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Microwave Radiometer — 3-Channel (MWR3C) Instrument Handbook

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ARM

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Acronyms and Abbreviations

AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
BNF	Bankhead National Forest
ENA	Eastern North Atlantic
HPBW	half power beam width
IR	infrared
MWR3C	microwave radiometer – 3-channel
NSA	North Slope of Alaska
OLI	Oliktok Point, Alaska
RMSE	root-mean-square error
SGP	Southern Great Plains

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1.0 Instrument Description

The microwave radiometer – 3-channel (MWR3C, RPG-LWP-U90) deployed by the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility provides time-series measurements of brightness temperatures from three channels centered at 23.834, 30, and 89 GHz. These three channels are sensitive to the presence of liquid water and precipitable water vapor.

1.1 Technical Specifications

Detailed specifications can be found in the manufacturer's technical manual.

IR radiometer: 9.2-10.6 µm band, accuracy 1 K, noise: 0.2 K RMS

Channel bandwidth: 2000 MHz @ 90.0 GHz, 230 MHz @ all other frequencies

System noise temperatures: <400 K for K-band, < 750 K for 90 GHz channel (RPG-LWP-U90 only)

Radiometric resolution: K-Band: 0.10 K RMS, 90 GHz: 0.20 K RMS @ 1.0 sec integration time

Absolute brightness temperature accuracy: 0.5 K in K-band, 1.0 K at 90 GHz

Absolute calibration: tip curves

Receiver and antenna thermal stabilization: Stability better than 0.03 K over full operating temp. range

Integration time: 1s

HPBW: 3.5° for K-band, 3.2° @ 90 GHz

1.2 Instrument/Measurement Theory

The three channels of the MWR3C are highly sensitive to the presence of water vapor and liquid water in the atmosphere. The 90-GHz channel provides increased sensitivity to the presence of cloud liquid water compared to a 2-channel system.

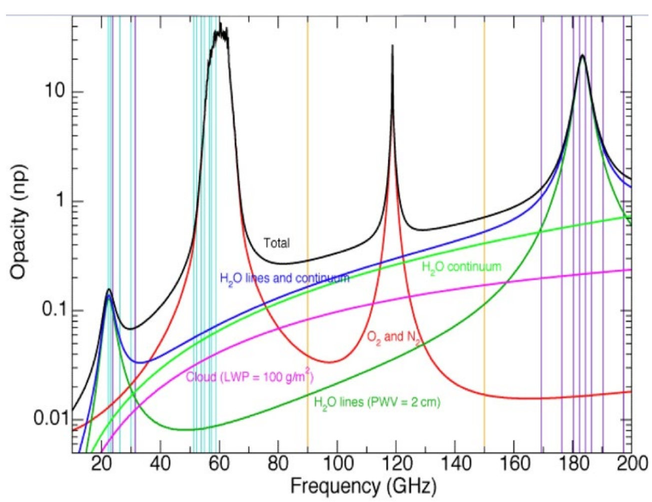

Figure 1. The microwave spectrum.

Once in the field, the MWR3C calibrates exclusively with tip curves. The radiometers perform 1 tip scan every hour. All ARM MWR3Cs are calibrated using an algorithm developed by ARM. Tip curves are processed, selected, and used to determine the receiver temperature to be used in the calibration of the instantaneous measurements. In the tip curve procedure, 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 with known radiometric temperature. Once a sufficiently large number of acceptable tip curves are collected (the number of points as well as the acceptance criterion are selectable) they are processed, and a mean value is used in the computations of brightness temperatures.

1.3 Data Quality and Uncertainty

N/A

1.4 Examples of Data

N/A

2.0 Historical Background

Table 1. MWR3Cs and their status.

Serial Number	Manufactures	Location	Date Installed	Date Removed	Status
	Radiometrics	SGP/C1	2011/10/01	2020/10/13	Retired
	Radiometrics	AMF2	2011/01/11	2017/11/09	Retired
	Radiometrics	AMF1	2012/07/25	2017/11/01	Retired
	Radiometrics	SGP/E32	2016/06/29	2022/09/27	Retired
	Radiometrics	SGP/E41	2016/06/10	2019/03/14	Retired
	Radiometrics	SGP/E39	2016/03/31	2019/08/12	Retired
	Radiometrics	SGP/E37	2016/03/28	2021/04/21	Retired
	RPG-G4	ENA	2014/03/03		Operational
	RPG-G4	OLI/BNF	2013/09/09		Operational
	RPG-G5	AMF1	2019/10/18		Operational
	RPG-G5	AMF2	2019/10/18		Operational
	RPG-G5	SGP/C1	2021/01/27		Operational
	RPG-G5	NSA/C1	2021/04		Operational

3.0 Maintenance Plan

The radiometers are monitored daily to ensure cleanliness of the window and functioning of the external sensors.

