DOE/SC-ARM/TR-080

Microwave Radiometer – High Frequency (MWRHF) Handbook

April 2007

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

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1. General Overview

The Microwave Radiometer – High Frequency (MWRHF) provides time-series measurements of brightness temperatures from two channels centered at 90 and 150 GHz. These two channels are sensitive to the presence of liquid water and precipitable water vapor.

2. Contacts

2.1 Mentor

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2.2 Instrument Developer

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3. Deployment Locations and History

Table 1: Status and Location of the MWRHF

Serial Number	Property Number	Location	Date Installed	Date Removed	Status
001		SGP/C1	2006/10/18		Operational

4. Near-Real-Time Data Plots

Plots of near-real-time data can be viewed at the DQHands (Data Quality Health and Status) system accessible through the website: http://dq.arm.gov/. Click on "QC Metrics and Plots" and select the desired site and data stream. The MWRHF is located at the site Southern Great Plains ("SGP"), the data stream is "sgpmwrhfC1.b1" and the facility is "C1."

5. Data Description and Examples

5.1 Data File Contents

Datastreams available from the Atmospheric Radiation Measurement program Archive are:

- **sgpmwrhfC1.b1:** Calibrated brightness temperatures

5.1.1 Primary Variables and Expected Uncertainty[1]

The primary variables measured by the MWRHF are brightness temperatures at 90 and 150 GHz.

Table 2: Primary Variables

Variable Name	Quantity Measured	Unit	Uncertainty
Tbsky90	90 GHz sky brightness temperature	K	0.5 K
Tbsky150	150 GHz sky brightness temperature (filtered)	K	0.5 K

5.1.1.1 Definition of Uncertainty

N/A

5.1.2 Secondary/Underlying Variables

Table 3: Secondary Variables

Variable Name	Quantity Measured	Unit	Uncertainty
Time	Time offset from midnight	s	

5.1.3 Diagnostic Variables

Table 4: Diagnostic Variables

Variable Name	Quantity Measured	Unit	Uncertainty
Temp	Ambient temperature	K	0.5
Pressure	Pressure	KPa	2
Rh	Relative humidity	%	5
Rain flag	Rain flag	N/A	N/A

5.1.4 Data Quality Flags

Data quality flags are named qc_'fieldname' (i.e. qc_tbsky90). Possible values for qc_flags are: 0 (value is within the specified range), 1 (missing value), 2 (value is less than the specified minimum), 4 (value is greater than the specified maximum), and 8 (value failed the valid "delta" check). Specified maximum and minimum values are shown in Table 5.

[1] See section (6.5) for a definition of uncertainty.

Table 5: Data Quality Thresholds

Field Name	Min	Max
Tbsky90	0	310
Tbsky150	0	310
pressure	80	110
temp	233.15	323
rh	1	110

5.1.5 Dimension Variables

Table 6: Dimension Variables

Field Name	Quantity	Unit
base_time	Base time in Epoch	seconds since 1970-1-1 0:00:00 0:00
time_offset	Time offset from base_time	s
Lat	north latitude	degrees
Lon	east longitude	degrees
Alt	altitude	meters above Mean Sea Level

5.2 Annotated Examples

In this section are some examples of data collected during the initial evaluation of the instrument. Figure 1 shows a comparison of measured and modeled brightness temperatures for 90-GHz data collected during March 2007. In Figure 2 is a similar plot showing a comparison of measured and modeled brightness temperatures for 150-GHz data during the months of December 2006 and January 2007.

