Geosci. Instrum. Method. Data Syst. Discuss., 5, C56–C62, 2015
www.geosci-instrum-method-data-syst-discuss.net/5/C56/2015/

Geoscientific Instrumentation Methods and Data Systems
Discussions
Open Access

Interactive comment on "A wing pod-based millimeter wavelength airborne cloud radar" *by* J. Vivekanandan et al.

J. Vivekanandan et al.

vivek@ucar.edu

Received and published: 22 July 2015

Comments:

1. Page 122, line 23, Are the authors concerned about the limited Nyquist velocity and was dual PRF for example considered?

Since the primary objective of the HCR is to detect micron-sized cloud and ice particles and measurements of light precipitation, the limited Nyquist velocity is not a major limitation of the system. The dual PRF was not considered.

2. Page 124, Line 22, " . . . .cross polarization lower than 40 dB at the bore sight". According to Figure 4, the cross-pol level at the bore sight is about -38 dB. Also for

polarimetric measurements, integrated cross-pol power is used instead of just crosspol signal at bore sight.

Cross polarization value in the text has been corrected. ICPR calculated from antenna pattern data indicate -27 dB.

Page 126, Section 4.1, the authors discussed the relationship between number of independent samples and Doppler velocity measurement accuracy. In fact, Doppler measurement accuracy is directly related to the number of pulse pair products integrated, not necessarily independent samples. The adjacent pairs of pulses need to be correlated for Doppler phase estimates. Integration of independent samples is necessary to increase the accuracy of reflectivity and improve SNR.

Accuracy of Doppler velocity measurements can be computed as shown in Doviak and Zrnic, 1993, equations 6.22 to 6.23. The counts of independent sample pairs are required for estimating the dwell time of radar beam for desired Doppler velocity measurement accuracy. Particularly for airborne radar, the accuracy of Doppler velocity measurement depends on PRF, spectrum with, signal to noise ratio and dwell time of the radar beam.

3. Page 127, Line 20, the sensitivity improvement by integration of 0.1 s (1000 samples). How is 8 dB calculated? For noise estimates, averaging 1000 samples should improve SNR by 15 dB not 8 dB.

The above sensitivity computation takes into account of the time-to-independence. Time-to-independence (TD) determines number of independent samples in a specified time interval and it is a function of spectrum width and transmit wavelength. For a Doppler spectrum width of 0.2 m s-1, the TD is 0.0018 s and averaging over 0.1 s is equivalent to 55 independent samples. For the 55 samples SNR improves by 8.7 dB.

4. Figure 7: Add a comment on sensitivity improvement through averaging. Figure 7 implies a 10 dB improvement in sensitivity by averaging 1000 pulses. This conflicts

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

with the 8 dB stated in the text. Make this consistent with response to comment #4.

Thank you for pointing out the inconsistency. The typographical error has been fixed.

5. Airborne and spaceborne radar along track resolution is determined by antenna beamwidth, platform ground speed and along track integration time. Page127ïijN Line ËĞ 27, “. . . along track resolution 20 m. . .” The antenna beamwidth is 0.68 degree, for GV altitude, âĹij 45,000 ft, the 3 dB footprint should be âĹij 160 m. Counting in the 0.1 s integration time, the along track resolution should be a little larger than 160 m, not 20 m (which is the aircraft travel distance within 0.1 s). Also, Figure 8 needs to be revised since it shows a linear relationship between along track resolution and number of samples.

The sentence has been revised as follows: The along track resolution is a function of aircraft speed, and dwell time of the beam. The footprint of the HCR beam is 3 m at the range of 250 m and it increases to 180 m at 15 km range. Since the aircraft traverses 20 m during 0.1 s or 1000 sample averaging, the footprint of the HCR beam increases from 20 to 200 m as the range increases from 250 m to 15 km.

Figure 8 has been deleted.

6. Page 128, Line 19, Noise diode temperature stability better than 0.004 dB over 30 degree C temperature range. Could the authors provide details on this? For reference, NoiseCom NC5000 temperature stability is âĹij 0.01 dB/degree C, which means 0.3 dB for over 30 degree C range.

A Quinstar noise source was used in the HCR system. As documentation of the noise source is limited with regard to excess noise ratio due to temperature variation, we use the following equation in the Agilent application note for estimating temperature dependency of the noise diode:

ENR(corrected)= ENR(Calibrated)+ [(T_0 - T_s)/T_0] dB

A temperature sensor is attached to the on the noise diode for accurate estimate of its

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

physical temperature. The excess noise ratio (ENR) correction is extremely small, i.e. 0.004 dB over 30 degree change in temperature (or 0.00014 /degree).

