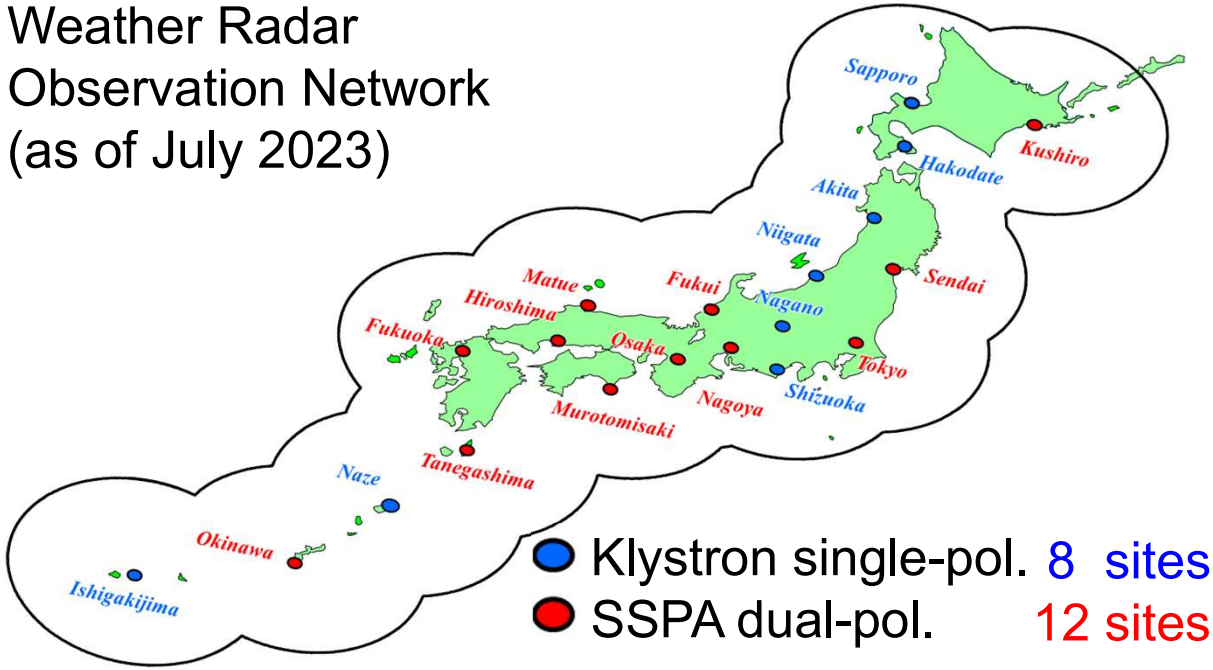
Maintenance experience with SSPA dual-polarization weather radar

Morihiro SAWADA,
Y. KAJIWARA, H. OKUMURA, H. Inoue, and T. HIKIDA
Observation Division, Atmosphere and Ocean Department, JMA
9th Nov. 2023

Contents

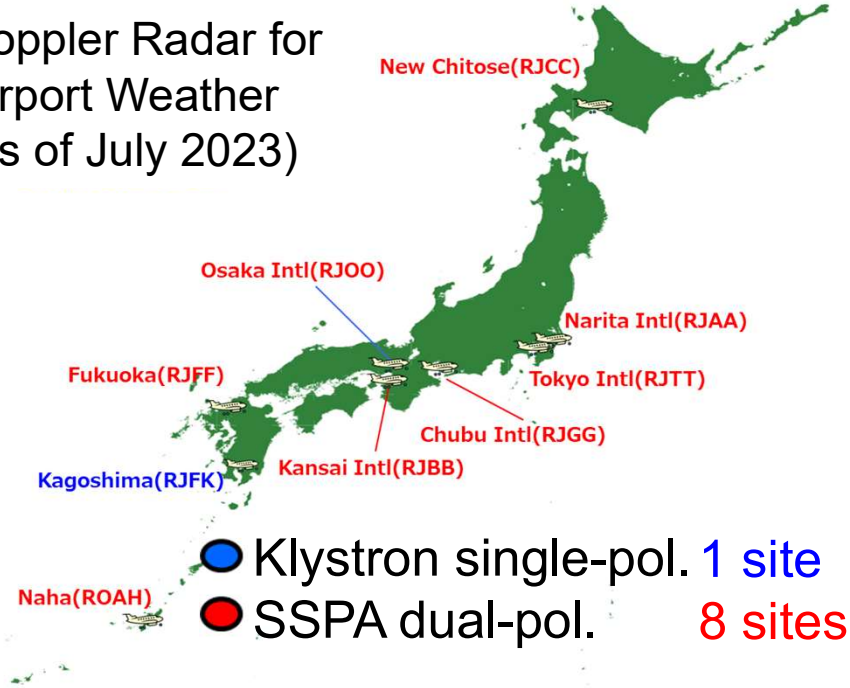
SSPA dual-pol. weather radar in Japan

Weather Radar Observation Network (as of July 2023)



