Weather Radar Range Velocity Ambiguity Analysis Using Staggered PRT

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Abstract – *The staggered pulse repetition time (SPRT) algorithm is to mitigate range and velocity ambiguities in Doppler weather radars by decreasing velocity aliasing while extending the radar coverage. The practical aspect of implementing the SPRT algorithm centered around three major issue:(1) providing adequate clutter filter suppression, (2) resolving overlay echoes, and (3) obtaining quality estimates with low variance. Resolution of the first and third issues (clutter suppression and quality estimates) with the introduction of the Spectral Algorithm for Clutter Harmonics Identification filter for a 2/3 PRT ratio. The second issue was mitigated by ensuring the unambiguous range of the shortest PRT (ra1 = cT1/2) encompassed the range extent of expected weather.*

Key Words: Staggered PRT, Ambiguity, Overlaid Echoes, Clutter Harmonics etc.

1. INTRODUCTION

Radar is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects. It is used to detect aircraft, ships, spacecraft, motor vehicles, weather formations, and terrain. A radar system consists of a transmitter producing electromagnetic waves in radio or microwave domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving) and a receiver and processor to determine properties of the objects.

1.1 Weather Radar

Weather radar is also called as weather surveillance radar (WSR) and Doppler weather radar, is a type of radar used to locate precipitation, calculate its motion, and estimate its type (rain, snow, hail etc.). Modern weather radars are known as pulse-Doppler radars, capable of detecting the motion of rain droplets in addition to the intensity of the precipitation. Both types of data can be analysed to determine the structure of storms and their potential to cause severe weather. Weather RADAR has been applied to many areas, an important one being weather monitoring. Through detecting raindrops in the atmosphere, the weather radar is a very effective tool for monitoring severe weather such as tropical cyclones, thunderstorms and heavy rain.

1.2 Clutter

Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators. Such targets include natural objects such as ground, sea, and when not being tasked for meteorological purposes, precipitation (such as rain, snow) atmospheric turbulence and other atmospheric effects, such as ionosphere reflections, meter trails, and Hail spike. Clutter may also be returned from man-made objects such as buildings and, intentionally, by radar countermeasures such as chaff.

2. Staggered PRT

The staggered PRT technique was first proposed in the context of weather surveillance radars Implementation of staggered PRT required close cooperation between the sequencer, host computer, and signal processor With this technique, transmitter pulses are spaced at alternating PRTs T1 and T2, and pulse-pair autocorrelation estimates are made independently for each PRT. These estimates are suitably combined, so that the effective maximum unambiguous velocity becomes va = λ/[4(T2 – T1)]. In addition, the unambiguous range is ra=cT1/2, corresponding to the shorter PRT. This implies that the staggered PRT is equivalent to a uniform PRT of T2 – T1 for the unambiguous velocity and a uniform PRT of T1 for the unambiguous range, and each can be independently selected. The implementation of the staggered PRT technique on weather radars has been disqualified mainly due to the difficulties in designing efficient ground clutter filters. In addition, due to the non-uniform spacing between pulses, spectral processing of time series is a challenge, because the pulse pair autocorrelation is obtained from independent pairs , slightly larger standard errors of estimates are expected. Spectral processing of the staggered PRT sequence was used for filtering the ground clutter. In this procedure, the staggered sample sequence is first converted to a uniform sequence by inserting zeros in places where the samples are missing. This, of course, is possible if T_1 and T_2 are selected appropriately, as integer multiples of a basic uniform PRT, T_u. The constructed uniform sequence (with inserted zeros) is expressed as a product of a uniform sample sequence (without missing values) and a binary code sequence. Thus, the spectrum of the staggered PRT sequence is a convolution of the signal spectrum with the spectrum of the binary coded sequence. The spectral processing is proposed only if clutter needs to be filtered; otherwise, the pulse pair processing is sufficient to estimate the spectral moments and is better in terms of estimate errors and computational complexity. The idea central to the filtering of the clutter from the staggered PRT sequence is to recover the spectral coefficients of the weather signal in the region where the clutter and signal spectra overlap.

