Calibrating ZDR on nonlinear 88D receivers

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Differential reflectivity (Z_{DR}) is one of the major dual-pol radar parameters

Definition: $$Z_{DR} = 10\log_{10}\left(\frac{P_h - N_h}{P_v - N_v}\right)$$ (dB)

$P_{h,v}$ – powers in the horizontal/vertical polarization channels

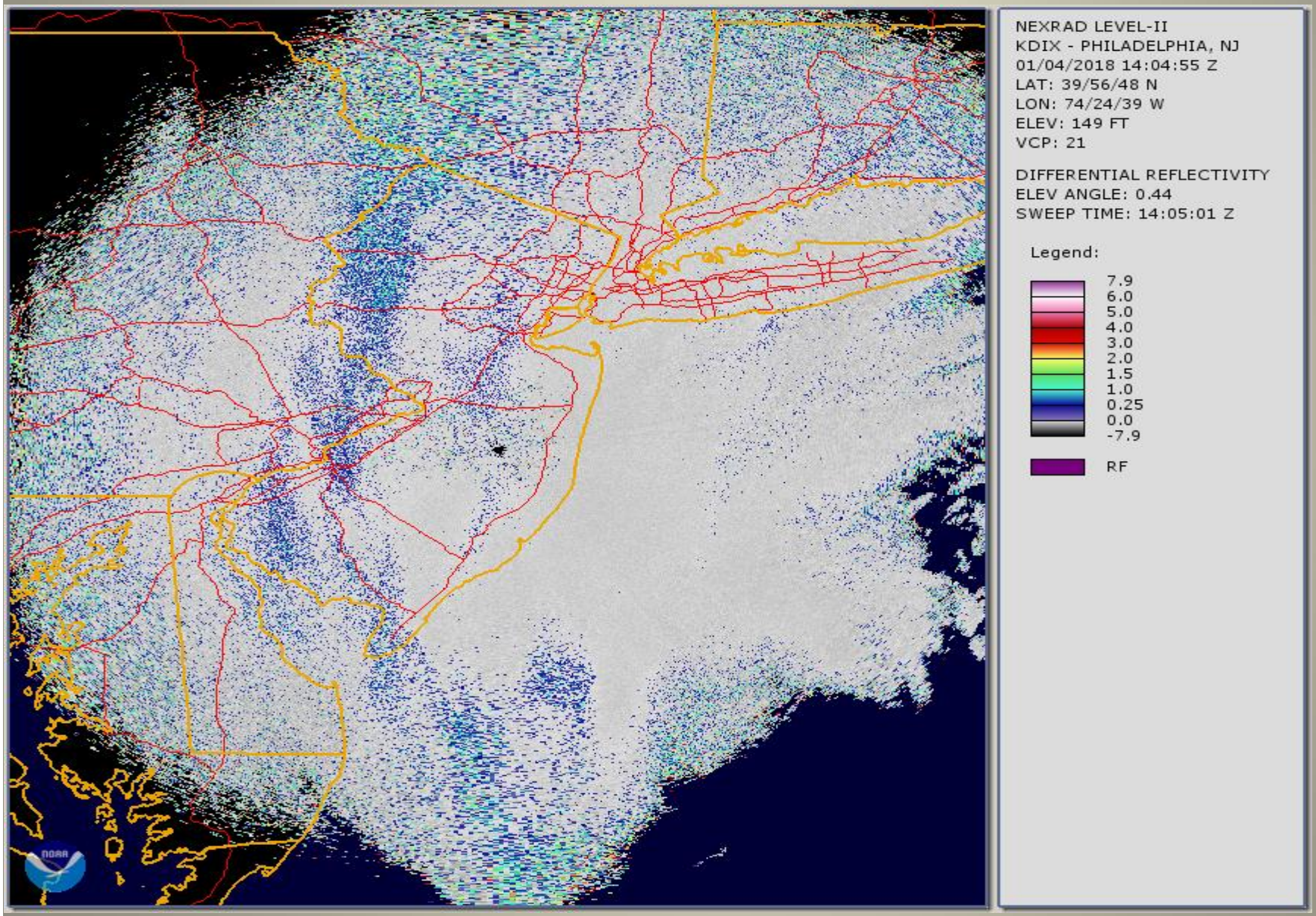
$N_{h,v}$ – noise powers in the channels

