A Novel Z_{DR} Estimator for Improved Measurement Accuracy from Weak Signals

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Differential reflectivity is one of the most important polarimetric variables and is used for scatterer discrimination as well as precipitation rate estimation. It is defined as the ratio of horizontal (H) and vertical (V) signal powers. In its direct form (i.e., as unitless ratio denoted as Z_{dr}) it is used primarily for precipitation rate estimation while the logarithm of the unitless ratio (denoted as Z_{DR}) is utilized by the hydrometeor classification algorithms (HCA) as well as some precipitation rate estimators. The conventional differential reflectivity estimator produces output by computing the total H and V powers (i.e., signal+noise powers), then subtracting the estimates of H and V noise powers (N_h and N_v), and finding the ratio of so obtained signal powers (to produce estimates of Z_{dr}) as well as its logarithm (to produce estimates of Z_{DR}). The logarithm of a unitless ratio is an unbiased estimate of overall differential reflectivity (i.e., the difference between H and V signal powers imposed by both hydrometeors and radar system) at all Signal-to-Noise-Ratios (SNRs) if H and V signal and noise powers are equal. But if these powers are different, the conventional Z_{DR} estimator becomes increasingly biased with SNR decrease. Another estimator which computes the ratio of H and V lag-1 autocorrelations has also been proposed and dubbed the lag-1 differential reflectivity estimator. It does not use the estimates of H and V noise powers and therefore is impervious to noise power measurement errors. However, it requires sufficient coherency in sample time to produce estimates of the same quality as the conventional estimator (given accurate knowledge of noise powers). For this reason, it is not suitable for scans with small unambiguous velocity (e.g., on the order of ~8 m s^{-1}). In addition, it also becomes increasingly biased as the SNR decreases just like the conventional estimator. To address the SNR related bias, a novel Z_{DR} estimator is proposed herein. It uses the same inputs as the conventional estimator along with the signal processing window weights. The performances of the conventional and novel estimators are analyzed and compared using simulated time series as well as those from real radars.

Keywords: Weather Radar Polarimetry, Weather Radar Signal Processing, Polarimetric Variable Estimators

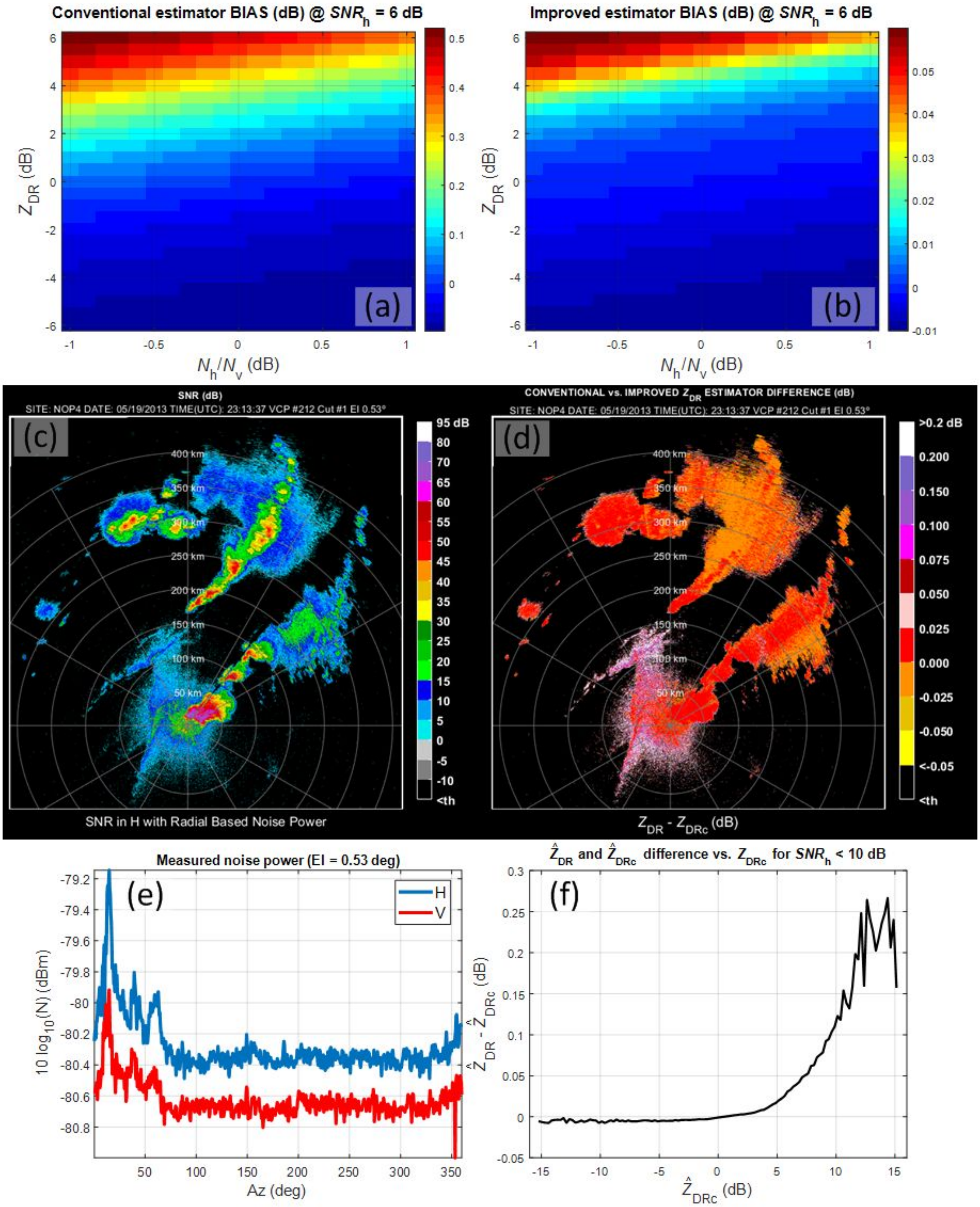

Figure 1. (a) The conventional and (b) the improved estimator biases (computed via simulations) vs. the overall Z_{DR} (i.e., the difference between H and V signal powers imposed by both hydrometeors and radar system) and N_h/N_v at SNR_h = 6 dB. (c) The SNR field. (d) The difference field between the conventional ($\hat{Z}_{DR}$) and the improved ($\hat{Z}_{DRc}$) estimators. (e) Noise power estimates. (d) The mean differences between $\hat{Z}_{DR}$ and $\hat{Z}_{DRc}$ vs. $\hat{Z}_{DRc}$ for SNR in H less than 10 dB.