PALINDROME
REMOTE SENSING

Using target simulators for transmitted differential phase and absolute calibration measurements

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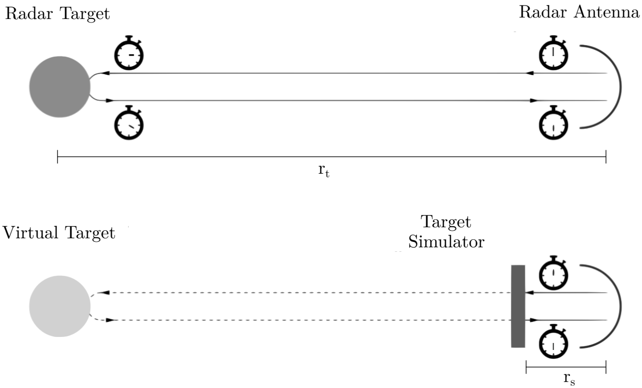
4th weather radar calibration workshop WXRCALMON 2023
Exeter, UK, November 9, 2023

Target Generation



- Polarimetric reception and re-transmission of incoming radar pulses
- Full control on time delay, phase and amplitude.

Experiments

CHILL (CSU)

9.41 GHz magnetron

Gregorian offset antenna: 0.3° beam width; 9 km far field; 53 dB Gain

Inflatable pressurized radome

SPLASH (CSU)

Radar design similar to CHILL

Conventional dual-pol antenna: 1.3° beam width

10 kW transmit power per channel.

PX-1000 (ARRC)

9.65 GHz solid state

Two individual 200 W transmitters.

Frequency agile; full polarimetric control on transmission.

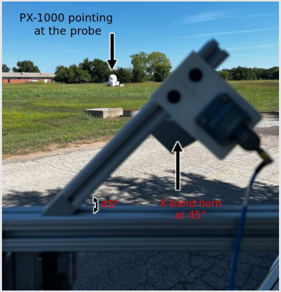
Additional measurements

Sphere

Comparison with CHILL and SPLASH

Results yet to come

Power meter



45° tilted horn antenna

Determination of differential phase on transmission for PX-1000

Drone

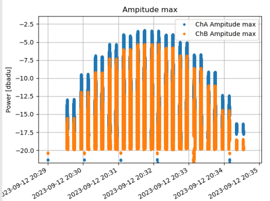
Power sensor and horn antenna on drone

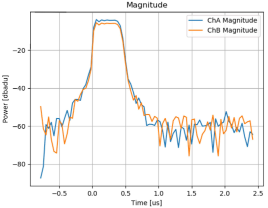
Similar principle as the tilted power sensor

Multi-path mitigation

SPLASH: Setup and measurements

Scan amplitudes



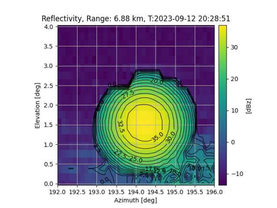


Setup

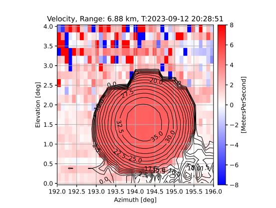
- Distance to RTS: 430 m
- Elevation to RTS: 1.5°
- 14 elevations; 0.2° spacing
- 10 degree azimuthal range

