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Adaptation of Hybrid Spectrum Width Estimator to Staggered PRT for WSR-88D

Gregory Meymaris[1] and John Hubbert[2]

National Center for Atmospheric Research, Boulder, CO [1]Research Applications Laboratory [2]Earth Observing Laboratory

Introduction

An improved spectrum width estimator, the Hybrid Spectrum Width estimator (HSW), is slated to be deployed on the NEXRAD WSR-88D fleet (build 13). The NEXRAD Turbulence Detection Algorithm (NTDA), developed under the FAA's Aviation Weather Research Program, uses the NEXRAD spectrum width as the key input for providing in-cloud turbulence estimates (eddy dissipation rate, EDR). The HSW estimator will directly benefit the accuracy and/or coverage of the NTDA product.

Hitherto, the HSW has been developed for evenly spaced pulse schemes, which is used exclusively on the current NEXRAD system. However, staggered-PRT is currently slated to be deployed with build 14. Staggered-PRT, a popular scheme for mitigating the unambiguous range-velocity dilemma of weather radars, is a pulsing scheme in which the radar pulses alternate T_1, T_2 where T_1 and T_2 are pulse repetition times (PRT) where $T_1/T_2 = 2/3$. The default spectrum width estimator for staggered PRT in the literature is the pulse pair estimator R0/R2, which has poor performance for narrow widths and low SNR. To apply HSW to this pulsing scheme necessitates adaptation.

Adaptation to Staggered-PRT

The first step is to assemble a collection of spectrum width estimators. Because of their ease of calculation, we used autocorrelation-based estimators.

The autocorrelation (AC) of a staggered-PRT time-series is not evenly sampled. If Tc is $T_1/2$ (and thus T_2 is 3Tc), then the AC cannot be directly estimated at R1 or R4 (AC at time 1Tc, 4Tc, resp.). See the figure 2, at right, which shows the number of pairs going into the AC estimate for each lag.

From this a candidate list of estimators is chosen. The performance (via an I&Q simulator) of these are shown in the figure 3, at right, for T_1=880 µs and 80 pulses (taken from a preliminary SPRT VCP). From this we selected the best estimators to use for different categories (R0R2R3R5, R0/R3, and R0/R2) as well as determine the category boundaries. *All* the estimators are then put into a decision tree to help derive the logic that is used to determine the category.

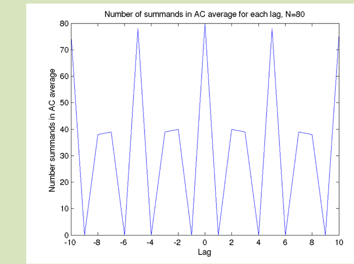

Figure 2: Number of points in AC estimation for each lag (N=80).

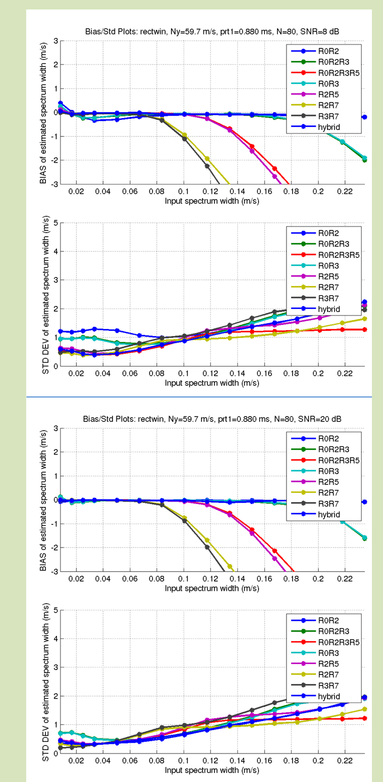

Figure 3: Bias and standard deviation of various AC-based estimators for 8 (top) and 20 (bottom) dB SNR. X-axis is W/Nyq

Results

Statistical evaluations were performed using an I&Q simulator in which the model input spectrum width is taken as truth.

The first set of plots, figure 4, show statistics, the bias and standard deviation, comparing the hybrid and R0/R2 estimators. As is seen there is a marked improvement in performance for the 5 dB SNR case for either of the two operational modes shown (N=80, T_1=880 µs; N=46, T_1=1497 µs). For the 20 dB SNR case, the estimators perform similarly.