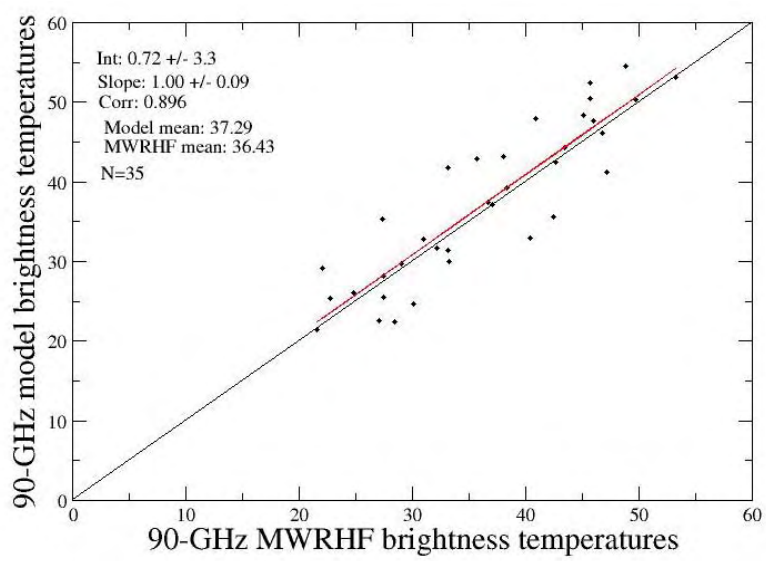

Figure 1: Comparison of 90-GHz Measured and Modeled Brightness Temperatures

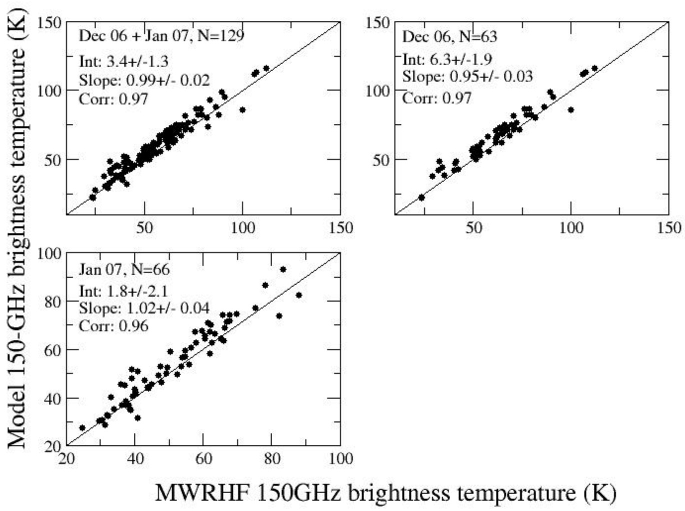

Figure 2: Comparison of 150-GHz Measured and Modeled Brightness Temperatures

5.3 User Notes and Known Problems

An analysis of clear-sky data collected between October 2006 and February 2007 showed that the threshold chosen for acceptance of tip curve data needed to be improved. On March 1, 2007, the $\chi 2$-threshold for the 90-GHz channel was reduced from 1 to 0.5. This improved the comparison of data with the model.

On February 25, 2007, a hardware malfunction caused the failure of the 150-GHz channel.

5.4 Frequently Asked Questions

This section is not yet available.

6. Data Quality

6.1 Data Quality Health and Status

Daily quality check on this data stream can be found at the DQHands page: http://dq.arm.gov/. Click on “QC Metrics and Plots” and select the desired site and data stream. The MWRHF is located at the site “SGP,” the data stream is “sgpmwrhfC1.b1” and the facility is “C1.”

6.2 Data Reviews by Instrument Mentor

The instrument mentor submits a monthly summary report Instrument Mentor Monthly Summary accessible from the instrument web page. Some of the general checks performed by the instrument mentor are shown below.

1. In general the brightness temperature time series should be smooth and with low noise levels.

2. Brightness temperatures should be greater than 2.75 K and less than approximately 310 K.

3. External temperature readings can be compared to tower measurements. The agreement should be +/- 2 K.

4. External pressure readings can be compared to tower measurements. The agreement should be +/- 5 KPa.

5. External relative humidity readings can be compared to tower measurements. The agreement should be +/- 5%.

6. Measured brightness temperatures are also compared with model computations as a general quality check.

6.3 Data Assessments by Site Scientist/Data Quality Office

The Data Quality office daily data assessment can be view at the DQHands web page.

6.4 Value-Added Products and Quality Measurement Experiments

No Value-Added Procedures are available at this stage.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

- RF section: Radiometer RPG-150-90.
- Desktop PC host computer with monitor, keybord and mouse
- Radiometer stand
- Blower assembly
- Cables.

7.1.2 System Configuration and Measurement Methods

In this section we give a brief description of the MWRHF hardware configuration. The material in this section can be found in [1]. Refer to the same reference and to [2] for further details on this instrument.

The radiometer has two direct detection receiver units. An off-axis paraboloid mirror is used to focus microwave radiation onto a corrugated feedhorn. The microwave radiation entering the instrument is first decomposed in two beams through a wire grid beam splitter. Each beam is directed in a feedhorn to generate a beam of the desired divergence (~3° HPBW). At each receiver input, a Dicke Switch periodically switches the receiver inputs to an internal black body with known brightness temperatures. This is used to continuously determine the system noise temperature of the radiometers. A 40-dB low noise amplifier boosts the input signal before it is filtered and boosted again by another 20-dB amplifier.