4.0 Calibration Plan

All radiometers are **self-calibrated** with algorithms developed by ARM. Although the implementation of the calibration algorithm varies with the model, all radiometers are self-calibrated using tip curves.

The calibration of Radiometrics and RPG-G4 models is described in the legacy MWR3C handbook (https://www.arm.gov/publications/tech_reports/handbooks/mwr3c_handbook.pdf). The G5 models do not provide noise diode data; therefore, the calibration is performed using tip curves and black body. Tip curves are processed, filtered, averaged, and used to calibrate instantaneous zenith sky voltages. To process tip curves, we start from an initial brightness temperature *TBn* and corresponding *Trec* from the LV0 file. We calculate the opacity, and then use the slope of the airmass-opacity fit to estimate an initial zenith-sky brightness temperature. We use the estimated value together with the black body readings to calculate new gain and *Trec*. We then compare the new *Trec* with the previous *Trec*: if their difference is larger than a certain amount, we use the new *Trec* and gain to estimate a new *TBn* and we repeat the entire process until *Trec* converges. The new *Trec* values are stored in a file. The iterative process used to calculate *Trec* is shown in Figure 2.

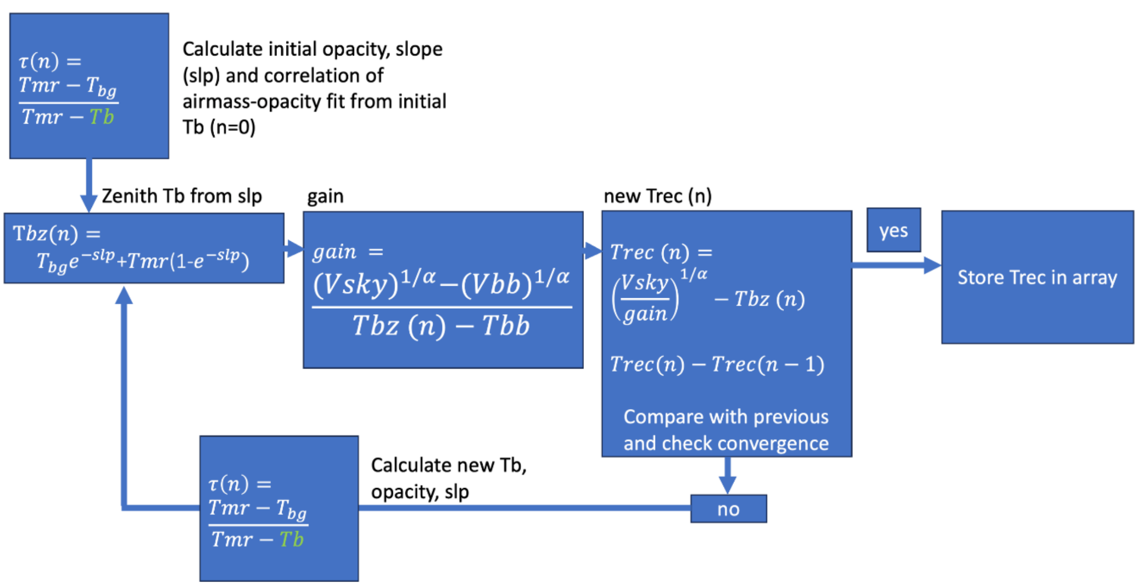

Figure 2. Iterative process to calculate *Trec* from one successful tip scan.

Once enough successful tip points (*Trec*) are collected, their running average, $\bar{T}_{rec}$, is used in the calibration equation:

$$Tb_{sky} = \left(\frac{V_{sky}}{G}\right)^{1/\alpha} - \bar{T}_{rec} \qquad (1)$$

Figure 2 shows *Trec* from instantaneous tip curves (black points), *Trec* in the LV0 file (green points), and the running average of the instantaneous *Trec* (red line) that is used in the calibration equation above. The gain used in (1) is estimated as:

$$G = \frac{V_{bb}}{(T_{rec}+T_{bb})^{\alpha}} \tag{2}$$

The uncertainty in calibrated brightness temperatures is calculated from the calibration equation. The largest term is the uncertainty on the receiver temperature that is directly calculated from tip curves.

$$\Delta Tb_{sky} = \sim\Delta T_{rec} \tag{3}$$

The uncertainty ΔT_{rec} is determined as the RMSE between the running mean and the instantaneous tip curves, and it comes to ~0.6 K for 23.8 and 31.4 and about 2 K for 90 GHz.

5.0 User Notes and Known Issues

N/A

6.0 Frequently Asked Questions

N/A

7.0 Citable References

Cadeddu, MP. 2021. Microwave Radiometer – 3-Channel (MWR3C) Instrument Handbook. U.S. Department of Energy, Atmospheric Radiation Measurement user facility, Richland, Washington. DOE/SC-ARM-TR-108.

8.0 Version History

N/A

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