Antenna Performance.

[17] GPS satellite tracking and special neural net processing software is available by special order.

2.2.2 Noise Diode Injection Device

The Noise Diodes are mounted in high thermal mass metal blocks. The physical temperature of the Noise Diode mounts is measured and thermostatically controlled within a few tenths of a degree. The typical noise temperature injected by the Noise Diodes and coupler, referenced to the antenna, is 100-200 K.

2.2.3 Dual Junction Isolator

The isolator is a conventional Y-junction 4-port circulator with 2 ports terminated, providing more than 40 dB isolation between the receiver input and the antenna. The high isolation is required in a radiometric receiver due to the stringent requirements for stability in the presence of variable antenna impedance resulting from changes in the mirror pointing-angle.

2.2.4 LNA & Balanced Mixer Downconverters

The 22-30 GHz receiver uses a low noise amplifier (LNA) on the front end, followed by a MMIC mixer. This configuration provides the lowest economical noise figure (NF) in this band. The typical LNA NF is 3.0-3.5 dB.

The 51-59 GHz receiver uses a patented matched diode mixer front end, followed by a low noise IF amplifier. The resulting NF is 5-5.5 dB typically, providing a better NF than can be economically implemented in this band using a 51-59 GHz LNA.

2.2.5 IF Amplifier

The IF amplifier consists of a 2-stage discrete component preamplifier followed by 2 cascaded integrated amplifiers. The IF bandpass filter in this assembly determines the overall channel bandwidth. The nominal IF filter bandwidth is 10 to 160 MHz, producing an effective pre-detection double-sided bandwidth of 300 MHz (-160 MHz to +160 MHz with a 20 MHz center frequency notch).

2.2.6 Detector and Video Amplifier

A tunnel diode detector is used providing excellent sensitivity, low input and output impedance, and lack of DC (direct current) bias requirement. The video amplifier utilizes a high stability instrument operational amplifier.

2.3 Surface Meteorological and IRT Sensors

2.3.1 Surface Meteorology Sensors

Surface temperature, relative humidity and barometric pressure are required for determination of temperature and water vapor profiles. Temperature and relative humidity sensors are located in the Superblower inlet where they are well ventilated with ambient air. A barometric pressure sensor is located inside the Profiling Radiometer housing. Surface barometric pressure, relative humidity, and temperature measurements are automatically made during the instrument observation cycle (**ret** and **sky** commands). Surface barometric pressure measurements are also made during LN2 calibrations to determine the boiling point of the liquid nitrogen.

2.3.2 Rain Sensor

The Profiling Radiometer has a rain sensor on the top of the Superblower. The rain sensor panel is approximately 8 x 10 cm, and consists of interleaved conductive traces on a printed circuit board. For testing purposes, placing a few drops of water on the panel will cause an increase in the Rain Voltage logged in the *level0* data, and activate the Rain Flag in the *level1* data. Since the detector board can become contaminated with use, especially in salt environments, it is field replaceable.

NOTE: *The solid-state detector circuit attached to this sensor is, like all solid-state devices, sensitive to static electricity. Though protected by design, the user should touch the metal housing of the radiometer before touching this panel to minimize the chance of static discharge damage.*

2.3.3 Infrared Thermometer

A Heimann ElectroOptics KT19.85 (or functionally equivalent KT-15.85) infrared thermometer (IRT) remotely measures temperature in the 9.6 to 11.5 micron waveband. The minimum detectable temperature is -50° C. The IRT 5° field of view is directed downward to a front-surface mirror that reflects energy from the zenith, thereby measuring the temperature of the cloud base if clouds are present. If clouds are not present, the measured IRT temperature is typically -50° C. A cover shields the IRT from rain and direct heating of the sun, and a hinged access cover allows viewing of the integral liquid crystal display on the rear of the instrument.

2.4 GPS Receiver

The model TP/WVP-3000A and WVP-1500A instruments may be fitted with an optional Global Positioning System (GPS) receiver. If the GPS option is installed, it will provide real-time pointing vectors (azimuth and elevation) to the operating code. These pointing vectors are used to automatically point the instrument antenna towards those GPS satellites in view, using the **gps** command described in section 6.1.2.1.8. *Note that if the GPS option is installed, Version V3.23 (released 12-16-2005) or later operating code is required*.

Figure 6. Left: GPS Receiver on WVP-1500A. Right: GPS connector on signal panel.

The GPS receiver cable must be plugged in to the connector labeled “GPS” in Figure 6. Profiling Radiometers fitted with the GPS option may be operated without the GPS receiver installed if necessary. However, in the event the receiver is disconnected, the operating code will not function correctly if a **gps** command is executed.

3 Installation

The standard Profiling Radiometer package consists of the following components:

- Profiling Radiometer instrument
- Windows 2000 or XP computer (if ordered)
- TP-2000 Telescoping Tripod (if ordered)
- power cable for the Profiling Radiometer
- power cable for the Superblower (and autotransformer if for 230VAC)
- communications cable to interconnect the computer and the Profiling Radiometer
- T-Bolt
- Spare fuse, radome and Superblower inlet filter
- Operators Manual
- IRT (TP/WVP-3000A only)
- Cryogenic LN2 Calibration Target (TP/WVP-3000A and TP-2500A only)
- GPS receiver (if GPS option is ordered)

In addition, the optional Azimuth Positioner may be supplied. These components are packed in custom-lined air cargo qualified shipping cases.

Before starting the installation, check to verify that all required components are on hand. Notify Radiometrics and the transportation provider if any items are missing. To install the instrument, follow the steps below.

3.1 Site Selection

Select a suitable site for the Profiling Radiometer and the computer. The Profiling Radiometer can be set up on the ground (concrete, asphalt, or other firm surface), or on the roof of a building. When selecting a site, it is important to consider the following factors:

- It is essential to select a site where the antenna field of view will not be contaminated by earth surface features, such as mountains, trees, buildings, etc. The antenna elevation angle changes during normal operation from near the horizon in one direction to near the horizon in the opposite direction. The antenna “looks out” through the radome, so the elevation angle changes in the plane orthogonal to radome. For best TIP calibration performance, it is desirable to position the antenna down to an elevation angle of 25 degrees in each direction. To prevent earth surface radiation from contaminating the TIP calibration, there should be no surface feature above 5 degrees in elevation angle if within 20 degrees of the elevation steering plane. If the optional Azimuth Positioner is installed, then there should be no surface feature above 5 degrees in elevation angle for all azimuth angles of interest.

- The site must have a solid surface for mounting and securing the tripod. It is not necessary for the surface to be level[18], but it must be stable so that the instrument will remain level over time and changing wind load. Under strong wind conditions (>100 km/hr), the side loads are very high, producing high forces on the legs. The best way to ensure the integrity of the system under strong wind conditions is to use both the center pull chain, and bolts in the tripod feet. See Appendix A and Figure 43 for details.

- Access to the instrument will be necessary for maintenance. A site should be chosen that provides security from unauthorized persons, while making access for maintenance convenient.

- The standard power cable set is 30 m long. Longer cables can result in low voltage. Therefore, primary power should be available within 30 m. If power is not available within 30 m of the preferred site, a new primary power circuit should be installed rather than using long extension cords.

- The standard RS232 data cable is also 30 m long. If possible, select a site within 30 m of the location chosen for the computer. If a longer data cable is desired, there are several options, including the use of RS232 to RS422 converters or a serial port server connected via Ethernet. If necessary, contact Radiometrics for assistance selecting the best option to extend the data cable over 30 m.

[18] The instrument is leveled by adjusting the tripod leg-length. Therefore, the tripod can be mounted on a moderately uneven or sloped surface.

- The surface meteorological sensors are high performance devices, but the data can be biased by local sources of air contaminated by roof top exhaust vents, nearby roads, etc. Therefore, the Profiling Radiometer site should be separated a reasonable distance from all local sources of contaminated air.

- The Profiling Radiometer uses one or more sensitive, wideband microwave receivers. To minimize the risk of contamination from radio transmitters, a site should be chosen free of all in-band radio frequency interference greater than –144 dBm/MHz (30 dB below kTB). Out-of-band interference can also result from HF, VHF, UHF or microwave transmitters very near the Profiling Radiometer.

3.2 Site Preparation

Once sites have been selected for the Profiling Radiometer and the controlling computer, provisions should be made for the tripod anchoring technique chosen, and the routing of cables. If the installation will be permanent, the use of conduit pipe(s) for the cables should be considered. Conduit will help protect the cables from rodent damage, moisture and lightning induced transients. A solid earth ground should be connected to the tripod at any convenient attachment point (customer provided equipment).

3.3 Assembly and Setup

The Model TP-2000 telescoping aluminum tripod is typically furnished with the Profiling Radiometer. The tripod is shown in Figure 7 with a TP/WVP-3000A radiometer and optional Azimuth Positioner mounted. Detailed tripod assembly instructions are included in **Appendix A**.

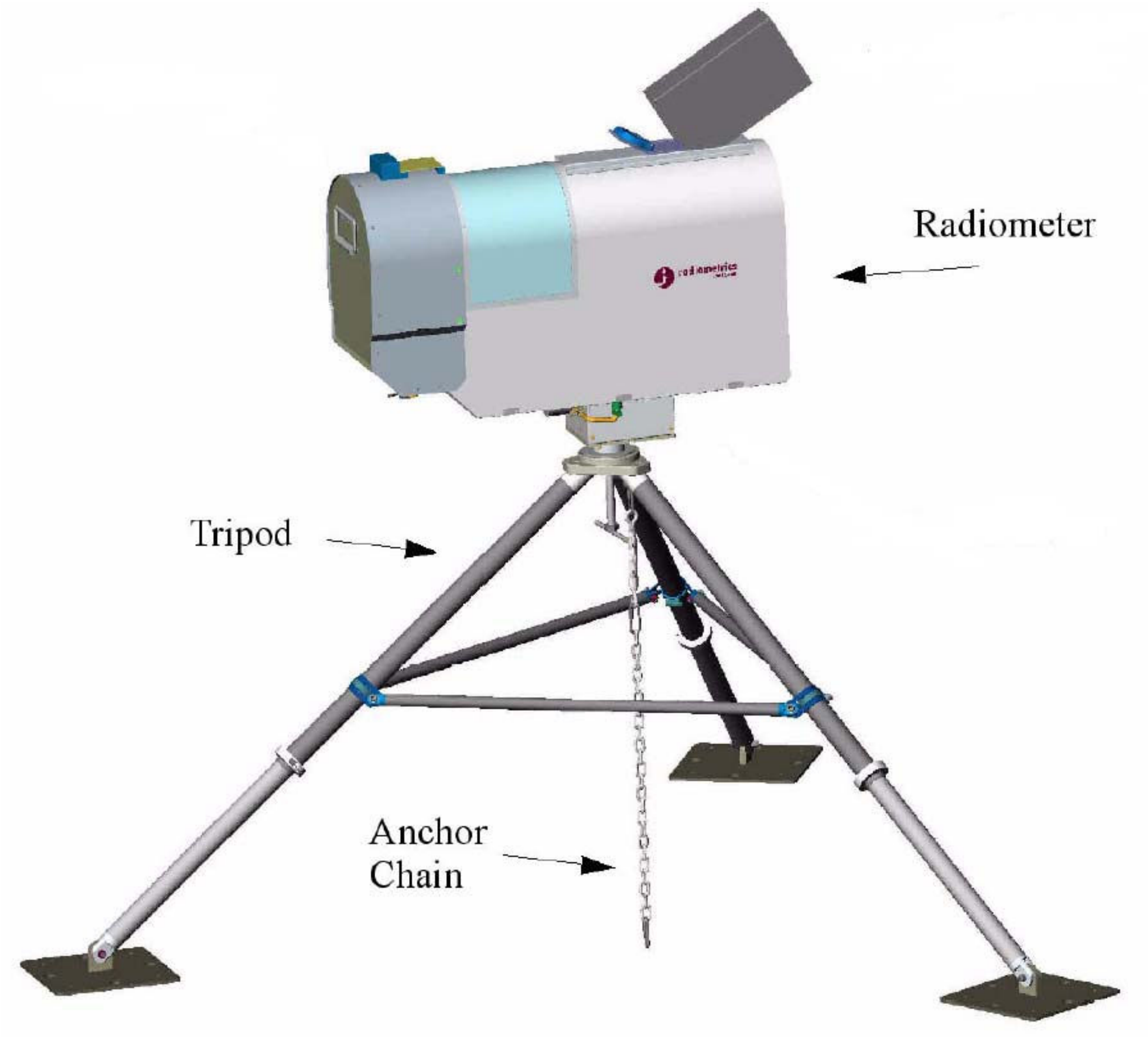

Figure 7. Tripod and anchor chain with Profiling Radiometer.

CAUTION: The instrument should be handled only by its lifting handles or its base. It is strongly recommended that two people be available to mount the radiometer on the tripod.

NOTE: The instrument cover, which contains a foam dielectric radome, must not be used to support or lift the Profiling Radiometer. The microwave radome will be degraded by abrasive contact and foreign matter. It should not be touched intentionally.

3.4 Leveling the Tripod

Before installing the Profiling Radiometer, the mounting surface must be leveled using the bubble level supplied with the TP-2000 Tripod (or similar). The instrument must be mounted on a level surface to ensure accurate antenna elevation angles and TIP calibrations. If the triangular Tripod Top Plate is not level within 1/8th of a bubble in all directions when the tripod is in position at the installation site, adjust one or more of the telescoping tripod legs to different lengths as required to make it level. First, align the level in the plane of the leg to be adjusted first. Then loosen the leg collar clamp on that leg using the 1/4” Allen wrench as shown in Figure 8. The lower leg will slide freely inside the upper leg. To adjust the leg length, move the lower leg up or down as necessary. When the bubble in the level is centered, tighten the collar clamp. Repeat for each leg as necessary to make the triangular Tripod Top Plate level in all directions.

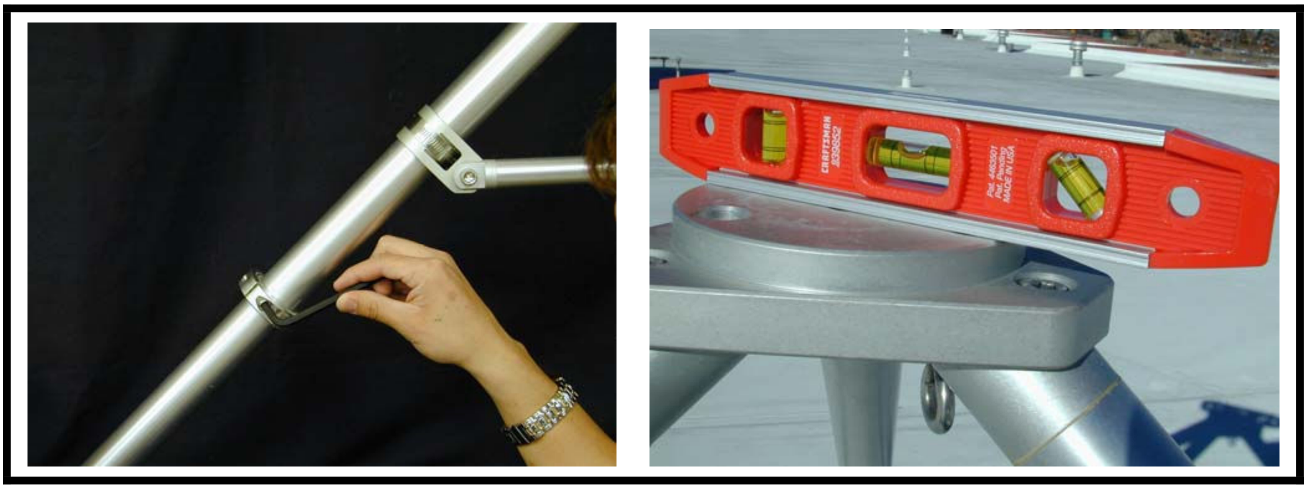

Figure 8. Leveling the TP-2000 Tripod

3.5 Securing the Tripod

Secure the tripod to the ground or building roof using one of the methods recommended in **Appendix A**. The supplied center pull anchor chain and turnbuckle provide a robust, flexible way to secure the tripod to the surface below using a single eyebolt. This method is especially useful when the height may need to be adjusted from time to time. The addition of anchor bolts in the feet is advised if the height and location are permanent. After securing the tripod, check to make sure it is still level, *as secured*. If the tripod is not level within $1/8^{th}$ bubble, loosen the chain and/or foot security bolts/stakes as required, and refine the leveling as described in Section 3.4. Then retighten all fasteners.

3.6 Mounting the Profiling Radiometer

NOTE: Before proceeding with this step, if the center pull chain method is used to secure the tripod, the chain should be *temporarily* loosened as required to turn the T-bolt to mount the Profiling Radiometer.

Using the lifting handles located on each end of the Profiling Radiometer, lift the Profiling Radiometer from its shipping container. If the optional Azimuth Positioner is to be installed, follow the separate instructions supplied with the Azimuth Positioner to install it on the bottom of the Profiling Radiometer. Place the Profiling Radiometer (with Azimuth Positioner if installed) on the Tripod Top Plate and secure with the 5/8-11 T-bolt. The connector panel should be oriented due east.[19] If the center pull chain was loosened, retighten the chain.

Figure 9. Securing the Profiling Radiometer with the T bolt

3.7 Installing the IRT

Locate the IRT assembly with IRT sun shield and mounting hardware kit. The IRT and front-surface mirror base assembly are provisioned to mount on the top of the Profiling Radiometer. First, remove the sun shield from the IRT assembly by removing the six 8-32 screws on the sides. Position the assembly with the mirror end adjacent to the radome as shown in Figure 9. This assembly is attached to the channel on the top of the Profiling Radiometer using six 6-32 SS screws (supplied). The IRT cable is connected to a "military style" circular connector on the bottom of the Profiling Radiometer, close to the end of the cabinet opposite the Superblower. (The capped connector near the bottom center is for the optional Azimuth Positioner.)

