Defining and Validating the Minimum Detectable Weather Signal for an X-band Weather Radar System

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Abstract

Minimum detectable weather signal (MDWS) describes how weak target can be detected by the radar at a certain range. In this study, the MDWS of a Vaisala WRS400 polarimetric X-band weather radar is examined. MDWS is first estimated using the conventional weather radar equation and the theoretical value of the signal to noise (SNR) required from the literature. After this, the actual performance of the installed WRS400 system is verified by analysis of actual weather data.

Theoretical Background

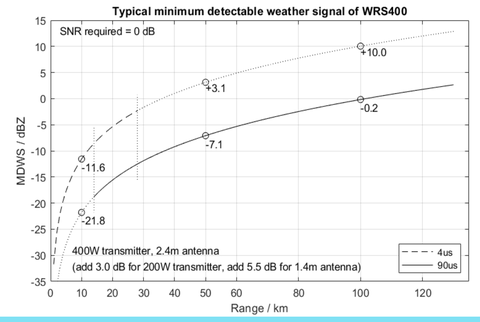
In the literature, there are theoretically computed values available for SNR required for different kind of fluctuations, false alarm rate (FAR), probability of detection (POD) and number of samples averaged. For example, if assuming weather target to fluctuate according to Swerling case 1, averaging 40 pulses and allowing FAR = 10-4 and POD = 50%, the resulting SNR required for detection according to Skolnik (1990) is 0 dB. When the SNR required for detection is known, so Z_{min} for a target with range r can be solved from the conventional weather radar equation as:

$$Z_{min} = \frac{1024 \ln(2)}{c\pi^3 |K|^2} \left(\frac{S}{n}\right)_{min} \frac{\lambda^2 r^2 n' b}{p_t \tau g_f g_e^2 \theta^2} a\, r \qquad (1)$$

WRS400 Weather Radar

Vaisala WRS400 is a polarimetric X-band weather radar with an antenna mounted transceiver, using solid state transmitter and Vaisala RVP signal processor technology.

In this study, the performance of the 90µs (using non-linear frequency modulation (NLFM) for pulse compression to 1.0µs) + 4µs hybrid pulsing is calculated. By substituting values (values are listed in Table 1 in the extended paper) to equation (1), produces values for MDWS which are shown in below figure. For example for the 90µs pulse, the MDWS at 100km range is typically -0.2dBZ.

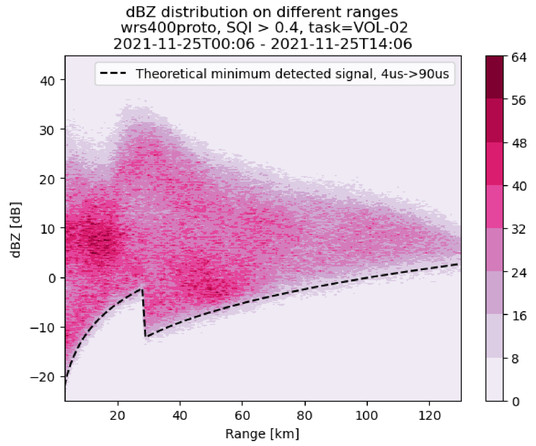


Actual Radar Measurements and Results

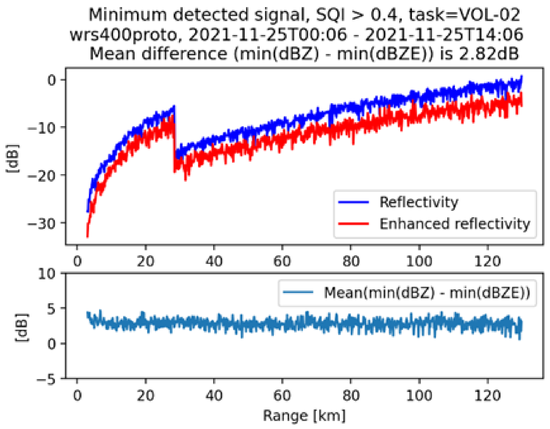
A PPI scan at 1° elevation from 50 scans over time span of 14 hours was used. Scan was configured to use 90µs + 4µs hybrid pulsing with 32 samples averaged.

A WRS400 system located in southern Finland, with 2.4m antenna and 400W transmitters was used to verify the actual MDWS with real weather data.

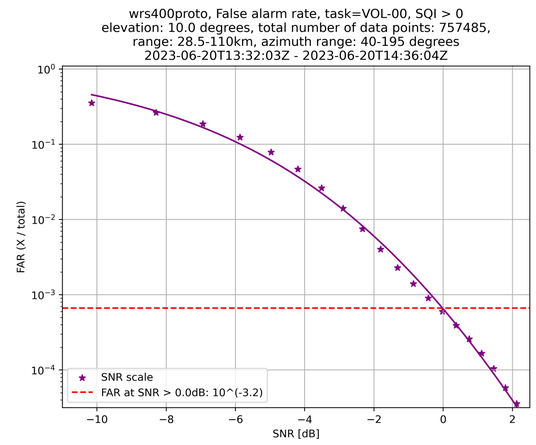
The measured reflectivity distribution clearly goes below the typical MDWS of the WRS400, plotted with a dashed line in the below figure. Note that these measurements were done with 32 averaged pulses, while the typical MDWS curve assumes 40 samples.



The average difference between minimum measured values of horizontal reflectivity and enhanced reflectivity from the same data set was 2.8dB, which is well in line with the theoretical values with 32 pulses are used.



Measured FAR as a function of applied SNR threshold when only noise is present (transmitter off) are presented in below figure.



Conclusion

This study verifies that an installed WRS400 X-band weather radar system achieves well the theoretically estimated minimum detectable weather signal, being typically -0.2dBZ at 100km range when SNR of 0 dB is assumed. The observed FAR of noise was slightly more than what was expected in the literature, but relatively well in line considering the number of pulses averaged in the measurements. The improvement of the MDWS using the enhanced reflectivity algorithm was verified to be 2.8 dB for 32 averaged pulses, which is in line of the expected value of approximately 3 dB with 40 averaged pulses.

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