- Klystron single-pol. 8 sites
- SSPA dual-pol. 12 sites

Doppler Radar for Airport Weather (as of July 2023)



- Klystron single-pol. 1 site
- SSPA dual-pol. 8 sites

Periodic inspection of dual-polarization Doppler radar (single-site)

Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar.

4 days
First-term periodic inspection
By manufacturer

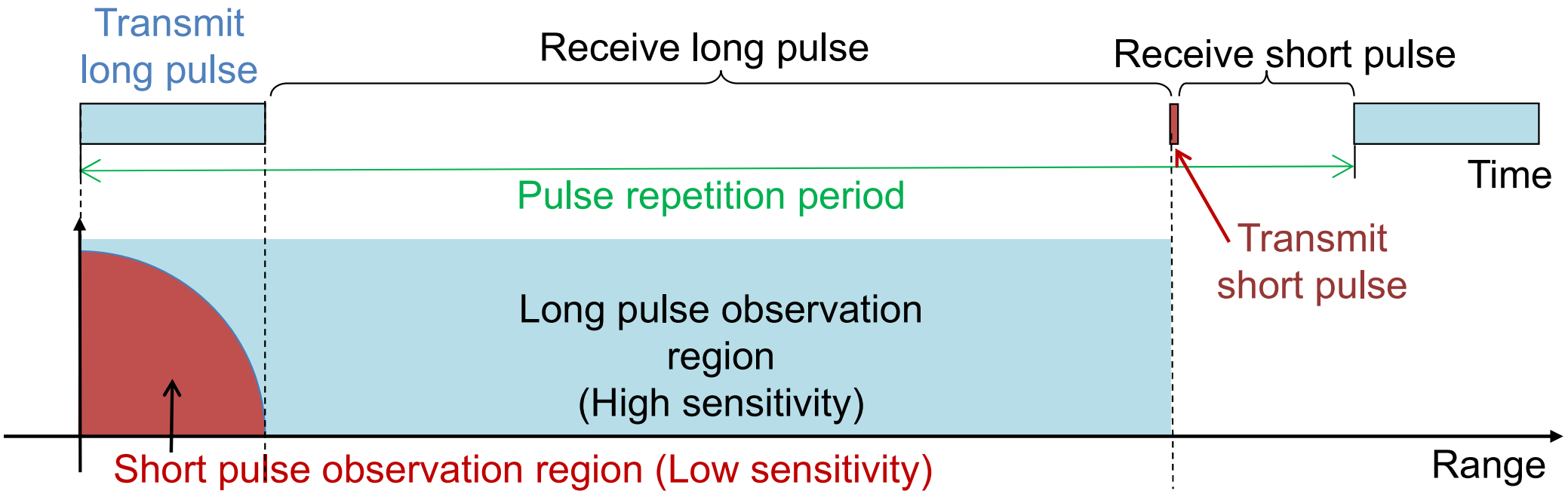
2 days
First-term periodic inspection
By JMA

