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, Ka-band, dual-polarized measurements of precipitation, the design presents an opportunity to study its operation in an active/passive mode. The opportunity arises from use of solid-state transmitters employing a multi-frequency waveguide and receiver 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 receiver channel can be repurposed to support passive measurements.

The paper focuses on progress in the characterization of the Ku/Ka-band 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/Ka polarized channel and be evaluated subsequently 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.

Fig. 1 D3R system deployed near Mocips, WA during the Olympic Mountain Experiment (OLYMPEX).

Antennas

(a) (c)

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, the temperature, efficiency 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 K-band concrete-based composite radome to reduce wind loading and are equipped with a super-hydrophobic coating described in (2) to prevent the development of a water film therefore reducing the effects associated. Table 1 summarizes specifications and figure 5 shows the Ku and Ka-band antennas within the Goldband anechoic chamber during acceptance testing.

Table 1 Antenna specifications

Parameter Units Ku-band Ka-band

Diameter [m] 1.8 0.71

Gain [dBi] 45.6 44.3

Half Power Beam width [deg] 0.86 0.90

Peak Sidelobe Level [dB] -25 -30

On axis corr pol [dB] 0.1

Beam efficiency [%] 75.5 87.5

Notes: Beam efficiency obtained from measured interpolated patterns using Eq. 1.

Calibration Approach

- End-to-end or tier 3 calibration as described in (5) is achieved from regular tip curve scans [5] during clear sky conditions.
- Eq. 5 is used to retrieve the atmospheric brightness temperature from a linear FF’s intercept point.
- Fitting results are quality controlled based on R².
- For now, noise sources are assumed to be stable and changes in injected power are proportional to gain fluctuations.

Fig. 5. Ku- and Ka-band digital receiver architecture.

Preliminary Observations

Finally, fig. 12 shows preliminary results obtained from cloud observations.

- Note the passive channel response to higher cloud reflectivities.
- Given that our own backscatter is a potential source for interference and that we’re operating within an active band, kurtosis is being considered for FF detection and also shown in fig 12 [6].
- Eq 7 was used to compute brightness temperatures corrected for the tip curve calibration.
- Note the enhanced radar sensitivity stemming from the use of the passive channel to estimate the active channel.

Fig. 12 Preliminary cloud measurement results collected at Wallops Flight Facility in April, 2018. (a) Ka radar reflectivity, (b) brightness temperature and (c) kurtosis.

Concluding Remarks and Future Work

Preliminary results show 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-efficiency effects.

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 larger sub-bandwidths. Offset reflector antennas could potentially improve beam-efficacy.

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References