Z_{DR} is a measure of non-sphericity of scatters

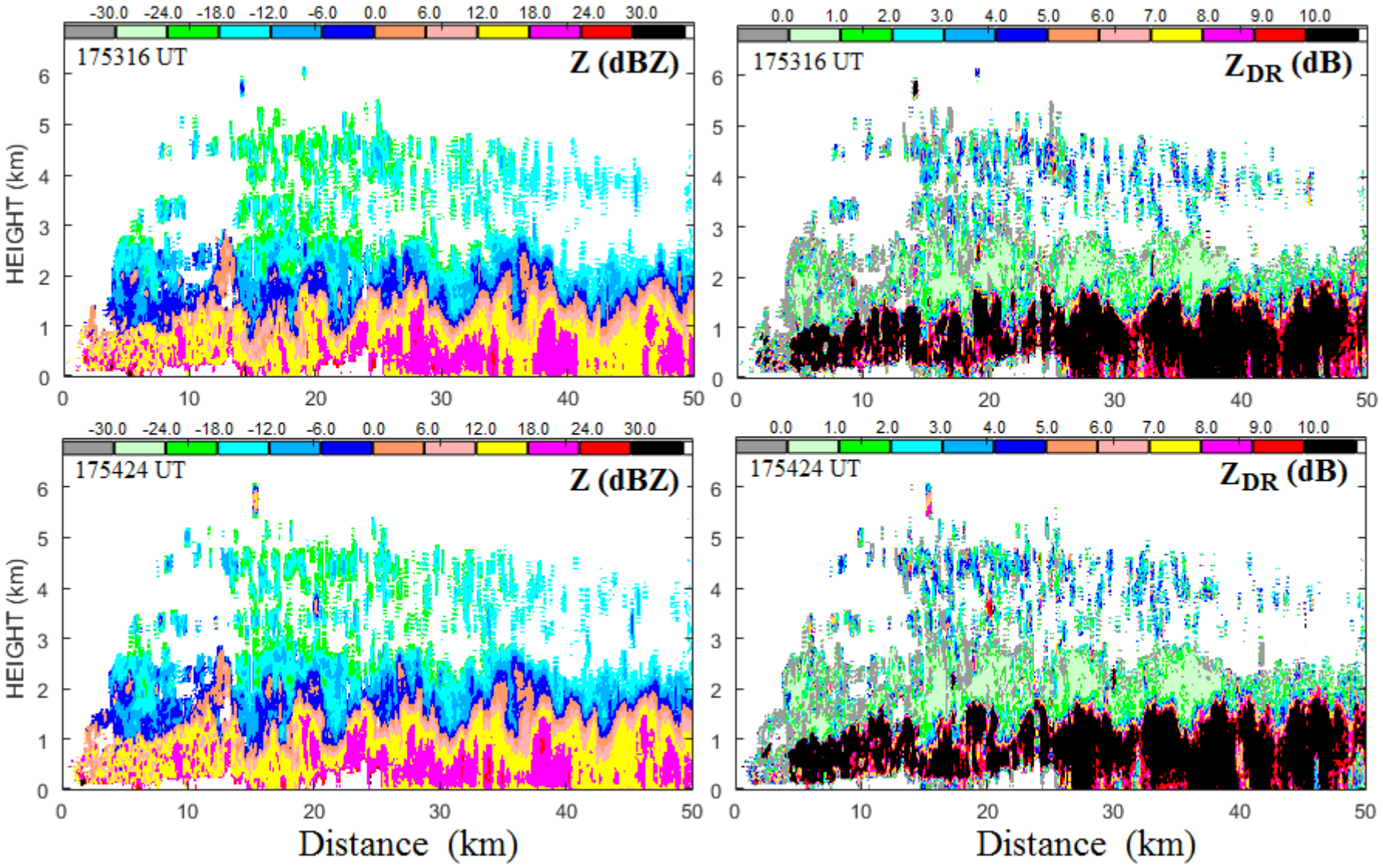
What Z_{DR} accuracy is needed in precipitation measurements and radar observations in clear air (Bragg scatter)?