4 days
Second-term periodic inspection
By manufacturer

2 days
Second-term periodic inspection
By JMA

Use of short and long pulses

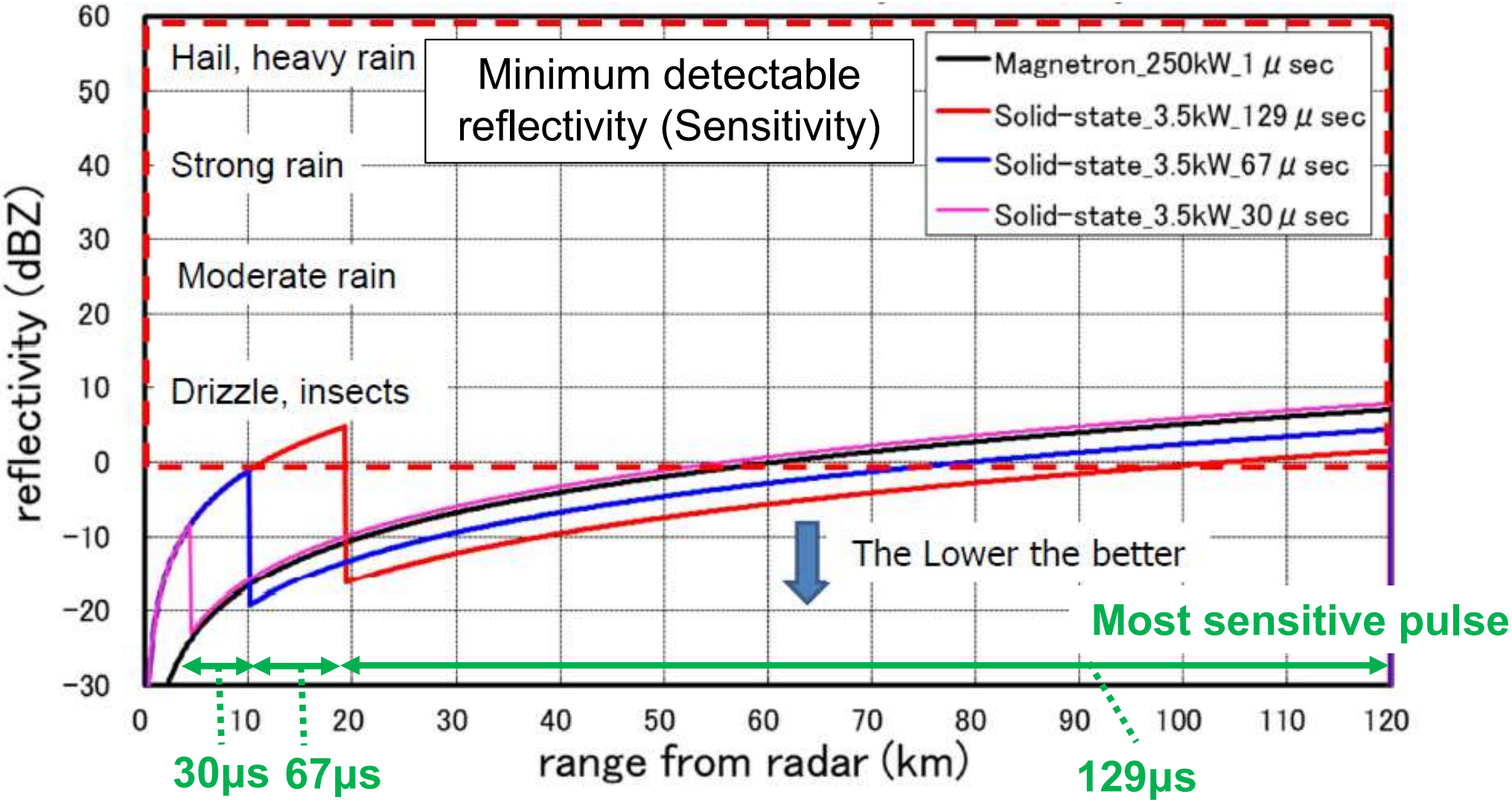
- Solid-state element transmitters are characterized by a low peak output (3 - 5kW).
- Reception sensitivity for low outputs is limited.



- Nationwide radars use one short and three long pulses.
- Pulse compression provides strong reflectivity and high range resolution.
- Observation modes which observe narrower area use shorter long pulses.

Pulse	Pulse width
short	1μs
long	32, 64,128μs

Use of short and long pulses



Calibration for four pulse types is needed with each polarization.

Requirements for accurate calibration

<Accuracy requirements>

※WMO/Guide to Instruments and Methods of Observation (GIMO)

※NOAA/National Weather Service Radar Functional Requirements (2015)

- Reflectivity factor (Z) : ±1dB
- Differential reflectivity (Z_{DR}) : ±0.1～0.2dB

