Enhanced detection capability for dual polarization weather radar

Reino Keränen¹, Chandrasekar V. ²,³
¹Vaisala Oyj, Helsinki, FINLAND • ²Colorado State University, Fort Collins CO, U.S.A. • ³University of Helsinki, FINLAND

1. The signal covariance matrix

\[ R = \begin{bmatrix} H \end{bmatrix} \begin{bmatrix} Y \end{bmatrix} = R_{hh} R_{hv} R_{hv} \]

leads us to consider the off-diagonal element as \( R_{hv} \) as a power estimator for precipitation echo.

- use the magnitude \( |R_{hv}| \) for estimating reflectivity factor \( Z \);
- reasoning: the noise is cancelled in \( R_{hv} \).

2. Echo power estimators from \( M \) samples:

\[ \hat{R}_{hh}(q) = \frac{1}{M} \sum_{i=1}^{M} r_{hh}(q) \]

\[ \text{SNR}_{hh} = \frac{\hat{R}_{hh} - \hat{P}_{hh}}{\hat{P}_{hh}} \]

\[ Z_{hh} = f(\text{SNR}_{hh}) \]

3. \( P'_{N_{hv}} \): residual noise in \( R_{hv} \) finite \( M \)

We calculated the expected means and variances of \( P'_{N_{hv}} \) for \( P_{hv} \) and \( P_{hh} \) 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 \( \hat{P}_{hv} \) versus \( R_{hv} \) 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 \( \hat{P}_{hv} \) 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 \( \Phi_{DP} \)).

6. Data validation

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

References


www.vaisala.com