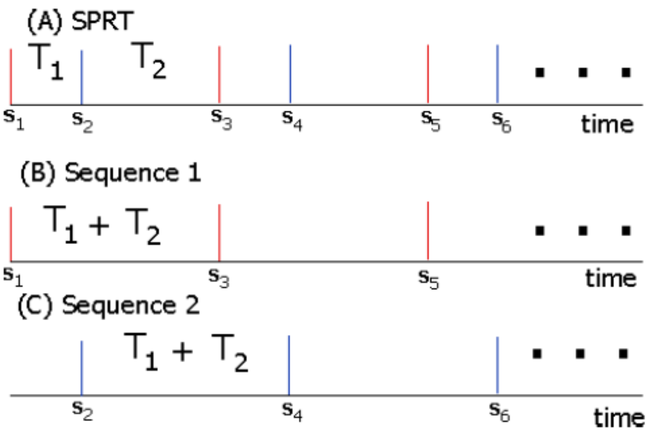

Figure 1: Staggered PRT Transmission

2.1 Pulse Pair Processing

To distinguish a moving target of a fixed object with help of the Doppler frequency, at least two periods of the deflection must be compared with each other. Since the Doppler-frequency (few Hertz) is small relatively to the transmitted frequency, therefore a phase comparison is more easily to carry out than a direct frequency comparison technically.

The echo signal of a moving target at the output of the phase-detector changes it's value and also the polarity in every pulse period. A fixed clutter signal will keep it's value and polarity in every pulse period. A pulse period is stored in a memory. This memory stage has got a memory cell for each range cell and delays the whole scan for one pulse period (PRT). Both periods, the actually period and its predator, are led to an extractor. The output of this stage is the difference of both input-signals. Clutter with a constant amplitude will be eleminated. Moving targets pass this stage. On this way the moving target produce an output signal and the fixed clutter don't do this.

A fixed target suppression happens by the phase comparison of the echoes received by several pulse periods (pulse- pair processing). If the phase relationship is always equal, then there isn't any phase difference and the target will be suppressed. If the target has moved, the phase difference is unequally zero

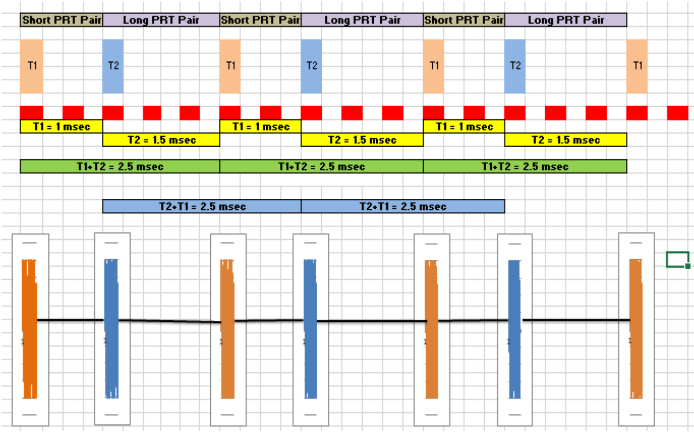

Figure 2: Pulse Pair Processing

- The transmitter produces a pulse with frequency f0 and duration of t.
- Some power with frequency f_0 is mixed with a signal from STALO and is passed to COHO
- COHO maintains f_0 of transmitted wave
- Receiver/mixer mixes signal from STALO and received signal
- Mixed signal is then amplified
- Phases of original and received signals are differenced, i.e., compute $f_1 = f_0 - f$. This is the phase of pulse #1.