SPLASH: Calibration Targets

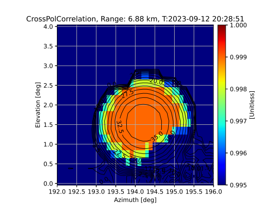
Z_h; Target: 39 dBZ



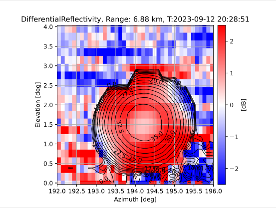
v_h; Target: 5m/s



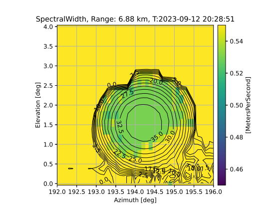
Correlation



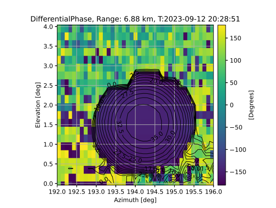
Z_{dr}; Target: 0 dB



Spectral Width

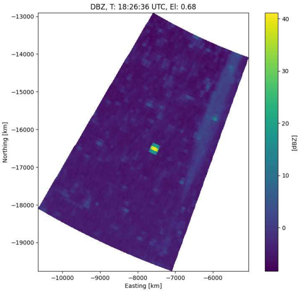


Diff. Phase

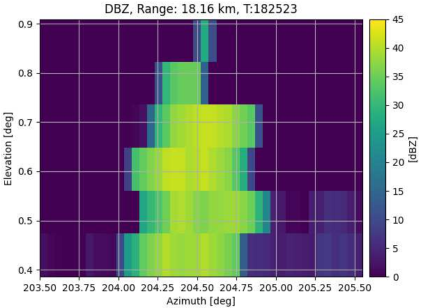


CHILL: Setup and measurements

PPI animation



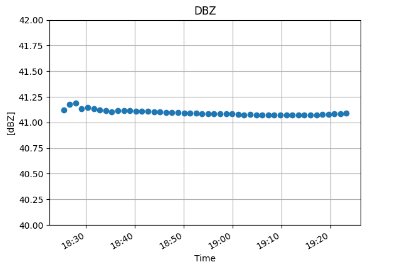
Vertical cut



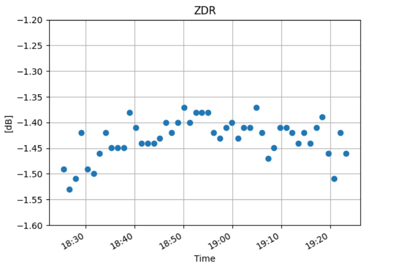
- 6 PPIs with 0.1° spacing (PPI no. 4 used for upcoming analysis)
- 10° azimuthal span
- 0.05° azimuth resolution
- 0.15° gear backlash in scan direction

CHILL: Calibration target time series

Z_h; Target: 40.9 dBZ



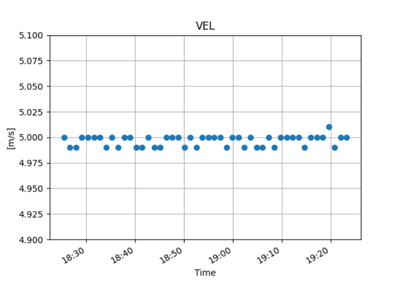
Z_{dr}; Target: 0 dB



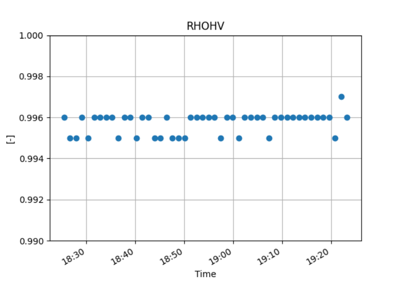
- Target size = 40.9 dB if HPBW = 0.3°
- HPBW = 0.3° from antenna simulations
- RTS distance: 470 m. Antenna far field: 9 km. → Influence on measurements?

CHILL: Calibration target time series (2)

Doppler; Target: 5 m/s

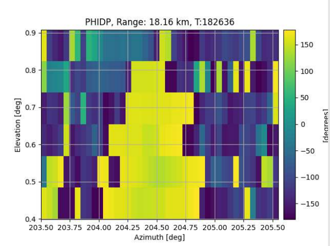


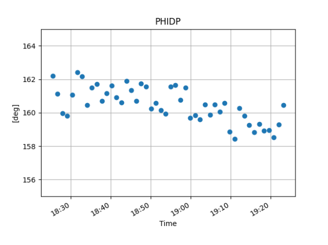
Correlation



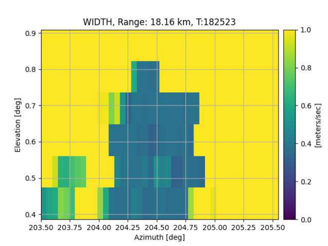
CHILL: Calibration target time series (2)

