Assessing the antenna characteristics and pointing accuracy of a polarimetric weather radar

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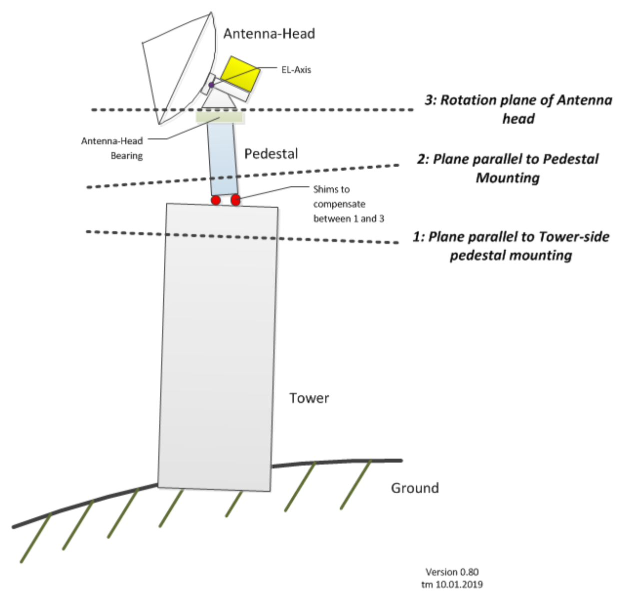
Motivation & Goals

Practical methods are needed to continuously monitor and guarantee the required radar specs throughout the lifetime of a dualpol weather radar (20+ years), which includes:

- antenna pattern characteristics (here we consider the differential power pattern).
- antenna pointing accuracy as a function of azimuth and elevation.

Target pointing accuracy: 0.1° in azimuth and elevation for **each** azimuth and elevation angle, in H **and** V

Whether we can achieve this target accuracy is one question we want to address here.



The radar system

The data was gathered using the
C-Band research radar Hohenpeißenberg:
EEC DWSR5001C/SDP

identical to the 17 radars of the
German weather radar network.

Solar box scans

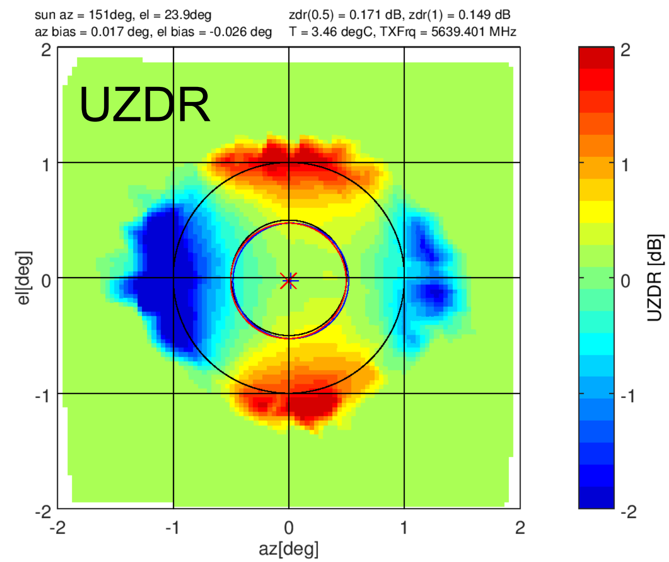
- using sun as well defined source: end-to-end assessment (RX-only) of ZDR

Scan procedure:

1. compute position of sun -> scan template is adjusted.
2. noise sample @ 0.8 µs
3. box scan @ 0.8 µs (duration ~ 4:30 min)
4. noise sample @ 0.4 µs
5. box scan @ 0.4 µs (duration ~ 4:30 min)
6. repeated every 10 Minutes, use scheduler

box scan parameterization:

az speed 2°/s
el step: 0.1°
az and el range about 8/5°
time sampling 128 pulses
125 RR , 250 m range sampling
PRF 800 (1600) Hz, 0.8 (0.4) µs
constant duty cycle
TX stays on!