2.2Range Overlaid Signals

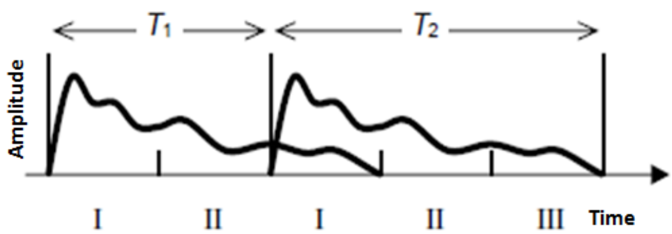

Figure 3: Removal of Overlaid Signals

The above figure shows the removal of the overlaid signal and romanan numericals indicate segment numbers used in reflectivity computations.

Doppler velocities *v*1 and *v*2 are computed from *R*1and *R*2, the pulse-pair autocorrelation estimates corresponding to *T*1 and *T*2. The difference of the two velocity estimates is used to determine the aliasing interval of the true velocity, and the velocity estimate corresponding to the shorter PRT is de-aliased using this information.

The removal of the overlaid signal steps:

- If the Target is detected, Range and Velocity is Fixed.

- Velocities are computed from the Range, then the pulse pair autocorelation estimates T1 and T2
- Removal of the overlaid signals and making the signal accurate, so signals won't get overlaid.

3. RESULTS

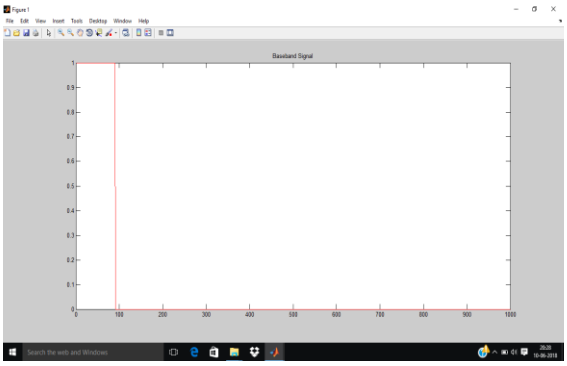

Figure 4: Baseband signal without noise

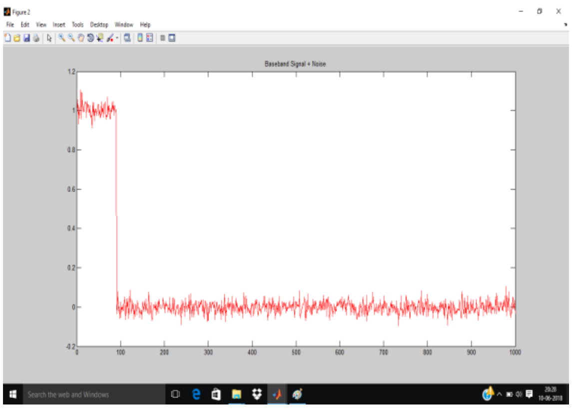

Figure 5: Baseband signal with Noise

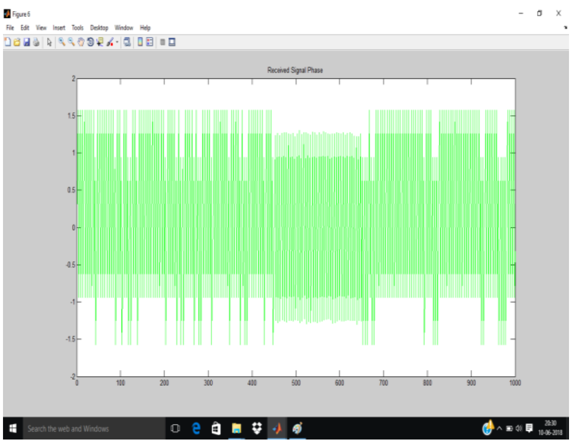

Figure 6: Received Signal Phase

4. CONCLUSIONS

Staggered PRT is able to provide good maximum range resolution.

Theoretically, the use of dual pulse train is supposed to give maximum velocity resolution using T1 and T2 pulses. In Practice environmental disturbances and radar noise limits the performance.

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