The waveguide bandpass filters bandwidths and centre frequencies are listed in Table 7. All channels are detected and integrated simultaneously. The receivers are based on the direct detection technique, where the signal is directly amplified, filtered and detected.

The radiometer receivers are thermally stabilized to an accuracy of ± 0.02 K. Due this extremely accurate stability the instrument can run without gain calibration for about 30 minutes maintaining a radiometric accuracy of ± 0.3 K. A block diagram of the instrument is shown in Figure 3. The instrument located at the SGP does not have the noise diode after the Dicke switch and relies on the Dicke switch for calibration.

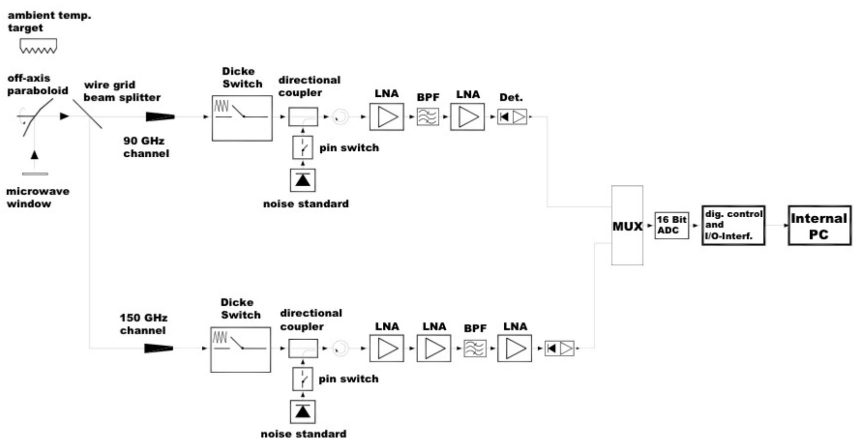

Figure 3: MWRHF Simplified Component Level Block Diagram

7.1.3 Specifications

Table 7: Instrument Specifications

Parameter	Value
Receiver noise temperature 90 GHz	< 750 K
Receiver noise temperature 150 GHz	< 1650 K
Channel bandwidth	2000 MHz
Absolute system stability	1 K
Radiometric resolution	0.2-0.4 K RMS@1 s integration time
Receiver and antenna thermal stabilization	< 0.05 K
Integration time	>=1 s
HPBW 90-GHz channel	1.8^o
HPBW 150-GHz channel	1.5^o
Temperature range	-30 to +45 C (Environmental Chamber tested)
Power consumption	< 150 W, Max 350 W without dew blower

7.2 Theory of Operation

The MWRHF measures brightness temperatures from two channels centered at 90 and 150 GHz. These two frequencies are located in the so-called window region of the microwave spectrum and they are sensitive to cloud liquid water. The water vapor contribution at these frequencies comes from the water vapor continuum region. In Figure 4 is shown the contribution of various atmospheric gases to the opacity as a function of frequency. The two vertical yellow lines indicate the location of the two MWRHF channels. Since the cloud liquid water contribution to the microwave signal increases roughly with the square of the frequency, the window regions above 90 Ghz are more sensitive to cloud liquid than the region below 45 GHz.

Simulations show that, by adding measurements at 90 and 150-GHz to measurements at 23.8 and 31 GHz (from the microwave dual channel radiometer MWR), it is possible to reduce by approximately 50 % the root mean square error of the retrieved LWP.

7.3 Calibration

7.3.1 Theory

The MWRHF absolute calibration is conducted using two calibration targets. A cryogenic and ambient reference targets are used to perform absolute calibration and determine the equivalent noise temperature of the diode (in the model where the diode is used). During absolute calibration the receiver gain coefficient, G, the system noise equivalent temperature, T_{sys}, and a non-linearity coefficient, α, are determined.

