Detection Performance of Meteorological Radars

Reflector and Phased Array Antennas

For the WSR-88D, sensitivity is important for reliable detection of phenomena featuring weak signal returns. These include fronts and outflow boundaries, snow, biological targets, smoke, volcanic ash, clear air turbulence, and winds aloft. Some recent examples demonstrating detection performance are shown below.

The weather radar equation relates target size (Z_e) to power received at the radar as a function of range and other variables such as transmitter power (Doviak and Zrnic, 1993 eq. 4.34)

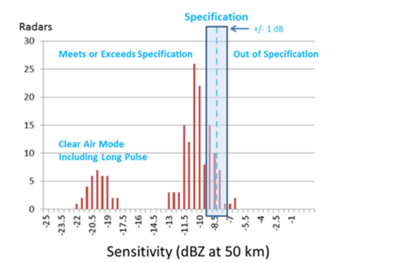
$$P(\mathbf{r}_0) = \frac{\pi^3 P_t g^2 g_s \theta_1^2 c \tau |K_W|^2 Z_e}{2^{10}(\ln 2)\lambda^2 r_0^2 l^2 l_r}$$

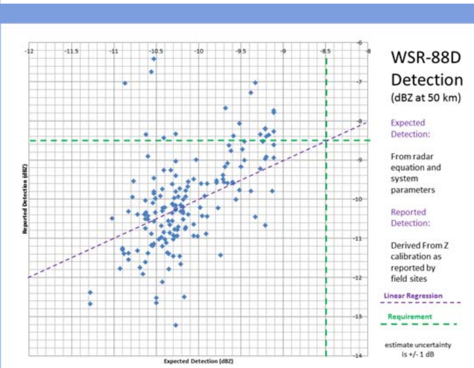
The radar equation can be re-cast as a function of signal to noise ratio available at the receiver, target size, atmospheric attenuation, range, and a radar constant dBZ_0 as described in the equation below. This is the standard calibration relationship used in the WSR-88D. The calibration constant includes transmitter power and all hardware gains and losses.

$$SNR = Z_e - dBZ_0 - ar - 2r$$

dBZ_0 is the value of Z_e at 1 km that provides a return signal with an SNR of 0 dB at the radar

Sample WSR-88D Detection Performance (dBZ0 adjusted to 50 km - the WSR-88D Specification)

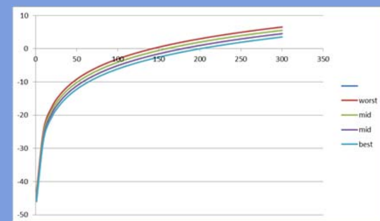




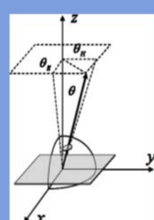
Design Considerations for Evolving Detection Performance Needs from Reflectors to Phased Arrays

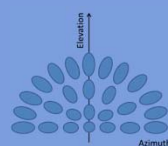
NCAR S-Pol Antenna, R. Ice Photo

Parabolic Reflector Antennas



- Detection capability only dependent on range
- 100's of KW available with vacuum tube transmitters





Courtesy Dusan Zrnic, NSSL

$$\theta_u \varphi_v = \frac{\theta_{B0}^{br}\varphi_{B0}^{br}(\lambda/\lambda_0)^2}{\cos\theta}$$

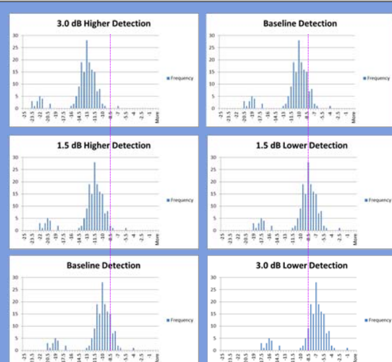
$$\theta = \arctan\{[(\tan\alpha)^2 + (\tan\beta)^2]^{1/2}\}$$

Weather Radar Equation for Phased Array Antenna

$$G = e_r D = e_r \pi c_x c_y \frac{A_p}{\lambda^2}\cos\theta$$

$$Z = \left[\frac{1024 \ln 2 \lambda_0^4}{\pi^3 (c\tau)|K|^2 \lambda_0^2}\right]\left[\frac{1}{(\theta_{B0}^{br}\varphi_{B0}^{br})}\right] \times \left[\frac{L_s}{P_t G_{rx} G_0^2}\right]\left[\frac{L_a P_{out}}{(f/f_0)^4 \cos\theta}\right](R^2)$$

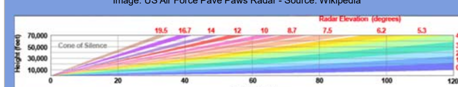
Knorr, "Weather Radar Equation Correction for Frequency Agile and Phased Array Radars" IEE Transactions on. Aerospace and Electronic Systems, Vol 43, N0. 3 July 2007



Loss between ~1.5-3.0 dB off broadside

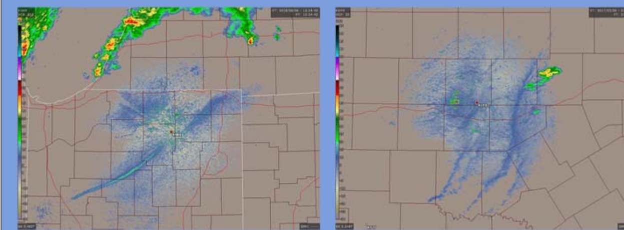
- Detection capability dependent on angle from broadside
- Power limited to 10's of KW for active arrays
- What is the optimum array tilt angle (θ_T)?

Image: US Air Force Pave Paws Radar - Source: Wikipedia

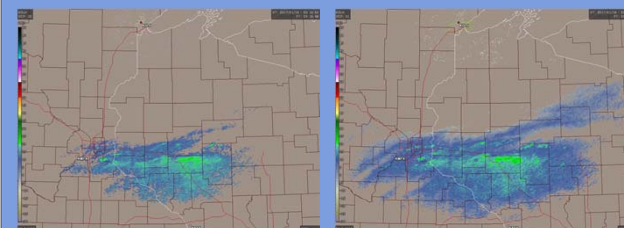


Iowa State University Met 432 Kevin Snow NWS Des Moines, IA
https://www.meteor.iastate.edu/classes/mt432/lectures/ISURadarTalk_NWS_2013.pdf

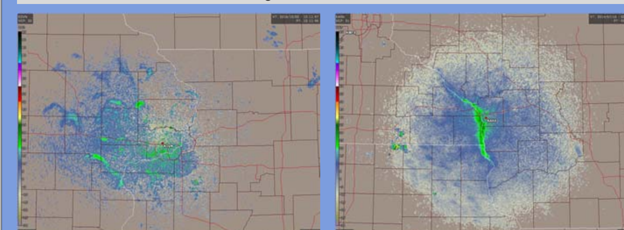
Detection of fronts and boundaries



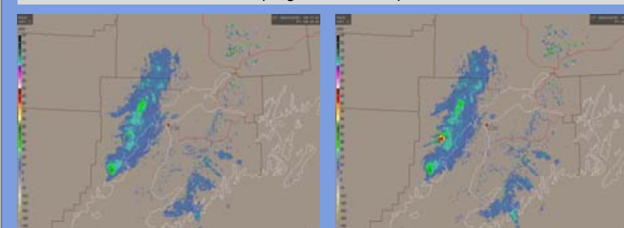
Winter precipitation…WSR-88D short pulse (left) and long pulse (right)



Biological returns observed



Volcanic ash…progression of eruption in Alaska



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