The second set of plots, figure 5, show the 2-D histograms comparing the input spectrum width to the estimated spectrum width from R0/R2 and hybrid estimator. Only the 5 dB SNR plots are shown for the two different operational modes described above. The improvement is visible for the narrow spectrum widths.

Conclusions

The methodology used for the evenly-spaced pulsing schemes is easily adapted to the staggered-PRT pulsing strategy. A hybrid approach that combines various AC-based estimators markedly improves spectrum width performance for low SNRs and small input spectrum widths. This will allow for greater coverage of high quality spectrum widths.

Hybrid Spectrum Width

The basic idea comes from the fact that different estimators have various strengths and weaknesses. For example, R0/R1 works well for wide spectrum widths (relative to the Nyquist velocity), R1/R2 performs well for medium spectrum widths, and R1/R3 performs well for narrow.

Other estimators are used first to determine whether the spectrum width is small, medium, or large, taking into account that certain types of mistakes are worse than others. The logic for this step is determined a-priori by using simulations in conjunction with decision trees. Once the size category has been determined, the appropriate estimator is used: R1/R3, R1/R2, or R0/R1 for small, medium, and large (resp.).

See figure 1 for a KOUN case study.

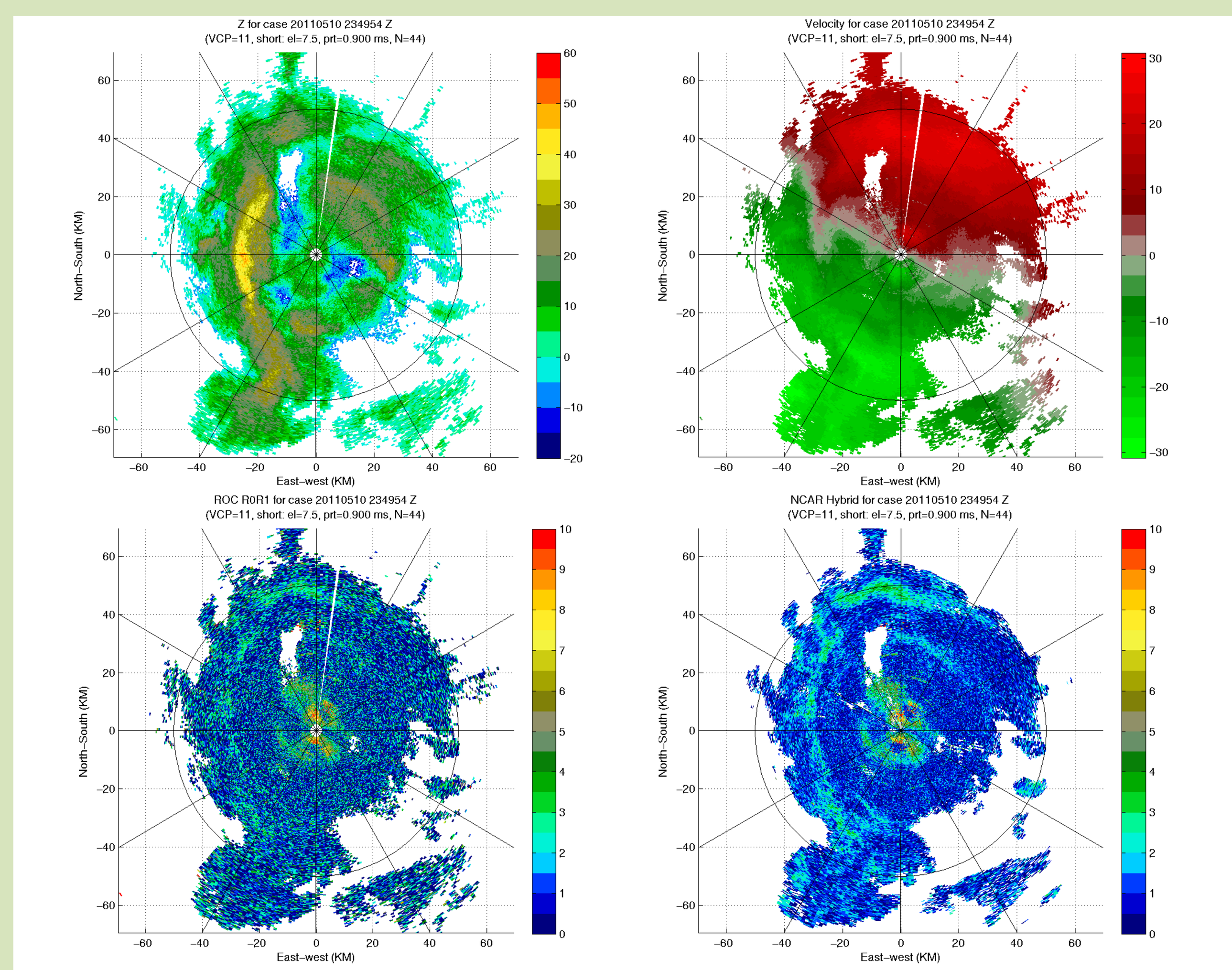

Figure 1: HSW example: KOUN 2011/05/10 23:49 Z, VCP 11, 9º

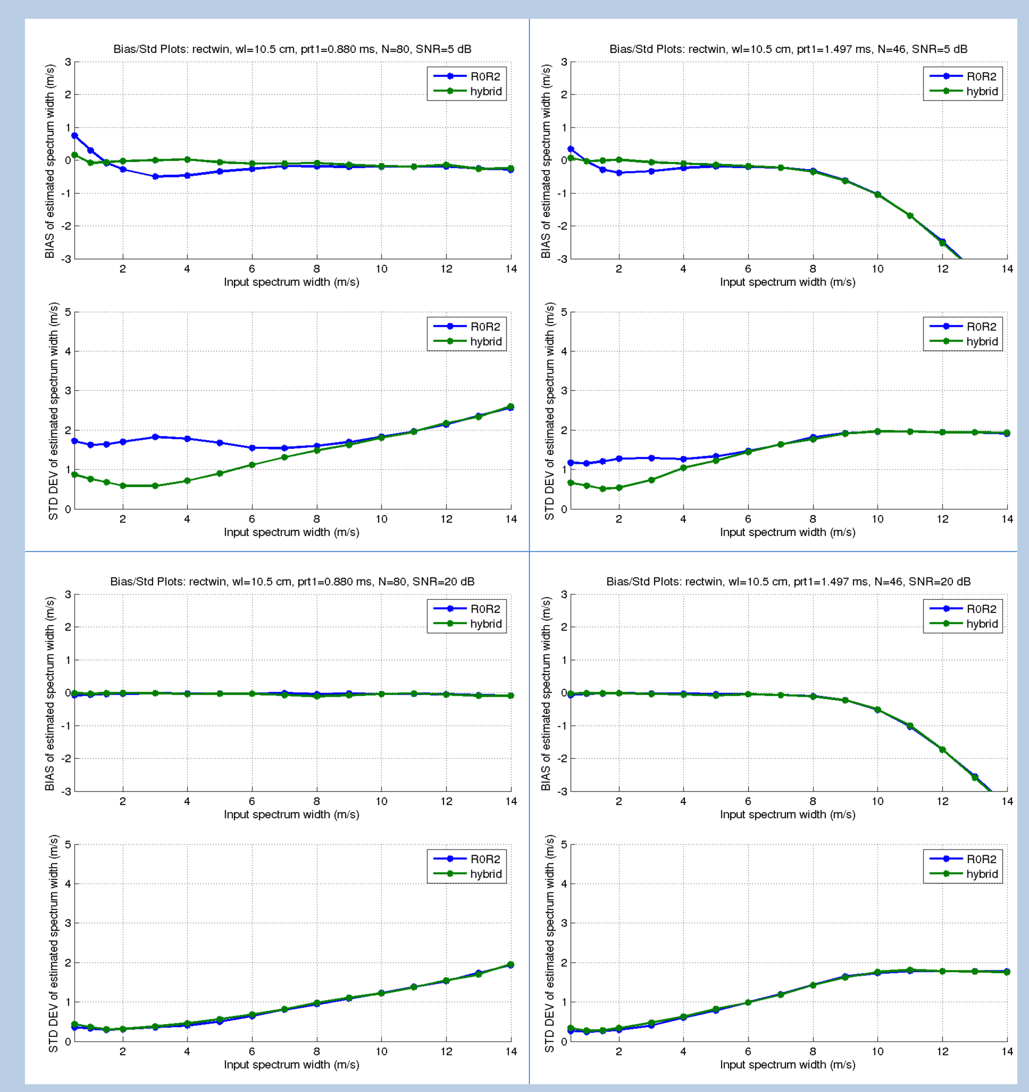

Figure 4: Bias and standard deviation of R0/R2 and HSW for 5 (top) and 20 (bottom) dB SNR, for 2 different operational modes (left/right).

