ONLINE DETERMINATION OF NOISE LEVEL IN WEATHER RADARS

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1. MOTIVATION

- Weather radars estimate system noise power by either offline measurements or through periodic automatic calibrations (e.g., NEXRAD network)
  - This value is used at all antenna positions along azimuth.
- Noise changes with time and antenna position.
- This creates possibility for incorrect noise power measurements which can lead to
  - Reduction of coverage when noise power is overestimated.
  - Radar product images cluttered by noise speckles if the noise power is underestimated.
  - Biased meteorological variables at low SNR.

To obtain the best quality of radar products it is desirable to estimate receiver noise at each antenna position

Consequently, noise power needs to be computed while performing weather scans (i.e., from data containing mixed signal and noise).

2. THE NOVEL NOISE ESTIMATION TECHNIQUE

Produces noise power estimate from samples classified as containing noise only.

To describe the technique, we use data collected with the National Weather Radar Testbed Phased-Array Radar (NWRT PAR) in Norman, Oklahoma

- Samples are 60 m apart in range.
- The transmitted pulse is roughly 240 m long.
- The number of samples in the dwell time is 15 (*M*).

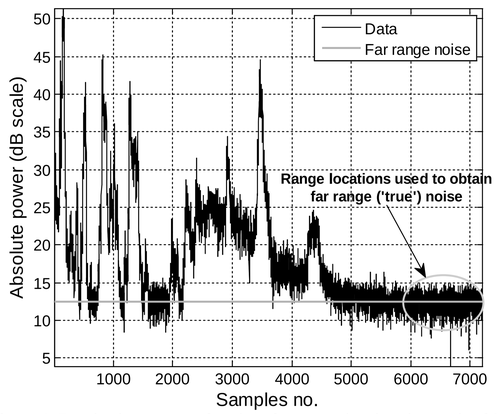


Figure 1. Received power as a function of range at the elevation angle of 0.5 deg. The number of samples for each radar volume is 15 and the range sample spacing is 60 m. The "true" noise power is indicated with a grey line. This data was collected using the NWRT PAR in Norman, OK.

3. THE NOVEL NOISE ESTIMATION ALGORITHM DESCRIPTION: STEP 1

The portions of power profile with flat power are identified as this is an indication of the potential signal-free regions.

- This is done by estimating

$$Var_{dB}(k) = \sum_{n=k}^{k+K-1}\left(\hat{P}_{dB}(n) - \frac{1}{K}\sum_{l=k}^{k+K-1}\hat{P}_{dB}(l)\right)^2$$

where

$$\hat{P}_{dB}(k) = 10\log_{10}\left(\frac{1}{M}\sum_{m=0}^{M-1}\left|V(m,k)\right|^2\right)$$

at each range location *k* along radial.

- Range location is considered potentially signal-free if the $Var_{dB}(k)$ estimate is smaller than the predetermined threshold.

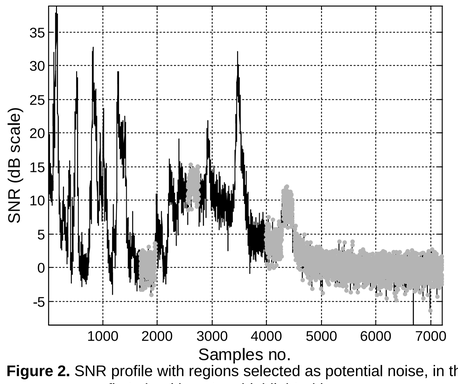


Figure 2. SNR profile with regions selected as potential noise, in the first algorithm step, highlighted in grey.

3. THE NOVEL NOISE ESTIMATION ALGORITHM DESCRIPTION: STEP 2

Because the previous step classifies flat signal regions as potentially noise only, these are discarded.

- The mean power is calculated for each set of contiguous range locations classified as noise.
- Out of these estimates the smallest one is taken to be the intermediate noise estimate (N_{int}).
- Then, we discard all samples at range locations for which power estimate is larger than the threshold THR_{int} obtained from N_{int}.