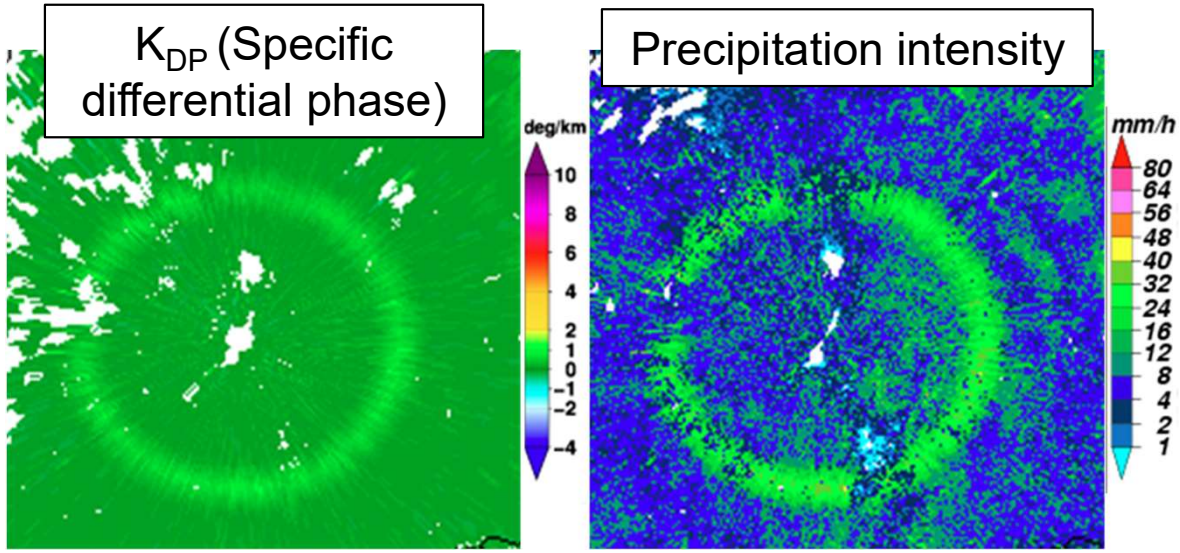
<Use of short and long pulses>

- Differential phase (ψ_{DP}) : Generation of the bias between short and long pulses

Without polarimetric parameter calibration…

Compromised accuracy

- Overestimation of precipitation intensity
- Incorrect classification of precipitation type



Polarimetric parameter for short and long pulses must be calibrated accurately.

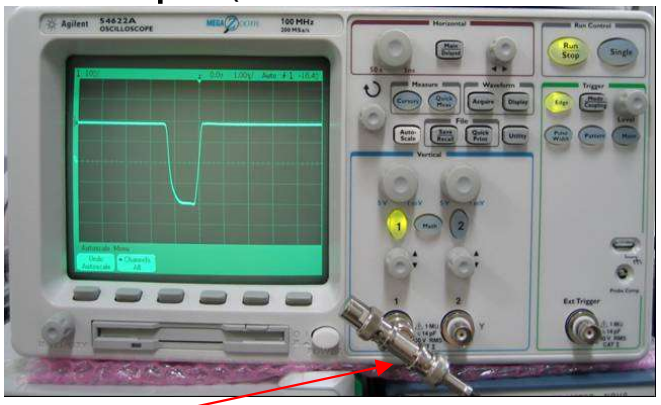
Contents

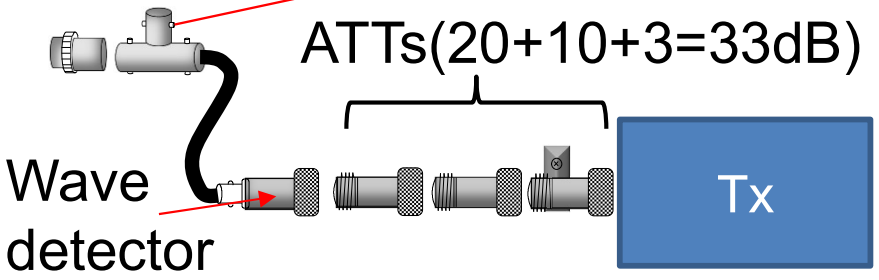
Efficient pulse inspection

Before the installation of peak power sensor

Pulse width measurement

Oscilloscope (Agilent Technologies 54622A)





- Pulse width is measured by adjusting the ATTs.

Peak power measurement

- Average power is measured by a power sensor and a power meter.
- Rate of duty cycle (Du) is needed to calculate peak power.
- Rate of duty cycle (Du) is calculated based on pulse width and pulse repetition interval.

A lot of work is needed for inspection.

