370 Sensitivity of operational weather radars

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Motivation

The NEXRAD program is upgrading the WSR-88D radar network, adding polarimetric capability. The design employs simultaneous transmit and receive functionality for establishing the horizontal and vertical polarization basis. This necessitates splitting the transmit power, resulting in a minimum of 3 db of loss in a single H polarization transmit channel and thus a loss of sensitivity for basic radar estimates. This study compares expected and measured sensitivity performance differences between baseline ***(KCRI)*** and modified ***(KOUN)*** WSR-88D test radars.

Radar Equation Analysis

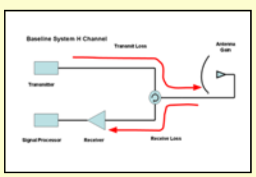
Begin with Eq. 4.34, Doviak and Zrnic, 1993, for returned power (casting for MKS units):

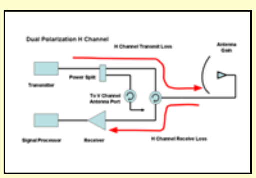
$$P(\mathbf{r}_0)=\frac{\pi^3 P_t g^2 g_s \theta_1^2 c\tau |K_W|^2 Z_e}{2^{10}(\ln 2)\lambda^2 r_0^2 l^2 l_r}$$

Reduce down to frequency dependent terms, transmitted power, and noise to derive Signal to Noise Ratio (SNR):

$$SNR=\frac{P(\mathbf{r}_0)}{P_N}=\frac{1}{P_N}\frac{P_t g^2\theta_1^2}{\lambda^2}C_1$$

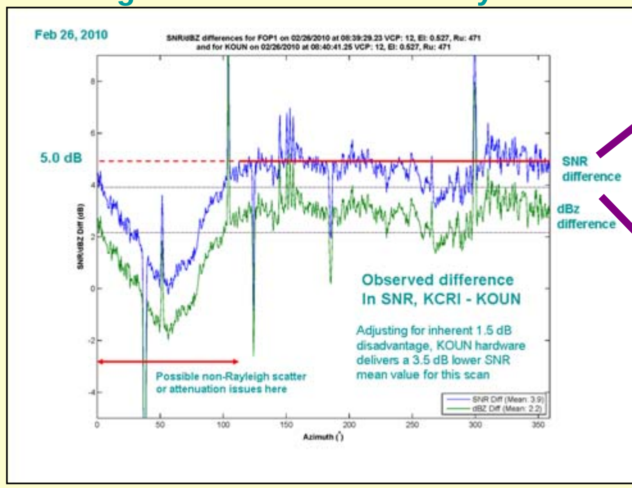
P_t, power at the antenna port, is a key factor in sensitivity performance. The polarimetric radar divides available power between the H and V channels, lowering sensitivity in a single channel. For the test radars, differences in wavelength affect antenna gain and also have a direct affect on returned power, resulting in additional sensitivity losses for the polarimetric system





Signal loss differences for transmit and receive paths between baseline and dual polarization are nominally 3.5 dB. For the test bed radars, Antenna gain and other wavelength dependent differences between the test radars account for 1.5 dB. Thus the KCRI and KOUN test radars should have an observed sensitivity difference of 5.0 dB because they have different wavelengths. Radars in the field will not change wavelength upon modification.

Signal to Noise Ratio Analysis



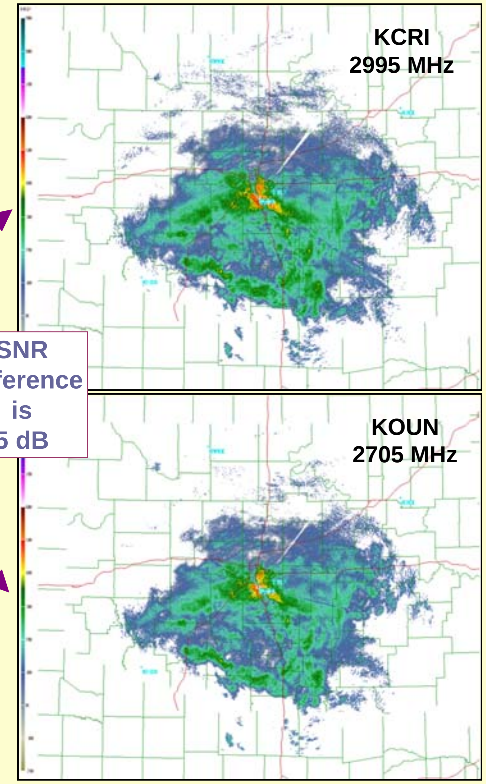
February 26, 2010, Rain and Snow Event

- data plotted: observed differences between KCRI and KOUN
- the plots are average differences per radial
- blue line: average SNR difference is 5.0 dB
- expect 1.5 dB due to wavelength difference of KCRI and KOUN
- discard radials with possible non Rayleigh scatter
- green line: average reflectivity difference (un-calibrated)
- **data confirms sensitivity loss in a fielded radar will be 3.5 dB**

Improving Sensitivity

some sensitivity performance could be recovered by the following: (1) increase frequency to achieve more antenna gain, possibly to the 3500 – 3600 MHz band (2) increase transmitter power (3) reduce hardware insertion losses (4) increase number of bits in the digital receiver A/D converter (5) incorporate pulse compression.

Test Radars Coverage Comparison



Summary

expected sensitivity difference between KCRI (baseline) at 2995 MHz and KOUN (polarimetric) at 2705 MHz due to wavelength change is about 5.0 dB. Observed difference in the SNR plots of 5.0 dB for the ***February 26, 2010*** event confirm theoretical estimates. This is also seen in the sample radar reflectivity plots in the above panel showing the coverage resulting from the 5.0 dB loss. Accounting for wavelength effects between the two test radars, the expected loss of sensitivity in a modified network WSR-88D should be ***only 3.5 dB***, less than seen in the reflectivity here. Operational assessments have determined this results in minimal operational impact.

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