[19] If the optional Azimuth Positioner is not installed, orienting the connector panel due east will result in elevation angle pointing in a north-south plane, with 0 degrees elevation due north, 90 degrees zenith and 180 degrees due south. If the user prefers a different elevation scanning plane, adjust the azimuth accordingly.

Reinstall the sun shield over the IRT, after the base assembly is mounted on the Profiling Radiometer, secured with six 8-32 SS screws. This shield keeps the IRT from absorbing excess heat from the sun and becoming too hot. A hinged cover at the rear allows access to the display panel.

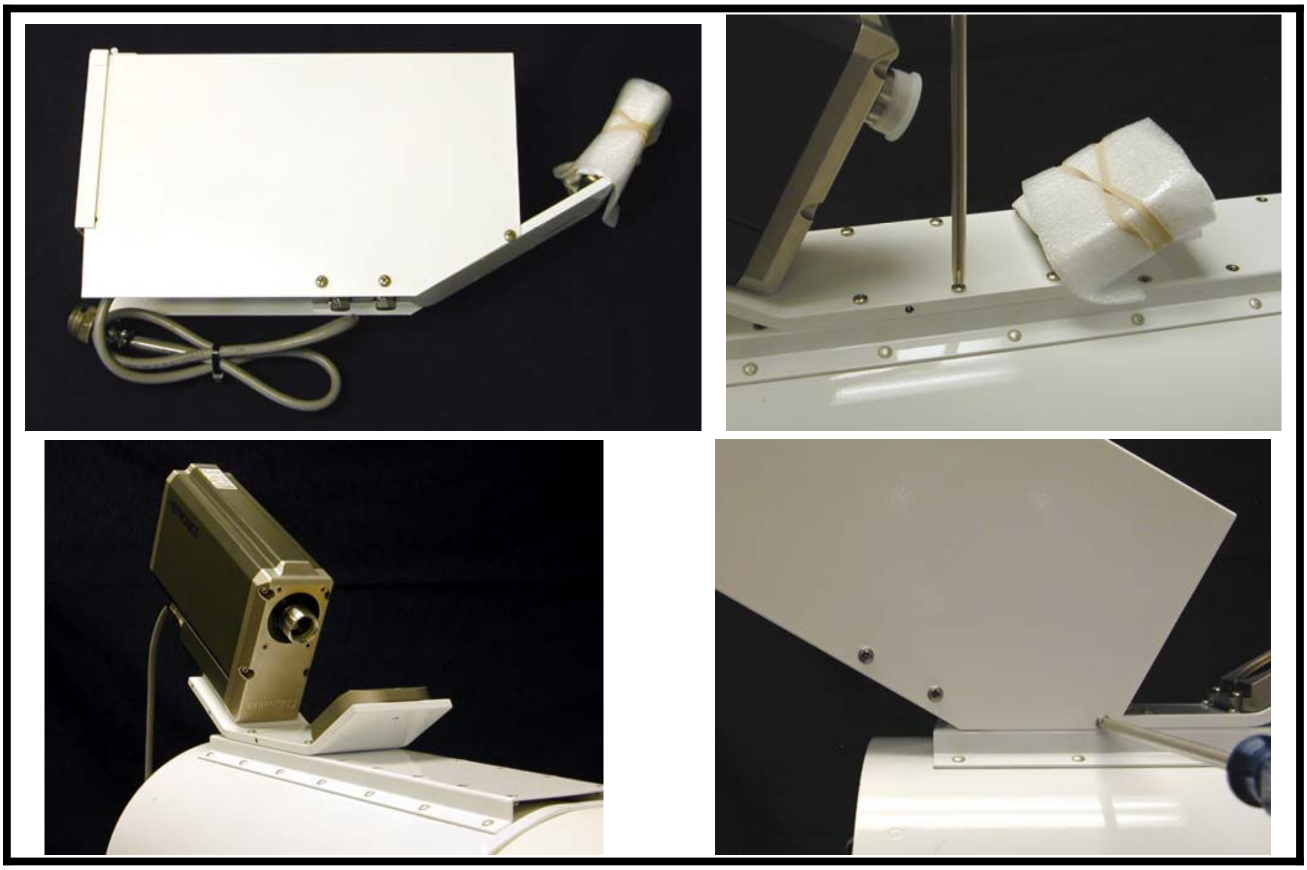

Figure 10. IRT as delivered & as mounted on the Profiling Radiometer

3.8 Attaching the Power Cables

To ensure safe operation, power cables must be connected to properly grounded mains receptacles. The power cables are normally supplied with mains connectors installed for the receptacles used in the region to which the Profiling Radiometer is delivered. Always disconnect power cables from the main supply before disconnecting cables from the Profiling Radiometer and Superblower. This ensures ground integrity in case of a fault condition. Only qualified personnel should service this equipment. Hazardous voltages are accessible after removal of cover.

Locate the connector panel at the base of the Profiling Radiometer, on the Superblower end, as shown in Figure 11.

Figure 11. Power/fuse/connector panel

Two power cables are required. One provides power to the Profiling Radiometer and connects to the power panel. The other one powers the Superblower and connects to the Superblower housing. The Profiling Radiometer requires 200 watts, while the Superblower uses a maximum of 100 watts. Mate the power cable plugs and secure by rotating the locking collars into their detents. Connect the other ends of the power cables to the mains receptacles. The Profiling Radiometer can be protected from power failures by utilizing an uninterruptible power supply (UPS). The power cables should be connected to grounded outlets for safety, as well as static and transient protection.

NOTE: All Profiling Radiometers operate from either 115VAC or 230VAC (50 or 60 Hz), but the standard Superblower operates from 115VAC ONLY.[20] To operate the standard Superblower from 230VAC, an autotransformer is provided to convert 230VAC to 115VAC at the source. If used, the autotransformer should be located near the mains receptacle, and the 115VAC Superblower power cable should be used to connect the Superblower to the autotransformer.

[20] A 230 VAC Superblower is also available by special order.

3.9 Attaching the Data Cable

The circular connector end of the RS232 data cable should be plugged into the Profiling Radiometer RS232 port marked “Computer RS232” in Figure 11. The other end of the cable should be plugged into an available RS232 serial port on the controlling computer.

NOTE: An auxiliary RS232 port is furnished for user applications such as a GPS receiver or auxiliary meteorological sensors. Due to the wide variety of protocols that RS232 connected devices use, the standard Operating Code does not support the use of this port except for use with the GPS Option. Contact Radiometrics for information on custom versions of the Operating Code if the use of this port is desired.

3.10 Securing the Cables

The cables should be secured to a tripod leg using tie wraps or tape. If the optional Azimuth Positioner is installed, it is necessary to provide a service loop in the cable bundle as shown in Figure 12 so that it does not become restricted when the Profiling Radiometer changes azimuth position.

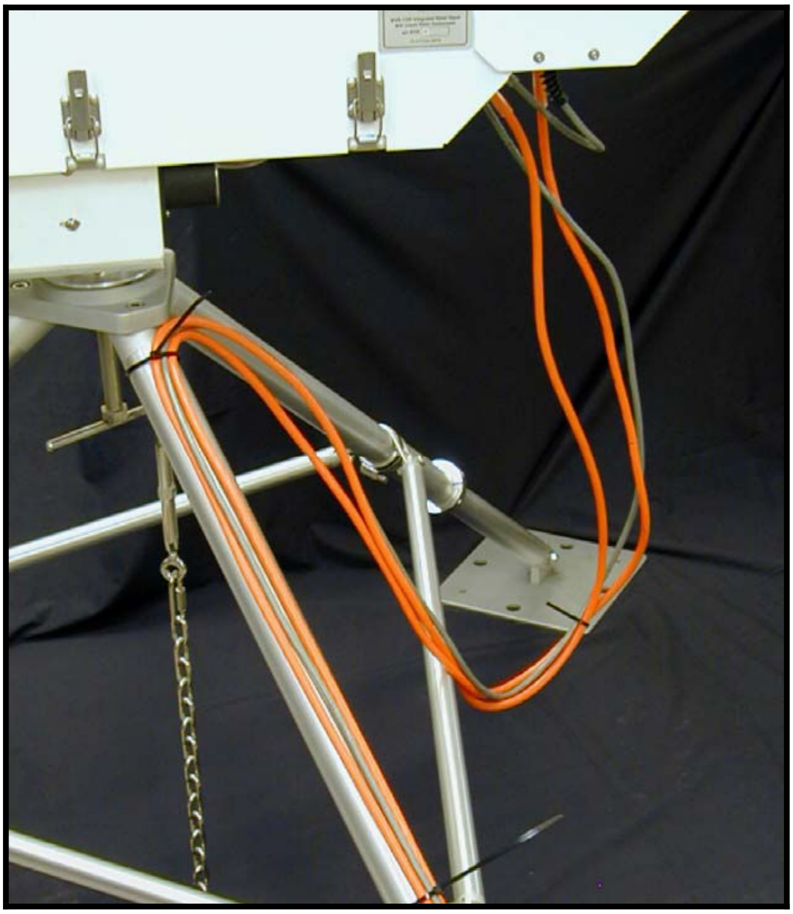

Figure 12. Cable service loop for use with Azimuth Positioner

3.11 Installing the Computer

All software and files needed for the normal operation of the Profiling Radiometer are preinstalled on computers supplied by Radiometrics. If the user supplies the computer, then the software should be installed in accordance with the instructions supplied on the installation CD. The Operating Code (mp321.exe or similar) and all associated input files (configuration file, neural network files, Procedure Files, and list files) are stored in one folder referred to herein as the “Operating Folder”. The Operating Folder can have any name, and it can be located anywhere within the disk directory structure. As delivered from the factory, “shortcuts” (aliases) for the Operating Directory, Operating Code, Microsoft Notepad (Notepad) and Windows Task Scheduler are located on the desktop. All output files are stored in the Operating Folder.

The controlling Windows 2000/XP computer should be located in a suitably protected indoor environment. Connect the DB-9 connector on the data cable to an available serial port. Normally, the standard serial port on a computer is associated with com1 in the Windows 2000/XP Operating System. If a different serial port is used, then the associated com port should be specified in the configuration file (mp.cfg) to match the serial port used. To change the com port in the configuration file from the default value of 1, open the file mp.cfg in Notepad. Change the number defining the com port, then save the file.

4 Initial Operation and Test of the Instrument

To begin operation of instrument, locate the power switch on the connector panel of the Profiling Radiometer and move it to the ON (up) position. The Azimuth Positioner (if installed) may run to seek its index position, and the elevation stepper motor will be heard stepping to its index position. Once the Profiling Radiometer reaches its azimuth index position, it must be reoriented to align the antenna to the north-south plane. To align the Profiling Radiometer, loosen the T-bolt slightly and gently rotate the Profiling Radiometer so that the connector panel points due east, and then re-tighten the T-bolt. This alignment only needs to be performed after installation, or after movement of the tripod or Profiling Radiometer.

NOTE: Orienting the connector end of the instrument to the east sets the pointing direction of the mirror in a north-south plane, the reference plane of observation of the instrument. Any error in this orientation will result in an equivalent error in azimuth pointing direction. The user may want to use a compass for this orientation. If so, the magnetic declination at the installed site must be included in the determination of true north.

NOTE: If the elevation stepper motor is not heard when power is first turned on, check the fuse in the connector panel (Figure 11) by turning the fuse cap counterclockwise, removing the fuse, and visually inspecting. If intact, check the power source with a voltmeter or similar device. If unable to determine the cause of the lack of power, contact Radiometrics for assistance.

NOTE: Before attempting to calibrate the instrument or collect data, the instrument must reach its stable operating temperature. If the Profiling Radiometer is in equilibrium with ambient air temperature, it will require up to 30 minutes for the microwave receivers to thermally stabilize (depending on the ambient temperature). Immediately following the movement of the Profiling Radiometer from one environment to another (i.e., from a warm warehouse to cold outdoors), then up to 5 hours may be required for the Profiling Radiometer to reach complete equilibrium. The Profiling Radiometer may be operated safely during the period it is stabilizing, but the data may be slightly biased.

Turn on the computer by locating its power switch and moving it to the ON position. The computer will start Windows 2000/XP.

To start the Operating Code, double click the Operating Code shortcut icon on the Windows 2000/XP Desktop. This will load the Profiling Radiometer program (mp321.exe or similar). Diagnostic tests will be automatically performed immediately. The tests include:

- communications port
- supply voltages
- A to D converter calibration
- receiver stability

Figure 13 shows the display following a successful power on test.

```
          ________________________________________________________
          |      RADIOMETRICS CORPORATION MICROWAVE PROFILER       |
          |________________________________________________________|
          |Software  Version  3.20  (1200 baud) November 2004      |
          |          Copyright 1990  All rights reserved.          |
          |________________________________________________________|

Serial port set to 38400 baud and cleared.

Initializing Antenna Elevation to Index Position...

System Integrity Check in progress.
Performing MP system voltage and sensor checks.
 Blackbody T1 sensor OK
 Blackbody T2 sensor OK
  MP V-band Mixer temp sensor OK
  MP K-band mixer temp sensor OK
  MP V-band Noise Diode/RF deck temp sensor OK
  MP K-band Noise Diode/RF deck temp sensor OK
 +15 volt supply OK
 -15 volt supply OK
  MP barometer installed
  MP V-band Video amp dark voltage OK
  MP K-band Video amp dark voltage OK
  MP +10 volt precision reference OK
  MP Rh sensor installed
  MP V-band Noise diode OK
  MP K-band Noise diode OK
 -19 volt supply OK
 +19 volt supply OK
Voltage check: OK
DIAGNOSTIC SELF TEST ROUTINES:  PASSED
```

Figure 13. Operating Code display after power-on tests have completed.

NOTE: If any of the diagnostic tests fail, the operator is so informed, and the appropriate remedy is suggested. If the failure renders the instrument inoperable, the program automatically terminates. If the program is still operable, the operator is informed of any limitations that exist in the operation of the instrument, and the program continues.

NOTE: If the cursor is moved to the lower edge of the screen while in Windows XP, the full screen display will change to a windowed display with bars at the top and bottom of the screen. Other programs can then be selected from the bottom tool bar. To return to full screen, press **Alt-Enter**.

Once the power-on test is successfully completed, the main menu screen will be displayed as shown in Figure 14.

```
1) Standard Procedure
2) User Procedure
3) LN2 Calibration
4) Enter Comments
5) Quit
Please enter selection
```

Figure 14. Main Menu Screen

From the Main Menu, the user may select from these 5 options:

1. Standard Procedure	Choose this option to select from a list of standard factory supplied procedures.
2. User Procedure	Choose this option to select from a list of previously written user defined procedures.
3. LN2 calibration	Choose this option to perform a user LN2 calibration using the external cryogenic target.
4. Enter Comments	Use this option to enter a brief note (free form text) that will be appended to the next level0 data file.
5. Quit	Causes the Operating Code to terminate execution after an orderly shutdown.

NOTE: The radiometer may be operated immediately after installation, but it should be recalibrated before "official" data collection begins, and after any transport.

To begin observations immediately using the Manual Mode and a factory-preconfigured procedure, choose option 1 (press the "**1**" key). The next screen will display the available standard procedures by scrolling through the list using the "**<**" and "**>**" keys. Scroll to the procedure named "1min_170.prc" and press "Enter" to begin zenith observations and profile retrievals once per minute.[21] This procedure also collects TIP calibrations once per minute (WVP-1500A and TP/WVP-3000A only). After a few observation cycles, the screen

[21] Procedure files are updated and changed frequently. If the radiometer operating directory has been updated, this procedure file may not be present. If the procedure 1min_170.prc is no longer available, try any other procedure that performs periodic retrievals. See Section 6.1.2 for information on writing procedures.

will display a set of real-time graphics similar to those in Figure 15. This screen displays profiles of temperature, water vapor and liquid water, as well as all the surface sensor data.

The Profiling Radiometer will continue to operate indefinitely when started manually.[22] During this time, the Operating Code will continue to update the display once per observation cycle and log data to the *level0*, *level1* and *level2* files. If successful TIP calibrations are completed, they will be logged to the *TIP* data file.