Efficient pulse inspection

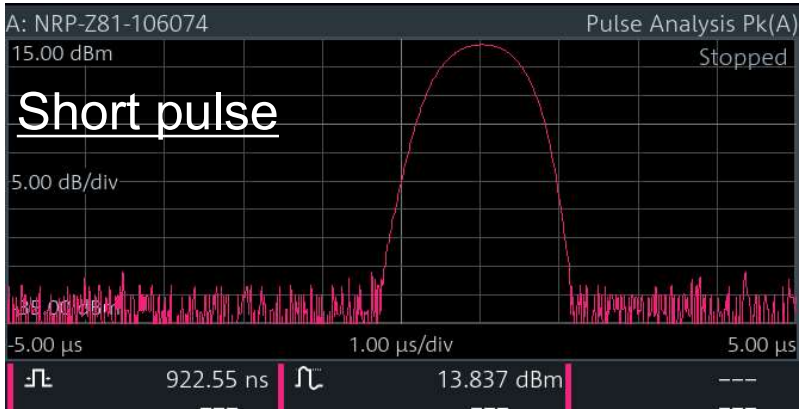
After the installation of peak power sensor

Measurement of pulse width and peak power

Tx

Peak power sensor
(ROHDE & SCHWARZ NRP-Z81)

Power meter (ROHDE & SCHWARZ NRX)

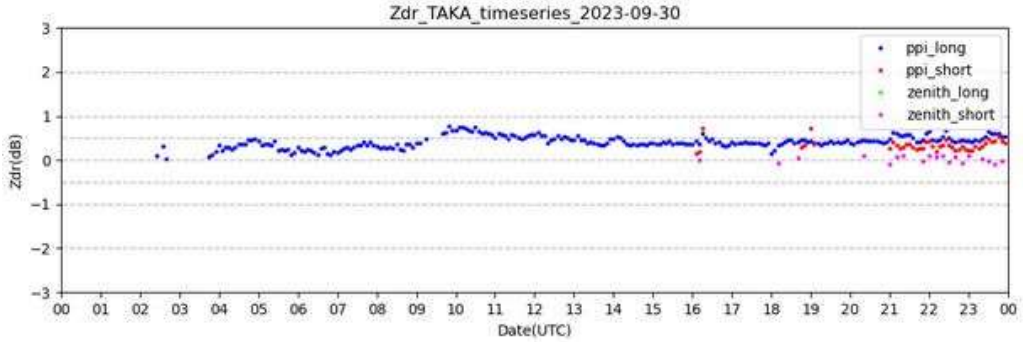


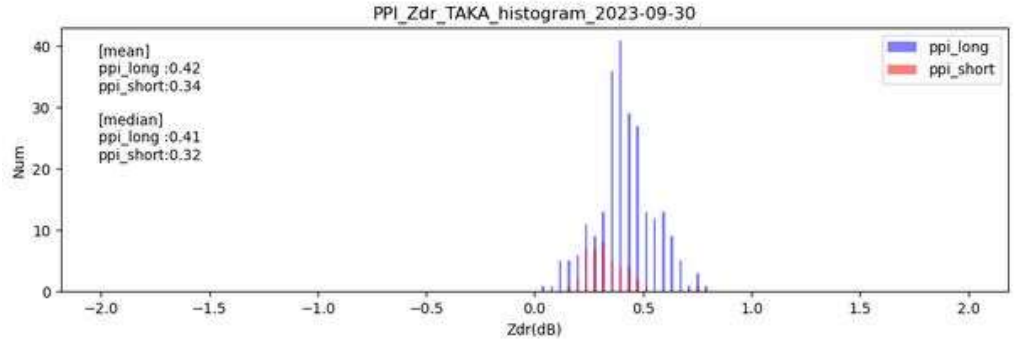
- Peak power sensor is capable of automatic pulse analysis.
- Analysis of pulse width and transmitted power is measured simultaneously.

