Pulse Doppler Radar

Assume a target at a distance R and has a radial velocity component of V_r. The round-trip distance to target is $2R$. This is equivalent to $2R/\lambda$ wavelengths or $(2R/\lambda)2\pi = 4\pi R/\lambda$ radians. If the phase of the transmitted signal is ϕ_o, then the phase of the received signal is

$$\phi = \phi_0 + \frac{4\pi R}{\lambda}$$

The change in phase *between* pulses is $\frac{d\phi}{dt} = \frac{4\pi}{\lambda}\frac{dR}{dt} = \frac{4\pi}{\lambda}V_r$. The left hand side of the equation is equal to the frequency $2\pi f_d$, so that

$$2\pi f_d = \frac{4\pi}{\lambda}V_r \Rightarrow f_d = \frac{2V_r}{\lambda} \qquad (1)$$

Alternatively, let the transmitted frequency be f_t. The received signal can be represented as $A_{\text{rec}} = K\sin(2\pi f_t(t - T_R))$. The round-trip time T_R is equal to $2R/c$. With a radial velocity of V_r the round-trip time is changing as $R = R_0 - V_r t$. Thus, the received signal is

$$A_{\text{rec}} = K\sin\left(2\pi f_t\left(1 + \frac{2V_r}{c}\right)t - \frac{4\pi f_t R_0}{c}\right)$$

Thus, the received frequency changes by a factor $2f_tV_r/c = 2V_r/\lambda$., which is the same as before. The Nyquist criterion says that $f_{\max}$ = PRF/2, combining this with Equation (1), results in

$$V_{\max} = \frac{PRF\lambda}{4} \qquad (2)$$

This is the **maximum unambiguous velocity**. Higher velocities cause *velocity folding* or *velocity aliases.*

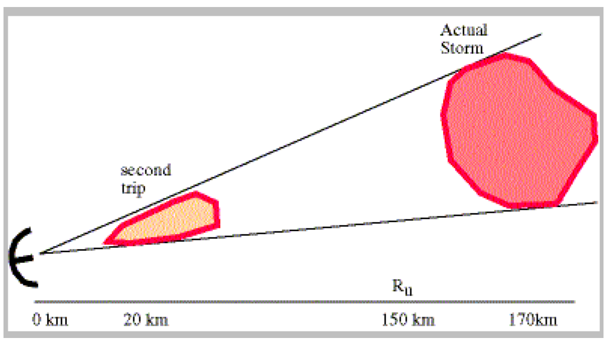
Maximum **unambiguous range** is $R_{\max} = \frac{c}{2PRF}$. This causes *range folding* or *range aliases*. Combining this with Equation (1) results in

$$\boxed{V_{\max}R_{\max} = \frac{c\lambda}{8}}$$

This summarizes the Doppler dilemma: a large $R_{\max}$ implies a small $V_{\max}$ and vice versa.

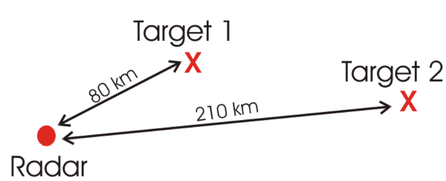
Recognizing and dealing with range an velocity aliases.

- Look outside.
- Examine horizontal and vertical shapes of object. For example range-aliased storms become skinny close-by objects. Storm heights are suspicious – convective storms are 10–15 km tall. Aliased they would be say 2 km tall, which is unrealistic.
- Examine reflectivities in conjunction with other factors,
- Change PRF–real echoes will not change position, but aliases will. This is not alwas an option.
- Velocity folding causes a change in sign, which is relatively easy to spot if the folding is within a larger region.
- Watch out, one can get multiple velocity foldings.



Example 1. A 3-cm radar with PRF of 1000 Hz is pointed towards a storm located 200 km from the radar. The radar display will show an alias at 200 km - $c/(2PRF)$ = 50 km. The storm is moving *away* from the radar with a radial velocity of 25 miles per hour, or 11.1 m/s. The radar will display the storm velocity as $(PRF \times \lambda)/4$ – 11.11 = 7.5-11.1 = 3.6 m/s *towards* the radar.