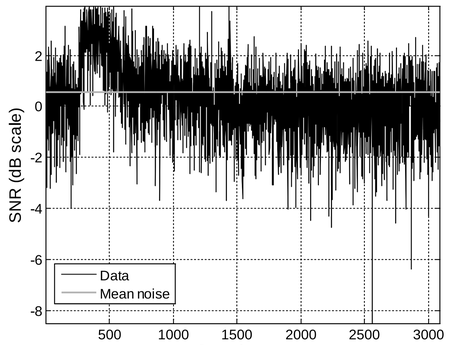


Figure 3. SNR profile of data after discarding samples at regions where power is larger than THR_{int}. The mean power is 0.552 dB above the far range noise.

4. THE NOVEL NOISE ESTIMATION ALGORITHM DESCRIPTION: STEP 3

Detects and removes larger sample powers that exhibit some continuity in range by applying a "range persistence" filter

- Finds 10 or more consecutive power values larger than the median power and discards them along with 10 samples on either side.

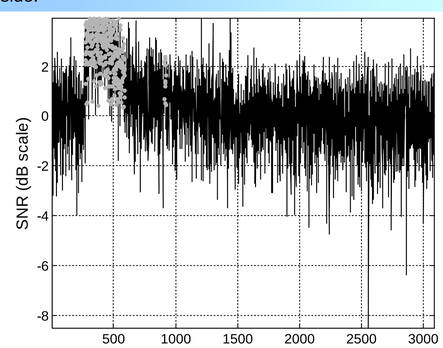


Figure 4. Highlighted range locations discarded by the range 'persistence' filter. The mean power of the resulting set is 0.23 dB higher than the "true" noise power for this case.

5. THE NOVEL NOISE ESTIMATION ALGORITHM DESCRIPTION: STEP 4

Discards remaining weak signal samples by performing range averaging.

The matrix of the remaining samples (sample-time vs. range-time) is reshaped into a single vector

- first *M* samples in the vector are from the first column of the matrix, samples *M*+1 to 2*M* belong to the second column of the matrix and so on.

Running average of *750* samples is performed.

All samples associated with the averaged points larger than the 110% of the mean are discarded

- Repeated until the number of discarded samples is larger than 0.38% of the total number of samples or up to a maximum of five times.

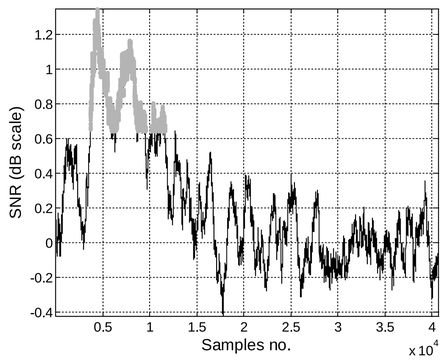
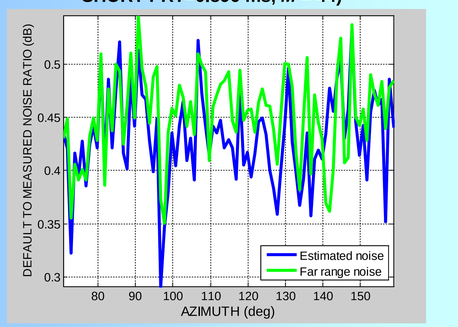
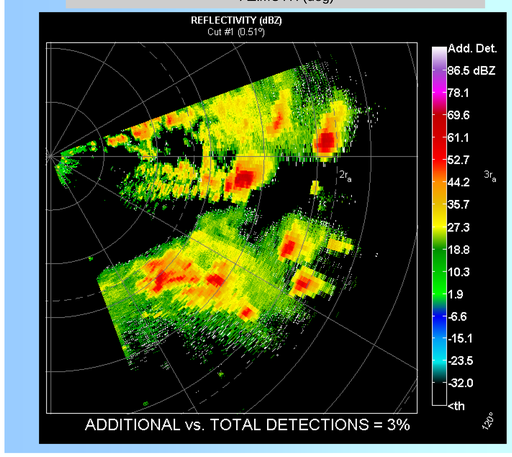


Figure 4. Power range profile after applying moving average with positions discarded in the first iteration of the algorithm highlighted in grey. After the last step, the mean power is 2.5 10^{-3} dB above the far range noise.

