The Airborne Millimeter-wave System Development and Performance Update for NCAR's HIAPER Cloud Radar

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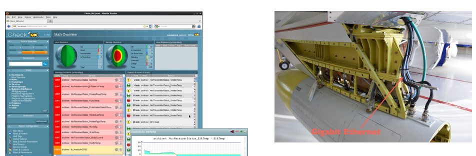
I. Introduction

The HCR was transitioned into the airborne configuration in 2012. Several intermediate engineering validations were conducted to evaluate the HCR performance: ground validation of the pod-based airborne system, integration with the HIAPER aircraft and finally, flight validation during a test flight in February 2013.

Figure 1. HCR installed on NCAR GV aircraft. Front large pod: HIAPER Cloud Radar; rear large pod: counter weight.

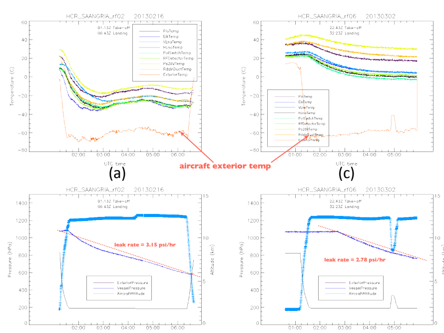
II. Engineering Efforts

To better understand HCR's underwing, pod environment, extensive engineering effort has been devoted to a real-time environmental monitoring (Figure2.a). A total of 13 temperature sensors and 2 pressure sensors are installed on various key components of the receiver. With this detailed information, radar performance such as receiver gain variation, transmit peak power, and receiver sensitivity can be closely observed. The radar system is required to be free of electromagnetic interference with air traffic communication. A minor interference was identified and located in the pylon. (Figure 2.b)



(a) (b)

Figure 2. (a) HCR real-time environmental/status monitoring toolbox. (b) 125MHz EMI to aircraft communication is the Gigabit Ethernet located in the pylon.



(a) (c)
(b) (d)

Figure 3. (a,b) HCR temperature and pressure profiles during flight #2. (c,d) increased system temperature and reduced leak rate.

III. System Performance

For SAANGRIA-TEST flights, GV maintained a constant, 40,000 ft cruising altitude. Figure 3(a,b) illustrates temperature measurements on Feb. 16, 2013. For an exterior air temperature of around -70C, the HCR temperature was around -40C during flight. The effective conduction cooling puts the system below desired operating temperature. The exterior air duct was closed and an insulating layer was installed to increase system temperature. Figure 3(c,d) shows the significant improvement.

IV. System Performance

Figure 4 shows the receiver noise floor fluctuation versus system temperature. The noise floor shows an inverse correlation with temperature. The variation can be has large as 2.06dB. The transmit peak power was also affected by ambient temperature. Approximately 45 minutes of unstable warm-up period was observed. About 3dB of peak power variation is also contributed from the environmental effects. The 2dB variation in receiver noise floor will directly affect system sensitivity. The transmit peak power fluctuation also has the same effect.

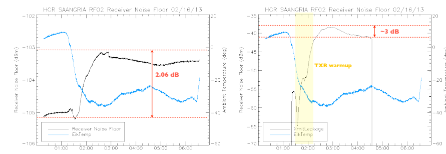


Figure 4. HCR receiver stability. Left: noise floor fluctuation versus temperature. Right: transmit peak power versus temperature.

V. Airborne Cloud Observation

A sample cloud observation is shown in Figure 5. A minimum reflectivity -35 dBZ was observed in the dataset (left figure). Basic noise correction was applied with a received power threshold at -98.25 dBm. The strong reflection around 250 m altitude represents the ground echo. The velocity (right figure) was corrected using HCR in-pod INS navigation data. A mean ground velocity after correction is approximately -0.0024 m/s. [1]

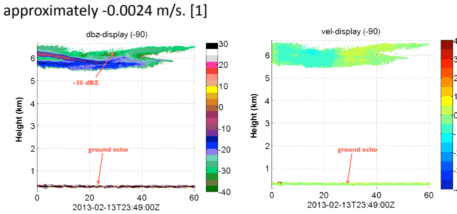


Figure 5. A sample airborne cloud observation on February 13, 2013. Left: reflectivity (dBZ); right: Velocity (m/s) [1]

VI. Wyoming Cloud Radar & HCR Intercomparison

HCR was brought to University of Wyoming for the collaborated engineering assessment. By comparing with the well-calibrated, mature Wyoming Cloud Radar (WCR), the deficiencies and performance of HCR can be easily verified. With comparable radar specification such as wavelength, transmit power, beamwidth and receiver gain, both radars are expected to have similar performance. Both radar systems were set up inside the hangar, pointing southwards. The collocated radar system were configured as Figure 6. WCR was set up on a rotatable platform. The elevation angle of HCR is achieved by manually adjusting the rotatable reflector.

Figure 6. WCR/HCR intercomparison setup.

A 30-minute stratoform rain event was observed by both radars on September 27, 2012. To accurately evaluate the performance, minimum time and range interpolation was performed on WCR data. Similar patterns were recorded by both systems. Patterns in far ranges seem more skewed than close ranges. (figure not shown). This suggests these two systems may not be perfectly aligned in azimuth direction. HCR shows good correlation with WCR with in SNR (Figure 7).

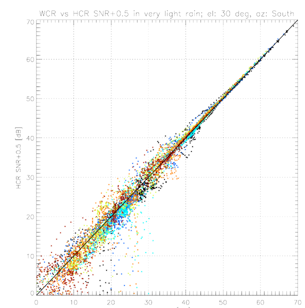


Figure 7. WCR/HCR signal-to-noise ratio scatter plot.

VII. Summary

This paper summarizes the engineering challenges and performance of the HIAPER cloud radar during its first test flights and in comparison with WCR. The preliminary analysis shows good agreement between WCR and HCR measurements. The flight data and environmental analysis indicates good radar sensitivity and attitude correction. The radar system still faces several engineering challenges in stabilizing the system temperature to achieve high sensitivity and receiver gain and minimizing pressure leakage to prolong its flight time.
HCR is currently participating in IDEAS-V deployment for its second test flights. Deficiencies discovered during SAANGRIA-TEST flights have been addressed and will be tested again during this deployment.

Reference

[1] **8A.6** S. Ellis, J. Vivekananda et al., *Initial Evaluation of the HIAPER Cloud Radar Doppler Velocity Measurement*