WSR-88D KDIX (Philadelphia) 01/04/2018. Snow event

ZDR values are smaller than 1 dB.

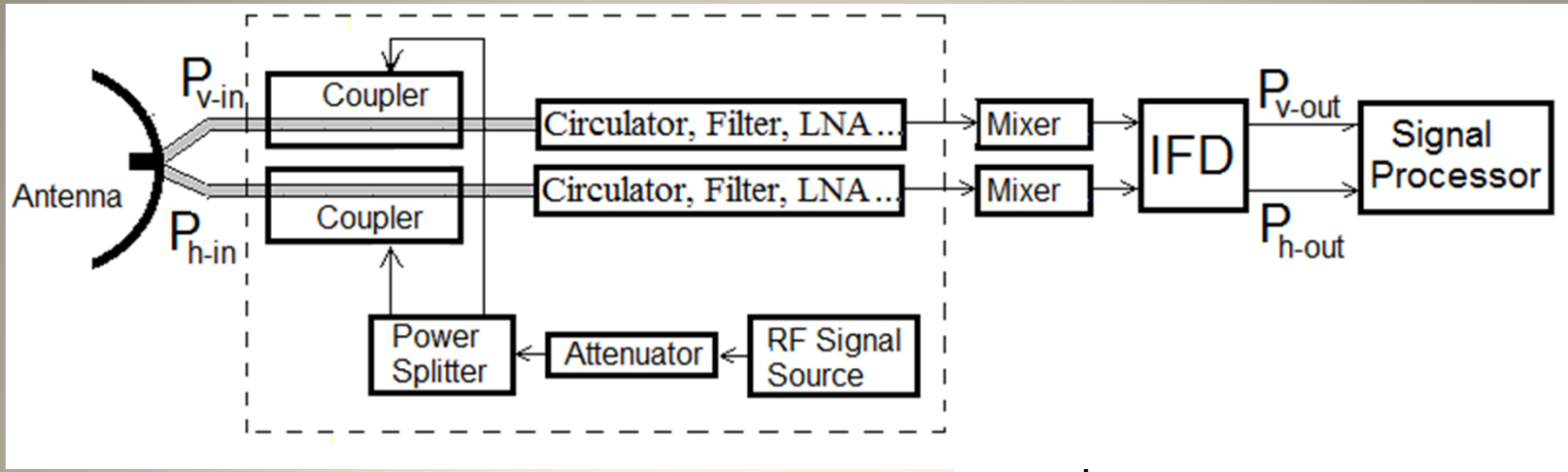


WSR-88D KOUN, Norman, OK. RHI. Convection in clear air.

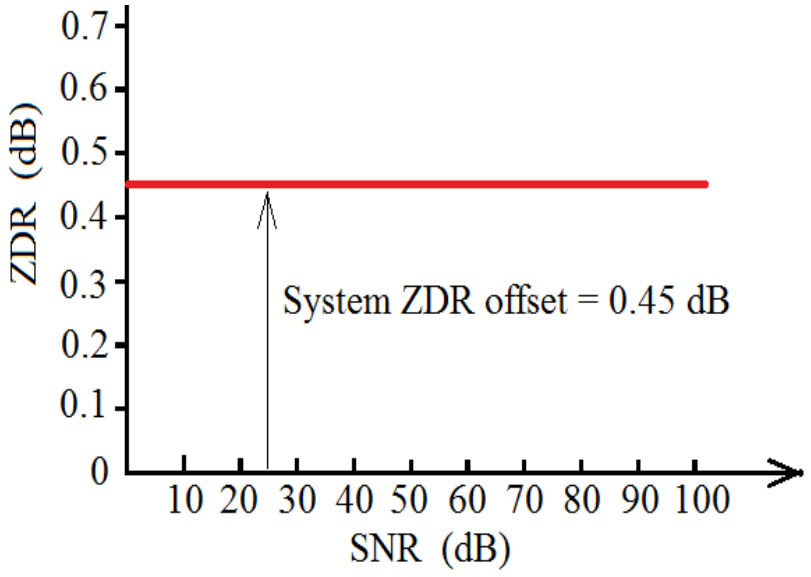


ZDR values in Bragg scatter areas are close to 0 dB and should be measured with accuracy better than 0.2 dB

