Enhanced detection capability for dual polarization weather radar

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1. The signal covariance matrix

$$R = \left\langle \begin{bmatrix} H \\ V \end{bmatrix} \begin{bmatrix} H & V \end{bmatrix}^{*} \right\rangle = \begin{bmatrix} R_{hh} & R_{hv} \\ R_{vh} & R_{vv} \end{bmatrix}$$

leads us

- to consider the off-diagonal element as R_{hv} an power estimator for precipitation echo;
- use the magnitude $|R_{hv}|$ for estimating reflectivity factor Z;
- reasoning: the noise is cancelled in R_{hv}

=> the H+V mode wins over the H-only mode in detecting weak echo: we see more in dual-pol

Precipitation: R^{S}_{hh}, R^{S}_{vv}, $\rho_{HV}(0) \sim 1$; **white noises:** P^{N}_{h}, P^{N}_{v}

$$R = \begin{bmatrix} R^{S}_{hh} + P^{N}_{h} & R^{S}_{hv} \\ R^{S*}_{hv} & R^{S}_{vv} + P^{N}_{v} \end{bmatrix}$$

noise present

noise cancelled

$$\left| R^{S}_{hv} \right| \overset{|\rho \approx 1|}{\cong} \sqrt{R^{S}_{hh} R^{S}_{vv}}$$

2. Echo power estimators from M samples:

$$\hat{R}_{hh,vv}(\bar{q}) = \frac{1}{M} \sum_{q_i=0}^{M-1} \left| V_{h,v}(q_i) \right|^{2}$$

$$SNR_{h,v} = \frac{\hat{R}_{hh,vv} - P^{N}_{h,v}}{P^{N}_{h,v}}$$

$$Z_{h,v} = f\left(SNR_{h,v}\right)$$

noise to be subtracted
=> *uncertainty due variability in the internal and external noises*

=> *low SNR must be censored*

$$\left| \hat{R}_{hv}(\bar{q}) \right| = \frac{1}{M} \left| \sum_{q_i=0}^{M-1} H^{*}(q_i) V(q_i) \right|$$

$$SNR'_{hv} = \frac{\left| \hat{R}_{hv} \right|}{P'^{N}_{hv}}$$

$$Z_{hv} = \sqrt{Z_h Z_v} \cong Z_h = f\left(SNR'_{hv}\right)$$

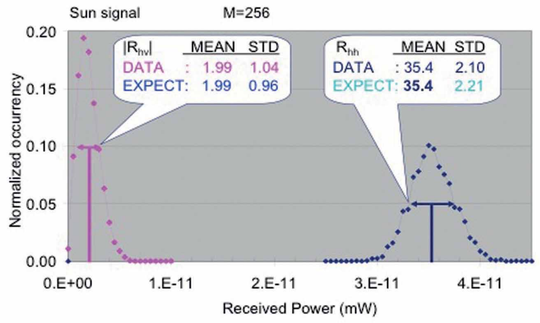
signal only

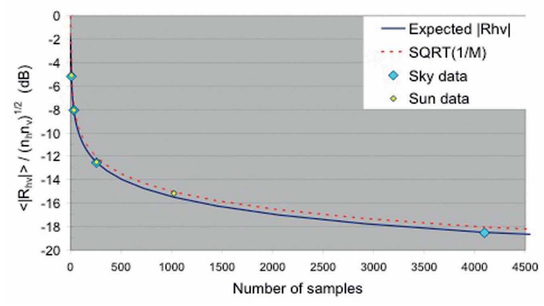
=> *reduced bias and uncertainty*

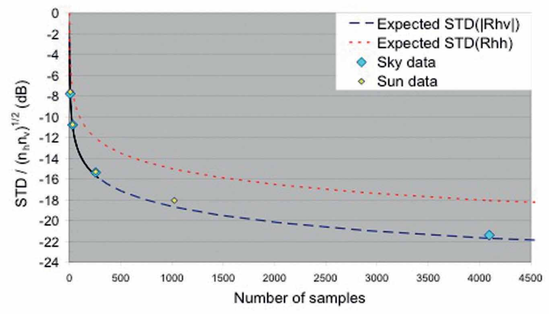
=> *enhanced detection capability, with consistent censoring policy on SNR'*

3. P'^{N}_{hv} : residual noise in $|R_{hv}|$, finite M

We calculated the expected means and variances of $P'^{N}_{hv} = f(P^{N}_{h}, P^{N}_{v}; M)$, for white Gaussian noises. We validated the expressions using numerical simulation, and against sun and cold sky data.