Example 2. A scanning radar with a PRF of 1000 Hz observes two identical distributed targets located at R_1 = 80 km and another at R_2 = 210 km (see below). Sketch and dimension a PPI up to 200 km.

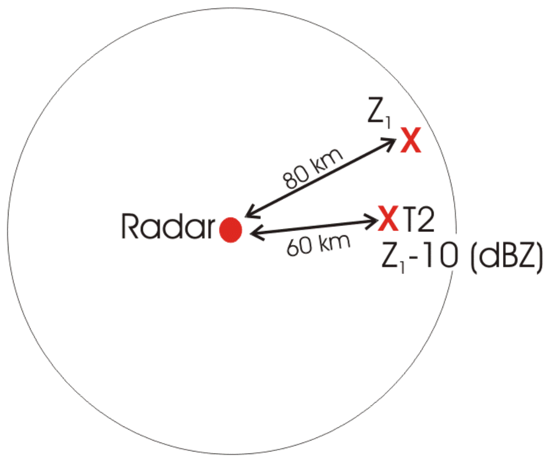


Answer. The unambiguous range for the radar is $c/(2PRF)$ = 150 km. The first target will not alias, the radar measures P_1 and R_1 and its processor outputs a reflectivity factor

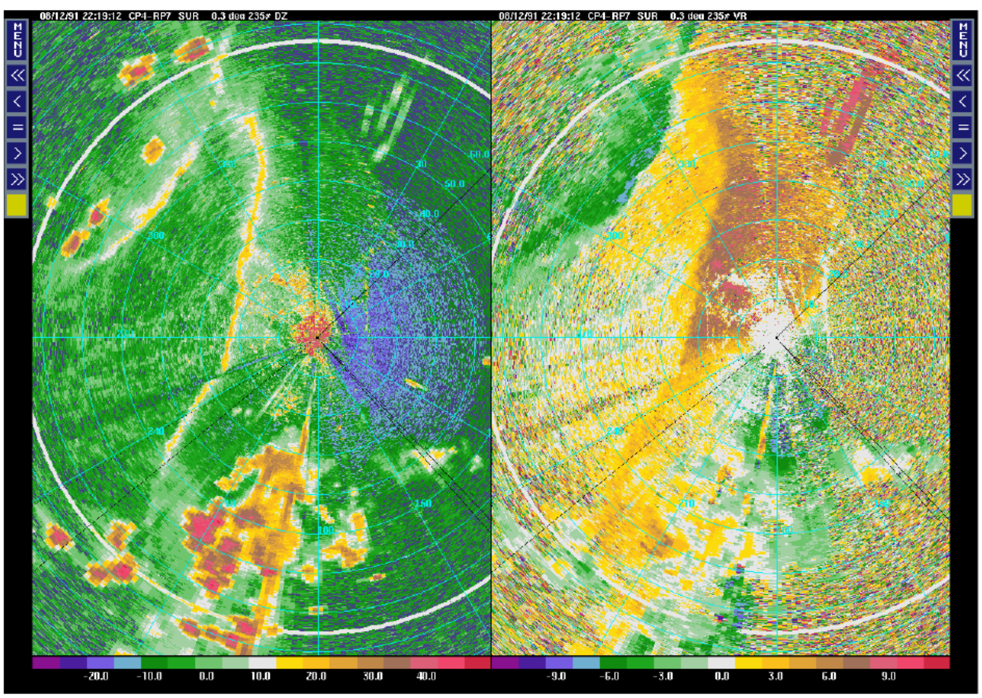
$z_1 = c_3 P_1 R_1^{\ 2}$. The radars measures a power $P_2 = P_1(R_1/R_2)^2$ for the second target. However, this target aliases to R_a = 210-150 = 60 km, so the processor outputs

$$
\begin{aligned}
z_2 &= c_3 P_2 R_a^{\ 2} \\
&= c_3 P_1 (R_1 / R_2)^2 R_a \\
&= c_3 P_1 R_1 \left(\frac{R_a}{R_2} \right)^2 = z_1 \left(\frac{R_a}{R_2} \right)^2
\end{aligned}
$$

Substituting the numerical values we get $z_2 = 0.082 z_1$. Thus, $z2$ is about –10 dBZ less that z_1.



Example 3



Reflectivity (dBZ) Velocity (m/s)