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Range and velocity ambiguity mitigation using spectral reconstruction for Doppler weather radars

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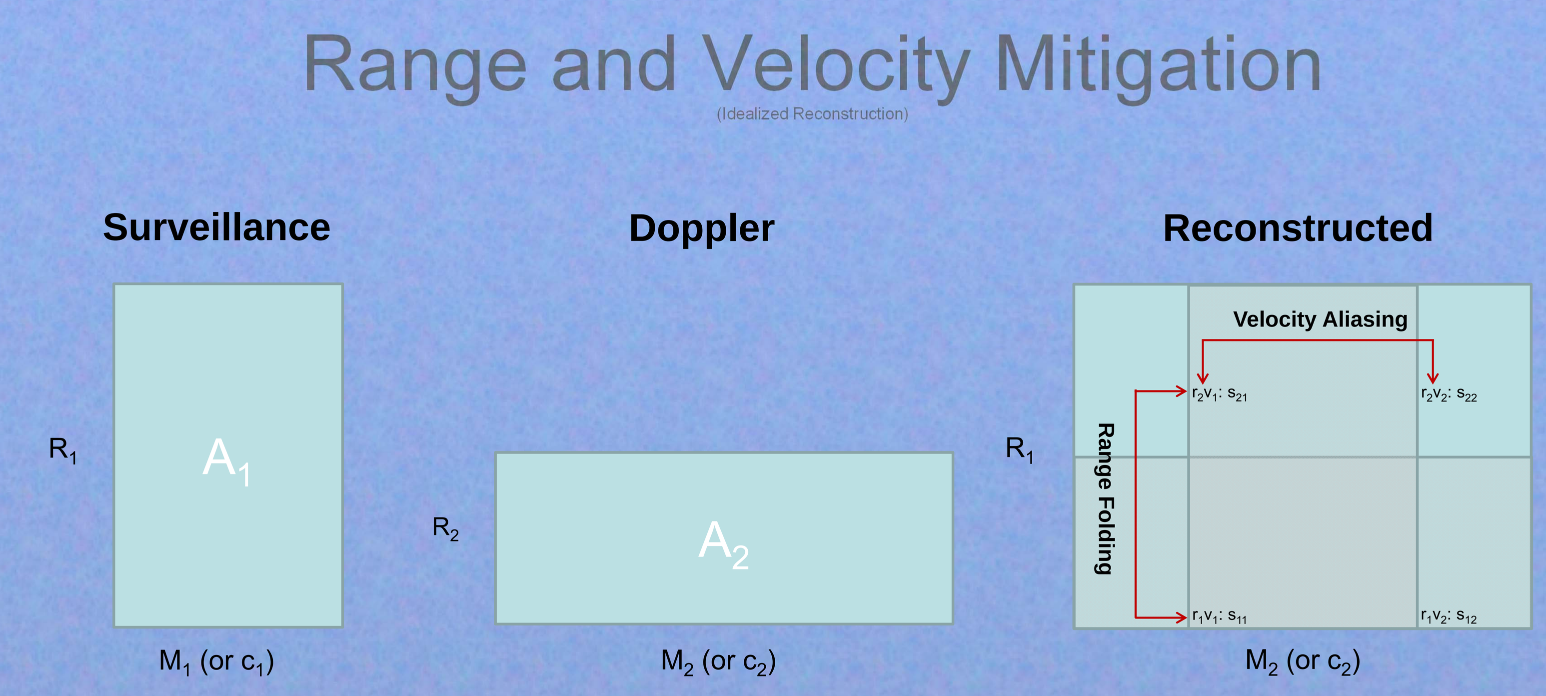
Problem

In pulsed Doppler weather radars, range and velocity ambiguities arise due to the large spatial extent and high wind velocities associated with some weather phenomena. That is, when using a constant (uniform) pulse repetition time (PRT), the PRT can be made long enough to ensure unambiguous range placement of all echoes of interest; however, high radial velocities may alias making wind retrieval ambiguous. Likewise, the PRT can be made short enough to ensure unambiguous velocity measurements; however, long-range weather echoes may become range folded (and possibly overlaid with echoes from nearer range locations) making range determination ambiguous. Schemes exploiting both time coding (using staggered PRTs) and phase coding (using systematic phase changes) have been proposed for range and velocity ambiguity mitigation; however, these schemes require specialized hardware, unconventional ground clutter filters, and/or complex signal processing software.

For weather radars that lack any of these, effective range and velocity ambiguity mitigation is typically realized with multiple scans using different PRTs (two or more batches of uniform PRTs). For example, a surveillance scan using a long PRT can recover reflectivities (powers) unambiguously. This can be followed by a Doppler scan using a short PRT to unambiguously measure Doppler velocities and spectrum widths. However, these Doppler moments are unrecoverable in the case of overlaid echoes unless they correspond to a dominant (i.e. much stronger) echo. In this paper, a novel technique to mitigate range and velocity ambiguities in overlaid-echo situations is presented. The technique combines the ambiguous range-Doppler spectra from the surveillance and Doppler scans to reconstruct an ideal, unambiguous range-Doppler spectrum from which velocity and spectrum width can be effectively estimated.