Solar box analysis products

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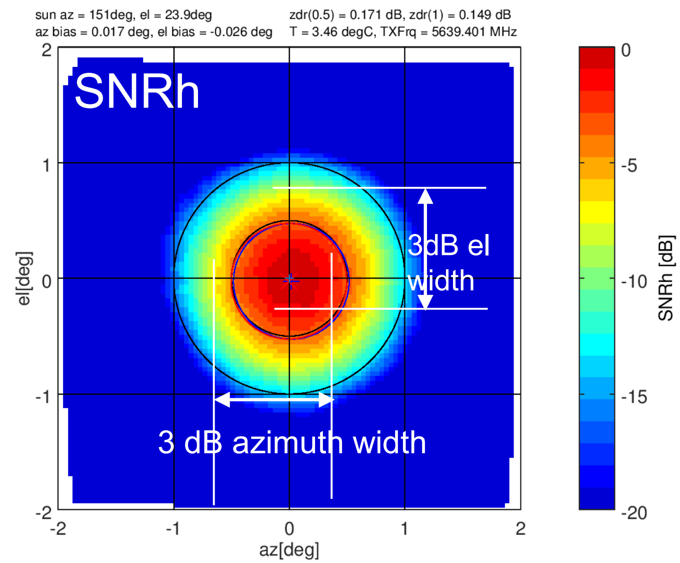
- ZDR is integrated over a radius of +/- 0.5° from center of sun relative to H
- investigate ZDR variability as a function of az/el
- beam width estimate
- RX calibration bias: DRAO power – solar power from radar
- antenna gain
- pointing error as a function of az/el
- beam squint based on pointing error H/V



The measurements employed here:

since 13.04.2018: 3 lightning rods removed, in total 1366 box scans are used in this work.

Method & data collection

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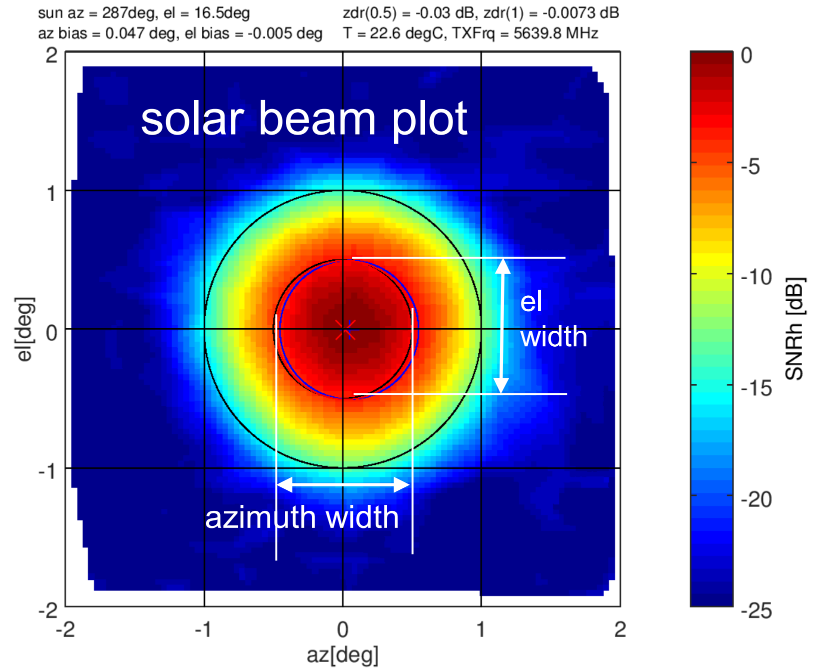
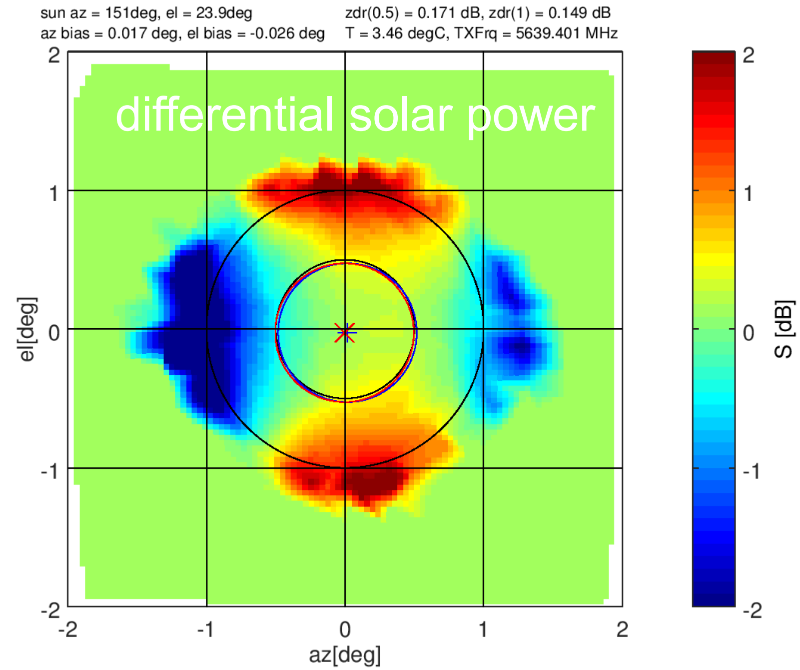
we extend the methods established by Huuskonen & Holleman (2007).