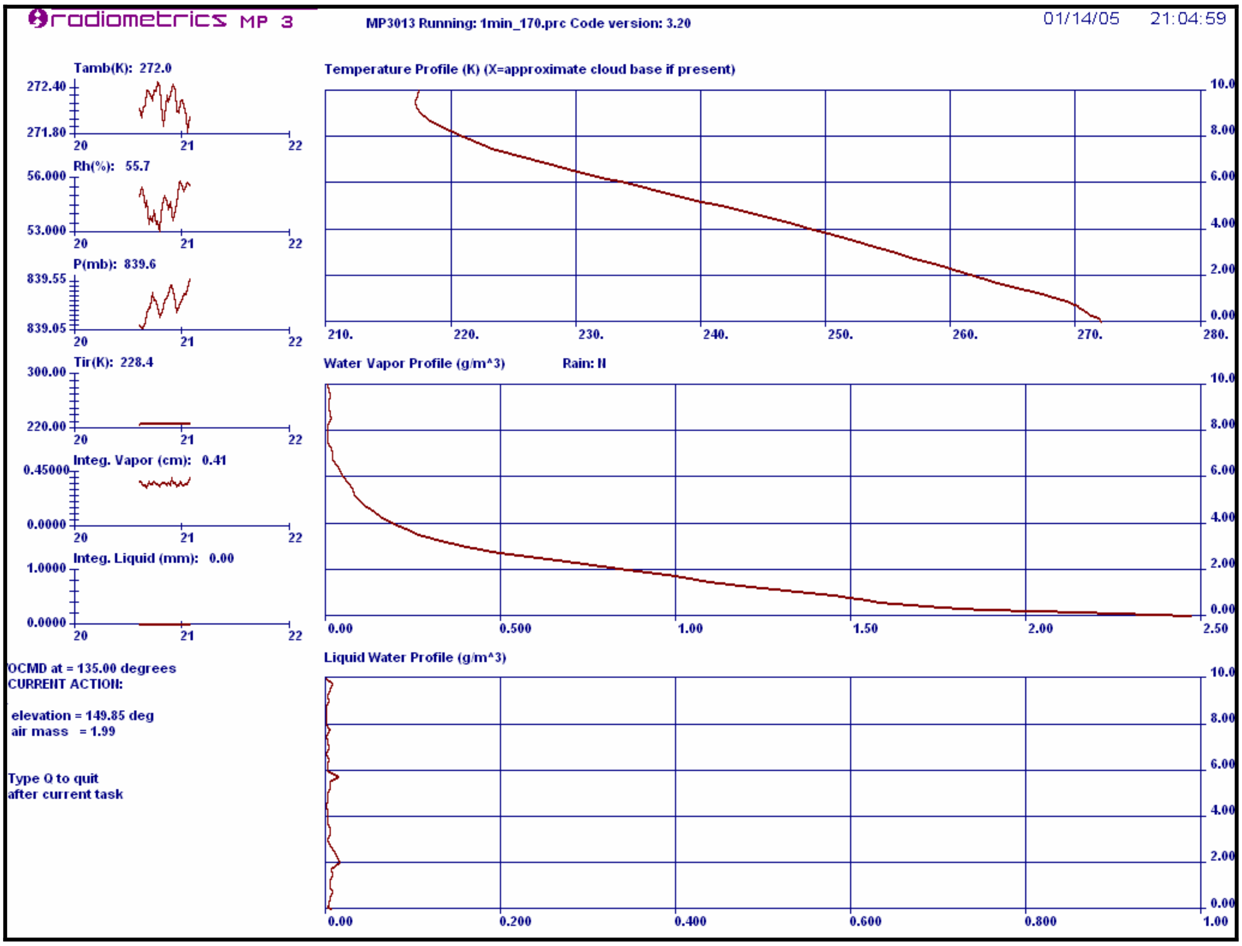

Figure 15. Profile Display with Water Vapor (press P to view)

[22] If left operating in the Manual Mode for long periods (several days), the output file lengths will become quite large, and the risk of data loss will increase in the event of a computer failure. For data collection periods longer than one day, the automatic mode is recommended. In automatic mode, new files are started automatically at 00:00 UTC each day.

While the Profiling Radiometer is profiling, the user may toggle between the Profile Display in Figure 15 and four other displays as shown in Figure 16, Figure 17, and Figure 18. These alternative displays are selected by pressing a single key as follows:

- **P** View **P**rofiles displayed with water vapor density in g/m^3
- **R** View Profiles displayed with **R**H in %
- **O** View TIP calibration progress (K band Tnd and **O**pacity graphs)
- **B** View **B**rightness temperatures for all channels
- **G** **G**PS Observations (Mapped to Zenith)

NOTE: The availability of P, R, O and G displays will depend on the procedure file used.

The data presented in these displays is mostly self explanatory. The radiometer serial number and procedure in use are displayed at the top. The rain flag is displayed above the water vapor graph. (Y=sensor above threshold; N=sensor below threshold) Information about the current action is displayed in the lower left corner. Note that the height scales for the large graphs are on the right, and the units are km. The small graphs on the left provide time series of the Met Sensor values, Integrated Vapor and Integrated Liquid. The horizontal axis (hour of day) auto scales depending on the frequency of observations.

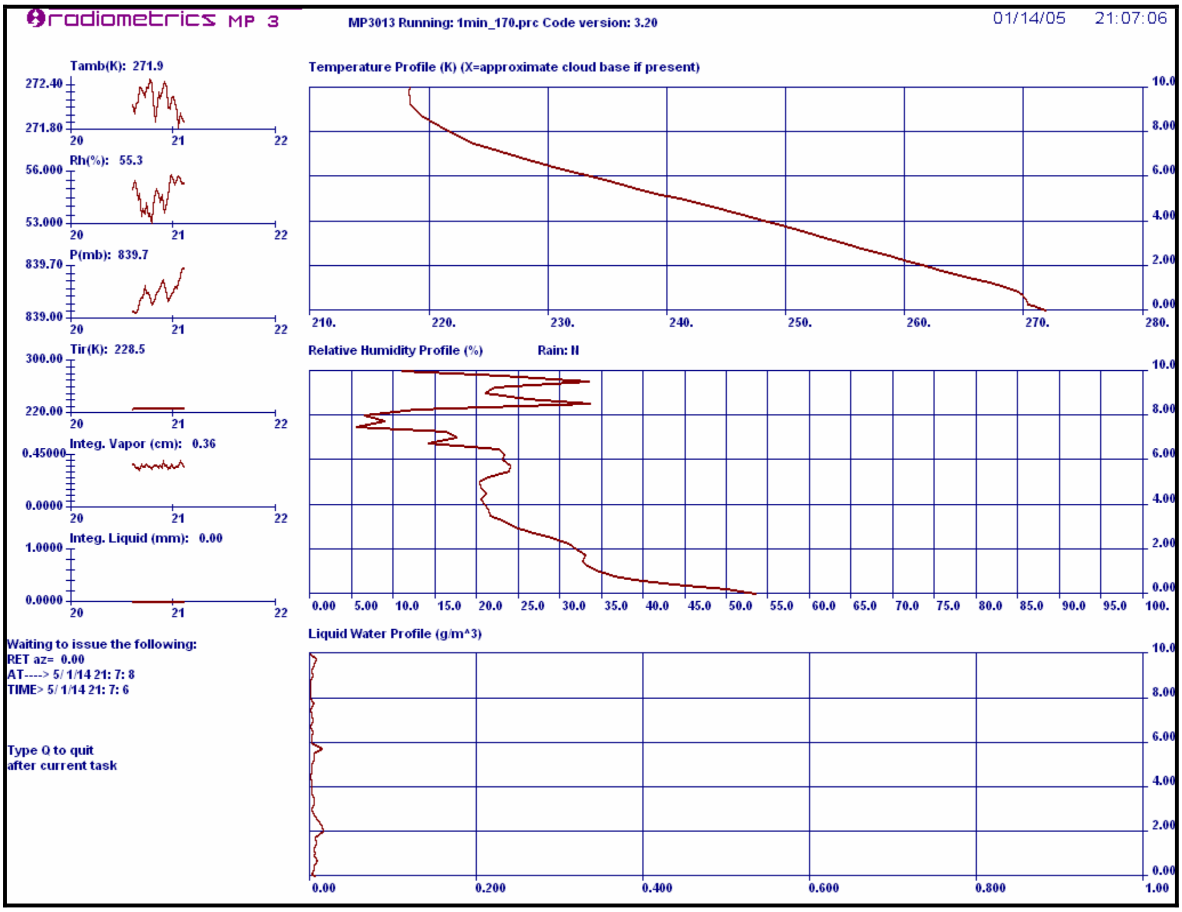

Figure 16. Profile Display with RH (press R to view)

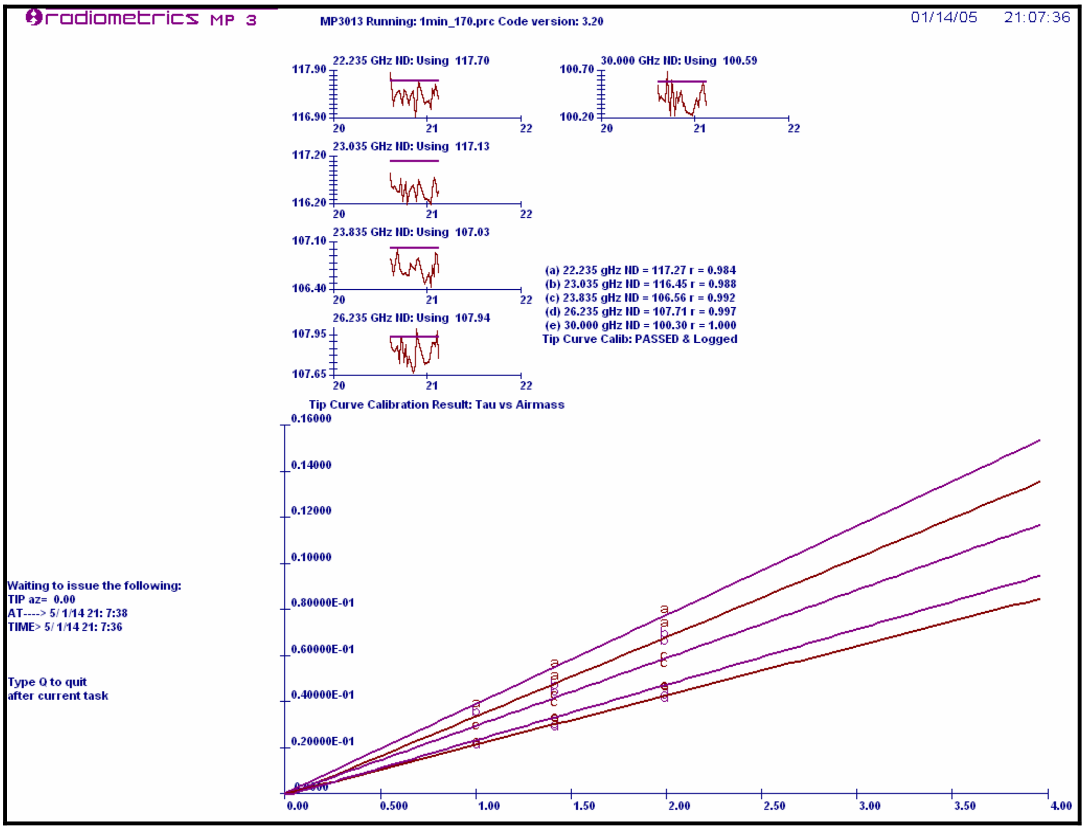

Figure 17. Opacity Display; K band Noise Diode calibrations (Press O to view)

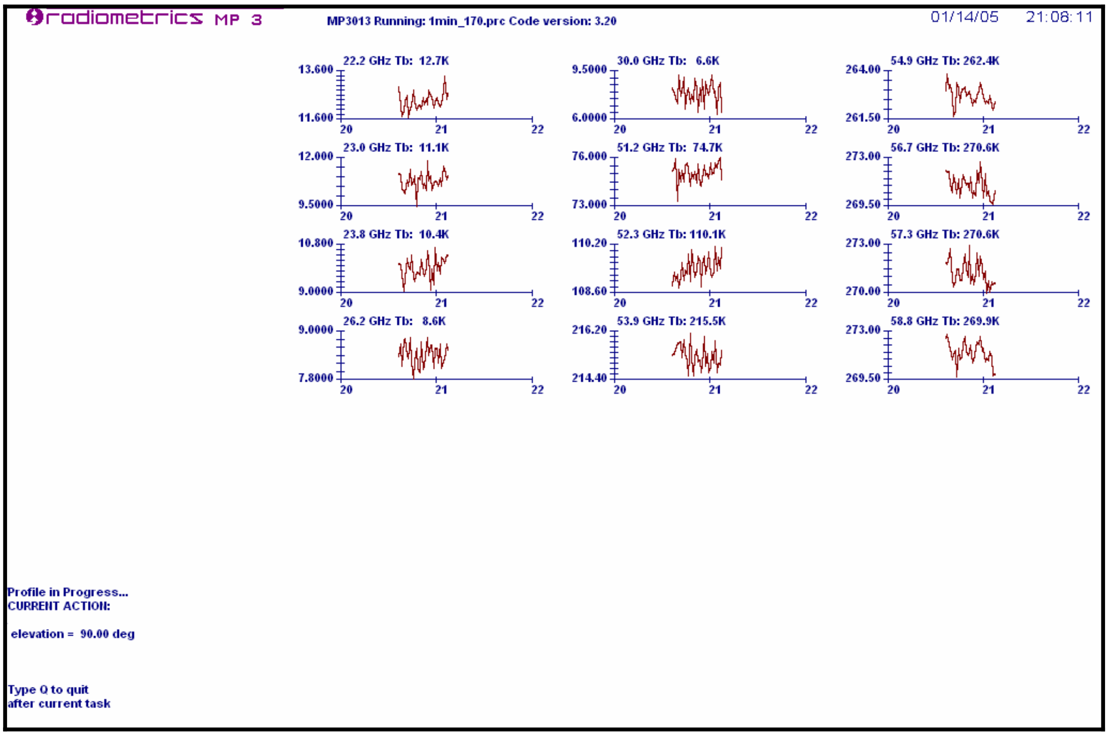

Figure 18. Sky Brightness Temperature Display (Press B to view)

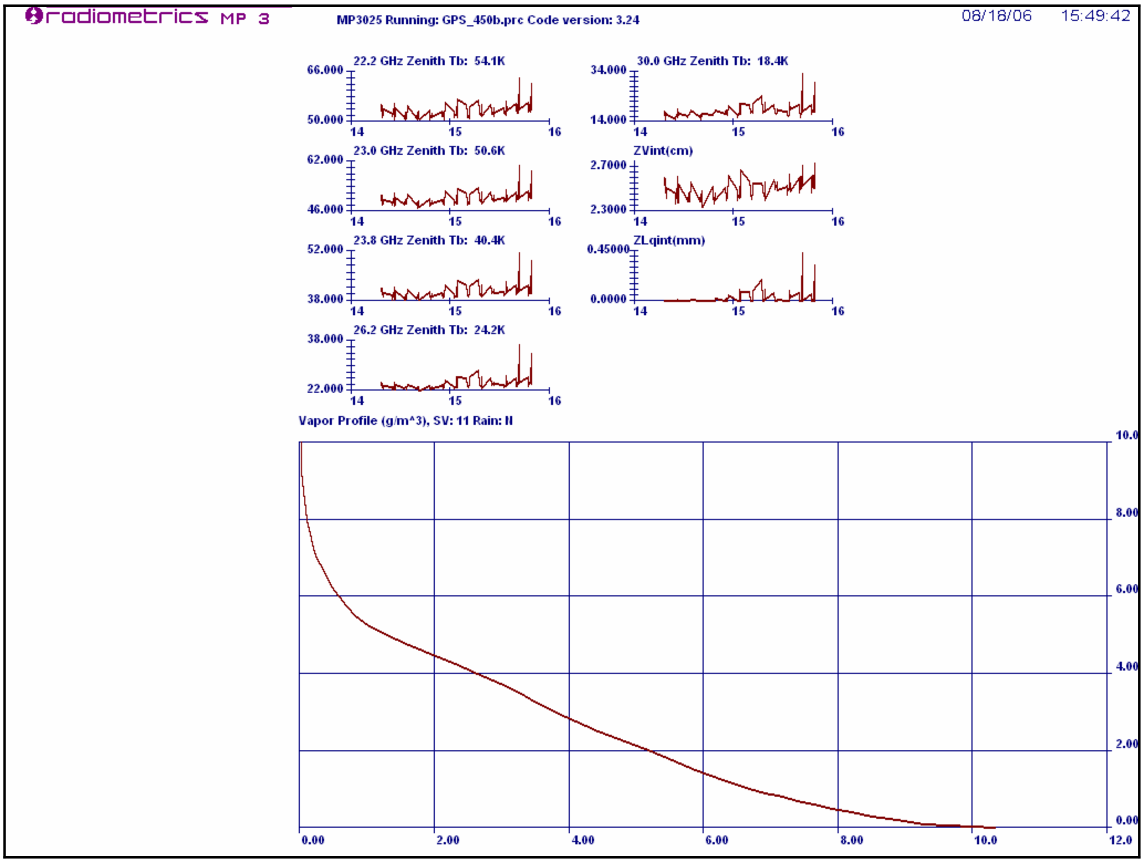

Figure 19 GPS zenith mapped brightness temperatures and water vapor (gm/m^3) vs. altitude (km AGL). Press G to view.

At any time during data collection, *copies* of the data files (*level0*, *level1*, *level2, LN2* and *TIP*) may be made and opened to examine the contents. *Do not open any output file currently in use by the Operating Code.* <u>Copies</u> of files may be opened in Microsoft Excel (Excel) or a similar data analysis application to verify the data. After some minor formatting, a *level1* file containing sky brightness temperatures should look similar to Figure 20.