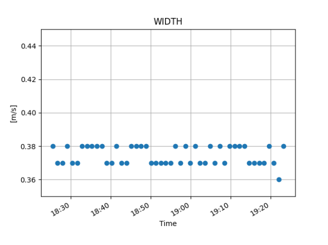
Phidp





Spectral width



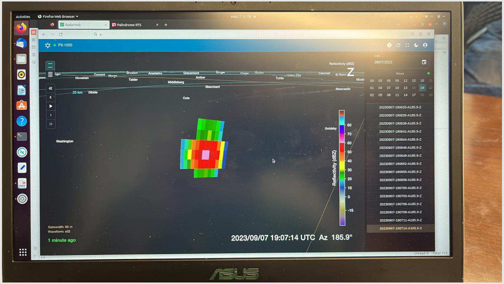


PX1000: Setup and measurements

RTS

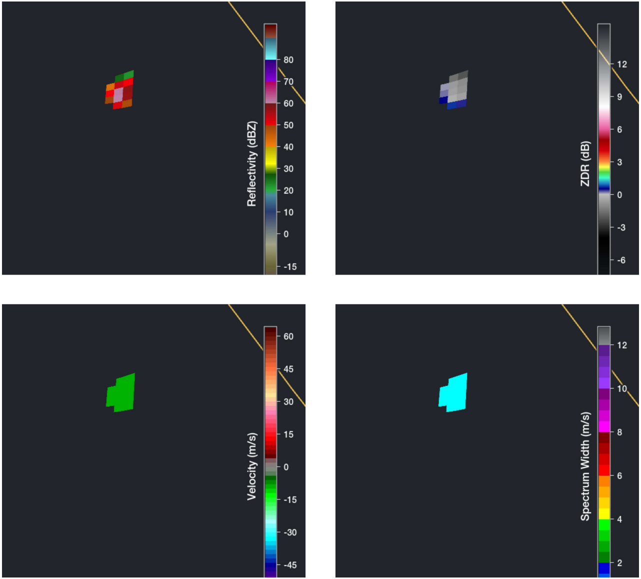
- Distance to radar: 200 m
- RHI scans around RTS.
- Fixed pointing for phase measurements

Real time results

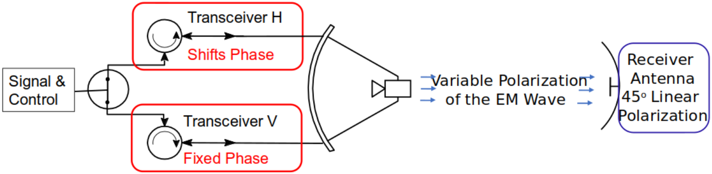


- 60 dBZ target.
- -10 m/s Doppler velocity.
- 0 dB Z_{dr}.

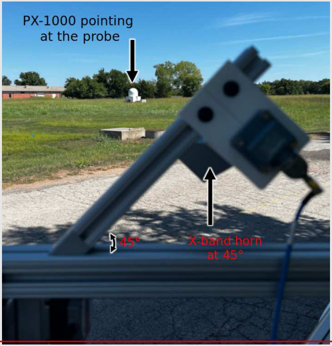
PX1000: Calibration measurements



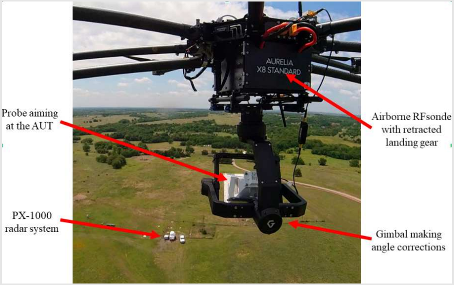
PX1000: Transmit phase setup



Power meter

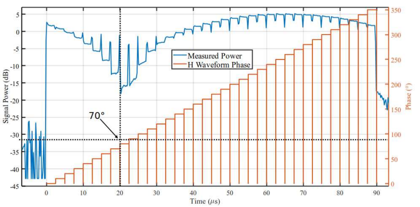


Drone



PX1000: Transmit phase results

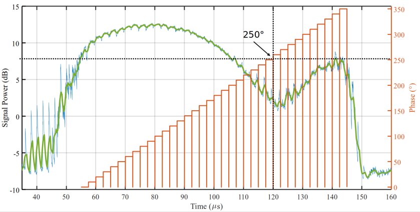
Power meter



The measured phase difference:
$\arg(HV^*) \approx 180^\circ - 70^\circ = 110^\circ$