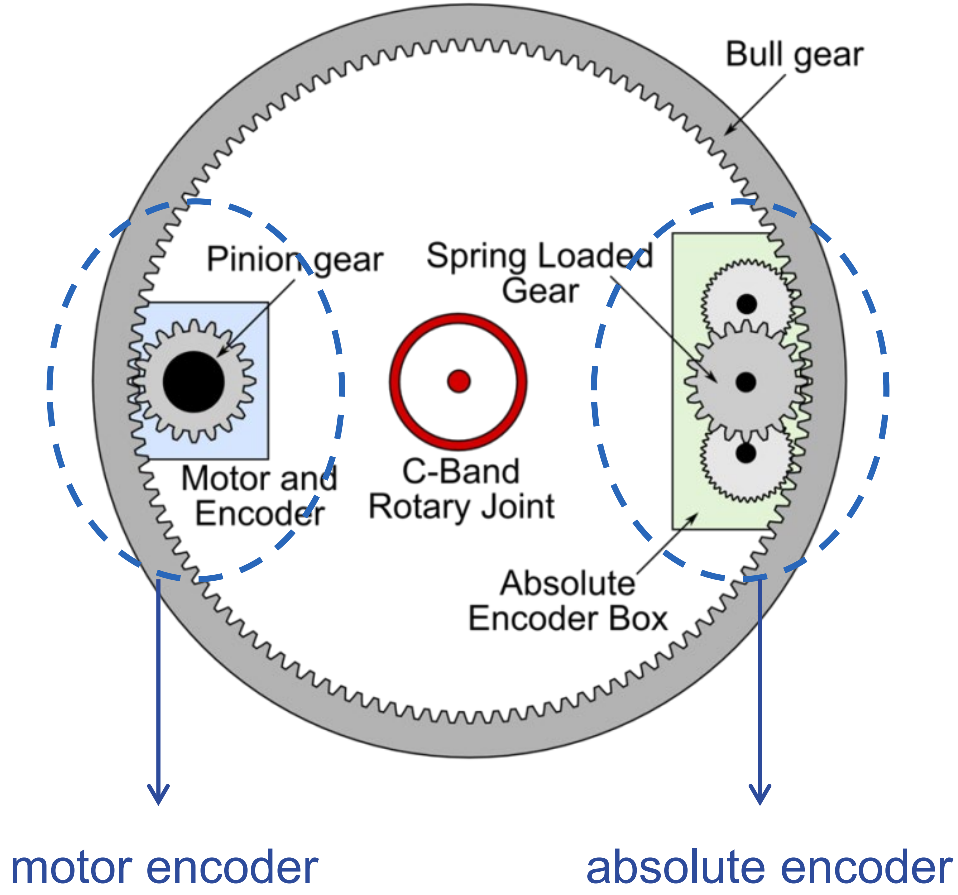
- we use dedicated solar box scans centered around the sun.
- box scans are performed every 10 minutes.
- ~ it takes about 5 minutes to complete a box scan; every ~ 2° in azimuth we measure the sun, ~90 boxscans per day (in summer), azimuth range covered in our latitude ~55° – 300°).
- we determine pointing bias, beam width, beamsquint and integrated differential solar power from each box scan.