Record	Date/Time	10	Tamb(K)	Rh(%)	Pres(mb)	Tir(K)	Rain	Azim	Elev	TkBB(K)	22.235	23.035	23.835	26.235	30	51.25	52.28	53.85	54.94	56.66	57.29	58.8
1	1/12/2005 00:01:19	11	275.17	83.24	819.7	264.20	N	0	90	287.22	21.64	19.88	17.56	12.76	12.17	78.95	111.21	216.99	265.83	273.71	274.23	274.44
2	1/12/2005 00:02:19	11	275.03	83.10	819.7	265.80	N	0	90	287.22	22.18	20.93	17.89	12.92	11.34	79.16	111.29	216.97	265.99	273.51	274.09	273.49
3	1/12/2005 00:03:19	11	275.01	83.34	819.8	268.80	N	0	90	287.21	22.13	20.42	17.84	13.32	12.29	80.07	111.99	217.33	265.25	273.55	274.07	273.97
4	1/12/2005 00:04:19	11	274.94	83.56	819.8	270.80	N	0	90	287.20	22.86	21.59	19.23	13.80	12.78	80.91	112.13	217.40	265.29	273.78	273.70	274.00
5	1/12/2005 00:05:19	11	275.07	83.55	819.9	270.10	N	0	90	287.20	22.73	20.90	18.26	13.55	12.19	79.76	111.87	218.03	266.48	273.73	273.59	273.70
6	1/12/2005 00:06:19	11	275.03	83.40	819.9	269.90	N	0	90	287.19	23.11	21.84	18.78	13.90	12.83	80.40	112.03	217.18	263.78	273.70	274.08	273.83
7	1/12/2005 00:07:19	11	275.01	83.55	819.9	267.10	N	0	90	287.17	22.49	20.88	18.30	13.12	11.44	79.52	111.89	217.34	265.52	273.63	273.58	273.83
8	1/12/2005 00:08:19	11	275.01	83.60	819.8	263.00	N	0	90	287.17	23.01	21.50	18.53	12.76	11.96	78.42	110.83	217.28	266.04	273.99	274.02	274.64
9	1/12/2005 00:09:19	11	275.01	83.74	819.8	265.30	N	0	90	287.16	22.17	21.05	18.68	13.47	12.96	79.75	111.82	217.92	266.58	273.92	273.99	274.93
10	1/12/2005 00:10:19	11	274.97	83.66	819.8	268.10	N	0	90	287.15	22.84	20.91	18.42	13.79	12.59	80.70	111.79	218.14	266.40	274.38	273.98	274.47
11	1/12/2005 00:11:19	11	274.86	83.71	819.8	268.70	N	0	90	287.14	22.76	20.72	18.16	13.16	12.18	79.97	111.49	217.85	265.84	274.20	273.68	274.18
12	1/12/2005 00:12:19	11	274.74	83.93	819.9	269.60	N	0	90	287.13	22.30	21.37	18.29	13.45	12.95	79.80	111.95	217.55	265.93	273.46	274.29	274.22
13	1/12/2005 00:13:19	11	274.80	84.23	819.9	270.30	N	0	90	287.12	23.42	21.39	19.00	13.59	12.83	79.93	112.76	218.00	265.94	273.72	274.47	273.76
14	1/12/2005 00:14:19	11	274.90	84.34	819.9	270.60	N	0	90	287.11	22.86	21.10	18.83	13.33	12.65	80.24	111.99	217.35	265.14	273.22	275.19	274.29
15	1/12/2005 00:15:19	11	274.94	84.28	819.8	270.20	N	0	90	287.09	22.88	21.42	18.33	13.38	12.04	80.31	112.20	217.26	264.95	273.56	274.67	273.74

Figure 20. Example of TP/WVP-3000A *level1* file opened in Excel.

In Figure 20, the columns to the right of the Black Body physical temperature (TkBB) contain the brightness temperatures (in Kelvins) corresponding to the frequency channel (in GHz) appearing in the header above the column. The number of brightness temperature columns will be dependent on the number of frequencies defined in the configuration channel block (Figure 22). Columns to the left of TkBB contain Surface Met and antenna position data as indicated in the header.

For the limited purpose of this initial test, it is sufficient to verify that the instrument and software produce displays similar to those viewed above. Section 6 will provide a more detailed description of the operation of the instrument.

To terminate the data collection test, press the "**Q**" key. This causes the Operating Code to stop in an orderly manner after completing the current observation.

Caution: ***Ending the program by closing the window may corrupt data files.***

This completes the basic post installation check and tests. Data in the files produced by the test can be plotted to verify data consistency. Figure 21 shows an example of typical *level1* K band data plotted using Excel.

Detailed instructions for instrument configuration and operation begin at Section 6. Before beginning operations for the first time, users are urged to read Sections 5 "Radiometer Calibration". Even if the user chooses not to calibrate the Profiling Radiometer or Met Sensors at this time, the information contained in this section provides part of the background required to choose the best configuration for operation of the instrument. For the highest accuracy observations, the instrument should always be recalibrated after transport.

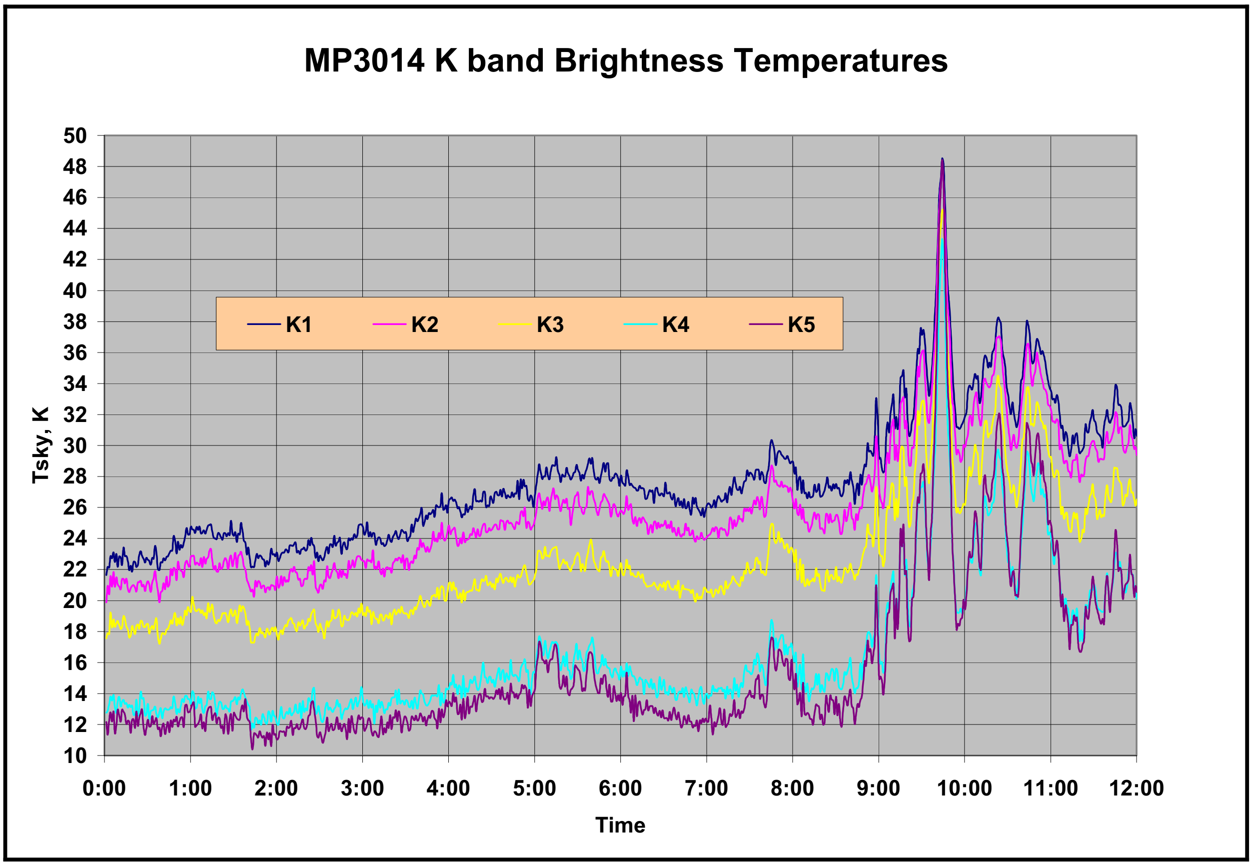

Figure 21. Example of *level1* time series data (K band only) plotted using Excel

5 Radiometer Calibration

Most of the Profiling Radiometer parameters that require calibration remain stable for many years. These parameters are calibrated at the factory, over the full operating temperature range, and normally require no user adjustment. The *effective* Noise Diode Temperature (Tnd) is also very stable, but it should be recalibrated after transport of the instrument, and once every 3-6 months to ensure the best accuracy. Two methods are available to calibrate the Noise Diodes. The LN2 method is applicable to all channels in all models, but the TIP method is applicable only to the K band channels in the WVP-1500A and TP/WVP-3000A models. Each method is described below.

The Channel Calibration Block in the configuration file (mp.cfg) 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 22 shows an example of a typical Channel Calibration Block for the TP/WVP-3000. Except for the values of Tnd associated with the 22-30 GHz channels, highlighted in red, values in this table should not be changed by the user unless directed to do so by factory service personnel. The five values of Tnd highlighted in red may be changed by the user in accordance with the TIP calibration procedure described below.

```
CHANNEL CALIBRATION BLOCK:
2005/01/11 15:13:37   Date of last factory LN2 calibration
2005/01/10 16:59:11   Date of last user LN2 calibration
.90           :target tolerance for ln2 cal
12            :number of frequencies
Frequency,MRT,Window Coef,alpha,dtdg,k1,k2,k3,k4,Tnd
22.235,275.0,.000140,0.98034,-222706.5,  0.20482903E+03, -0.21481055E+01,  0.66601838E-02, -0.58222925E-05, 144.32
23.035,275.7,.000140,0.98783,-240241.5,  0.21949979E+03, -0.23365833E+01,  0.76572988E-02, -0.76210362E-05, 133.12
23.835,276.0,.000150,0.98550,-229159.2,  0.29366148E+03, -0.30809905E+01,  0.10126111E-01, -0.10323512E-04, 119.71
26.235,275.4,.000164,0.99882,-463197.2,  0.21693914E+03, -0.22963036E+01,  0.76016840E-02, -0.78032193E-05, 110.70
30.000,274.1,.000200,0.98033,-477343.2,  0.19747642E+03, -0.20842194E+01,  0.66887620E-02, -0.63790103E-05, 134.91
51.250,274.1,.000200,0.97302,-414995.7, -0.11318704E+03,  0.10981614E+01, -0.35123333E-02,  0.36945950E-05, 197.15
52.280,274.1,.000200,0.96335,-372310.0,  0.13108214E+03, -0.17183013E+01,  0.70703064E-02, -0.93233639E-05, 162.07
53.850,274.1,.000200,0.97153,-323926.0, -0.21953128E+02,  0.19707591E+00, -0.63559843E-03,  0.74849080E-06, 179.63
54.940,274.1,.000200,0.96662,-126650.4,  0.20694177E+03, -0.17091959E+01,  0.51577626E-02, -0.59470576E-05, 208.70
56.660,274.1,.000200,0.96914,-160397.6,  0.33174421E+03, -0.30663686E+01,  0.97124545E-02, -0.10632446E-04, 209.05
57.290,274.1,.000200,0.97425,-589776.5, -0.35059174E+03,  0.36020619E+01, -0.12287096E-01,  0.13913590E-04, 191.11
58.800,274.1,.000200,0.97257,-349221.7,  0.73179476E+02, -0.60599092E+00,  0.18400564E-02, -0.21399341E-05, 165.76
```

Figure 22. Example of Channel Calibration Block in Configuration File

The seven frequency dependent factory-calibrated parameters 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 effective Noise Diode Temperature at TkBB = 290K

5.1 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 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 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 **bbc** command is executed. The effective target temperature of the cryogenic target is calculated automatically by the Operating Code, based on “first principles” as described in section 5.1.1.

5.1.1 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 during the calibration through coefficients entered 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 surface 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 listed in Table 3. Ambient temperature of 300° K and a target temperature of 77° K are assumed.

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

Table 3 Typical contributions to cryogenic target Black Body temperature

5.1.2 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.
- 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 not necessary for the software to be running.)
- When LN2 is in the target, the outside will eventually cool, and may reach the atmospheric dewpoint. 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 (dewpoint is depressed).
- The calibration procedure should be allowed to continue for an hour if possible to obtain a large number of observations, thereby reducing measurement noise.

Warning: Contact with LN2 can cause burns and skin damage - - handle with care!

5.1.3 LN2 Calibration Procedure

If the Profiling Radiometer has not been powered on for at least 30 minutes, wait until it has been on for 30 minutes, then proceed.

Unfold and install the Target Saddle over the Profiling Radiometer radome as shown in Figure 23. Note that the Target Saddle has a notch on one side to fit over the Rain sensor.

Figure 23. Calibration target and saddle.

> **Caution:** The Target Saddle legs may damage the radome if one comes in contact with the soft foam. Take care to install the Target Saddle so as to keep the legs from contacting the radome.

Fill the target with LN2. The target should be filled to a height of 30-50 mm above the black foam inside the target. Place the filled target on the Target Saddle as shown in Figure 23.

Refer to the “TP/WVP-3000A Graphic User Interface Presentations” document.

5.2 TIP Calibrations

The use of an external cryogenic target is required to calibrate the 51-59 GHz receiver Noise Diode. 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 is 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 Diode cannot be reliably calibrated using the TIP method due to the relatively small difference observed between the upper V band zenith brightness temperatures and the built-in ambient Black Body target.

5.2.1 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. The key to obtaining a high quality TIP calibration is to make sure the Profiling Radiometer is level, and use a spreadsheet to select only data from periods when the atmosphere is very stable. This process will be described in detail in Section 5.2.2.

5.2.2 TIP Calibration Procedure

Refer to the “TP/WVP-3000A Graphic User Interface Presentations” document.

5.3 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 7.1

5.3.1 Rotronic S3 Temperature and Relative Humidity Sensor

Radiometrics Profiling Radiometers manufactured after March 2004 are fitted with a new 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.[23] The Superblower incorporates a Rotronic S3 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 S3 sensor from direct sun. The sunshade and continuous airflow ensure negligible bias due to solar radiation.

Figure 24. Superblower with End Cover removed; S3 sensor and filter.

The Rotronic S3 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 S3 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 blower) is 0.2K higher than the air temperature recorded by the Profiling Radiometer, then an offset of +0.2 should be entered in the field provided for the Tamb offset in the mp.cfg file. Because the expected difference is normally very small, it may be necessary to average the data for 1-2 hours to obtain a meaningful estimate of the bias.

5.3.2 Barometric Pressure

Barometric pressure is measured by a solid-state transducer (Vaisala PTB100A) located inside the radiometer cabinet. It has no user adjustable settings or serviceable parts. No periodic maintenance or calibration is normally required. The following coefficients in the mp.cfg file specify the linear transfer function that converts level 0 voltage data (Vpres) to level1 Barometric pressure data:

```
+800.00   :Air press C0
+52.00    :Air press C1
```

…where barometric pressure (mb) = C0 + C1*Vpres. (normally, 800-1060 mb)

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

5.3.3 Rain Sensor

The Rain Sensor is an analog device that measures conductivity across a grid of inter-digital, gold plated conductors etched on a conventional fiberglass circuit board. The analog output from the device varies approximately as shown in Figure 25.

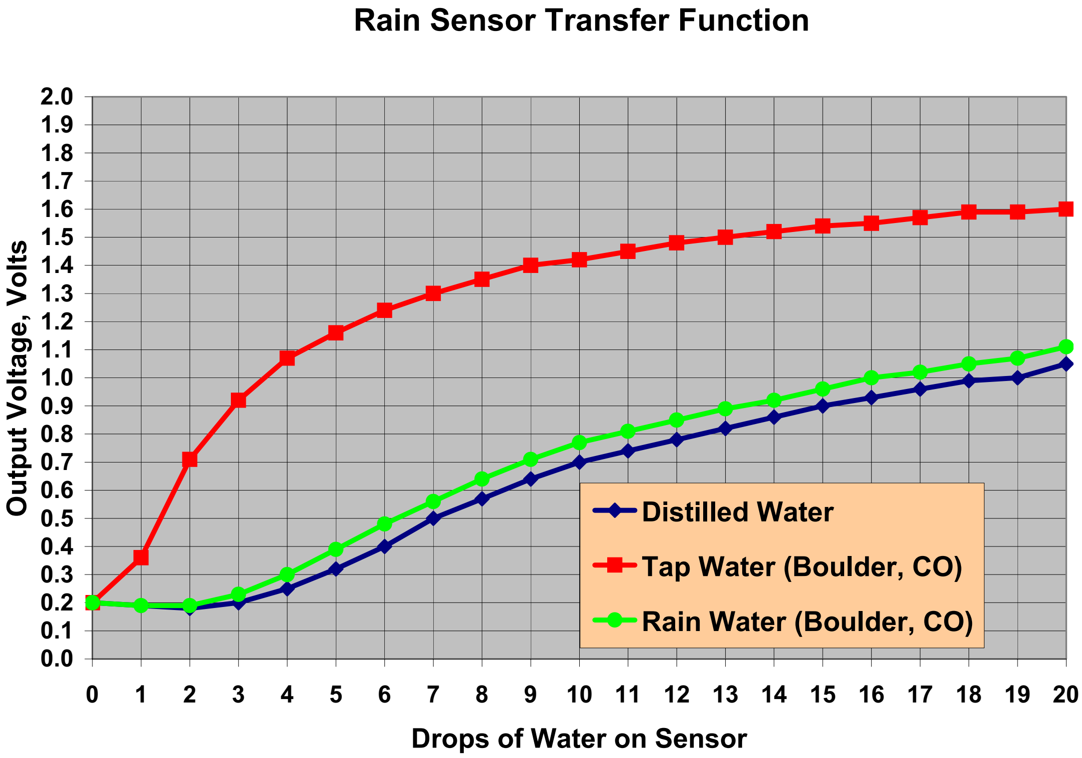

Figure 25. Typical Rain Sensor transfer function

This sensor is intended to provide a "Flag" for data that is potentially contaminated by some liquid water on the radome. It is not intended to provide rain rate or total rainfall information. A typical threshold setting of 0.4 to 0.8 volts, specified in the configuration file, is used to "turn on" the Rain Flag (Y or N) in the *level1* and *level2* data files. The Flag is also displayed on the "Profile Screens". The Flag can also be used to suppress TIP calibrations during rain (specified in mp.cfg). To observe the Rain Flag in *level1* data, the Profiling Radiometer must be executing a Procedure File containing **ret** commands.