Combining Spectra from Long and Short PRT



$$A_1 = A_2 \Rightarrow \frac{R_1}{R_2} = \frac{M_2}{M_1} = \frac{c_2}{c_1} = \frac{PRT_1}{PRT_2} \Rightarrow \frac{\Delta R_1}{\Delta R_2} = \frac{\Delta v_1}{\Delta v_2} = 1$$

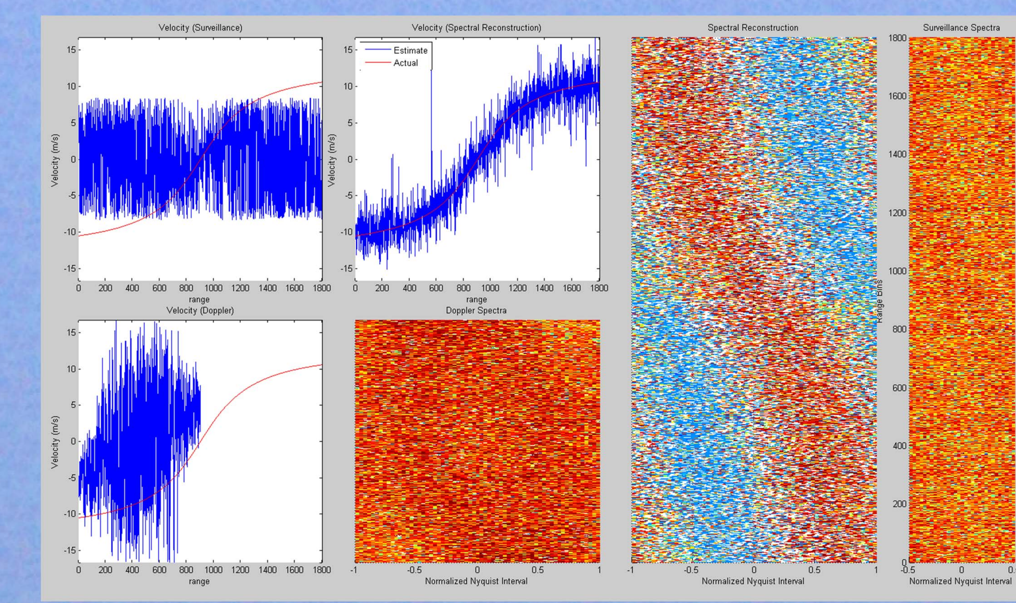
Assumptions
No weather beyond unambiguous range of long PRT
No aliasing beyond Nyquist of short PRT
σ_v < Nyquist of long PRT

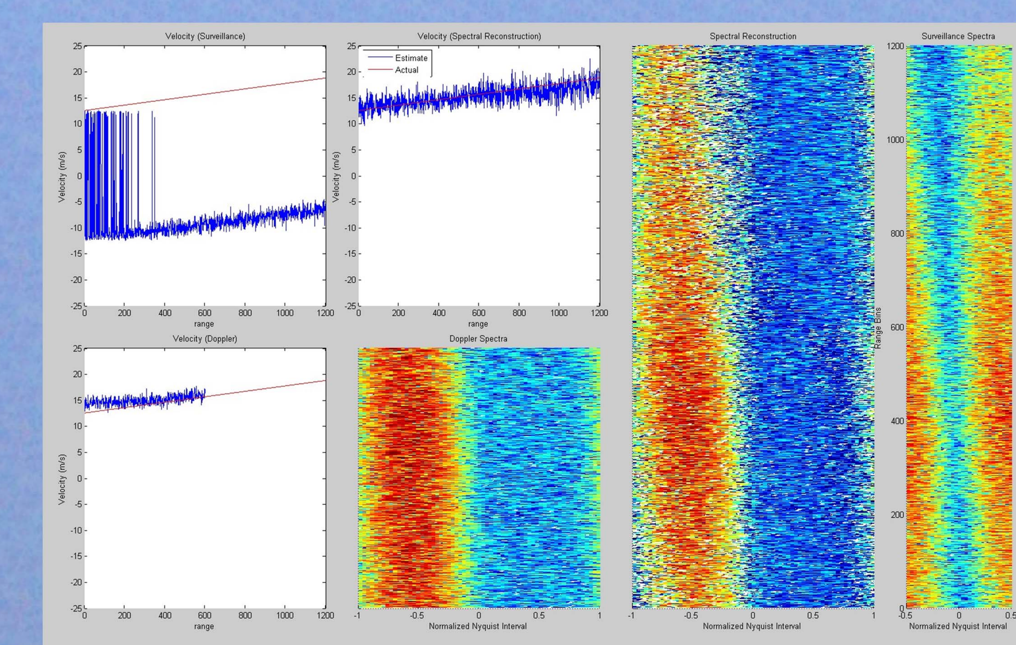
$$P_{surv\_r1} = as_{11} + bs_{12}$$
$$P_{surv\_r2} = cs_{21} + ds_{22}$$

$$P_{dopp\_c1} = as_{11} + cs_{21}$$
$$P_{dopp\_c2} = bs_{12} + ds_{22}$$

Dopp	P_{dopp_c1}		P_{dopp_c2}	
Surv	P_{surv_r1}	P_{surv_r2}	P_{surv_r1}	P_{surv_r2}
			1	1
	1			1
		1	1	
	1	1		

Simulations





Future Work

Spectral reconstruction shows promise in mitigating range and velocity ambiguities when overlaid echoes are nearly equal in strength. In this case, operational range unfolding algorithms fail to recover any Doppler information. Performance of the algorithm decreases as correlation between the long and short PRT spectra decreases; however, improvements are still realized. Additionally, the algorithm complexity grows rapidly as the PRT ratio increases (i.e. more overlaid echoes). Further investigation into improvements are ongoing as well as creating a real-time practical implementation that considers uneven dwell times between PRTs (i.e. velocity resolution is different between PRTs).

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