Ideal system ZDR response



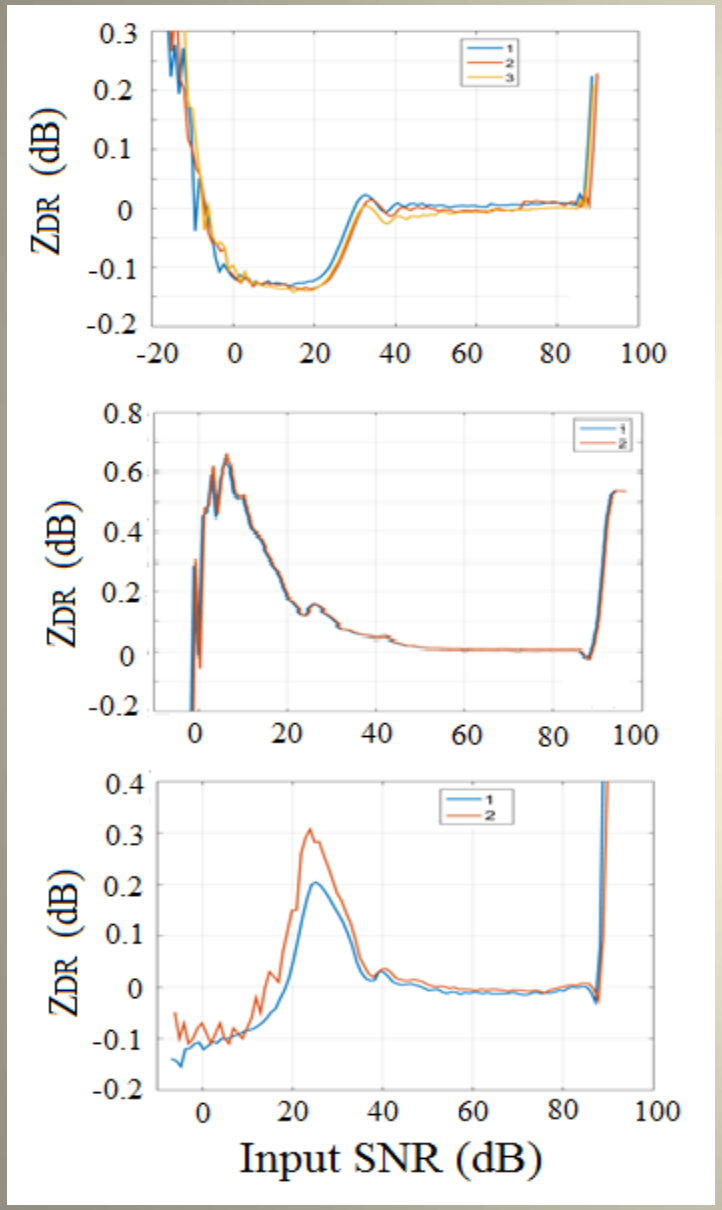
Simplified schematic of the measurements of system ZDR in receive as a function of the input power. Current ZDR calibration measures receiver calibration at ~ 50 dB SNR.



In an ideal radar, the system ZDR offset does not depend on the input signal power, i.e., Signal-to-Noise Ratio (SNR)