Angle acquisition in the DWD radar system

there are two angle sources



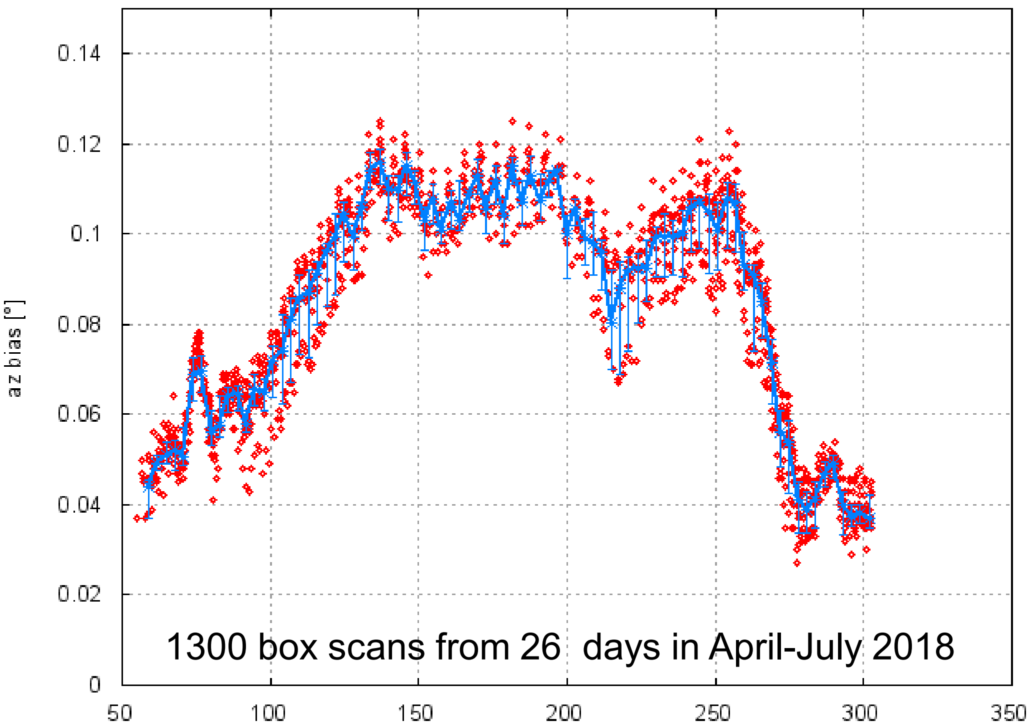
operationally, absolute encoder angles are used to tag each pulse

positioning of antenna: commanded through the motor encoder.

a pulse can be tagged either with the absolute or motor encoder through a software switch.