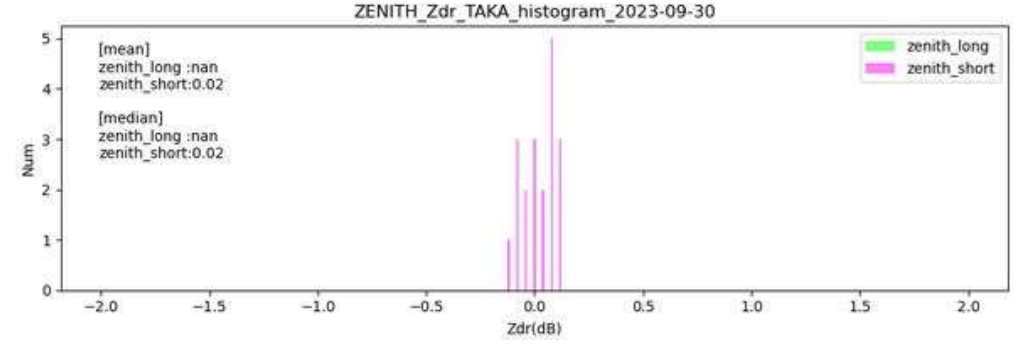
Contents

Bias-monitoring tool development

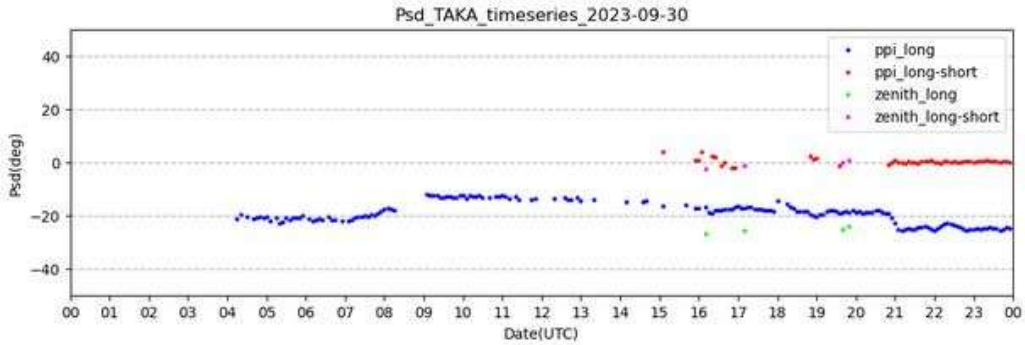
Z_{DR}

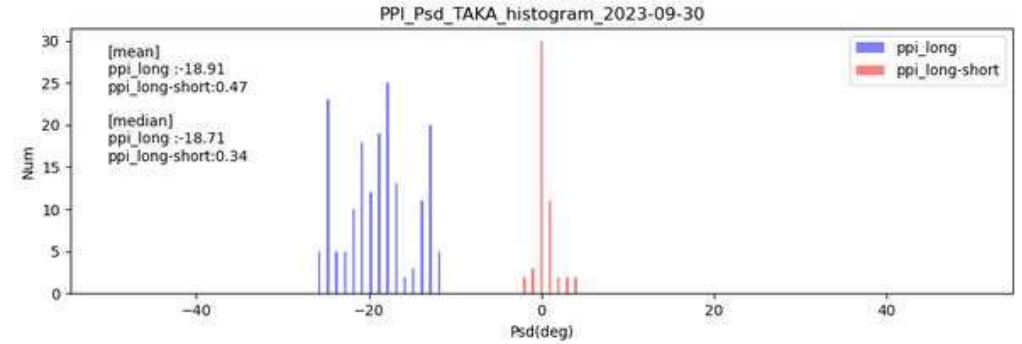


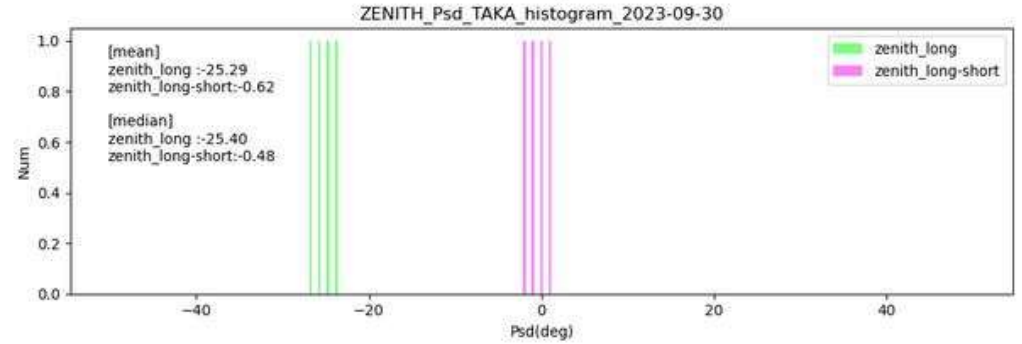




Ψ_{DP}



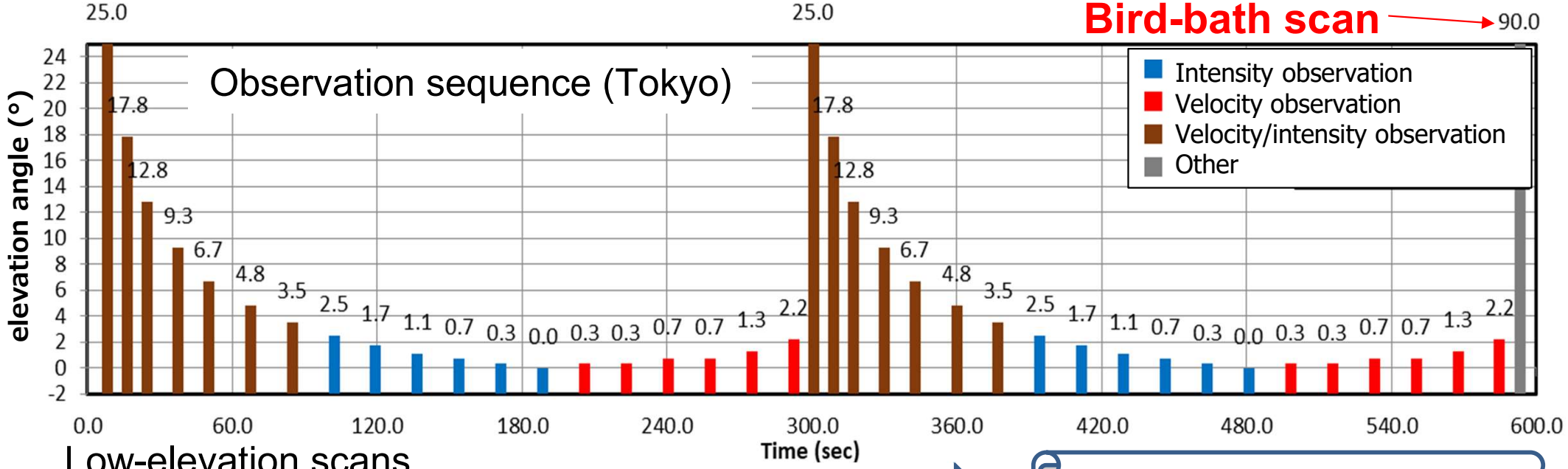




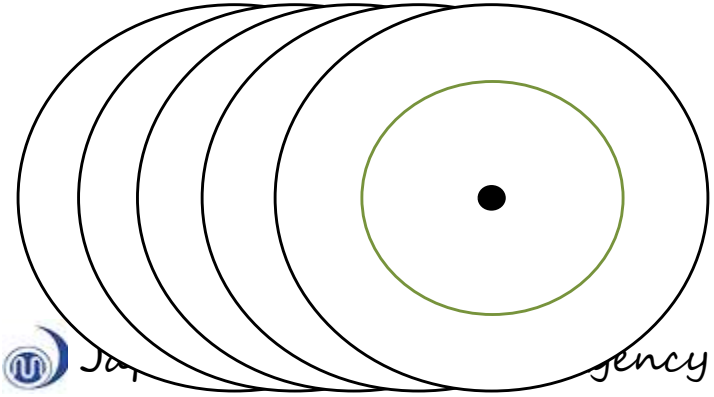
- Monitoring of Z_{DR} and ψ_{DP} in bird-bath and low-elevation scans
- Capacity for checking of daily and monthly time-series representations