Results of the measurements

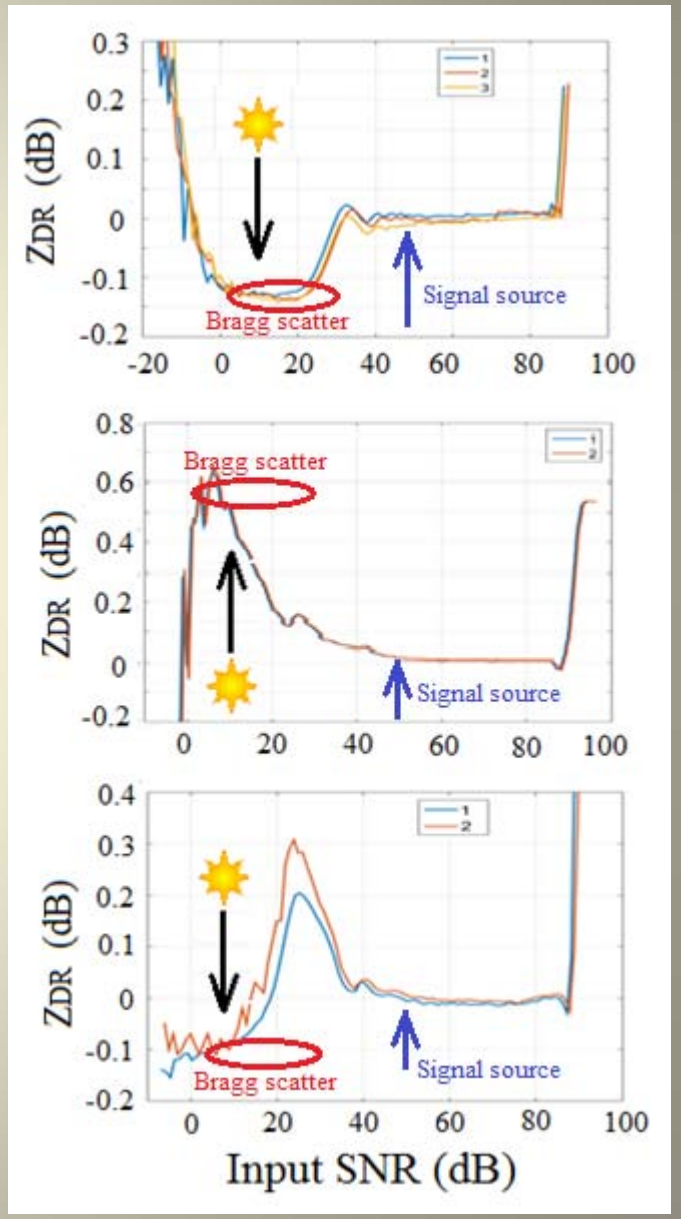
ZDR calibration using the Sun, Bragg scatter, and radar signal source