7. Page 129, Section 5.1.2 discusses external calibration using measurements from light rain and presents modeled and measured radar reflectivity from light rain in close range. I don't think this approach is very appropriate for HCR: 1) This approach is based on measurements from light rain at close range, âĹij 250 m. Unless the Tx pulse is very short, otherwise, the T/R switch transition time may affect measurement at this range; 2) How do you to verify the rain rate is within 3-10 mm/hour?; 3) At this close range, rain/condensation on the splash plate and antenna could be significant and affect the calibration accuracy. For an airborne radar like HCR, the convenient way to perform radar calibration is to use surface water, such as lake of ocean. Atmospheric attenuation for that situation could be estimated and corrected by using sounding data or standard atmospheric profile.

Ans: The calibration procedure using the measurements from light rain presented in this study is applicable only for a ground-based configuration of the HCR. Also the radome should be protected from rain and condensation by a canopy shelter. The HCR transmitted 512 ns or 75 pulse width and the receiver oversampled the return signal for obtaining 19.2 m range resolution. The far field range for the HCR is 57 m. The HCR collects data 120 m range onwards. The closest range is determined by high power circulator and receiver protection circuit timings.

The rain rate for the radar measurements presented in figure 10 was ascertained from a rain gauge located within 100 m of the radar.

The following sentences have been added to the section 5.1.2: The calibration procedure using the measurements from light rain is presented only for a ground-based configuration of the HCR. Its radome is protected from rain and condensation by a canopy shelter. The HCR transmitted 256 ns pulse width and the receiver oversampled the signal for obtaining 19.2 m range resolution. The far range for the HCR is 57

m. The HCR collects data 75 m range onwards.

As per reviewer's comments we plan to verify the ground-based calibration results presented in this study using the calibration results from ocean surface scattering in the future.

8. Page 129, Also did you take into account signal attenuation due to the rain in your calibration? From [Haynes 2009 Rainfall retrieval over the ocean with spaceborne Wband radar], the two-way path attenuation through 5 mm/hr rain could be as much as 6 dB per km, so your measured reflectivity of 1.5 dB below the theoretical at 250 m range could be correct.

Yes, the calibration procedure included attenuation due to rain.

9. Page 129, line 10-15, Would it be possible to fly microphysics probes on the GV to provide in situ validation since there is no way to precisely know the rain rates?

Yes, the GV carries microphysics probes.

In an ongoing field deployment we are in the process of collecting measurements of cloud droplets and drizzle and these dataset will be analyzed in the coming years for validating LWC, mean droplet size and rain rates estimated from the HCR.

10. Page 130, lines 14-15, There is an old paper that discusses this as well (Heymsfield 1988) that maybe can be referenced.

The reference has been included.

11. Page 133, Line 11, "Along track resolution is normally about 60 m", which is not consistent with 20 m mentioned in Page 127 even though 20 m does not sound a right number.

The sentence on page 127 has been revised as follows: The along track resolution is a function of aircraft speed, and dwell time of the beam. The footprint of the HCR beam is 3 m at the range of 250 m and it increases to 180 m at 15 km range. Since the aircraft traverses 20 m during 0.1 s or 1000 sample averaging, the footprint of the HCR beam increases from 20 to 200 m as the range increases from 250 m to 15 km.

12. Table 1, in the line "Sensitivity (-6.5 dB SNR, . . .", where is -6.5 dB calculated? What are the sensitivity values for scanning mode? What is the cross-track scanning rate (this parameter need to be added into the table). The -6.5 dB SNR thresholding as compared to the 0 dB SNR thresholding for the single pulse case would imply a 6.5 dB increase in sensitivity. Also, what is the reflectivity and Doppler sample spacing in range?

The phrase '6.5 dB SNR' has been deleted. The table 1 has been revised. It includes revised sensitivity values and transmit pulse length.

Sensitivity of the scanning mode depends on the dwell time of the beam. For a 3.50 scan rate for covering 600 sector, the sensitivity of the HCR will remain same as in nadir or zenith pointing mode with 0.1 s dwell time i.e. -43.3 dBZ at 1 km. Reflectivity and Doppler sample spacing along the range is 19. 2 m.

Editorial, 1. Pg 119, Line 16, "Cloud Resolving System" should be "Cloud Radar System (CRS)".

2. Figure 3 labels are too small to read. The figure has been revised.

3. Please add unit and legends for the data products (reflectivity, Doppler velocity and spectrum width et al.) in Figure 12, 13 and 14.

Figures 12, 13 and 14 have been revised.

4. Pg 127: "A factor of two coarser in range resolution" Maybe reword to "Reducing the range resolution by increasing the pulse length by a factor of two improves sensitivity by 6 dB."

5. Pg 129: Mean reflectivity should be dBZ (it currently just says dB)

6. Pg 136, Line 21, "The spectrum in Fig. 16 . . ." should be Fig. 15.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Thank you for the editorial comments and they have been fixed.

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., 5, 117, 2015.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper