P1.7

NOISE CORRECTION OF POLARIMETRIC RADAR MEASUREMENTS

M.Seminario, K. Gojara and Dr. V. Chandrasekar
Colorado State University, Fort Collins, CO

1. INTRODUCTION

Noise in weather radar systems is usually not a problem except when the echoes are weak and farther away from the radar. In the case of reflectivity measurements, weak power returns will slowly merge into the background and can be thresholded based on the power level of the signal. On the contrary, noise affects the dual polarized observations in different ways and do not appear as obvious features on displays. If there are regions when noise contamination is too high the noise power can be removed to recover the signal features. This paper presents to do the same. Noise also tends to increase the variance in the observations. One of the important problems with noise removal is the estimation of the noise level, which can vary by several dB. This paper presents a spectral procedure where explicit estimation of noise power is not needed for noise correction.

2. NOISE SOURCE AND VARIABILITY

All objects with a physical temperature greater than 0^{o} K generate noise. This noise can be external or internal to the receiver system. Noise due to an external source received by a receiver of bandwidth B and source noise temperature T_N is described by $P_N = kT_NB$, where k is Boltzman's constant. This noise will then go through receivers with gain G, which will itself amplify this noise and add its own noise in the system (N_D). This is described by $P_N = GT_NB + N_D$. Antenna noise is the major contributor to the external noise in the receiver chain. This includes the noise received by the whole antenna pattern. This may include noise from surrounding structures, such as buildings, mountains and even precipitation.

The antenna noise varies with elevation angle. At higher elevation angles, this noise tends to be smaller than at lower elevation angles. At lower elevation angles the noise temperature increases due to the warm temperature of the Earth. Antenna noise is also dependent on the precipitation being observed. When viewing clear air the noise temperature is virtually constant, but in the presence of precipitation the noise temperature increases due to warm precipitation.

The observed noise power during routine operations were estimated for the three different days as a function of elevation angle as shown in Fig. 1. It can be seen from Fig. 1 that in each case there is a slight increase in noise power at low elevations and the noise floor changes in the presence of rain. This result is well known, but the estimation in radar context is important for noise correction.

Case 1 was in the absence of any echo in the vicinity. Whereas case 2 and 3 correspond to presence of precipitation in the direction in which the beam was pointing. Case 3 corresponds to 50dBz echo at a distance of 15km. It can also be seen that the noise floor is slightly different for v and h channels. This process may also be used for calculating Z_{dr} in a similar manner.

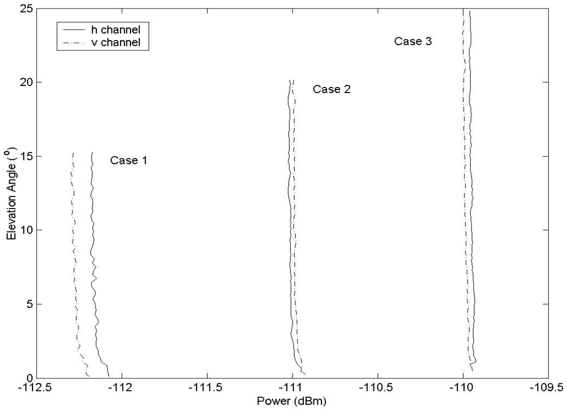

Figure 1. Variation of noise power with elevation angle for three different days during STEPS(Severe Thunderstorm Electrification and Precipitation Study) for Case 1 (06/12/00), Case 2 (06/03/00) and Case3 (06/20/00).

3. IMPACT OF NOISE ON RADAR PARAMETERS

The impact of noise on polarimetric observations can be shown to be (Bringi and Chandrasekar, 2001),

$$Z_{dr}(S+N)=\frac{\dfrac{1}{SNR}+1}{\dfrac{1}{Z_{dr}}+\dfrac{1}{SNR}}$$

and

$$LDR(S+N)=\frac{\dfrac{1}{SNR}+LDR}{\dfrac{1}{SNR}+1}$$

where Z_{dr} and LDR are the true differential reflectivity and linear depolarization ratios uncorrupted by noise, SNR is the signal to noise ratio, Z_{dr}(S+N) and LDR(S+N) correspond to observations in the presence of noise.

By plotting Z_{dr} and LDR vs SNR we can appreciate how noise influences these parameters. From Fig. 2 it can be seen that having a low SNR underestimates/overestimates the true value of Z_{dr} and LDR significantly. As the SNR increases, the measured value approaches the true parameter value. For example, it can be seen that when the SNR is 4dB, Z_{dr} will be observed as 1.9dB when its true value is 3dB. Doing the same for LDR, its observed value would be –5.5dB when its true value is –30dB. Spectral processing filters this noise so the estimated values are closer to

---

* Corresponding author: V. Chandrasekar. Colorado State University. Ft. Collins, CO, 80523

the true parameters values, which is the main topic of this paper.