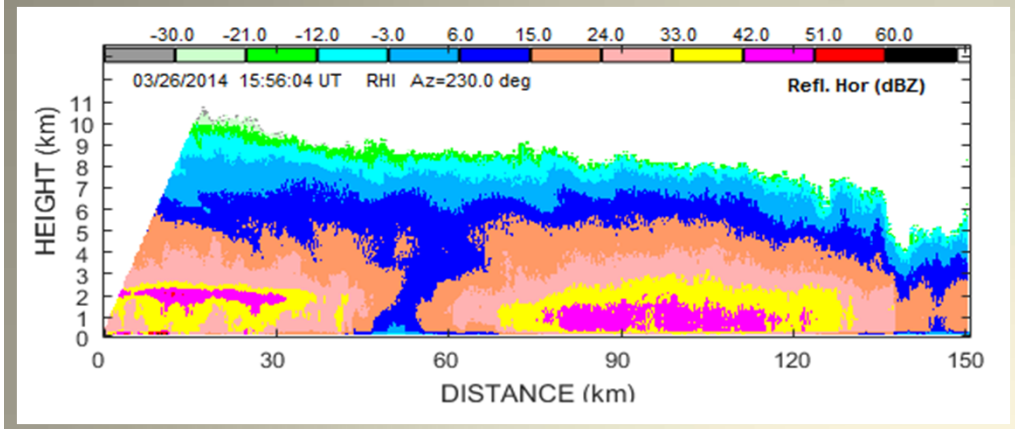
WSR-88D KREX

WSR-88D KOUN

WSR-88D KJIM

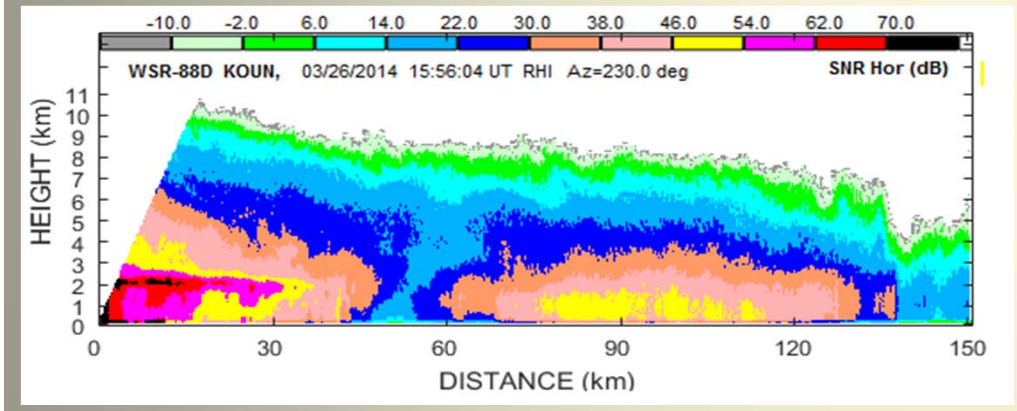


Measured Z_{DR} is a function of SNR.

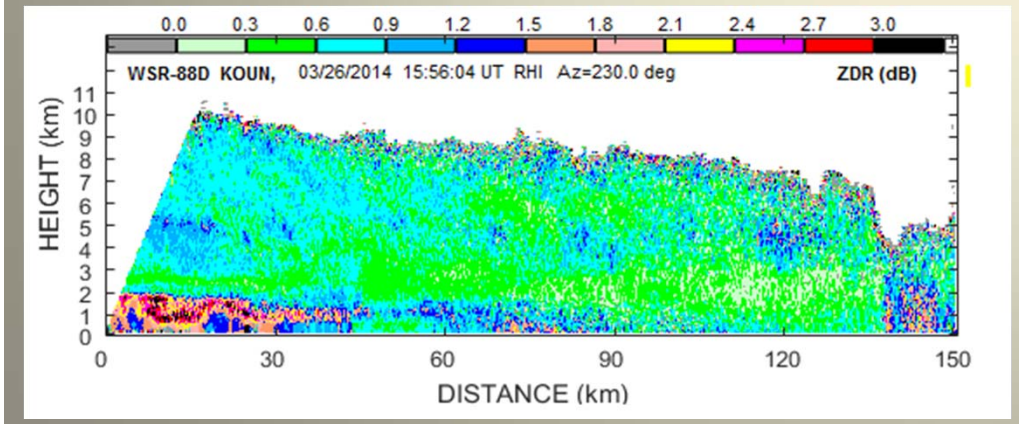


Vertical cross section (RHI)

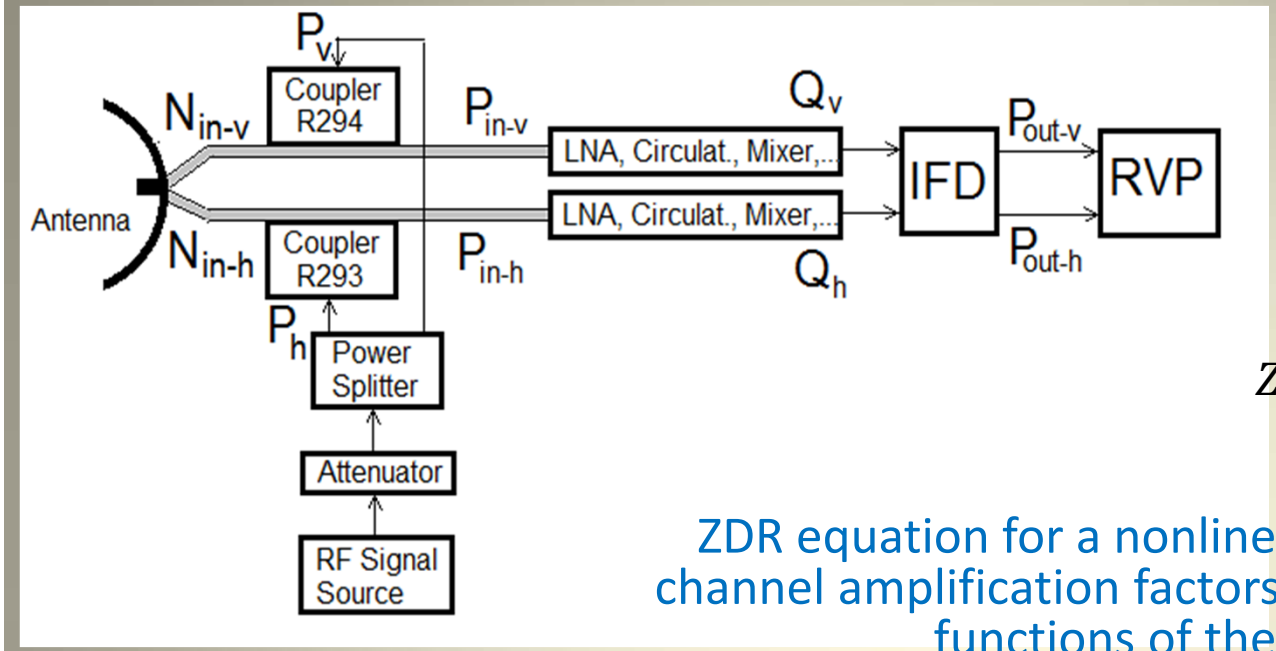
WSR-88D KOUN. RHI. 26 March, 2014.
1556 UTC