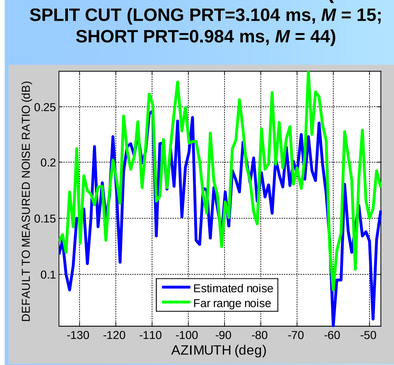
5. PERFORMANCE EXAMPLES

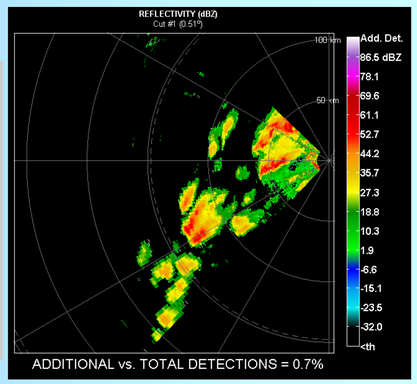
National Weather Radar Testbed (NWRT)
SPLIT CUT (LONG PRT=3.104 ms, *M* = 15; SHORT PRT=0.896 ms, *M* = 44)



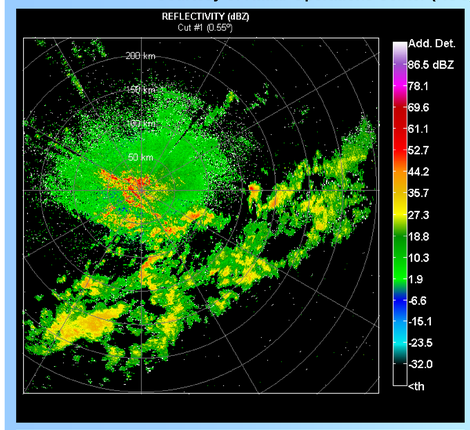


National Weather Radar Testbed (NWRT)
SPLIT CUT (LONG PRT=3.104 ms, *M* = 15; SHORT PRT=0.984 ms, *M* = 44)

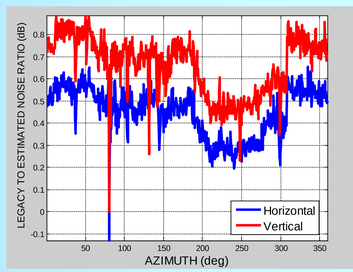


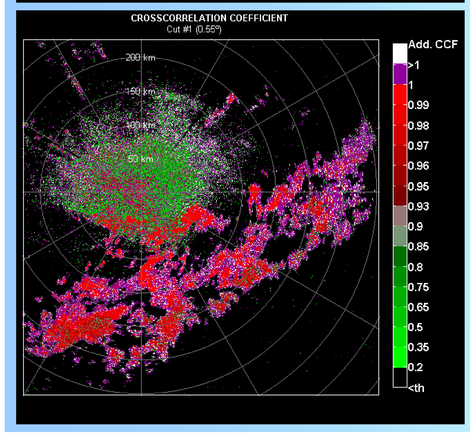


WSR-88D KOUN (Open Radar Data Acquisition ORDA)
PRT=3.1 ms, *M* = 28
Courtesy of Radar Operations Center (ROC)



REFLECTIVITY	*Total detections*
Legacy noise	419493
Estimated noise	435397
Difference	15904 (3.8%)





CROSS CORRELATION COEFFICIENT	Legacy noise	Estimated noise
Total detections	411313	430335
Greater than one	145921 (35.5%)	130328 (30.3%)

6. SUMMARY

The presented technique produces noise power estimates at every antenna position in parallel with weather data collection

- A data set with noise-only samples is created using classifications based on the shape of the power profile, SNR, and range continuity.
- The noise power is calculated from samples classified as signal free.

The algorithm was verified by comparing its results to noise powers obtained from the data at the far range positions devoid of visible signals

- The algorithm produces noise powers with an improved accuracy compared to offline measurements or periodical calibrations.
- Produces an improvement in radar sensitivity.
- Improves estimates of meteorological variables at low SNR.

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