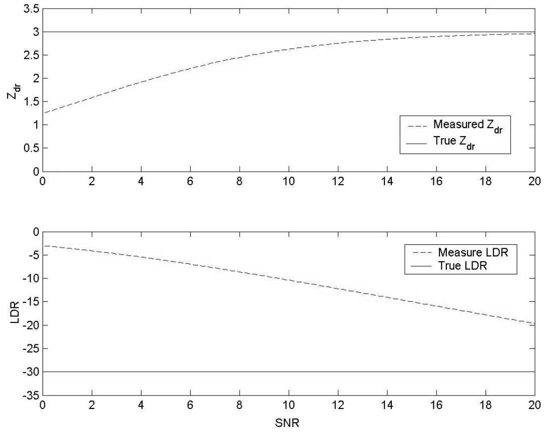

Figure 2. Impact of noise on Z_{dr} and LDR observations. Top panel Z_{dr} as a function of SNR. Bottom panel shows LDR as a function of SNR.

4. Spectral Processing

a. Simple Technique

One simple technique to eliminate noise power from return co-polar and cross-polar signal is done by estimating and removing noise power in regions of low return power for v and h channels. This constant noise estimate can then be subtracted from the received power to estimate the true return power of the returned signal. These estimates can then be used to calculate true LDR

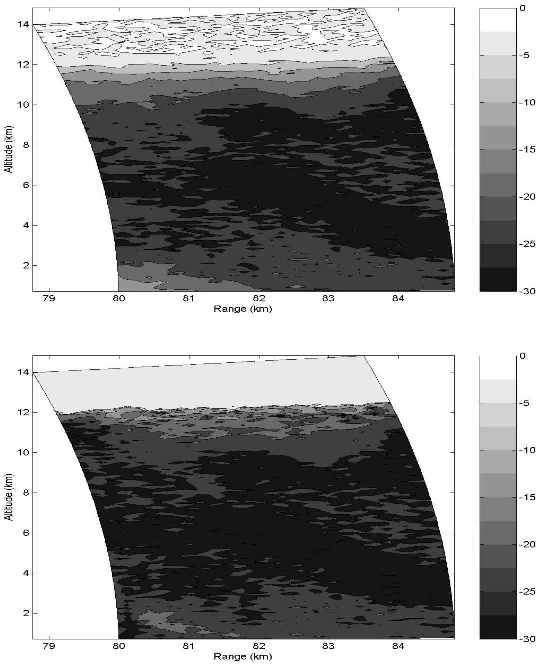

Figure 3. Top panel shows received LDR before noise removal. Bottom panel shows LDR after simple noise removal subtracted from the signal.

The result of removing a constant noise power estimate can be seen in the improvement of LDR values. It is seen that values of LDR increase after noise removal and becomes more representative of the true LDR.

b. Spectral Processing

The influence of noise in the system is greatly reduced by doing spectral processing. We have developed frequency domain techniques that can be used to eliminate noise. The details are skipped here for brievity.

Simulations were run to evaluate spectral processing. The simulation takes into consideration Z_{dr}, ρ_{hv}, SNR, mean velocity and σ_v. With this information a gaussian shaped spectrum satisfying these parameters is formed. The noise added to the spectrum is incoherent. The signals are subsequently simulated using the procedure described in (Chandrasekar et al, 1986). The advantage of using simulation is that the input parameters are known. Controlling the SNR then enables us to study the impact of noise. In the simulation result shown in Fig. 4.The SNR is 4dB and the simulation was run in alternating sample mode (VH mode). On the average, the time domain algorithm underestimates the true Z_{dr} entered into the simulation considerably. It can also be seen that with spectral processing, the average value in the system is more consistent with the true value of Z_{dr} entered in the simulation.

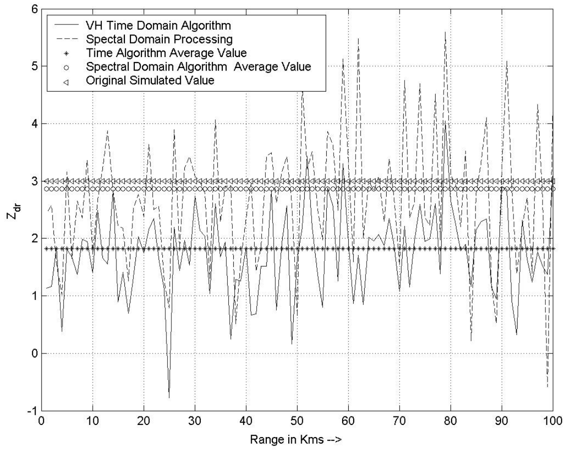

Figure 4. 4dB SNR Simulation of VH data. Spectral processing algorithm is less susceptible to noise degradation in the system.

The spectral processing algorithm was also applied to data collected from the CSU-CHILL radar during the STEPS program.

The result shown in Fig. 5 shows the advantage of spectral processing over time domain processing. In this data set, collected in simultaneous transmission / receiving mode (VHS mode), it can be seen that the time domain algorithm underestimates the value of Z_{dr}. It is also seen how the spectral algorithm removes this underestimation without having to explicitly estimate the noise level.

