Status of Radiometer RFI Detection and Mitigation

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Outline

- Brief algorithm review
- Issues
- Accomplishments and future work
RFI Detection and Mitigation

- long accumulations
- computation of calibration gain and offset
- gain
- offset
- unfiltered short accumulations
- RFI detection
- RFI flags
- RFI mitigation
- RFI-filtered short accumulations
- short accumulations to antenna temperature
- RFI-filtered antenna temperature
- unfiltered antenna temperature
## RFI Detection Algorithm

### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_m$</td>
<td>10</td>
</tr>
<tr>
<td>$W_d$</td>
<td>2</td>
</tr>
<tr>
<td>$\sigma_s$</td>
<td>$\sim 0.5$</td>
</tr>
<tr>
<td>$g$</td>
<td>0.8-1.6</td>
</tr>
<tr>
<td>$\tau_m$</td>
<td>1.5</td>
</tr>
<tr>
<td>$\tau_d$</td>
<td>4.0</td>
</tr>
</tbody>
</table>

### Algorithm Steps

1. **Selection of Moving-Average Data**
   - $W_n = \{ k = n - W_m, \ldots, n + W_m : k \neq n \}$
   - $S_n = \{ s_k | k \in W_n \}$

2. **Computation of “Dirty” Mean**
   - $f'_k = \begin{cases} 
   1 & \text{if } s_k \text{ is invalid} \\
   0 & \text{otherwise}
   \end{cases}$
   - $S'_n = < s_k >_{k \in W_n}$

3. **Computation of “Clean” Mean**
   - $S_n = < s_k >_{k \in W_n}$
   - $K_n = \{ \tau_m \}$
   - $T_n = g \tau_m \sigma_s$
   - $F^{'}_n , n - W_s \leq k \leq n + W_s$
   - $F'_k = \begin{cases} 
   1 & \text{if } | s_k - S'_n | > T_n \text{ or } f'_k = 1 \text{ for all } k \in W_n \\
   0 & \text{otherwise}
   \end{cases}$

4. **Flagging of Sample $s_n$**
   - $F'_k = \begin{cases} 
   1 & \text{if } f'_k = 0 \text{ for all } n - W_s \leq k \leq n + W_s \\
   1 & \text{otherwise}
   \end{cases}$

5. **Flagging of Neighboring Samples**
   - $F_i = \begin{cases} 
   0 & \text{if } F'_i = 0 \text{ for all } n - W_s \leq k \leq n + W_s \\
   1 & \text{otherwise}
   \end{cases}$
Issues

- Problem with Short Accumulation 1
- Equalization of false alarm rate
- Tuning of geographically dependent parameters
- Missed detection of low-level RFI
Values of Short Accumulation 1 (SA1) inconsistent with values of Short Accumulations 2 to 5

Solution: removal of Short Accumulation 1 from radiometer processing
RFI Detection Algorithm Thresholds

Two thresholds:

- \( T_m = g(\text{beam}, \text{pol}) \sigma_s \tau_m(\text{lat}, \text{lon}) \) for removing outliers
- \( T_d = g(\text{beam}, \text{pol}) \sigma_s \tau_d(\text{lat}, \text{lon}) \) for RFI flag decision

- \( g \) is the gain used in the conversion from short accumulations to antenna temperatures
- \( \tau_m \) and \( \tau_d \) tunable by geographical location (ocean, land, etc.)
- \( \sigma_s \) corresponds to the standard deviation of the measured antenna temperature (Noise Equivalent Delta T, NEDT)
values of $\sigma_s$ are chosen to yield a FAR of 4% over RFI-free ocean across all brams and polarization channels

before FAR equalization, $\sigma_s$ values are pre-launch estimates independent of beam:

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>V+H</th>
<th>V-H</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5157</td>
<td>0.4735</td>
<td>0.4735</td>
<td>0.4313</td>
<td></td>
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</tbody>
</table>

after FAR equalization, $\sigma_s$ values are given by

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>V+H</th>
<th>V-H</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam 1</td>
<td>0.558</td>
<td>0.551</td>
<td>0.540</td>
<td>0.532</td>
</tr>
<tr>
<td>Beam 2</td>
<td>0.543</td>
<td>0.562</td>
<td>0.548</td>
<td>0.538</td>
</tr>
<tr>
<td>Beam 3</td>
<td>0.552</td>
<td>0.548</td>
<td>0.554</td>
<td>0.546</td>
</tr>
</tbody>
</table>
## Percent of RFI over Ocean

Percentage of RFI-flagged samples for water fraction > 99.99%  
(week of December 8-14, 2011)

<table>
<thead>
<tr>
<th></th>
<th>without SA1 removal</th>
<th>with SA1 removal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without FAR equalization</td>
<td>without FAR equalization</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>V+H</td>
</tr>
<tr>
<td>Beam 1</td>
<td>25.8%</td>
<td>32.3%</td>
</tr>
<tr>
<td>Beam 2</td>
<td>24.6%</td>
<td>39.1%</td>
</tr>
<tr>
<td>Beam 3</td>
<td>25.6%</td>
<td>40.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>with SA1 removal</th>
<th>with FAR equalization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>V+H</td>
</tr>
<tr>
<td>Beam 1</td>
<td>4.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Beam 2</td>
<td>3.6%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Beam 3</td>
<td>3.7%</td>
<td>5.2%</td>
</tr>
</tbody>
</table>
Ongoing and Future Work

- Geographical tuning of RFI detection algorithm parameters (Cris Ruf and David Chen)
- Improve detection of low-level RFI.