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DATA QUALITY ASSESSMENT OF VAISALA'S NEW RADAR SIGNAL PROCESSOR RVP10

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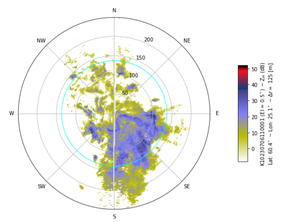


Keywords

"RVP10", "Radar signal Processor", "Quality Assessment/Control"

The Radar Signal Processor RVP10

- State-of-the-art components.
- Up-to-date methods and security.
- Easy maintenance and updates.
- Improved support for solid-state transmitters:
  - Pulse compression
  - Hybrid pulsing
  - Blending
  - Calibration
- Dual-pulsewidth and dual-frequency.
- Independent and parallel FIR filtering.

Hardware Properties

- RVP10 consists of IF Digital Receiver IFDR10 and Signal Processor Server RVP10SRV.
- IFDR10 is an FPGA-based product that answers low-latency signal needs.
  - Computes IQ data from 4 receiving and 2 burst channels of IF inputs.
  - 448 billion multiply/accumulate cycles per second FPGA performance.
  - IQ data transmission over 10 Gigabit Ethernet to the RVP10SRV.
- RVP10SRV
  - Uses dual multicore Xeon processor.
  - Runs RDA software, computes moments from IQ data.
  - Distribution of moments to IRIS or third-party software.
  - 16 bit resolution A/D and D/A conversion.
  - Sampling rate: 180MHz to 240MHz (software selectable).
  - 106 dB dynamic range without compression.
  - IF range: 10 to 120 MHz.
  - Pulse repetition frequency (PRF): 50 Hz to 20 kHz.
  - Input saturation level at 50Ω: +12.0 dBm.

Capabilities

- Signal phase coding, reversing, pulse grouping operation modes.
- CW, Linear FM (LFM), and Non-Linear FM (NLFM) transmission.
- Sampling of the transmit signal at the antenna.
- Max pulse width: 200 microseconds.
- 15 to 600 m range bin sizes.
- Up to 1024 km full unambiguous range.
- Various dual-polarization modes: alternating, simultaneous (STAR), H-only, and V-only.
- Dual PRF velocity de-aliasing ratios can be 2:3, 3:4, or 4:5 for 2X, 3X, or 4X velocity unfolding.

Abstract

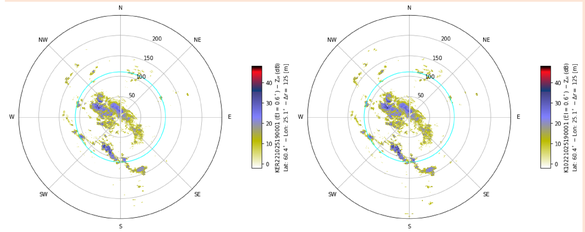
Vaisala recently has introduced the new Radar Signal Processor RVP10. The RVP10 is the latest in a line of Vaisala / SIGMET Radar Signal Processors that have introduced ground-breaking innovations to the Weather Radar sector. The RVP10 can operate both Magnetron-based Weather Radars and Weather Radars powered by Solid State Power Amplifiers (SSPA) relying on pulse compression.

First radar systems incorporating the RVP 10 have been delivered. This poster presents the methods of and results from data quality assessments performed with the RVP10. These include a period of side-by-side operation with an RVP9 in split-signal setup, as well as stand-alone operation of the RVP10 in Vaisala's WRM200 Research Weather Radar.

Data Quality

Intercomparison with Predecessor RVP9

RVP9 and RVP10 Signal Processors operated in parallel over a 4-month period, supplied with the same signal. Data from a passing rain band on 25/10/2022 was recorded and applied to both processors. Note that SNR cut-off for the processors is slightly different, leading RVP10 to display observations at ranges further from the radar more distinctly than RVP9.



Z_h on 25/10/2022 19:00 from Vaisala WRM200 Radar near Helsinki. Left displays RVP9, right RVP10. Both signal processing systems connected to same 3dB-split signal feed.

Evaluation of the **quality of observables** from RVP9 and RVP10:

1. Identify the Melting Layer Height (MLH) and its range.
2. Select data from closer ranges than MHL.
3. Mask data of Z_h for 10 dBZ ≤ Z_h ≤ 20 dBZ.
4. Mask data of Z_{DR} for e.g. $|Z_{DR}| \leq 0.5$.
5. Generate histograms of statistics for observables and fit theoretical functions.

