

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_0 , 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

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

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 $2f_t V_r/c = 2V_r/\lambda$, which is the same as before. The Nyquist criterion says that $f_{\text{max}} = \text{PRF}/2$, combining this with Equation (1), results in

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

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

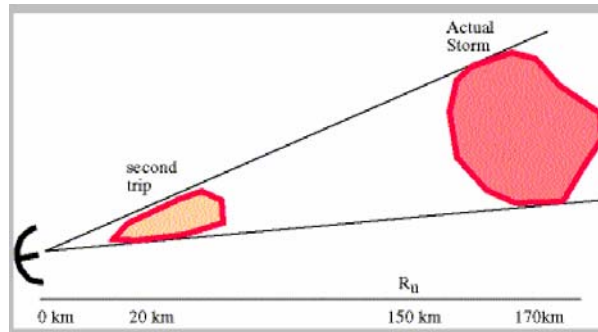
Maximum **unambiguous range** is $R_{\text{max}} = \frac{c}{2\text{PRF}}$. This causes *range folding* or *range aliases*. Combining this with Equation (1) results in

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

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

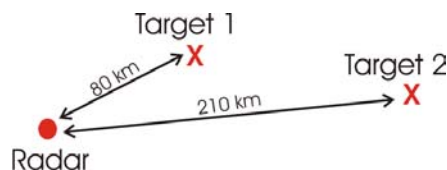
Recognizing and dealing with range and velocity aliases.

- 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 always 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 $200 \text{ km} - c/(2PRF) = 50 \text{ km}$. 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 $(PRF \times \lambda)/4 - 11.11 = 7.5 - 11.1 = 3.6 \text{ m/s}$ *towards* the radar.

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

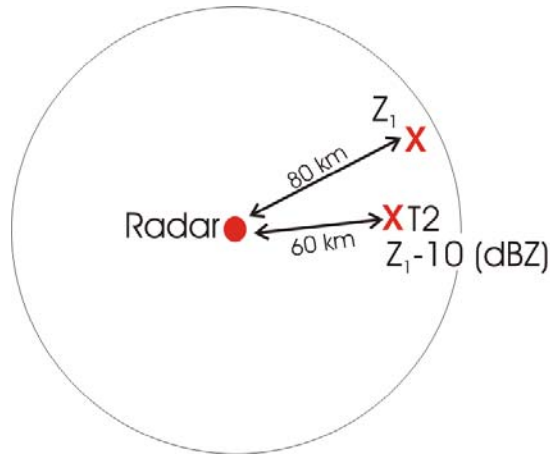


Answer. The unambiguous range for the radar is $c/(2PRF) = 150 \text{ km}$. The first target will not alias, the radar measures P_1 and R_1 and its processor outputs a reflectivity factor

$z_1 = c_3 P_1 R_1^2$. The radar 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

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

Substituting the numerical values we get $z_2 = 0.082z_1$. Thus, z_2 is about -10 dBZ less than z_1 .



Example 3