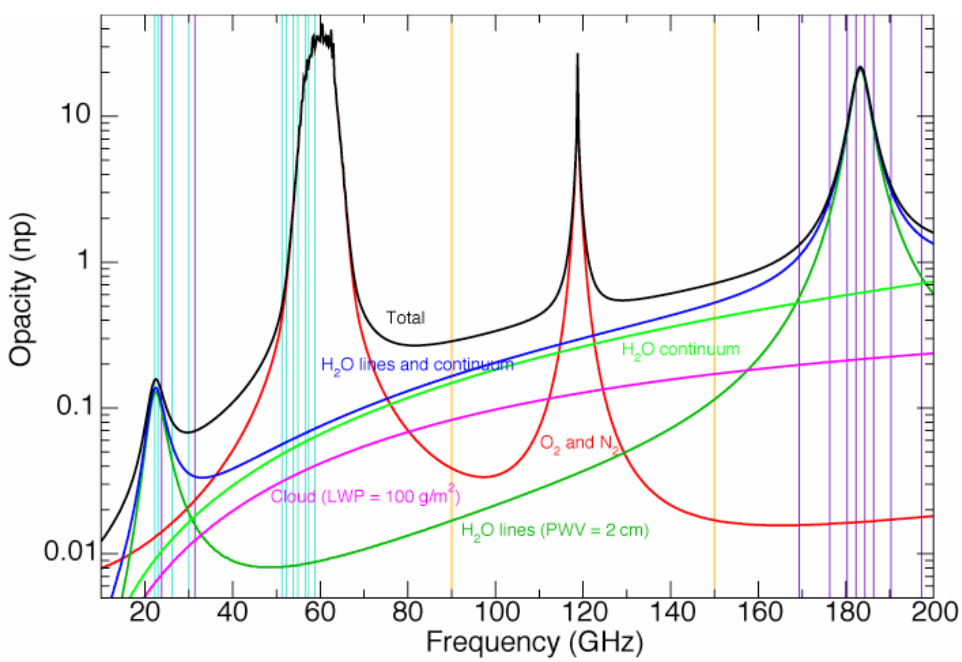

Figure 4: Atmospheric Opacity as Function of Frequency

Routinely, tip curves are collected to determine the system noise temperature and gain. A linear regression is performed between the optical thickness and the air mass. The straight line is extrapolated to zero air mass. The detector reading at this point corresponds to a radiometric temperature, which equals the system noise temperature plus 2.7 K. A second detector voltage is measured with the radiometer pointing at the ambient temperature (or Dicke switch) with known radiometric temperature.

7.3.2 Procedures

Brightness temperatures T_{sky} are produced for each channel according to:

$$T_{sky} = \frac{V_{sky}}{G} - T_{sys} \ , \tag{1}$$

where V_{sky} is the signal recorded when the reflector is oriented towards the sky and T_{sys} is the system noise equivalent temperature. The gain G and T_{sys} are determined by using tip curves. When the optical thickness is extrapolated to zero airmass the corresponding voltage V_{sys} is:

$$V_{sys} = G(T_{sys} + 2.7). \tag{2}$$

On the other hand, when the radiometer is pointing to the ambient target with known radiometric temperature T_d, the corresponding detector voltage is:

$$V_d = G(T_{sys} + T_d). \tag{3}$$

Tipping curves are selected based on a linear correlation threshold of 0.9995. Since the radiometer scans only on one side of the sky an additional χ^2 threshold is set to 0.5 for the 90-GHz channel and to 1 for the 150-GHz channel.

7.3.3 History

- Deployed in Oklahoma on October 11, 2006.

7.4 Operation and Maintenance

7.4.1 User Manual

See [1].

7.4.2 Routine and Corrective Maintenance Documentation

N/A

7.4.3 Software Documentation

N/A

7.4.4 Additional Documentation

N/A

7.5 Glossary

Uncertainty: We define uncertainty as the range of probable maximum deviation of a measured value from the true value within a 95% confidence interval. Given a bias (mean) error *B* and uncorrelated random errors characterized by a variance σ^2, the root-mean-square error (RMSE) is defined as the vector sum of these,

$$RMSE = \left(B^2 + \sigma^2\right)^{1/2}.$$

(*B* may be generalized to be the sum of the various contributors to the bias and σ^2 the sum of the variances of the contributors to the random errors). To determine the 95% confidence interval we use the Student's *t* distribution: $t_{n;0.025} \approx 2$, assuming the RMSE was computed for a reasonably large ensemble. Then the *uncertainty* is calculated as twice the RMSE.

See the ARM Glossary.

7.6 Acronyms

DQHands	Data Quality Health and Status
MWRHF	Microwave Radiometer – High Frequency
RMSE	root-mean-square-error
SGP	Southern Great Plains

Also, see ARM Acronyms and Abbreviations.

7.7 Citable References

[1] Rose, T, and H Czekala. RPG-150-90 High Sensitivity LWP radiometers-Operating Manual.

[2] Rose, T, S Crewell, U Lonhert, and C Simmer. 2005. "A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere." *Journal of Atmospheric Research* (75)183-200.