This is an SNR field. SNR varies in a large interval from -5 to >70 dB. ZDR should be calculated by taking into account the nonlinear receiver response.



Z_{DR} calculations

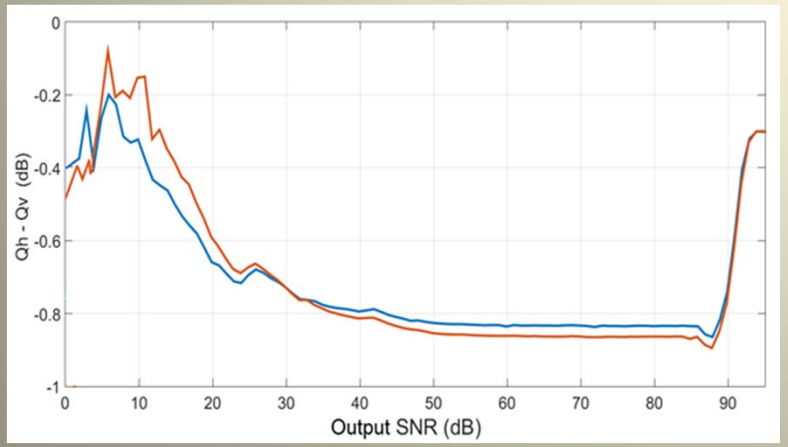


Current equation:

$$Z_{\mathrm{DR}} = 10\log\left(\frac{P_{\mathrm{out-h}} - N_{\mathrm{out-h}}}{P_{\mathrm{out-v}} - N_{\mathrm{out-v}}}\right)$$

ZDR equation for a nonlinear receiver contains the channel amplification factors $Q_{h,v}$ which are nonlinear functions of the powers P_{out}

$$Z_{\mathrm{DR}} = 10\log\left[\frac{P_{\mathrm{out-h}}}{Q_{\mathrm{h}}(P_{\mathrm{out-h}})} - N_{\mathrm{in-h}}\right] - 10\log\left[\frac{P_{\mathrm{out-v}}}{Q_{\mathrm{v}}(P_{\mathrm{out-v}})} - N_{\mathrm{in-v}}\right]$$



Q_h - Q_v as a function of SNR for WSR-88D KOUN. 21 and 23 June, 2018 (the blue and red curves, respectively)

Conclusions

- To use ZDR in precipitation measurements and observations of Bragg scatter, ZDR calibration should be accurate to at least 0.2 dB. About 1/3 of WSR-88D systems is out of this requirement.

- Studied radar receivers of WSR-88Ds are nonlinear. Nonlinearities can be larger than 0.2 dB, i.e., larger than needed ZDR uncertainty. Receiver nonlinearities should be accounted for in radar calibration and in ZDR measurements from precipitation.

Future work

-ZDR calibration procedure should be revised to take into account receiver nonlinearities. The receiver is used in calibration of the transmitter and in solar ZDR calibration. Therefore, all the calibration procedures should be revised.

- Calculations of ZDR from precipitation should be revised.

- ZDR responses should be obtained from several radars (especially from those with bad ZDR calibration) and analyzed for its possible cause of ZDR problems.