Precise calibration of the rain sensor is not necessary. The basic function can be verified by dripping a few drops of water on the sensor. When Vrain > Rain Threshold (set in the configuration file), the *level1* Rain Flag = "Y". Wiping the sensor dry should once again set the Rain Flag to "N". The threshold may be adjusted by opening the configuration file in Notepad and editing the threshold value in the TIP Configuration section. Depending on the sensitivity desired and mineral content of the rain, values between ~0.3 and 1.5 volts can be used. In Figure 25, the difference between distilled water and domestic "tap water" illustrates how mineral content affects the sensitivity.

The Rain Sensor should be wiped clean with a non-abrasive cloth or paper towel as required to keep dirt and mineral deposits from accumulating.

5.3.4 Infrared Thermometer

6 Data Collection and Processing

Refer to the “TP/WVP-3000A Graphic User Interface Presentations” document.

6.1 Input Files

There are four types of input files used by the Profiling Radiometer:

- **Configuration File**
- **Procedure Files**
- **Neural Network Files**
- **List Files**

These files are used by the Operating Code to configure the system, schedule observations, and convert raw data to higher level products. All the programmable features and options available in Profiling Radiometer are specified by the user through these files.

6.1.1 Configuration File

The configuration file contains all the static parameters used specify how the Profiling Radiometer will operate, and the calibration information necessary to convert *level0* data to *level1* observations. Figure 26 illustrates a typical configuration file. The configuration file may be edited in Notepad to change the configuration. Care should be exercised not to inadvertently change any parameter unintentionally. In particular, care should be taken to save changes to the file in plain text format only (no formatting).

The configuration information is grouped in logical blocks with block headers for each highlighted in red. Generally, parameters are specified in the first field of each line, with comments following a colon delimiter. The use of each is explained below.

In the MP TYPE block, the specific model and serial number are specified. These fields are specified by the factory and used by the Operating Code to determine what features are enabled for the specific instrument. The Serial Number specified appears in the real-time displays to distinguish different instruments under the control of one computer. The com port used by the controlling computer is specified on the next line. This port is typically com1, but may be changed by the user when necessary. The baud rate is factory set to 1200 baud and should not be changed. The Operating Code uses this speed at startup, and changes automatically to 38,400 baud after startup.

The TIMER block provides a means for the user to start the instrument in Manual Mode and shut down automatically after a specified length of time. Below the Timer field, a full path and filename can be specified for a copy of the level2 file to be written to an auxiliary directory, such as one set up for shared or FTP access.

The TIP configuration block specifies all parameters used by the TIP calibration algorithm. The regression coefficient is a threshold for data quality checks. It should be adjusted to a value between 0.97 and 0.99 normally. Higher thresholds impose a higher quality standard.

```
# Radiometrics V3.24 configuration file
# No more comments

MP TYPE:
MP3000A MP3025  :Model & Serial Number
1               :Windows com port (1 to 9)
1200            :baud rate

TIMER:
-1              :auto "Quit" after this many min, -1 means don't shut down
nul             :path for level2 files

TIP CONFIGURATION: (For all TIP Commands)
0.98            :regression coeff for a good tip
0.0             :Default Azimuth Angle
5               :Number of Elevation Angles
30.0            :Tip Elevation Angle #1
45.0            :Tip Elevation Angle #2
90.0            :Tip Elevation Angle #3
135.0           :Tip Elevation Angle #4
150.00          :Tip Elevation Angle #5
0               :0=No tips when rain sensor on, 1=allow tips w/rain on
0.6             :rain sensor threshold (volts)

DEFAULT CNF COMMAND:
12000,10000,1500,200,15

CHANNEL CALIBRATION BLOCK:
2006/07/27 03:49:44   Date of last factory LN2 calibration
2006/08/09 19:27:43   Date of last user LN2 calibration        TIP Cal Transferred 7-30-2006
.90             :target tolerance for ln2 cal
12              :number of frequencies
Frequency,MRT,Window Coef,alpha,dtdg,k1,k2,k3,k4,Tnd
22.235,275.0,.000140,0.94516, -0.19763457E+06,  0.37240370E+01, -0.12958515E+00,  0.71536603E-03, -0.10786267E-05, 126.08
23.035,275.7,.000140,0.97630, -0.26785121E+06, -0.51170118E+02,  0.45730732E+00, -0.14137552E-02,  0.15354384E-05, 104.13
23.835,276.0,.000150,1.01453, -0.35548078E+06, -0.94369478E+02,  0.93876129E+00, -0.31768184E-02,  0.36614511E-05, 123.61
26.235,275.4,.000164,0.96608, -0.16216569E+06, -0.14331284E+03,  0.14935073E+01, -0.51975853E-02,  0.60401266E-05, 111.35
30.000,274.1,.000200,0.98658, -0.77115109E+06, -0.18509041E+03,  0.20190631E+01, -0.73974761E-02,  0.90897476E-05, 126.68
51.250,274.1,.000200,0.97575, -0.22590883E+06, -0.33628753E+03,  0.35657478E+01, -0.12580668E-01,  0.14771202E-04, 108.08
52.280,274.1,.000200,0.97238, -0.18985500E+06, -0.46758345E+03,  0.49814440E+01, -0.17690171E-01,  0.20940099E-04, 169.79
53.850,274.1,.000200,0.97076, -0.17198053E+06, -0.48666138E+03,  0.51518983E+01, -0.18218511E-01,  0.21517391E-04, 229.78
54.940,274.1,.000200,0.97013, -0.19657703E+06, -0.31809650E+03,  0.33591886E+01, -0.12008329E-01,  0.14507863E-04, 260.51
56.660,274.1,.000200,0.96634, -0.17121081E+06, -0.71341138E+03,  0.74502393E+01, -0.26088462E-01,  0.30623709E-04, 283.39
57.290,274.1,.000200,0.96507, -0.19287824E+06, -0.10358436E+04,  0.10959226E+02, -0.38762441E-01,  0.45823501E-04, 283.29
58.800,274.1,.000200,0.95387, -0.27209117E+06, -0.32501423E+03,  0.35099341E+01, -0.12754619E-01,  0.15572463E-04, 298.49

COEF:           :Coefficients for LN2 calibration and surface sensors
13.0            :LN2 liq depth in cm
68.23           :LN2 BP C0, the LN2 boiling point linear equation
0.009037        :LN2 BP C1
0.0078          :LN2 interfaces correction
6.08e-6         :LN2 polystyrene dielectric loss coef ~ 1.16e-5 K/K-cm-GHz
5.1             :LN2 Styrofoam thickness [cm]
+801.00         :Air press C0 Vaisala PTB100A 800-1060mb, 0-5 volts
+52.00          :Air press C1
-0.00           :Tamb correction (edit with values for this instrument)
+0.00           :Rh correction   (edit with values for this instrument)
-1.50           :BB sensor correction (default= -1.50)

NEURAL NET FILE(S):
pectemal.net
pecvapal.net
pecliqal.net

GPS:            :(This Block Not required for V3.21)
15              :elevation angle cutoff
0               :minimum SNR
pecv1600.net    :neural net for gps retrieval (This line not required for V3.23)
```

Figure 26. Typical Configuration File for V3.24 Operating Code (mp.cfg)

The default Azimuth Angle specifies the azimuth for TIP calibrations when the optional Azimuth Positioner is installed. The next line specifies the number of elevation angles the instrument will use for the TIP calibration. This number must match the number of lines below, each specifying a specific tip angle. In general, it is recommended that the 5 default values specified in the example be used. TIP angles less than 20° may result in some sidelobe contamination. More angles can be used, but the extra time required must be considered. Longer times to complete the TIP can introduce sampling error as the atmosphere changes. In all cases, it is desirable (but not required) to specify TIP angles in complementary pairs (i.e., 045° and 135°, 030° and 150°) so that atmospheric gradients tend to be averaged. Following the last angle, a switch is provided to either allow, or not allow TIPs when rain is detected by the rain sensor. The last line in the block specifies the threshold defining when the rain sensor flag is switched as described in Section 5.3.3.

The next block provides a means to specify the default **cnf** command values to be used to configure the low level state machine. See Section 6.1.2.1.2 for the definition of all the parameters.

The CHANNEL CALIBRATION BLOCK contains all the factory and user LN2 calibration data. This block is set up at the factory and should not be edited by the user, except to transfer a new TIP calibration as discussed in Section 5.2.2.

The COEF block contains all the parameters needed by the Operating Code to computer the effective LN2 target temperature, and for the conversion of *level0* Met Sensor data to *level1*. These values are set at the factory and, except for LN2 depth, should not normally need to be adjusted by the user except as discussed in Section 5.3. LN2 depth should be adjusted form 20 cm to 12 cm if the new low volume "Mini LN2 Target" is used.

The NEURAL NET FILE block is used to specify the files to be used by the Operating Code to convert level1 data to level2 profiles. These file names should match the Neural Network Files to be used. Note that only one file name is required for the WVP-1500A and TP-2500A models. Further information on Neural Network files is provided in Section 6.1.4.

The GPS block is used to set the elevation cutoff and SNR cutoff values as described in section 6.1.2.1.8. The neural network file used to retrieve integrated vapor, integrated liquid and path delay associated with GPS observations is also specified in this block.

6.1.2 Procedure Files

A Procedure File is a list of high level commands that define a specific series of observations to be performed. Two basic types of procedures can be defined: "relative" and "absolute". Relative procedures are command lists that execute sequentially, with each command beginning immediately following the completion of the previous command. Absolute procedures are command lists in which each command is specified to execute at a specific time of day. Procedure files provide the user with a simple, but powerful way to customize the operation of the instrument for automatic data collection. All Procedure Files are ASCII text files with file names of 1 to 8 characters and the extension ".prc" (i.e., *1min_170.prc*). Procedure files can be generated using any text editor, such as Notepad.

However, absolute procedures with many commands are more easily generated using a spreadsheet to automatically compute the series of **absolute** command execution times.

6.1.2.1 Procedure Commands

Procedure Commands are the basic building blocks used to create a procedure. There are 10 high level commands available. Each command occupies one line in a Procedure File, starting in the first column of the line, and terminated by a carriage return (**CR**). Commands with required or optional parameters are delimited by one or more spaces, or one tab character may be used between fields in command lines.

NOTE: All procedure commands must be specified in lower case letters only.

6.1.2.1.1 Antenna Coordinate System

The coordinate system used in all commands to specify the antenna pointing vector is given in Table 4. The elevation angle is defined for the state when az=000°. Therefore, if the azimuth is rotated to 180°, the antenna will point to the south horizon when el=000°.

Azimuth (az)		**Elevation (for az=000)**	
000°	north	000°	north
090°	east	090°	zenith
180°	south	180°	south
270°	west	270°	nadir (BB target)

Table 4 Antenna Coordinate System

NOTE: There are always two az/el specifications that produce the same pointing direction. For example, the direction given by az=000°/el=045° is equivalent to the direction az=180°/el=135°. The Operating Code automatically chooses the coordinates that will reposition the antenna faster, regardless of which way the user specifies the coordinates.

NOTE: The elevation drive resolution is 0.45° (800 steps per revolution). If an angle is specified that is not an even multiple of 0.45°, then the Operating Code rounds the number to the nearest angle available, and the angle actually used is logged in the output files. For example, if the user specifies an elevation angle of 30.00°, the radiometer will use and record 30.15°.

Caution: In the unlikely event of a of a power failure while the antenna azimuth is positioned near 180°, it is possible for the instrument to wrap the cables around the tripod when power returns, due to the loss of the azimuth index. To minimize this risk, users are advised not to command the Azimuth Positioner to azimuth angles in the range 175° to 185°.

*6.1.2.1.2 The **eng** command*

The **eng** command records 48 housekeeping parameters as data type 91 with header 90. This command is also automatically implemented if the radiometer is put into standby under Procedure Control in the GUI (Graphic User Interface).

*6.1.2.1.3 The **cnf** Command*

The **cnf** command is used to change the low-level configuration of the state machine hardware that controls observations. Five parameters can be set with this command as detailed in Table 5. Parameters X1 through X4 can effect the calibration, but X5 has no effect on the calibration. The default values for X1 through X4 have been demonstrated to be optimum for common applications and do not normally ever need to be adjusted. For calibrated operation, X1-X4 should not be changed unless the instrument is recalibrated at the factory for the specific configuration required.

Symbol	Parameter	Function	Range	Standard value
X1	base state-time	Sets the half period of the Noise Diode switching frequency	1000 to 65535 μsec	12000 μsec
X2	base integration time	Sets the smallest increment of time that an observation can be integrated	1000 to 65535 μsec	10000 μsec
X3	integration start delay	Time following a state change before integration begins	0 to 10000 μsec	1500 μsec
X4	channel change delay	Time following a channel change before starting the next observation	0-1000 msec	>100 msec
X5	base cycles to integrate	Number of Noise Diode cycles integrated for one channel observation	1-255	10-50 typical

Table 5 cnf command parameters

NOTE: For proper operation, X2 and X3 must be set such that the sum of X1 and X2 is at least 400 μsec less than X1. If the sum of the integration time (X2) and integration start delay time (X3) is longer than the base state time (X1), the integration period will not complete before the beginning of the next Noise Diode half-cycle. To insure completion of the integration period before the start of the next half period, a minimum timing margin of 400 μsec is recommended.

For most users, the **cnf** command is used primarily to change the observation integration time. The total sky observation integration time is the product of X2 and X5. Thus, for the standard value of X2=10,000 μsec (10 msec), the integration time can be set in 10 msec increments. For example, setting X5 =1 results in an integration time of 10 msec, and X5=50 results in an integration time of 500 msec.

The **cnf** command also provides the means to calibrate the ADC using an internal precision reference voltage source. Absolute calibration of the ADC is not required for an accurate Profiling Radiometer calibration since the transfer function effectively uses voltage ratios, not absolute voltages. However, Met Sensor accuracy does depend on absolute ADC calibration. The ADC is very stable, and can be used for 24 hours without recalibrating. However, for the best possible Met Sensor accuracy, **cnf** commands should be included in procedures to recalibrate the ADC periodically.

The **cnf** command executes in approximately 3 seconds. When used in an absolute procedure, a minimum of 4 seconds should be allocated for this command to execute. The command format for the **cnf** command is:

hh:mm:ss cnf X1 X2 X3 X4 X5

*6.1.2.1.4 The **bbc** Command*

*6.1.2.1.5 The **tip** Command*

The **tip** command is applicable to the TP/WVP-3000A and WVP-1500A only. It causes the Profiling Radiometer to collect a series of 22-30 GHz observations at elevation angles specified in the configuration file. From these observations, estimates of the Noise Diode temperatures (Tnd) for all 22-30 GHz channels are derived. These estimates of Tnd are logged to the current *tip.csv* file for calibration use as described in Section 5.2.2.

The command format for the **tip** command is:

hh:mm:ss tip az

…where the optional value az = azimuth angle to be used for the **tip** observations, if the optional Azimuth Positioner is installed. The **tip** command also causes the Met Sensors to be sampled immediately prior to the Profiling Radiometer observations. The Met Sensor data is logged to all output files.

*6.1.2.1.6 The **sky** Command*

The **sky** command directs the Profiling Radiometer to point the antenna to a specific elevation angle (el), and if the optional Azimuth Positioner is installed, to a specific azimuth angle (az), and then measure the brightness temperature on all channels. If no Azimuth Positioner is installed, a dummy value of az = 000 should be included in the command. The command format for the **sky** command is:

hh:mm:ss sky az el

The **sky** command also causes the Met Sensors to be sampled immediately prior to the Profiling Radiometer observations. The Met Sensor data is logged to all output files.

*6.1.2.1.7 The **ret** Command*

The **ret** command is equivalent to a **sky** command pointing to zenith (90 degrees), followed by the conversion of the sky brightness temperatures to profile retrievals. The retrievals are logged in the current *level2* file. As with the **tip** and **sky** commands, all Met Sensors are sampled immediately before the sky observations and logged to all output files. The command format for the **ret** command is:

hh:mm:ss ret az

The parameter **az** is optional. It is used only if it is desirable to pre-position the azimuth for a subsequent command, such as **sky** or **gps**.

*6.1.2.1.8 The **gps** command*

The **gps** command is a special "macro command" used to observe brightness temperatures while pointing in the direction of those GPS space vehicles (SV) in view of the radiometer. It is equivalent to a series of **sky** commands, each using the azimuth and elevation required to point the Profiling Radiometer towards the GPS satellites. Up to 12 vectors can be observed with one **gps** command.

The pointing vectors are derived from the optional GPS receiver (section 2.4) mounted on the top of the radiometer and connected to the signal panel as shown in Figure 6. The GPS Receiver and Azimuth Positioner options must be installed and connected in order to use the **gps** command. The command format for the **gps** command is:

hh:mm:ss gps az

When the **gps** command is executed, it pre-positions the Profiling Radiometer to the azimuth specified, then interrogates the GPS receiver for the current pointing vector set. The GPS receiver provides azimuth and elevation angles for all SVs in view (up to 12 max), rounded to the nearest full degree.

Because the azimuth positioner moves relatively slowly, it is desirable to minimize the required azimuth travel. To do this, the Profiling Radiometer operating code takes advantage of its ability to position the elevation mirror to any angle from horizon to horizon (0 to 180 degrees). All southern hemisphere azimuth angles are inverted to equivalent northern hemisphere vectors as follows. For all vectors with an azimuth angle between 90 and 270 degrees, the azimuth is changed by adding 180 degrees (modulo 360), and the elevation is changed to: new elevation = 180 - old elevation. The resulting vector set is exactly equivalent, but requires only one half of the azimuth position change for each **gps** command. For example, if the GPS receiver provides a pointing vector of az=135 and el=30, the radiometer will point to az = 315 and el = 150.