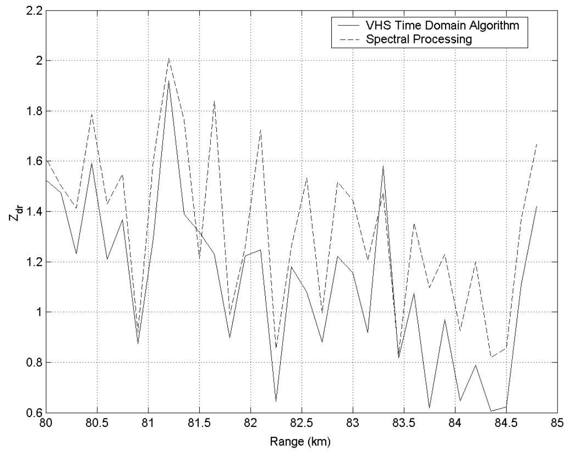

Figure 5. VHS data collected from CSU-CHILL. Time algorithm Z_{dr} underestimates value of true Z_{dr}. Spectral processing compensates for this.

Data was also collected in VH mode (show in Fig. 6 and 7). In this case it is shown how much influence noise may have in a system. The SNR is high everywhere except at 5.45Km. At this point it is seen how the noise dominates the returned signal. With spectral processing this same noise is filtered, giving a more accurate reflection on the value of the true Z_{dr} at that particular range.

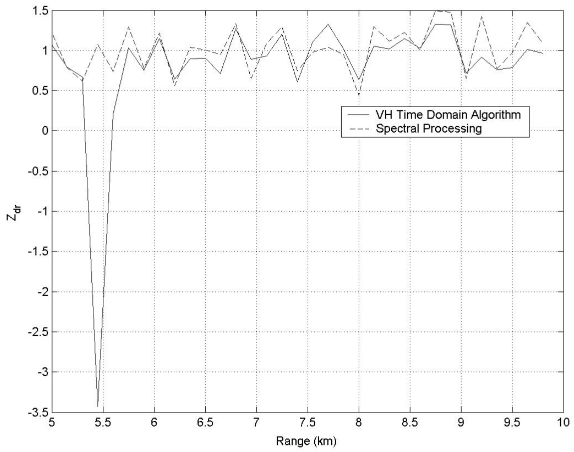

Figure 6. VH data collected from CSU-CHILL radar. Z_{dr} is highly corrupted by noise at 4.5km. Spectral algorithm filters this noise, its output being closer to the true Z_{dr}.

The following graph shows the result of using spectral processing vs time domain estimate for LDR correction.

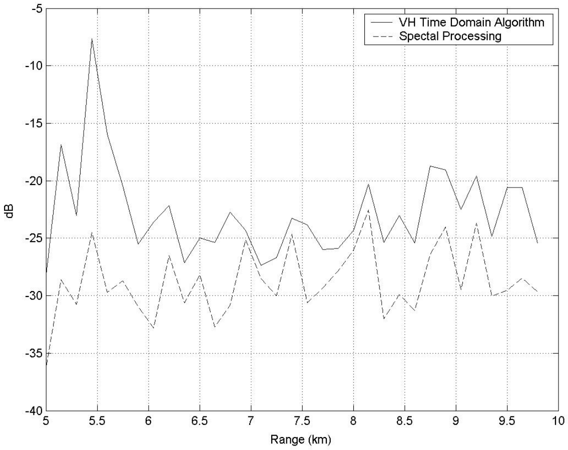

Figure 7. VH data collected from CSU-CHILL radar. Spectral algorithm maintains a lower LDR value, better reflecting the true value of LDR at those ranges, after filtering out noise.

From this data analysis, it is evident that the improvement on the estimate of LDR is significant. It is also seen how spectral processing lowers the variance of the return signal vs range, which will not happen by simple noise subtraction.

5. SUMMARY AND CONCLUSIONS

Noise can have a detrimental effect on calculating radar polarimetric parameters. One way to filter noise is through spectral analysis. It was shown through simulation and data how impact of noise can be minimized for polarimetric observations. This procedure has two advantages. Namely, 1) one need not explicitly estimate the varying noise level and 2) the variance of the polarimetric parameter estimates will be improved unlike the simple noise power removal.

7. REFERENCES

Chandrasekar, V., Brockwell, P.J., and Bringi, V.N.
Simulation of Multivariate Exponential Time Series
Proceedings of the 19th Symposium on the interface.
Computing Science and Statistics, Apr. 20,1987.

Bringi, V.N. and Chandrasekar, V (2001)
Polarimetric Doppler Weather Radar, Principles and Applications. Cambridge University Press.

8. ACKNOWLEDGEMENTS

This research is partially supported by NASA/TRMM. CSU-CHILL radar is funded by the National Science Foundation (ATM-9500108).