azimuth pointing bias

data from 3 and 15 June 2018
pointing bias in **H** and **V**



azimuth of sun

azimuth pointing bias is a function of azimuth

0.06° variation between az=70° and 300°

very good consistency of data

azimuth dependence of pointing bias:
mainly attributed bull gear excentricity

results for elevation bias:
see Frech et al., 2019

az bias of a radar is **not** independent of azmuth

elevation of the sun > 10°; refractive index variations are ruled out

elevation pointing bias

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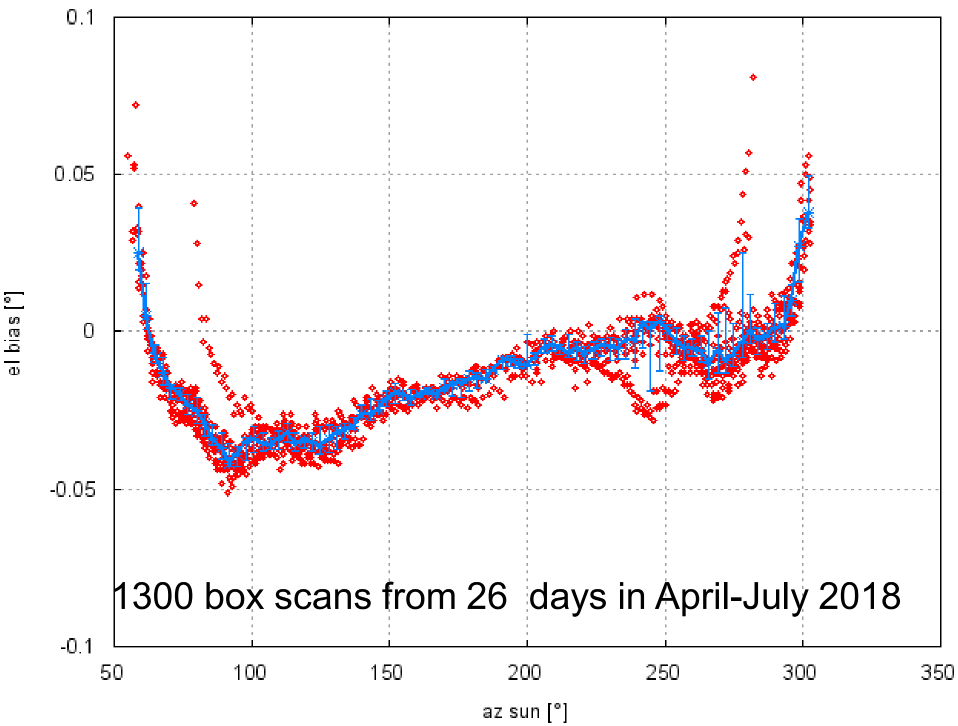
data from 3 and 15 June 2018
pointing bias in **H** and **V**



azimuth of sun

elevation pointing bias increase as a function of az position

increase 0.02° (100 – 250° az) points to a slight tilt of the pedestal

elevation of the sun > 10°; refractive index variations are ruled out

Comparision with operational monitoring

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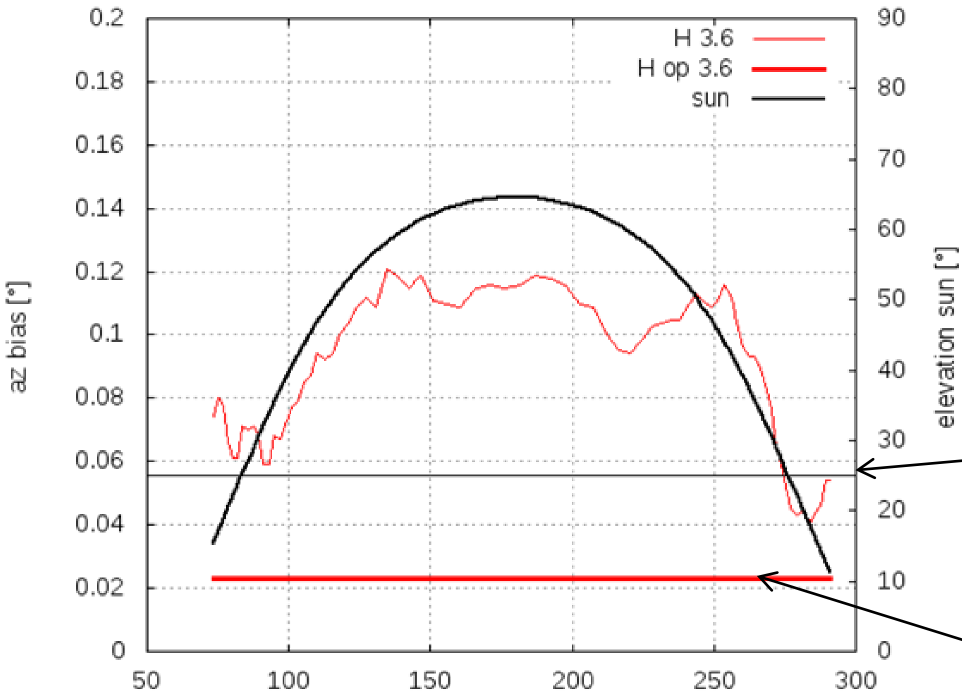
data from 3 June 2018, only **H**



azimuth of sun

for solar elevation < 25°:

operational az bias estimate: ~0.02°
from box scan data : ~ 0.06°

maximum elevation from operational scanning is 25°.