The operating code then sorts the modified vectors by azimuth angle, starting with the eastern most SV (typically near az = 90 degrees), and proceeding counter-clockwise (through north) to west (270 degrees). Depending on the number of GPS SVs that are visible, the number of channels observed, and the integration time, the gps command typically takes from 3 to 5 minutes to complete.

The **gps** command was first implemented with Version V3.23 of the operating code, which was designed to support GPS observations with the Model WVP1500A/1600. V3.24 extends the GPS command to operate with the TP/WVP3000. V3.24 requires *3 parameters* to be specified in the GPS Block at the end of the configuration file (section 6.1.1). The GPS *elevation cutoff angle* specifies the lowest elevation angle to be used for purposes of tracking GPS SVs. The *SNR cutoff value* specifies the lowest signal to noise ratio (SNR) to be allowed. An elevation cutoff angle of 15 degrees (or higher) is recommended to prevent the instrument from pointing too close to the horizon, where brightness temperatures will be corrupted by terrestrial emissions. The SNR cut off can be set to suppress tracking of weak SVs, but a value of 0 is recommended to ensure that all visible SVs (up to the limit of 12) will be tracked. The *GPS neural network file* is used to retrieve integrated vapor, integrated liquid, and path delay associated with GPS observations.

6.1.2.2 Relative Procedures

Relative procedures are generally used when the fastest possible observation cycle time is required, and control over the exact time of the observations is not as important. Relative procedures generally execute more quickly than absolute procedures because there is no wait-state time between commands. To specify that a procedure is a relative procedure, the first line in the file must contain the word "**relative**" followed by a carriage return (**CR**). Subsequent commands in a relative procedure each have dummy time fields with all zeros (00:00:00) followed by the command and parameters, if any.

Relative procedures are also useful to determine the execution times for each of the commands in a sequence of commands that the user desires to execute in an absolute file. The execution time of some commands depends on many variables, some of which cannot be easily predicted. For example, antenna movements from one position to another require different times depending on the specific start and ending angles. Thus, it is not practical to provide exact command sequence execution times for all commands in all cases. However, any user-defined sequence of commands can be timed using a relative procedure. Once the command execution times are known for a given sequence of commands, an absolute procedure can be written to provide sufficient time for the execution of each command, without wasting unnecessary wait-state time between commands.

6.1.2.3 Absolute Procedures

Absolute procedures are recommended for most observing plans because they provide uniform observation and calibration timing in the output files, best suited for most operational scenarios. Unlike relative procedures, each command in an absolute procedure is executed at a specific hour, minute and second, specified in the first field of the command (hh:mm:ss). To specify that a procedure is an absolute procedure, the first line in the Procedure File must contain the word "**absolute**" followed by a carriage return (**CR**). Subsequent commands in an absolute procedure each have execution times followed by the command and parameters, if any. The execution times must be sequential, and the time of execution for all commands must be specified to provide sufficient time for the previous command to complete. Commands specified to execute before the completion of the previous command will be skipped.

Typical absolute procedures contain a relatively short series of commands that repeat on a regular schedule. For example, the standard procedure *1min_170.prc* contains the following 4 command sequence that repeats every minute for 24 hours:

absolute						
0:00:20	**cnf**	12000	10000	1500	180	17
0:00:24	**bbc**	000				
0:00:38	**tip**	000				
0:01:08	**ret**	000				
0:01:20	**cnf**	12000	10000	1500	180	17
0:01:24	**bbc**	000				
0:01:38	**tip**	000				
0:02:08	**ret**	000				

Absolute procedures can also be programmed to provide different observation and calibration sequences at different times of the day. For example, a procedure could be written to collect only zenith observations during the day, and TIP calibrations during the night. Or, each hour of the day could be divided into two periods: one set of observations for the first 50 minutes, and different observations for the other 10 minutes of the hour. In this way, the user has complete control over the observation sequence and timing.

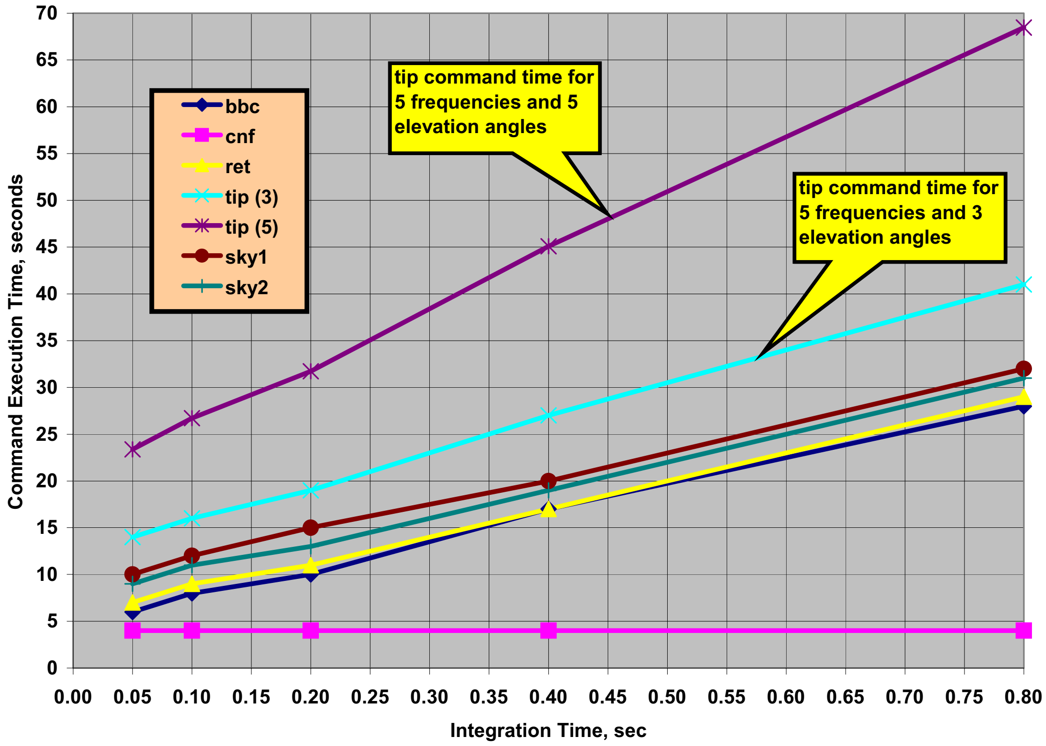

Figure 27. Typical Command Execution Times for the TP/WVP-3000A (12 channels)

6.1.2.4 Procedure Timing

As noted above, command execution times vary, depending on integration time, the previous state of the antenna position, and other factors. However, Figure 27 provides general guidance in planning an absolute procedure. To insure that all commands complete before the next is scheduled to execute, a new command sequence can be timed by using a relative procedure. Typical execution times can be determined by examining the *level0* file produced by a relative procedure, noting the times of each command execution. For example, if a given configuration and command sequence results in the **ret** command taking 13-14 seconds, the user might allocate 15 seconds for that command to provide some timing margin.

6.1.2.5 Choosing the Integration Time

As indicated in Figure 27, integration time is the primary variable affecting command execution time. It also affects the total observation random noise. With the exception of the **cnf** command, which has a constant execution time of ~3 seconds, longer integration times result in longer command execution times. Thus, for the maximum observation frequency, shorter integration times are desirable. However, shorter integration times result in a higher contribution of random noise resulting from the thermal noise inherent in all radiometers. Figure 28 illustrates the impact of integration time on the thermal noise component (ΔTn) of the total random noise.

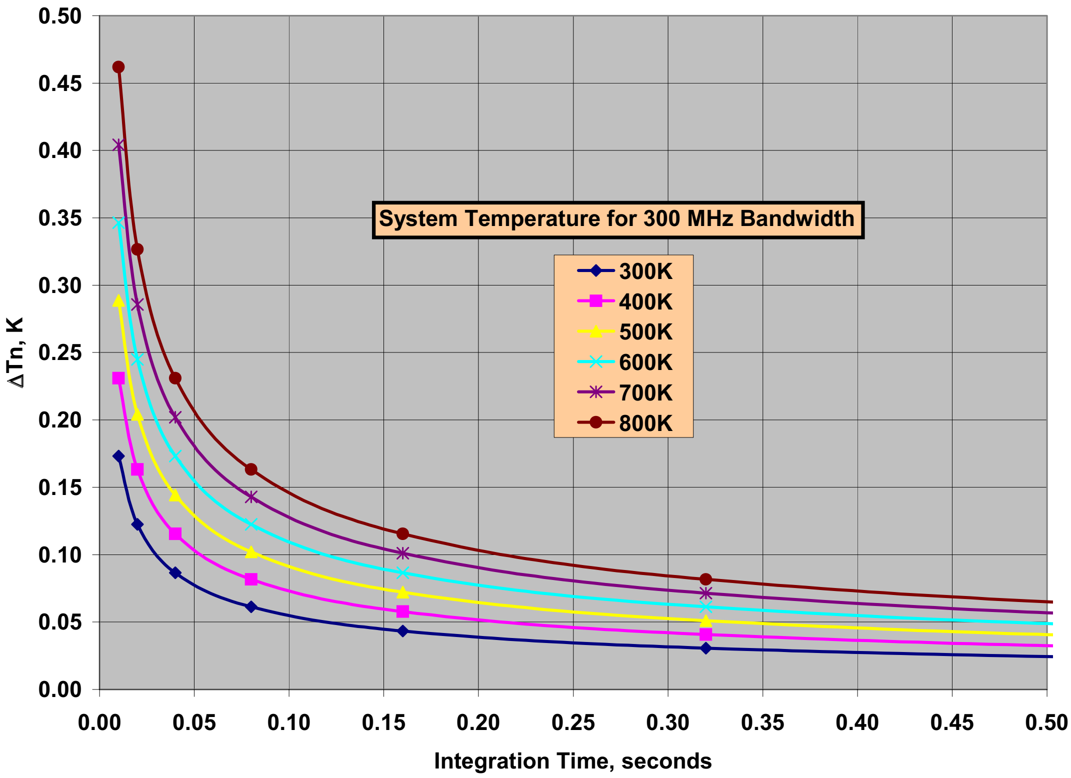

Figure 28. Theoretical Thermal Noise for Radiometers

For most applications, an integration time of ~200 msec is optimum for the Profiling Radiometers. Below 50 msec, ΔTn increases rapidly, and due to constant command overhead times, such as for antenna positioning between commands, further reduction of the integration time does little to reduce the command execution time. On the other hand, ΔTn reaches such a small value above 500 msec that other sources of noise (i.e., atmospheric and residual 1/f) become dominant. Thus, there is normally very little benefit in longer integrations.

6.1.3 Factory Procedure Files

The following standard procedure files are for the previous generation instrument. The new generation files are somewhat different.

Procedure File Name	Type	Description
1min_170.prc	absolute	Performs one black body calibration, one tip calibration and one zenith retrieval per minute for 24 hours starting at 00:00:00 GMT
5min_21.prc	absolute	Performs one black body calibration, one tip calibration and 21 zenith retrievals every 5 minutes for 24 hours starting at 00:00:00 GMT
tip_only.prc	relative	Performs continuous TIP calibrations (100,000)
B&L_V320.prc	relative	Test procedure. Provides continuous alternating observations of the internal black body target and an external LN2 target. Useful for verification of the calibration. (100,000)
gps_rel.prc	relative	Performs continuous gps commands and calibrations (tip and bbc) and a zenith retrieval (100,000)
gps_450.prc	absolute	Performs one black body calibration, one tip calibration one zenith retrieval and one gps command every 450 seconds (7.5 minutes) minutes for 24 hours starting at 00:00:00 GMT

6.1.4 Neural Network Files

Atmospheric temperature, humidity and liquid profiles are retrieved from Profiling Radiometer measurements (*level1*) using neural networks. The neural networks are trained using data from historical radiosonde soundings. Several years of radiosonde data from one or more sites in the same climatological region as the observation site are typically used for neural network training. The radiosonde soundings are forward modeled using atmospheric emission models and radiative transfer equations to provide brightness temperatures that would have been observed at ground level. The neural networks find the temperature, humidity and liquid profile (atmospheric state) retrievals that best correlate with the radiometric observations. For GPS observations, a separate neural network file is used. The neural network files are trained using the Stuttgart Neural Network Simulator and a standard back propagation method.

The neural network files used for real-time retrievals must be specified in the configuration file. Three files are required for the TP/WVP-3000A as follows:

- temperature
- water vapor
- liquid

These files must be located in the Operating Folder and specified in the configuration file (mp.cfg) under the heading NEURAL NET FILE(S). *They must be listed in the same order as listed above.* The WVP-1500A requires only one file for water vapor, and the TP-2500A requires only one file for temperature. When GPS commands are included in the procedure file, V3.24 code also requires the GPS neural network file to be specified in the GPS configuration block (section 6.1.1).

Neural network files provided by Radiometrics conform to the file naming convention **sssnxxxx.net** where **sss** is a site identifier, **n** =**t** for temperature, **v** for vapor and **l** for liquid. The field **xxxx** is used to specify details, such as high or low resolution versions of the neural network file. File names can be changed, but the file name extension must be **.net**, and the files must be listed in the correct order in the configuration file.

New Profiling Radiometers are sold with one set of neural network files included. The user must specify the region of operation, or radiosonde site to be used for training. Additional neural network files may be purchased for other sites. Contact Radiometrics Sales and Marketing for further information.

To change neural network files to be used for real-time level2 processing, simply add the new neural network files to the operating folder and change the neural network file names specified in mp.cfg.

NOTE: Operation of the radiometer with neural network files trained for a different site may produce profiles with significant error. However, the level0 and level1 data will not be affected. In the event the radiometer is operated with the wrong neural network files specified in mp.cfg, the level1 data can be reprocessed with the correct neural network files at a later time.

6.2 Output Files

There are 5 standard output files generated by the Operating Code. Common conventions used in all the files are described below, followed by descriptions of each output file type.

6.2.1 Output File Name Conventions

All output files use the .csv extension to indicate to other application programs that the files conform to the industry standard *comma separated variable* data base format. Most mathematical analysis, spreadsheet and database programs can open and manipulate the data in these files with little or no reformatting. All output files are named automatically using the following format:

yyyy-mm-dd_hh-mm-ss_xxx.csv

…where yyyy is the year when the file was started
mm is the month of the year
dd is the day of the month
hh is the hour of the day
mm is the minute of the hour
ss is the second of the minute

…and xxx defines the output file type as follows:

xxx=lv0	*level0* file
xxx=lv1	*level1* file
xxx=lv2	*level2* file
xxx=tip	*TIP* calibration file
xxx=ln2	*LN2* calibration file

This file naming convention orders the files chronologically when sorted alphabetically by name.

6.2.2 Record Number

All output files contain a sequential record number in the first field, starting with the number 1. In the event a file has been sorted for analysis purposes by record type, elevation angle, or any other parameter in the file, the record number field can be used to restore the order of the file to its original order.

6.2.3 Date/Time Conventions

All output files contain a date/time stamp in the second field of all records that contain time dependent data. All output files use the following date/time stamp convention for each record in the file:

mm/dd/yyyy hh:mm:ss

…where mm is the month
dd is the day
yyyy is the year
hh is the hour
mm is the minute
ss is the second

The time corresponds to the time of the completion (end) of the observation set.

NOTE: If a file is opened in Excel or similar applications, the date/time stamp can be reformatted easily to any other standard format and saved in that revised format.

6.2.4 Record Type Conventions

All output files contain a record type number in the third field of all records. The record type number defines the header or data type in that record. Record types for each file type are grouped in blocks and numbered sequentially beginning with the number assigned to the header for that block. Record headers define all the fields in each block.

Data is logged sequentially in the order of the observations. For some types of analysis, it is more convenient to sort the data based on different parameters. Sorting a file by record type is often a useful first step to analysis. When a file is sorted by record type (third column in a spreadsheet, for example), the data automatically sorts into logical blocks with the appropriate header for each block appearing at the top of each block. Second level criteria can be used to sort the data within each block by elevation or azimuth angle, ambient temperature, or any other field appearing in the record.

6.2.5 *Level0* File

Level0 files contain raw, unprocessed data in engineering units. A *level0* file is produced for all modes of operation and all options that can be selected from the main menu. *Level0* files contain 100% of the information needed to reprocess the raw data with alternative calibration information or algorithms. *Level0* files contain the following record types:

Record type	Description of Record Type
00	User memo record
10	Header for sky observations
11	ret observation (5, 7, or 12 frequencies)
12	sky observation (up to 40 frequencies)
13	tip observation for 1 elevation angle and all frequencies specified in mp.cfg
20	Header for observation of black body
21	BB observation for BBC command (up to 40 frequencies)
30	Header for cnf records
31	cnf parameters, RF deck temperatures (2 or 4), ADC zero and 10V cal)
40	Header for surface met records
41	Voltages for Tamb, RH, pressure, Tir and rain sensor
60	Header for LN2 calibrations
61	Record of LN2 cal data (includes BB, LN2 observations)
80	Header for GPS records (V3.23 and V3.24 Code only)
81	Record of sky observations (same as record type 12 except GPS SV ID and SNR are included)
90	Header for self test (eng command)
91	Self test voltages[24]
98	Error record
99	Record type for echo of mp.cfg file to level zero file

Figure 29. *Level0* Record Types

6.2.6 *Level1* File

Level1 files contain real-time brightness temperatures for each channel specified in the configuration file. Real-time *level1* files are produced from contemporaneous *level0* data and calibration information in the configuration file. *Level1* files contain the following record types:

[24] Appendix B provides a list of all the self test parameters.