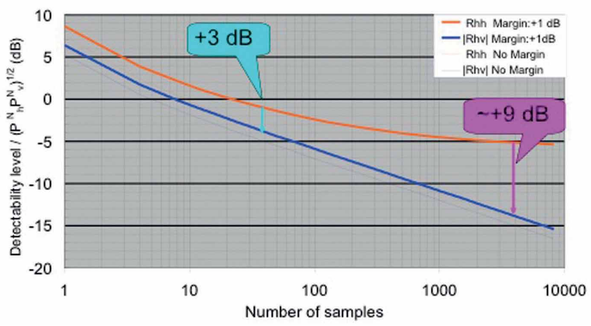


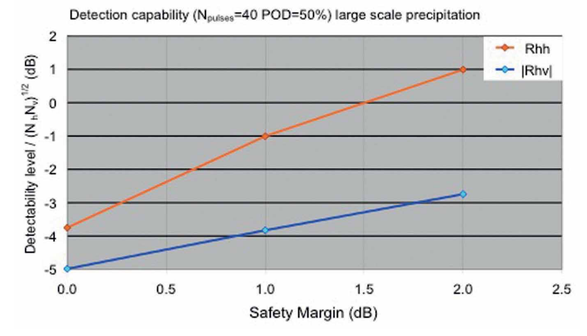


4. Enhanced detection capability

In the conventions of Skolnik (1990), we studied the expected detectability for realistic False Alarm Rates from 10^{-5} to 10^{-2}. At 50% probability of detection, for large scale echo, we compared $|R_{hv}|$ versus R_{hh} as function of M.

Realistic variability of noise floors accounted for, up to 2 dB margins, see Seminario (2001).



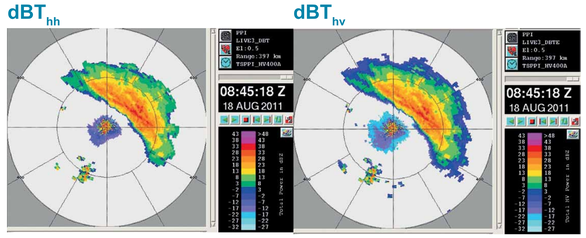


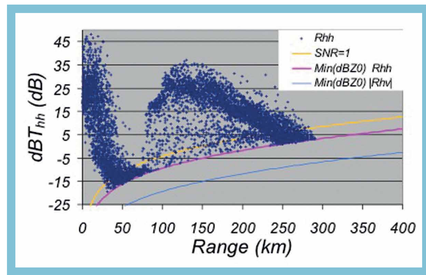
5. Findings:

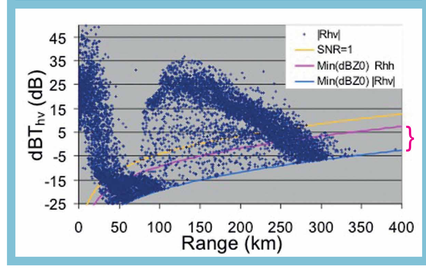
- a clear advantage of the $|R_{hv}|$ based echo estimator;
- the impact grows for safer SNR margins - atmospheric variability is up to 2 dB, Seminario (2001);
- the advantage grows very significant for large M, available as sums in range (locally stable Φ_{DP}).

6. Data validation

WRM200 C-band dual-pol radar, Kerava, Finland; M=4096, P/N threshold:1.1dB (margin:1dB)







~+10 dB

References

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Skolnik M. ed. 1990: "*Radar Handbook*" 2nd edition, McGraw.Hill; Seminario M., Gojara K. and Chandrasekar V. 2001: "*Noise Correction of Polarimetric Radar Measurements*" 30th Conference on Radar Meteorology.