pointing bias over a large az range cannot be monitored using the operational method.

operational bias estimate
(one value per day)

el sun > 10°; refractive index variations are ruled out

Encoder angles & pointing bias

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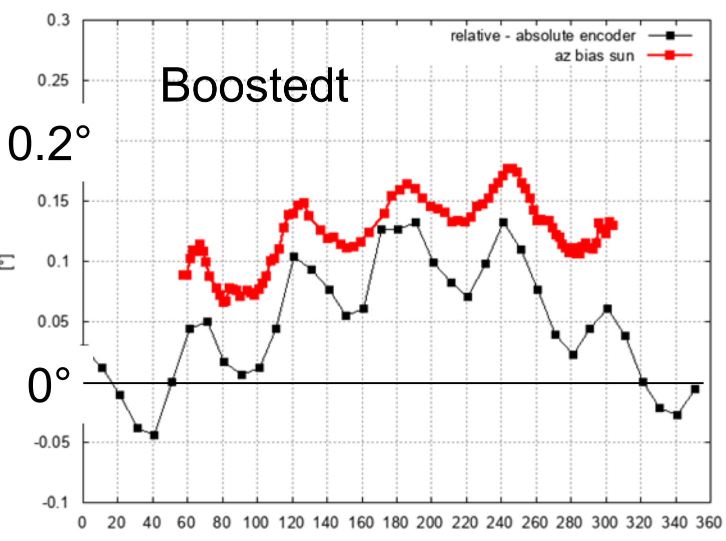
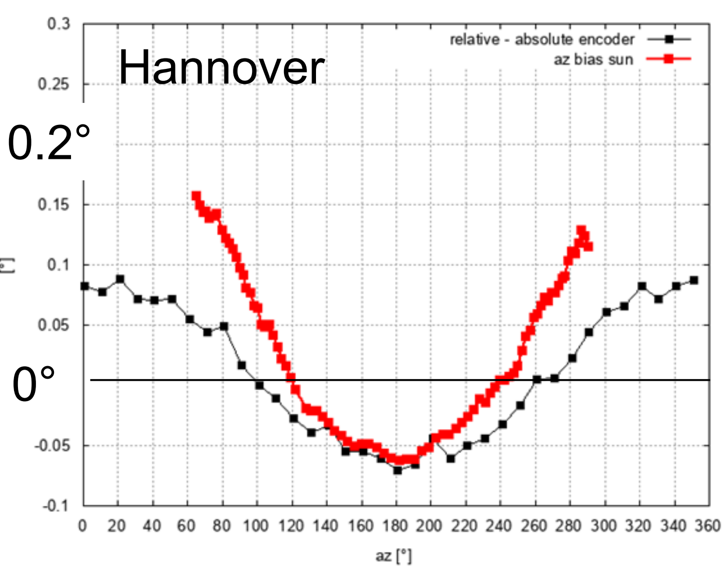


box scan data: distinct modulation of azimuth pointing bias

black curve:
difference between absolute encoder and motor encoder …this does **not** represent a pointing bias. Modulation is also visible.
Ideally, difference should be 0°

modulation is due to the gear drive ratio of the absolute encoder (-> absolute encoder has an issue).