Record type	Description of Record Type
10	Header for non-GPS Command Level1 records
11	Brightness temperatures resulting from an ret command
12	Brightness temperatures resulting from a sky command
80	Header for GPS Level1 records (V3.23 and V3.24 Code only)
81	K band Brightness temperatures resulting from a gps command (same as record type 12 except GPS SV ID and SNR are included)

Figure 30. *Level1* Record Types

6.2.7 *Level2* File

Level2 files contain records of real-time retrievals of temperature (K), water vapor (g/m^3), relative humidity (%) and liquid water (g/m^3) profiles. The retrievals are produced using the contemporaneous *level1* data and the neural network files specified in the configuration file. *Level2* files contain the following record types:

Record type	Description of Record Type
10	Header for non-GPS Level2 records
11	Temperature profile
12	Vapor density profile
13	RH profile
14	Liquid water profile
80	Header for GPS Level2 records (V3.23 and V3.24 Code only)
81	Vapor density profile (same as record type 12 except GPS SV ID, SNR and six additional GPS related parameters are added)

Figure 31. *Level2* Record Types

Figure 32 provides the definitions of the special GPS related products contained in type 80/81 records. Other parameters in the *level2* headers are self explanatory.

Parameter	Definition	Units
Vint	GPS Path integrated water vapor	cm
ZVint	GPS Path integrated water vapor *mapped to zenith*	cm
VDly	GPS Path delay due to water vapor	cm
ZVDly	GPS Path delay due to water vapor *mapped to zenith*	cm
Lqint	GPS Path integrated cloud liquid water	mm
ZLqint	GPS Path integrated cloud liquid water *mapped to zenith*	mm
LqDly	GPS Path delay due to cloud liquid water	cm
ZLqDly	GPS Path delay due to cloud liquid water *mapped to zenith*	cm

Figure 32. GPS *Level2* Record type 80 header definitions

6.2.8 *TIP* Calibration File

TIP files contain the results of *successful* tip calibration attempts. For each **tip** command in a Procedure File, the *level0* data is processed in real-time by the TIP calibration algorithm. For each TIP frequency specified in the configuration file, atmospheric opacity is computed for each elevation angle. The TIP calibration algorithm attempts to fit all the opacity values for each frequency to a linear function of air mass (number of equivalent atmospheres for a given elevation angle). If the linear regression for all channels is better than the regression threshold “r” specified in the configuration file, then the tip is considered “good”, and the computed values of Tnd and r for each frequency are included in the *TIP* output data file. *TIP* files contain the following record types:

Record type	Description of Record Type
10	Header for current calibration data in configuration file
11	Current calibration data
20	Header for TIP calibration results
21	Values of Tnd @ TkBB=290 K and r values for all frequencies in TIP Cal

Figure 33. *TIP* Calibration Record Types

A copy of the current Tnd calibration data contained in the configuration file is copied to the top of the *TIP* file (record types 10 and 11). This provides a quick way to compare new TIP calibration derived values of Tnd to the current operational values as described in Section 5.2.2. The values of Tnd are normalized to the value that would be observed when TkBB = 290 K.

6.2.9 *LN2* Calibration File

LN2 calibration files contain the values of Tnd computed from individual LN2/Black Body observation sets during an LN2 calibration, for all channels specified in the configuration file. *LN2* files contain the following record types:

Record type	Description of Record Type
10	Header for current calibration data in configuration file
11	Current calibration data
20	Header for LN2 results
21	Values of Tnd @ TkBB=290 K for all frequencies in configuration file

Figure 34. *LN2* Calibration Record Types

A copy of the current Tnd calibration data contained in the configuration file is copied to the top of the *LN2* file (record types 10 and 11). This provides a quick way to compare new LN2 calibration derived values of Tnd to the current operational values. The values of Tnd are normalized to the value that would be observed when TkBB = 290 K.

6.3 Time Synchronization

The date/time stamp in files and output file names is derived from the date/time in the Microsoft Windows Operating System. For the best accuracy, the Operating System should be configured to automatically synchronize using an internet UTC reference, such as the US National Institute of Standards and Technology.

6.4 Reprocessing

Users can reprocess *Level0* files with alternative calibration values or advanced algorithms to improve the accuracy or reduce the random noise in *level1* data. *Level1* files can be reprocessed with alternative retrieval algorithms. Radiometrics provides reprocessing codes for V3.21 code only.

7 Maintenance and Trouble Shooting

This Section provides information on routine maintenance and calibration of the Profiling Radiometer, including Surface Met Sensors, and the controlling computer.

7.1 Instrument Maintenance

7.1.1 Radiometer Calibration

When installed at a permanent site and left to operate on a continuous basis, in normal operating conditions, the Profiling Radiometer should remain calibrated within specifications for 6 months or longer. However, the calibration can be effected by radome degradation, long-term drift, extreme weather, changes to the installation environment, and other factors. It is therefore recommended that the calibration be monitored on a regular basis, at least monthly, and updated as needed.

The 22-30 GHz channels can be monitored easily by checking the TIP calibrations regularly. If **tip** commands are included in the procedure in use, pressing the **O** key will produce real-time graphs of all the Noise Diode values (Tnd) in current use (flat lines), and a time series of the most recent values derived from real-time TIP calibrations. The numeric values of Tnd in current use are also indicated on the **O** display. If the daily averages of the new values of Tnd deviate by more than 0.5% from the Tnd values in use, then the user should *consider updating* the values in use as described in Section 5.2. Note that it is normal for real-time values of Tnd to deviate from “truth” by up to 2% when the atmosphere is changing rapidly, such as when a front is moving through the area. Therefore, the calibration should be changed only if the average of many “good” TIP derived Tnd values deviates from the values in use. See Section 5.2 for the recommended procedures to identify when TIP calibration values are of good quality.

The 51-59 GHz and 22-30 GHz subsystems are predominantly independent. Therefore, the calibration status of one is not necessarily indicative of the other. The 51-59 GHz channels can only be calibrated using an external LN2 target. Therefore, it is recommended that an LN2 calibration be performed every 6 months, or sooner if accuracy is in question. Follow the procedures in Section 5.1 to perform an LN2 calibration.

7.1.2 Antenna Pointing Calibration

The accuracy of most sky observations is dependent on accurate antenna positions. The elevation angle accuracy is dependent on the accuracy of the leveling process described in Section 3.4. The instrument should be checked for proper leveling at least annually, following severe wind conditions, and any time TIP calibration attempts fail to pass the internal quality test more often than normally observed. Refer to Section 3.4 for proper leveling procedures.

If the optional Azimuth Positioner is installed, the instrument azimuth should be checked periodically. To check the azimuth reference position, end any data collection in progress by pressing **Q** on the computer, then cycle the Profiling Radiometer power by switching the power off for 10 seconds, then back on. Once the Profiling Radiometer reaches its azimuth index position, it should be reoriented with the connector panel due east and the antenna in the north-south plane. To adjust the Profiling Radiometer azimuth reference, loosen the T-bolt slightly and gently rotate the Profiling Radiometer so that the connector panel points due east, and then re-tighten the T-bolt. The user may want to use a compass for this orientation. If so, the magnetic declination at the installed site must be included in the determination of true north.

7.1.3 Radome Replacement

Airborne pollutants will eventually coat the radome. Any foreign matter on the radome may increase the observed sky temperatures. The radome may be washed by pouring clean water over it and left to air-dry. It should not be touched or rubbed with a sponge or towel. Doing so will degrade the hydrophobic material. When the surface of the radome becomes visibly dirty, and it cannot be cleaned with free flowing water, the radome should be replaced to ensure optimum performance of the Profiling Radiometer. The frequency of radome replacement is site dependent and should be determined by periodic examination. Check the radome every 30 days until a maintenance interval can be established by the user, based on local conditions.

To replace the radome, quit the current procedure in progress, if any, (Press **Q**) and turn off the power. Next, disconnect the two power cables, from the source first, then at the Profiling Radiometer. Disconnect the short “pigtail” cable between the Superblower and radiometer. If an IRT is mounted on the Cabinet Hood, remove the connector from the radiometer base. Then, remove the hood by unlatching the 6 latches located along the sides and carefully lifting it straight up and off of the Profiling Radiometer. Place the back end of the hood on a clean work surface so that the inside is accessible. Support the hood as necessary to protect the IRT assembly. Remove all 4-40 Nylock nuts (32) securing the Radome Window Retainer as shown in Figure 35. After all of the nuts are removed, carefully remove the Radome Window Retainer and the old radome.

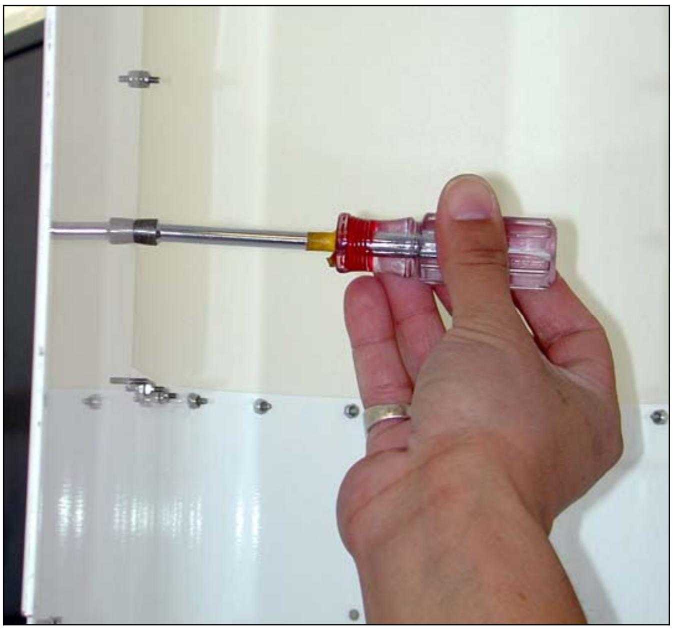

Figure 35. Radome replacement

To install the new radome, reverse the process. *Observe the labels indicating the inside and outside of the radome.* Avoid touching the surface of the new radome as much as possible. The new radome should be grasped only by the edges to ensure that the hydrophobic coating is not compromised. Tighten the nut just enough to slightly compress the radome. *Do not over-tighten the nuts*.

7.1.4 S3 Temperature and RH Sensor Maintenance

The Rotronic S3 Temperature and RH sensor is a precision instrument that will maintain calibration for 6 months or more in normal service. However, if dust or other local air pollution is excessive, the screen on the sensor may need to be cleaned more often. To access the S3 Temperature and RH sensor, loosen the 10 thumbscrews that secure the Superblower End Cover. Gently remove the cover by pulling outward with the handle while holding the bottom lip. See Figure 36.

To clean the S3 screen, the S3 probe can be left in the mounting socket. Simply unscrew the screen and remove to the right. See Figure 37.

Caution: The S3 sensor is a delicate instrument requiring careful handling. Nothing should be allowed to come in contact with the active sensor elements inside the screened protective cover.

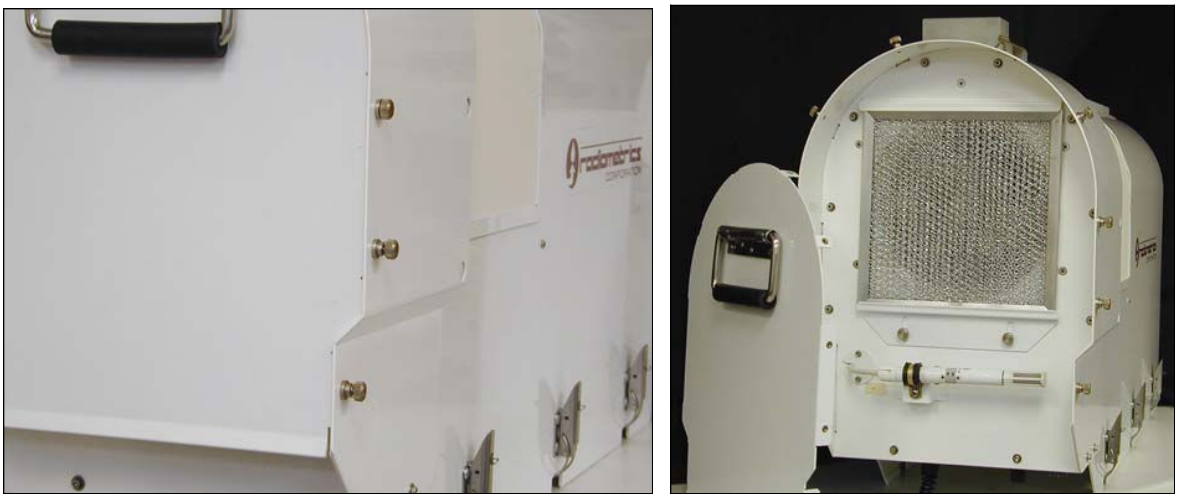

Figure 36. Superblower End Cover removal

To clean the screen in the field, use pure compressed air. Pure compressed air is available in small cans for cleaning photography equipment, computers, and other electronic equipment. Air should be blown through the screen from the inside to the outside as shown in Figure 37**.** Avoid using compressed air from an air compressor because oil and water from the compressor can contaminate the sensor.

If access to ultrasonic cleaning is available, it can be used with distilled water to clean the screen. Chemical cleaners should be avoided because of possible contamination.

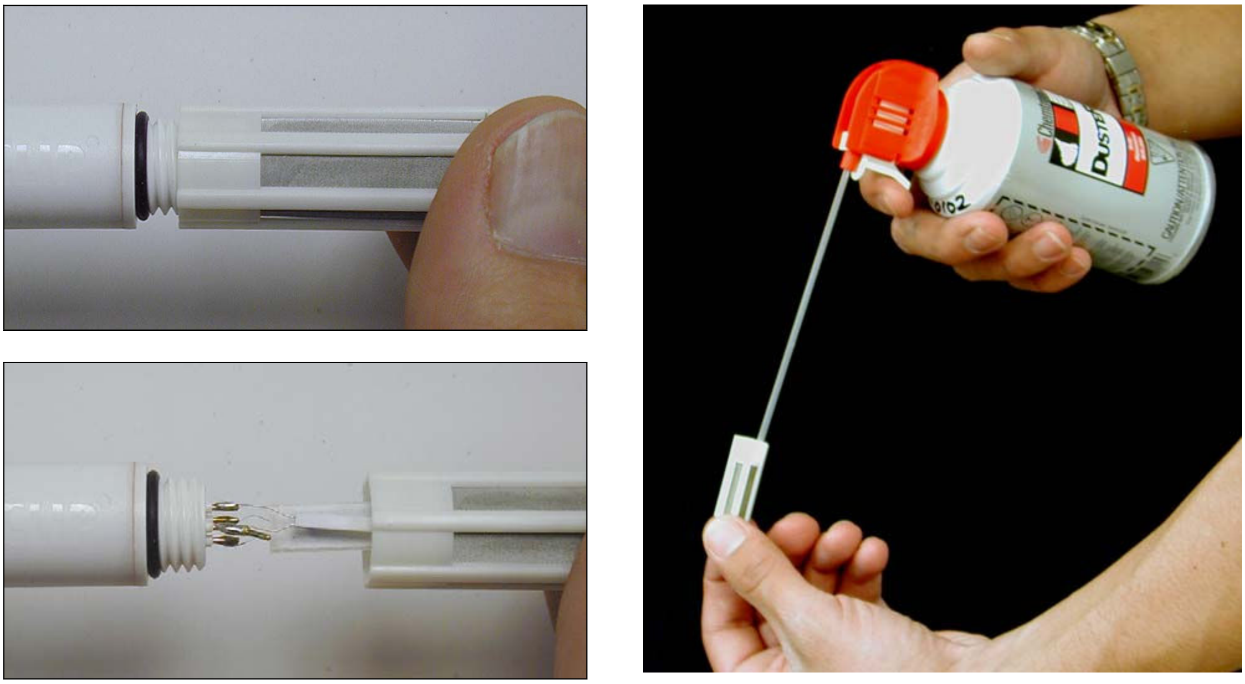

Figure 37. S3 screen removal and cleaning

To remove the S3 sensor for laboratory calibration or replacement, rotate the Gray Locking Collar on the probe until the black dots on the Gray Locking Collar line up with the black dots on each side of the Gray Locking Collar. Unplug the probe from the Gray Locking Collar by carefully pulling the probe to the right. See Figure 38.

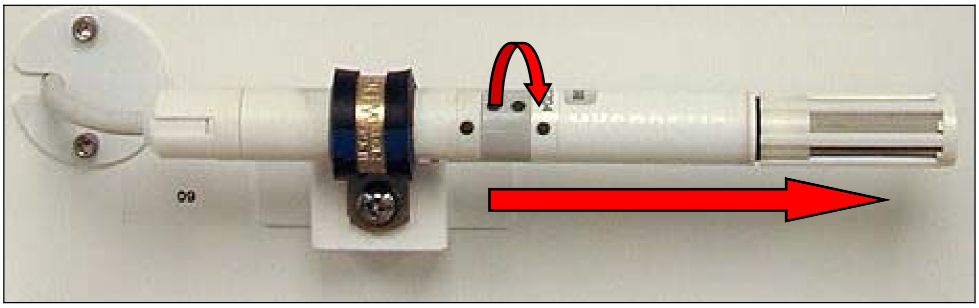

Figure 38. S3 sensor removal

New S3 sensors are available from Radiometrics, or directly from the Rotronic Corporation. The S3 sensor can be calibrated in the laboratory by the user by using the Rotronic communications pod, available directly from Rotronic.