Method of polarimetric parameter monitoring

- Bird-bath scans at all radars every 10 minutes
- Use of data from low-elevation scans due to difficulty of long pulses monitoring with bird-bath scans



Low-elevation scans
(Elevation angle:～0.7°)



Data extraction condition (light rain)

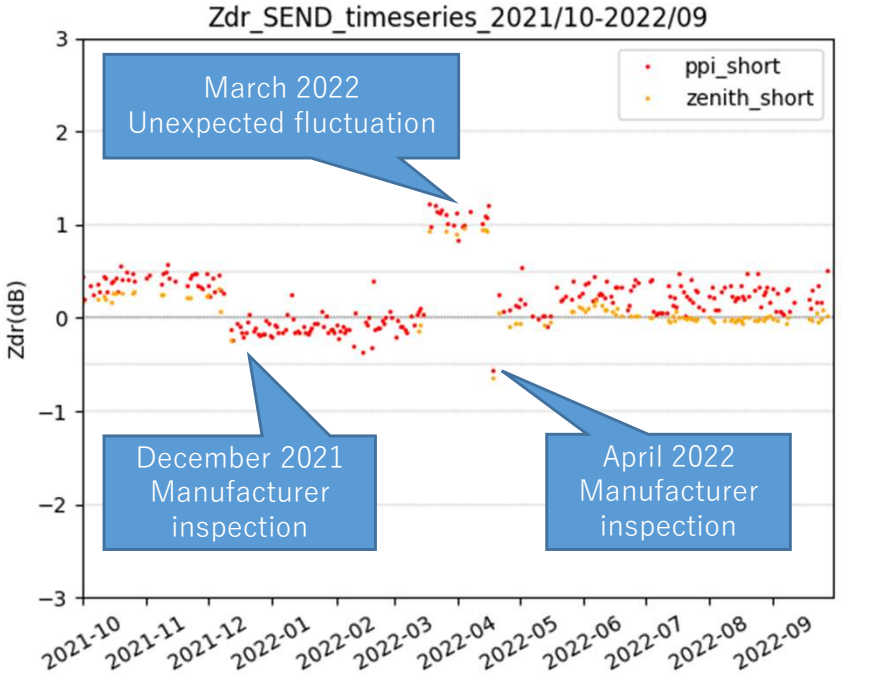
$|Z_{DR}| < 5.0$
$0.99 < \rho_{hv} <= 1.0$
$10.0 < Z_H < 15.0$
$|S(Z_{DR})| < 0.3$
$|S(\rho_{hv})| < 0.01$