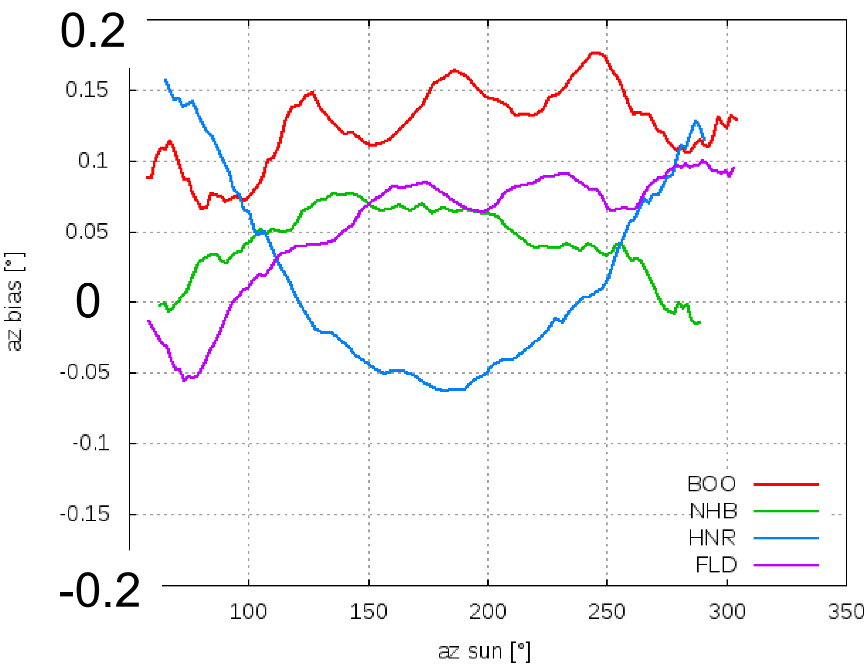
box scan data: large variation of pointing bias (0.2°)!

difference between absolute encoder and motor encoder: comparable variation.

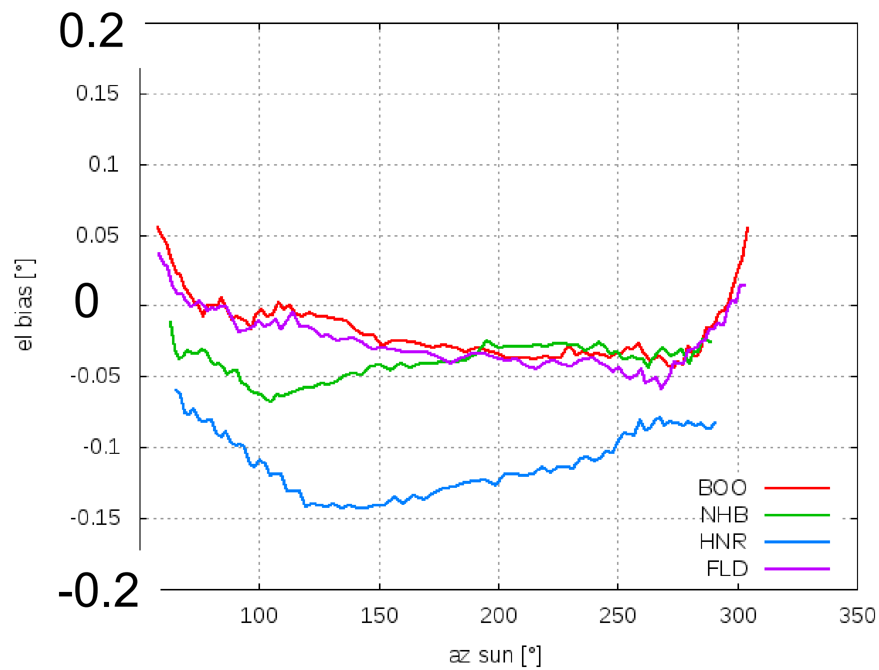
-> attributed to bull gear (needs to be replaced)

Examples from the DWD radar network

azimuth pointing bias



elevation pointing bias



Measurements end of July 2018

Radars Boostedt (BOO), Neuheilenbach (NHB), Hannover (HNR), Flechtdorf (FLD)

Conclusions

- We have presented a method to systematically assess the pointing bias, the health of the drive train and that of the gears using the sun as a reference.
- this practical method represents an end-to-end assessment because it includes the antenna assembly and the radome.
- contrary to the commonly used solar monitoring, the azimuth dependent pointing bias can be quantified over fairly large azimuth range.
- operational solar monitoring of pointing bias is blind to a large az range depending on the season and scan strategy.
- Full diurnal cycles of boxscans can be remotely scheduled with our radar software.
- We consider to apply this method every 1-2 years at every site or whenever there is a major hardware modification on a radar.

Reference:
Frech M., Theo Mammen and Bertram Lange, Pointing accuracy of an operational polarimetric weather radar, Remote Sensing, 2019, 11(9), 1115