Towards a Radar/Radiometer Mode on the Dual-frequency, Dual-polarized Doppler Radar (D3R) System

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Abstract

The dual-frequency, dual-polarized Doppler radar (D3R) system was developed in support of the ground validation segment of the Global Precipitation Measurement (GPM) mission [1]. Although its main purpose is to provide active, full-polarization measurements of precipitation, the design provides an opportunity to study its operation in an active/passive mode. The opportunity arises from use of solid-state transmitters employing a multi-frequency waveform and receiving system. Typically, a sequence of three pulses separated in frequency is transmitted to achieve its radar sensitivity and minimum range. However, use of the three pulses can be disabled with a tolerable decrease in sensitivity and its receive channel can be re-optimized to support passive measurements.

This work focuses on progress in the characterization of the Ku-band/Hi polarized passive channel operating simultaneously with two active as a step towards the provision of brightness temperatures along with the other radar derived products. The methodology developed will be applied to the Ku-band active channel and future improvements in the near future. The study consists on the analysis of the antenna performance, receiver architecture, transfer function and achievable number of independent samples, calibration method and preliminary observation analysis. All within the context of the instrument’s current configuration and possible future improvements.

Antennas

Within the dual-polarized radar realm of instrument design, antenna specifications are generally governed by spatial resolution, desired sensitivity, cross-polarized response performance and side-lobe levels among a few other important parameters. Many of these also apply to radars as well, however, these efficiencies and emission concerns are somewhat relaxed in the radar case. The following figures show efforts in an attempt to characterize the former.

The antennas employed on the D3R system are prime focus parabolic reflectors. They are equipped with A-scan radome cone-shaped composite radomes to reduce wind loading and are equipped with a super-heterodyne receiver described in [2] to prevent the development of a water film thereby reducing the effects associated. Table 1 summaries specifications and Figure 5 shows the Ku and Ka-band antennas within the Goddard anechoic chamber during acceptance testing.

Table 1 Antenna specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ku-band</th>
<th>Ka-band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter [m]</td>
<td>1.8</td>
<td>0.71</td>
</tr>
<tr>
<td>Gain [dBi]</td>
<td>45.6</td>
<td>44.3</td>
</tr>
<tr>
<td>Half Power Beam Width [deg]</td>
<td>0.86</td>
<td>0.90</td>
</tr>
<tr>
<td>Peak Sidelobe Level [dB]</td>
<td>-25</td>
<td>-30</td>
</tr>
<tr>
<td>On axis cross-pol [dB]</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Beam efficiency [%]</td>
<td>75.5</td>
<td>76.5</td>
</tr>
</tbody>
</table>

Calibration Approach

- End-to-end or Tier 3 calibration as described in [5] is achieved from the Ka-band reflectors using a circular sky.
- Eq. 5 is used to retrieve the active/passive brightness temperature from the linear FR/RF intercept point.
- Fitting results are quality controlled based on R².
- For new, noise sources are assumed to be stable and changes in injected power are proportional to gain fluctuations.

Preliminary Observations

- Finally, Fig. 12 shows preliminary results obtained from cloud observations.
- Note the passive channel response to higher cloud reflectivities.
- Given that our backscatter is a potential source for interference and that we’re operating within an active band, ka/ku is being considered for FR detection and also shown in fig 12 [6].
- Eq. 7 was used to compute brightness temperatures corrected for the Ka band calibration.
- Note the enhanced radar sensitivity stemming from the use of the passive channel to estimate the active channel noise.

Concluding Remarks and Future Work

- Preliminary results shown are encouraging and show potential in achieving simultaneous active/passive measurements from the D3R platform. Further analysis and experimentation is planned to improve the tip curve calibration procedure, apply corrections based on sub-system temperatures and beam-effect efficiencies.
- From a radar perspective, the passive channel is useful in providing a real-time noise estimation and correction method.
- Future system upgrades will aim to reduce the sub-channel bandwidth. Offset reflector antennas could potentially improve beam-efficiency.

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References