Brightness Temperature Calibration of SAC-D/Aquarius Microwave Radiometer (MWR)

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MWR Instrument Overview

- Two Frequency Bands
  - K – (23.8 GHz): H-Pol Only
  - Ka – (36.5 GHz): V, H, +45° & -45° Pol
- Two reflector antenna
  - Matched beamwidths
MWR Sensor Geometry

Satellite sub-track

Flight Direction

K Band MWR Beams

Aquarius Beams

Ka Band MWR Beams

Aquarius-MWR common swath
EIA – Earth Incidence Angle

<table>
<thead>
<tr>
<th>Objective</th>
<th>Description</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation, wind speed, sea ice concentration, water vapor</td>
<td>23.8 GHz and 36.5 GHz; 36.5 polarimetric; 23.8 H-pol; 390 km swath</td>
<td>50 km</td>
</tr>
</tbody>
</table>
Three State Dickie Radiometer

\[ C_{in} = GT_{in} + \text{offset} \]
\[ C_{in+n} = G(T_{in} + T_n) + \text{offset} \]
\[ C_o = GT_o + \text{offset} \]

Calibration Equation:

\[ T_{in} = \left\{ \frac{(C_{in} - C_o)}{(C_{in+n} - C_{in})} \right\} \times T_n + T_o \]
SW Matrix Cal: Primary & Secondary Path

- Transmission coeff ~ 70% (-1.6 dB)
- Self emission ~ 95K
- MWR thermal control ± 1 K
- PRT meas temps ~ 0.1 K

Secondary
- Main low loss path
- 2ndary low loss path
- Switch Leakage
OMT for Ka band horns
- 8 feed horns connects to a single receiver
- 3 layers of switch (4-2-1)
For a single feed horn path
- 4 waveguide loss sections
- 3 switch losses
- 1 feed horn, OMT loss
Choice of Windsat

Similarities

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WindSat</th>
<th>MWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>840 Km</td>
<td>657 Km</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.00134</td>
<td>0.00120</td>
</tr>
<tr>
<td>Orbit Inclination</td>
<td>98.7°</td>
<td>98.01°</td>
</tr>
<tr>
<td>Ascending Node</td>
<td>6 p.m.</td>
<td>6 p.m.</td>
</tr>
<tr>
<td>Channels</td>
<td>6.5, 10.7, 18.7, 23.8 &amp; 37 GHz (V.H)</td>
<td>23.8 GHz (H) &amp; 36.5 GHz (V.H)</td>
</tr>
<tr>
<td>Swath Width</td>
<td>~950 Km</td>
<td>~380 Km</td>
</tr>
<tr>
<td>Earth Incidence Angle</td>
<td>53°</td>
<td>52° &amp; 58°</td>
</tr>
</tbody>
</table>

Geometry

MWR and Windsat collocations swath in 45 hours
MWR On-Orbit Check-out
Ka Band V pol Diagnostics

Each point is an Orbit Average
Receiver Internal temperature was controlled within 0.5 K for a duration of approx. 6 days.
MWR OOCO Summary

OOCO – On Orbit Check Out

- MWR turn-on evening Aug 30th, 2011

- First Tb images were produced ~ 6 hours after data reception on Wed Aug 31st

- Preliminary inter-satellite Tb calibration with WindSat completed on Sunday Sept 4th

- First geophysical retrieval on Tues Sept 6th
First 5 days (only ascending passes)
First 5 days (only ascending passes)
23.8 GHz H-pol $T_b$

First 5 days (only ascending passes)
Inter-satellite radiometric calibration (X-Cal) was performed using the WindSat radiometer.

Near simultaneous, collocated comparisons between MWR and WindSat ocean Tbs:
- Initially 65 revs of MWR Tbs used (now 146 revs available)
- MWR Tbs converted to 53° Earth Incidence Angle (Using Radiative Transfer Model) before WindSat comparison – double differences
- Collocation cells were 1° x 1° Lat-Lon boxes
- Comparisons performed per beam basis
  - 3 chans x 8 beams = 24 total
MWR/WindSat 1st X-Cal Results
(46 revs ocean calib)
$1^\circ \times 1^\circ$ collocations for 65 revs of MWR $T_b$s used
Example Beam # 1, 23 GHz H-pol

Pre-Launch TV Calib
Tb v2.0

Post-Launch X-cal
Tb v2.1
Linear adjustment
Locations of outlyer points are associated with land masses and sea ice and therefore should be deleted from ocean calibration.
Beam # 1, 37 GHz H-pol

Pre-Launch

Tb v2.0

Post-Launch

Tb v2.1

Bias adjustment
Beam # 1, 37 GHz V-pol

Pre-Launch

Tb v2.0

Post-Launch

Tb v2.1

Bias adjustment
The slope-offset correction coefficients from the v2.1 algorithm was further tuned after obtaining 127 additional orbits of MWR/WindSat collocations.

Final APC with correct beam balancing (v2.2)
- Equate MWR Ta & WindSat Tb

The following charts compare orbital average histograms of MWR biases
- Pre-launch (v2.0) algorithm and the final post-launch algorithm (v2.2)

\[ MWR_{bias} = (T_a(\text{obs}) - T_b(\text{sim}))_{MWR} - (T_b(\text{obs}) - T_b(\text{sim}))_{\text{Windsat}} \]
23.8 GHz H-pol Bias Histogram

v2.2 MWR Data
ftp://aqst@podaac.jpl.nasa.gov/
36.5 GHz H-pol Bias Histogram

v2.2 MWR Data
ftp://aqst@podaac.jpl.nasa.gov/
36.5 GHz V-pol Bias Histogram

v2.2 MWR Data
ftp://aqst@podaac.jpl.nasa.gov/
Determination of MWR NEDT during cold space look

11/11/2011
Determination of MWR NEDT during cold space look
K Band H-pol Tb Time-Series (15th Sept 2011)

GMT Time

V2.2 Tb
K Band H-pol Tb Time-Series (15th Sept 2011)
Extracted Noise (Using FFT technique)
NEDT estimate vs. # of samples

Noise Std dev (K)

# of sample
(used to compute std dev)

23h
<table>
<thead>
<tr>
<th>Beam #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 H</td>
<td>.30</td>
<td>.30</td>
<td>.29</td>
<td>.27</td>
<td>.28</td>
<td>.28</td>
<td>.31</td>
<td>.26</td>
</tr>
<tr>
<td>37 H</td>
<td>.21</td>
<td>.22</td>
<td>.20</td>
<td>.20</td>
<td>.21</td>
<td>.22</td>
<td>.20</td>
<td>.22</td>
</tr>
<tr>
<td>37 V</td>
<td>.22</td>
<td>.24</td>
<td>.23</td>
<td>.22</td>
<td>.23</td>
<td>.21</td>
<td>.21</td>
<td>.22</td>
</tr>
</tbody>
</table>

Note: bandwidth of K-band receiver is less than that of Ka band; therefore NEDT is greater in K band.
Data Availability

- MWR turned on Aug 30 (day-1)
- Presently in 11\textsuperscript{th} 7-day cycle
  - Only two cycles have continuous measurements
ftp://aqst@podaac.jpl.nasa.gov/

Password restricted to Cal/Val members