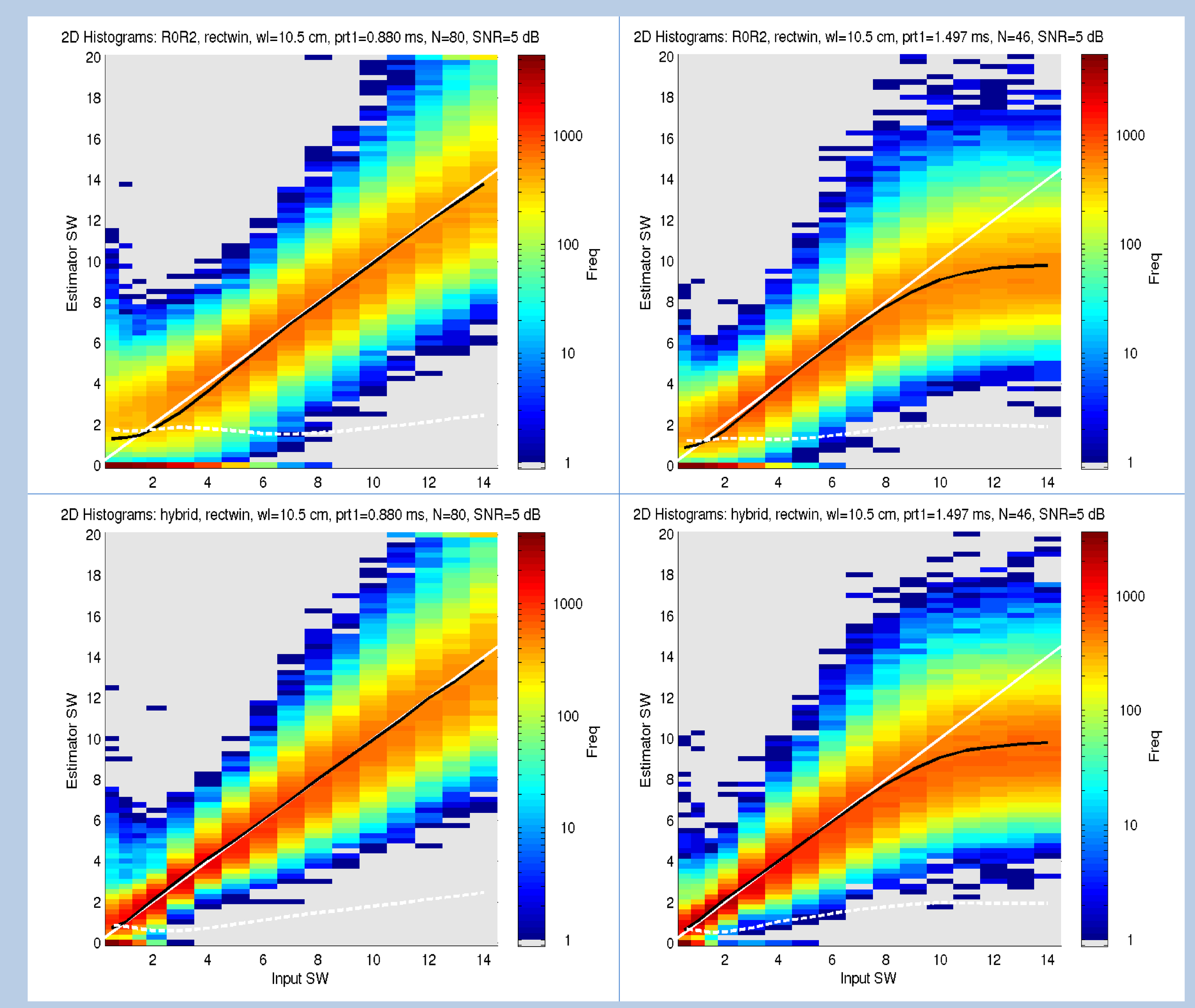

Figure 5: 2-D histograms of R0/R2 (top) and HSW (bottom) for 5 dB SNR, for 2 different operational modes (left/right).

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WSR-88D

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