Standard definition of differential phase: $\Delta\phi = \arg(H^*V) = -110^\circ$.

Drone



The measured phase difference:
$\arg(HV^*) \approx 180^\circ - 250^\circ = -70^\circ$

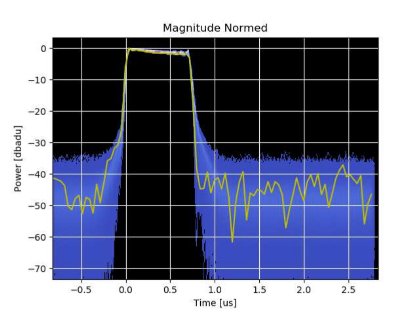
$-70^\circ + 180 = 110^\circ$

Standard definition of differential phase: $\Delta\phi = \arg(H^*V) = -110^\circ$.

Zrnic, D., Schvartzman, D., Melnikov, V., Cheong, B., Segales, A.: "Differential Phase on Transmission", presented at the 2023 AMS Conference on Radar Meteorology.

Transmit phase with RTS

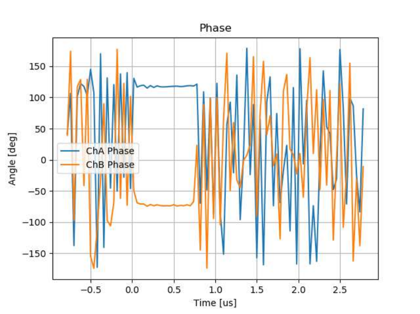
Pulse shape



Polarimetric pulse sampling with 25 MHz

$\approx$ 100000 pulses over 120 s

Uncorrected phase difference



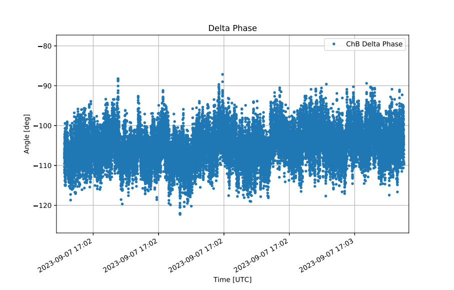
3 samples at pulse center

$$\Delta\phi = \arg\left(\sum_{k=\frac{N}{2}-1}^{\frac{N}{2}+1} \mathbf{S}_h^*[k]\,\mathbf{S}_v[k]\right)$$

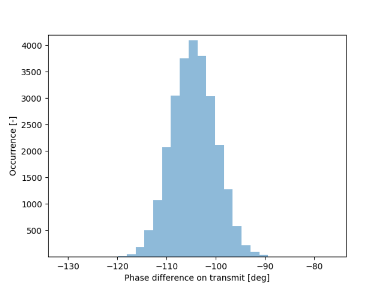
Offset corrected phase difference

- Correction procedure: Coupling of a differential signal with known and stable phase difference into both receivers at regular intervals.
- Usage of high performance phase stable antenna cables.
- Automatized antenna alignment.

Time series



Histogram: $-104.47° \pm 4.43°$



Conclusions and Outlook

Conclusions

- Target simulator measurements with three different X-band radars.
- Reasonable absolute calibration agreement ($\rightarrow$ data analysis still ongoing).
- High stability measurements with CSU CHILL radar.
- Transmit differential phase in good agreement with alternative method.

Outlook

- Comparison with sphere calibration data.
- Experimental determination of CHILL half power beam width.
- Investigate Z_{dr} offset.
- Measurements at C- and S-band.

Thank you!

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