Fit functions of **correlation coefficient** ρ_{HV} take the form:

$$f(x) = \frac{a}{\sqrt{2\pi} \cdot \sigma \cdot x} \cdot e^{\frac{(\log(x)-\mu)^2}{2\sigma^2}}$$

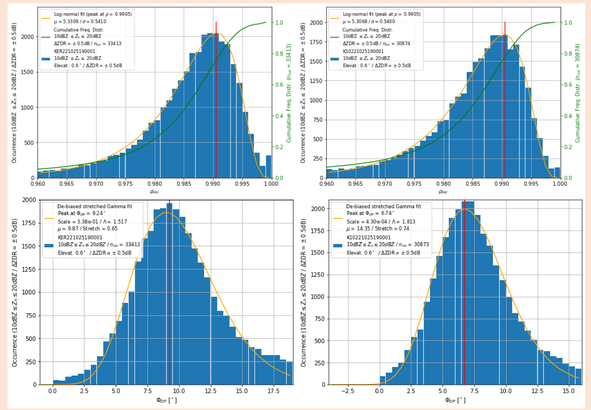
with $x = 1 - \rho_{HV}$.

Fit functions of **differential phase** Φ_{DP} take the form:

$$f(x) = a \cdot (s \cdot x)^{\mu} \cdot e^{\lambda}$$

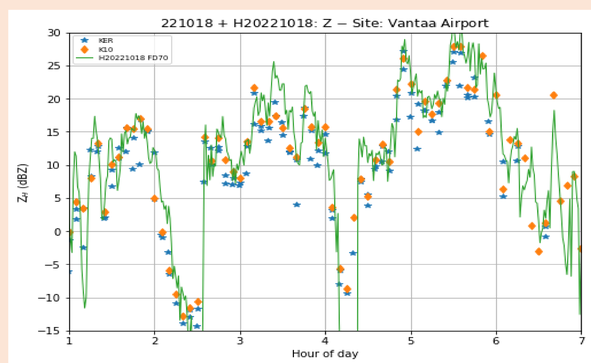
with $x = \Phi_{DP} - {}^{max}\Phi_{DP} + 10°$, where ${}^{max}\Phi_{DP}$ denotes the distribution's maximum. a is an amplitude factor, s a stretch factor, μ and λ are shape parameters.

Observations with RVP10 are on par with the well-established RVP9. The difference in the distribution peaks of Φ_{DP} is attributed to slightly different signal paths to each system. The narrower Φ_{DP} distribution, as indicated by the Gamma fit, hints at **superior observations from RVP10**.



Statistics of observations on 25/10/2022 19:00 with Vaisala WRM200 Radar. Left is RVP9, right is RVP10. Top shows ρ_{HV}, bottom Φ_{DP}. Green shows cumulative size distribution. Yellow shows fitted functions.

Radar reflectivity Z_h was **compared to ground observations** from Vaisala's Forward Scatter Sensor FD70.

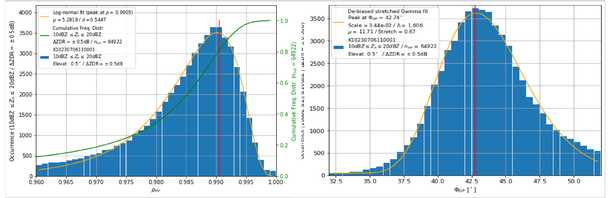


Z_h observations on 18/10/2022, with Vaisala WRM200 Radar at Kerava. KER denotes RVP9, K10 denotes RVP10. Green shows observations from Vaisala FD70 at Helsinki-Vantaa Airport.

Data Quality

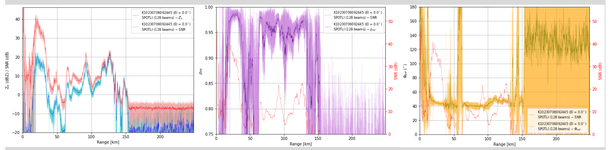
Stand-alone Assessment

Liquid precipitation moved over the Helsinki area, 06/07/2023. Observables ρ_{HV} and Φ_{DP} summarize observations for range cells below MLH, calculated by the same equations. 75% of values are found at $\rho_{HV} > 0.975$.



Statistics of ρ_{HV} (left) and Φ_{DP} (right) from observations on 06/07/2023 11:00. Green (left) indicates cumulative size distribution. Yellow lines show log-normal function fitted to reverse size distribution (left) and stretched Gamma function fitted to shifted distribution (right).

Statistics were generated from **fixed elevation/azimuth radar scans** operated by RVP10. The age of the radar's magnetron and observed weather contribute to the variability in observations.



Statistics of spotlight scans of Z_h and SNR (left), ρ_{HV} (centre) and Φ_{DP} (right) from observations on 06/07/2023 09:24 with Vaisala WRM200 Radar. Error bars indicate variability over 256 beams. Red lines in centre and right panel show average SNR.

Conclusions

- Significant upgrade, improved capabilities from predecessor RVP9.
- RVP10 and co-located RVP9 showed comparable returns for observables with a slight advantage for RVP10.
- Data quality assessment of the Vaisala WRM200 Radar operated exclusively by an RVP10 has shown great results.

Acknowledgment

Py-ART, the Python ARM Radar Toolkit (JJ Helmus and SM Collis, JORS 2016, doi: 10.5334/jors.119), has been used to create the intercomparison plots.

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