If the user has access to high accuracy field standards for Tamb and RH, and wishes to adjust the S3 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 Superblower) is 0.2K higher than the air temperature recorded by the Profiling Radiometer, then an offset of +0.2 should be entered in the field provided for the Tamb offset in the mp.cfg file. Because the expected difference is normally very small, it may be necessary to average the data for 1-2 hours to obtain a meaningful estimate of the bias.

7.1.5 Superblower Filter Cleaning and Replacement

The Superblower impeller produces a high volume of airflow. To protect the radome and impeller, the intake is filtered with a standard aluminum mesh filter. This filter should be inspected and serviced periodically. The frequency of service is site-dependent and must be determined by the user. Following installation at a new site, inspect the radome every 30 days until a maintenance interval can be established by the user, based on local conditions.

To remove the filter, first remove the Superblower End Cover as described in Section 7.1.4. Then loosen the two thumb screws holding the filter retaining bracket, as shown in Figure 39. Remove the filter by sliding the retaining bracket down and lifting the filter out.

If the filter is not matted with insects or other difficult to remove debris, compressed air can be used to clean it. For insects and other heavy debris, the filter should be cleaned with water and mild detergent, compressed air, and then rinsed thoroughly. Filters that cannot be cleaned due to excessive debris should be replaced with a new filter.

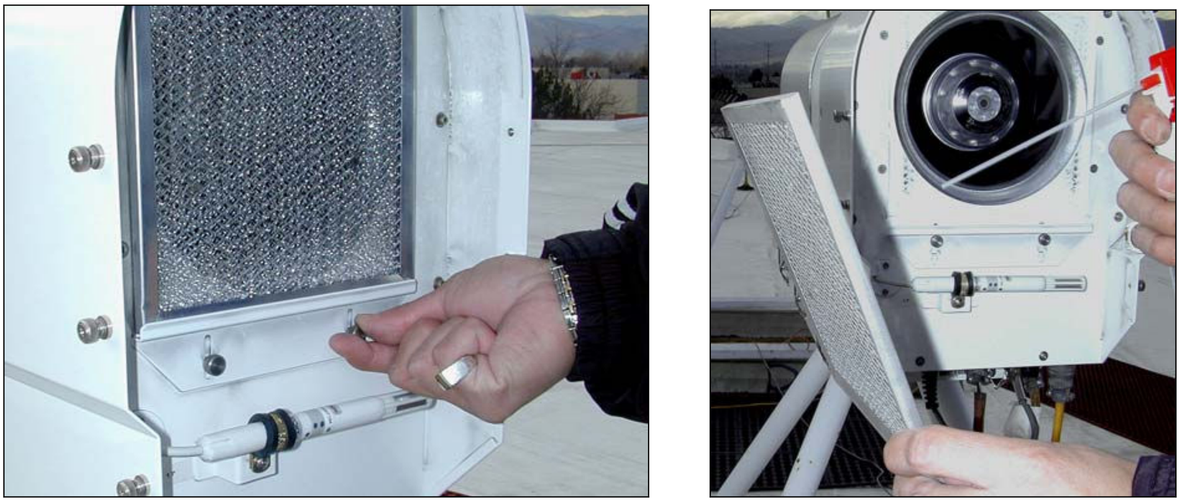

Figure 39. Superblower filter removal and cleaning

Replacement filters are available from Radiometrics and many local hardware stores. The nominal size is 8” X 8” X 3/16”.

7.1.6 Rain sensor Board

The rain sensor board, located on the top of the Superblower, detects the presence of liquid water by measuring the resistance between the inter-digital conductors. Excessive surface contamination from pollution, salt spray, etc. will alter the transfer function (volts/water-drop). This board should be cleaned periodically with fresh water and a non-abrasive cloth or paper towel to remove all foreign matter. The board is gold plated to minimize corrosion, but will degrade over time in severe environments. If the rain sensor fails to provide satisfactory service after cleaning, it may need to be replaced. Replacement boards are available from Radiometrics.

To replace the board, unscrew the four mounting 6-32 screws and gently lift the board up until the small connector on the bottom is visible (2-3 cm). Unplug the small connector on the old board, plug in a new board, and then replace the four mounting screws.

7.1.7 IRT Lens and Mirror Maintenance

The IRT lens and mirror, located on the top of the Profiling Radiometer, should be checked periodically for contamination. For accurate cloud base temperatures, these surfaces must be free of dust and other contamination. The frequency of service is site-dependent and must be determined by the user. Following installation at a new site, inspect the IRT lens and mirror every 30 days until a maintenance interval can be established by the user, based on local conditions.

A soiled lens or mirror can be cleaned with a standard camera lens cleaning kit available from photography stores. Paper towels and many types of cloth are too abrasive, and may damage the surfaces. Before using a lens cleaning tissue, cloth or brush to clean these surfaces, pure compressed air should be used to remove as much dirt as possible, as shown in Figure 40. A dirty lens or mirror can be easily scratched by touching the surfaces, or wiping the surfaces with a cloth or brush. Replacement lens and mirrors are available from Radiometrics.

Figure 40. IRT lens and mirror

7.1.8 Cables

Normally, the power and data cables do not require any periodic maintenance. However, it is good practice to inspect the cables periodically to ensure that they have not been damaged by accident, rodents, etc.

7.2 Controlling Computer

No periodic maintenance is required for the computer hardware beyond what is recommended by the computer manufacturer.

7.2.1 Operating System Updates

Microsoft releases updates to the Windows Operating System software (OS) quite often. The OS can be configured to update automatically or notify the user that updates are available. It is generally advisable to keep the OS up to date with revisions as they are released. However, the automatic update feature should not be enabled. Automatic updates can interfere with normal data collection, so it is better to install updates manually, at a time convenient to the user.

7.2.2 Operating Code Updates

Radiometrics may release updates to the Operating Code from time to time to enhance performance, add features or fix bugs. Generally, these updates can be installed by replacing the application file (**mp321.exe**) in the Operating Folder, without changing any other files. Occasionally, updates require the installation of additional files, or the modification of some existing files. Detailed installation instructions will be provided with all new code releases. Contact Radiometrics Sales and Marketing for information on the latest codes available, and advice on the best code to use for a given application.

7.2.3 Virus Protection

Radiometrics does not supply virus protection software with computers. However, if the user connects the controlling computer to the Internet, virus protection software may be added by the user, provided it is configured to operate without restarting the computer from time to time.

7.2.4 Error Messages

If the Operating Code encounters a fatal or non-fatal error, if will attempt to write an Error Message to the level0 file marked record type 98. Appendix C contains a list of all the Error Messages that may be written to the level0 file. In the event that the user encounters problems requiring factory assistance to resolve, be prepared to give the technician information about the Error Message history.

8 Warranty and Service

Radiometrics warrants its Profiling Radiometers for two years from the date of delivery against defects in workmanship and materials under normal use and service. Radiometrics will repair or replace, at Radiometrics option, any equipment found to be defective within this warranty period, FOB Boulder Colorado. This warranty excludes the notebook computer, as this computer is covered under the original equipment manufacturer's warranty.

For information or service, contact Radiometrics as indicated below. Be prepared to describe your problem in detail. If field repair is not considered possible, request a Return Materials Authorization (RMA). Radiometrics will remedy your problem as soon as possible and return the unit.

The Profiling Radiometers are protected under U.S. and foreign patents. The software and firmware are copyrighted.

Please direct inquiries to:

Radiometrics Corporation
2840 Wilderness Place, Unit G
Boulder, CO 80301-5414
USA

Tel: (303) 449-9192
Fax: (303) 786-9343

8.1 European Certification

The TP/WVP-3000A has received European Certification in conformance with the European Union Directives:

- 73/23/EEC (93/68/EEC) Low Voltage Directive
- 89/336/EEC Electromagnetic Compatibility Directive

Based on the following standards:

- EN61010 Safety of Electrical Equipment for Measurement, Control, and Laboratory Use
- EN 55022 (Class A) Limits and methods of measurements of radio interference characteristics of information technology equipment.
- EN 50082-1 Electromagnetic compatibility - Generic immunity standard -Industrial environment

8.2 Symbols Legend

Below is a description of the safety marking symbols that appear on the Profiling Radiometer. These symbols provide information about potentially dangerous situations which can result in death, injury, or damage to the instrument and other components.

	Caution, hot surface		Main power off
	Caution, refer to manual		Main power on
	Caution, risk of electric shock		Alternating Current

Appendix A: TP-2000 Tripod Assembly

Unpack and inspect the tripod parts for signs of damage or missing pieces. The following parts should be included:

(3 ea.) Foot Assembly.
(3 ea.) Telescoping Leg Assembly.
(3 ea.) Strut.
(1 ea.) Triangular Top Plate with eyebolt.
(1 ea.) Hardware Kit containing:

Foot Assembly Hardware:
(3) 3/8” x 1-3/4” cap screws.
(6) flat washers.
(3) lock nuts.

Cross Strut Hardware:
(6) 3/8”x 1” cap screws.
(6) Lock nuts.

Top Plate Hardware:
(6) 3/8”x 3/4” cap screws.

(1 ea.) Tool Kit containing:
(1) ¼” Allen wrench.
(1) 5/16” Allen wrench.
(1) 9/16” box / open-end wrench.
(1) 9” Magnetic bubble level.

(1 ea.) Center Pull Anchor kit. Containing:
(3) SS oval threaded connector.
(1) SS turnbuckle.
(1) SS eyebolt.
(3’) SS 3/16” corrosion resistant chain

Figure 41. Radiometrics TP-2000Tripod Parts.

Assembly Instructions

1. Attach (1) foot assembly to each leg assembly using (1) 3/8" x 1-3/4" cap screw, (2) flat washers, and (1) 3/8" lock nut. DO NOT TIGHTEN the screws at this step.

2. Attach the other end of each leg assembly to the triangular top plate using (2) 3/8" x 3/4" SS cap screws for each leg. DO NOT TIGHTEN the screws at this step.

3. Attach the (3) cross struts to the leg brackets using (2) 3/8" x 1" cap screws and (2) 3/8" lock nuts on each cross strut.

4. Tighten all screws using 5/16" Allen wrench and 9/16" box wrench.

5. Adjust to desired height as follows:

6. Loosen the (3) collar clamps using the ¼" Allen wrench. Extend the lower leg by pulling downward on the foot. Repeat this step for each leg as required to set instrument height. If the site is not level, adjust the legs to different lengths as required to level the triangular top plate. Re-tighten each collar clamp.

7. The tripod can be secured using any of the following methods:

   a) **Center Pull Guy Method:** If a single secure "Anchor Bolt" can be provided directly under the tripod, this method can be used as follows:

   - Position the tripod directly over the anchor bolt.
   - Attach the oval threaded connector of the pull chain assembly to the eyebolt on the triangular top plate.
   - Attach the other end of the chain to the anchor bolt using the threaded chain link, (moved to the required position on the chain).
   - When the chain is attached at both ends and the tripod is leveled at the desired height, take up the slack with the turnbuckle. A downward force of 25-30 lbs. is sufficient.

   b) The feet can be secured using **lag bolts** through the small holes in the feet.

   c) Tent **stakes** or similar can be used to secure the feet using the large holes.

   d) **Sand bags** or similar dead weights can be applied to the feet.

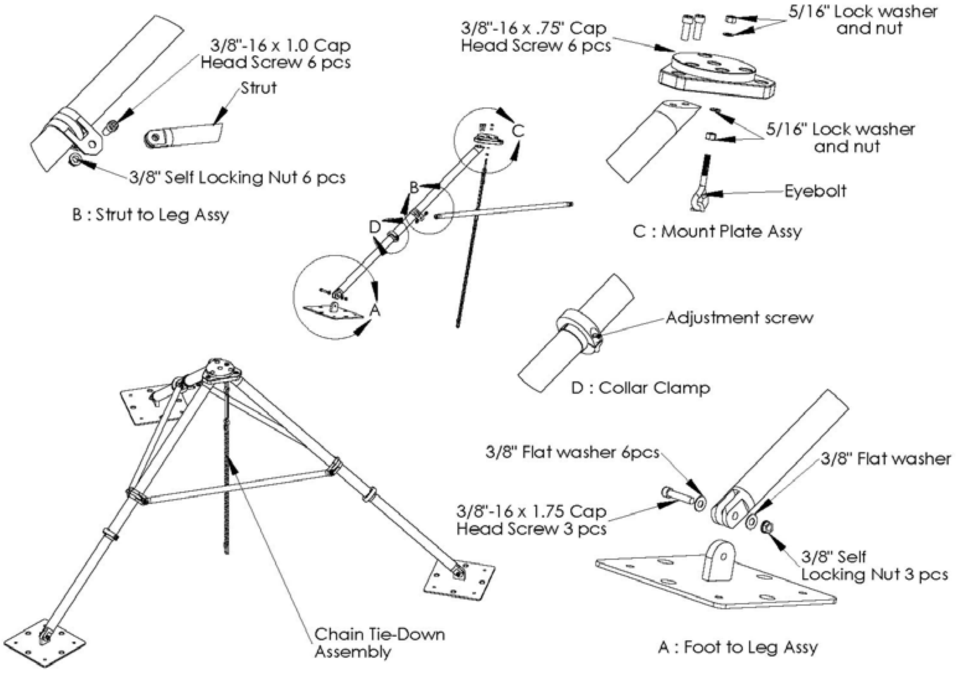

Figure 42. Tripod Assembly Components.

Figure 43. Tripod Fully Assembled

Appendix B: Power On Test Channels

Channel	Parameter Measured	Nominal Value (volts)
0	Black body temperature sensor 0 (-20C - +50C)	6.30 – 8.05
1	Black body temperature sensor 1 (-20C - +50C)	6.30 – 8.05
2	NOT USED	0
3	Ambient Temperature Sensor (-40C to +60C)	0 -1.00
4	V-band mixer temperature (+50C)	8.05
5	K-band mixer temperature (+50C)	8.05
6	V-band Noise Diode physical temperature (+50C)	8.05
7	K-band Noise Diode physical temperature (+50C)	8.05
8	NOT USED	0
9	NOT USED	0
10	NOT USED	0
11	NOT USED	0
12	Ground reference (used for V/F calibration)	0
13	Noise diode simmer voltage sense	0
14	+15 Volt supply (divided by 2)	7.50
15	–15 Volt supply [2/3(+15 volt supply)+1/3(-15 volt supply)]	5.00
16	Barometer (800-1060 mb)	0-5.00
17	V-band detector output	1.00-9.00
18	K-band detector output	1.00-9.00
19	+10 Volt reference	10.00
20	Relative Humidity (0-100%)	0-1.00
21	Infrared thermometer (-50C to +50C)	0 to 10.00
22	V-band Noise Diode drive sense	4.00
23	K-band Noise Diode drive sense	3.05
24	–19 Volt supply [2/3(+15 volt supply) + 1/3(-19 volt supply)]	3.67
25	+19 Volt supply (divided by 3)	6.33
26	Rain sensor voltage (dry)	0.20
27	NOT USED	0
28	NOT USED	0
29	NOT USED	0
30	NOT USED	0
31	NOT USED	0

Appendix C: Error Messages

Radiometer Command/Serial Port Errors

```
Could not open serial port for mp.  Aborting...
receive: clearing port
RS-232 time out in readbuf
rcmd retry, bad value
rcmd retry
icmd retry
zcmd retry
ecmd retry
fcmd retry
Warning: idest too big in ACMD!
acmd retry
ccmd retry
ocmd retry
qcmd retry
```

LN2 Calibration Errors

```
ERROR, can not open the MP.CFG file

Could not find the CHANNEL CALIBRATION BLOCK: line
in the MP.CFG file.  ShutDown.
```

Graphics Errors

```
error in newplot
error in addtrace
error in autoscale
error in graphics mode: fonts not found
error in graphicsmode: could not set font
error in display plot: could not set font
error in graphics mode: could not set font
error in symbol: could not set font
error in disptime: could not set font
error in menu: could not set font
menu: could not set font in put_text
```

Configuration File Errors

```
ERROR, can not open the MP.CFG file

 Could not find the MP TYPE: line
   in the MP.CFG file.  ShutDown.

 Could not find TIMER: line
    in the MP.CFG file.  ShutDown.

 Could not find the TIP CONFIGURATION: line
    in the MP.CFG file.  ShutDown.

 ERROR reading TIP data from MP.CFG

 Could not find DEFAULT CNF COMMAND: line
    in the MP.CFG file.  ShutDown.

 ERROR reading CNF data from MP.CFG

 Could not find the CHANNEL CALIBRATION BLOCK: line
   in the MP.CFG file.  ShutDown.

 Too many frequencies for microwave profiler

 Could not find the COEF: line
   in the MP.CFG file.  ShutDown.
```

Procedure File Errors

```
runproc: error, non digit, non delim at end
runproc: end on non digit, non delim
runproc: having trouble reading directory
```

Hardware Failure Errors

```
Synthesizer unlocked
Synthesizer retry
K Mixer temp out of bounds: //char(int(tkmixk))//K
V Mixer temp out of bounds: //char(int(tkmixv))//K
```

Misc File Errors

"Could not open "//mp_out_level1
"Could not open "//mp_out_level2
"Could not open "//mp_out_fname(1:12)
"gps retry" - an error was encountered when attempting to get gps position data.
"gpssv retry" - an error was encountered when attempting to get gps SV data.
"Warning - gps has lost fix" - the gps is reporting that it no longer can calculate position data. If this occurs repeatedly after moving the instrument to a new location, the gps pointing may be incorrect. If it occurs intermittently after a fix has been established, the gps pointing data will not be affected.