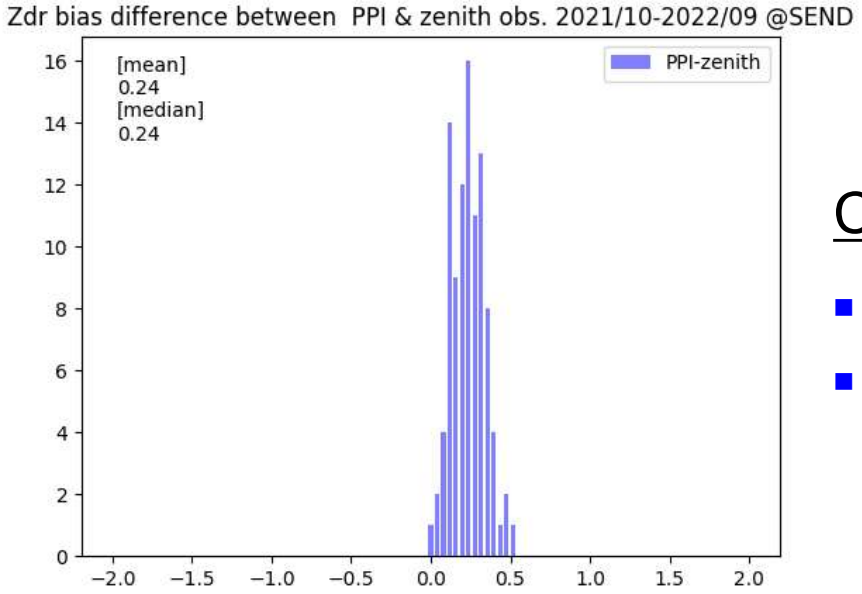
Calculation for individual pulse regions

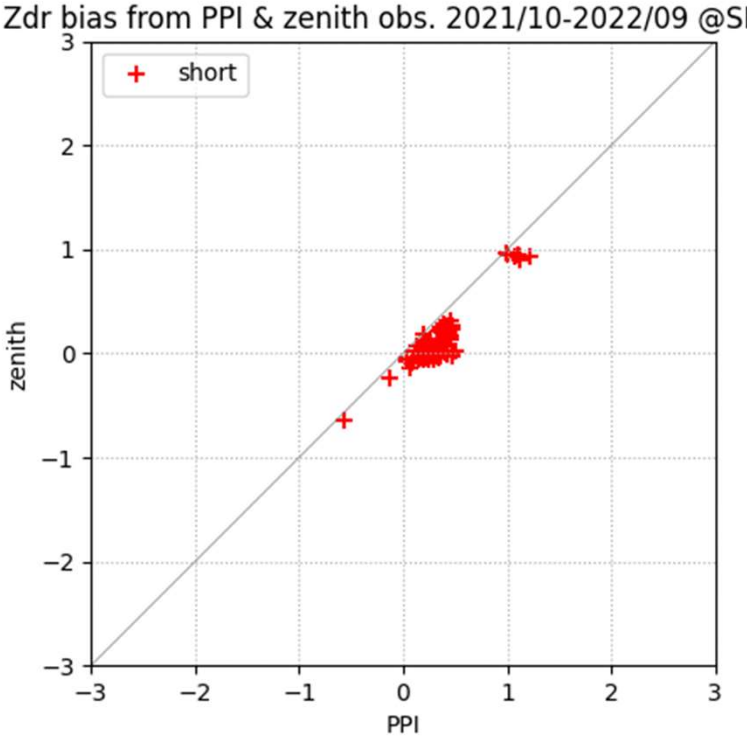
- Average
- Standard deviation
- Valid data count

(Hotta et al., 2nd WXRCalMon 2019)

Comparison of bird-bath and low-elevation scans (Sendai)



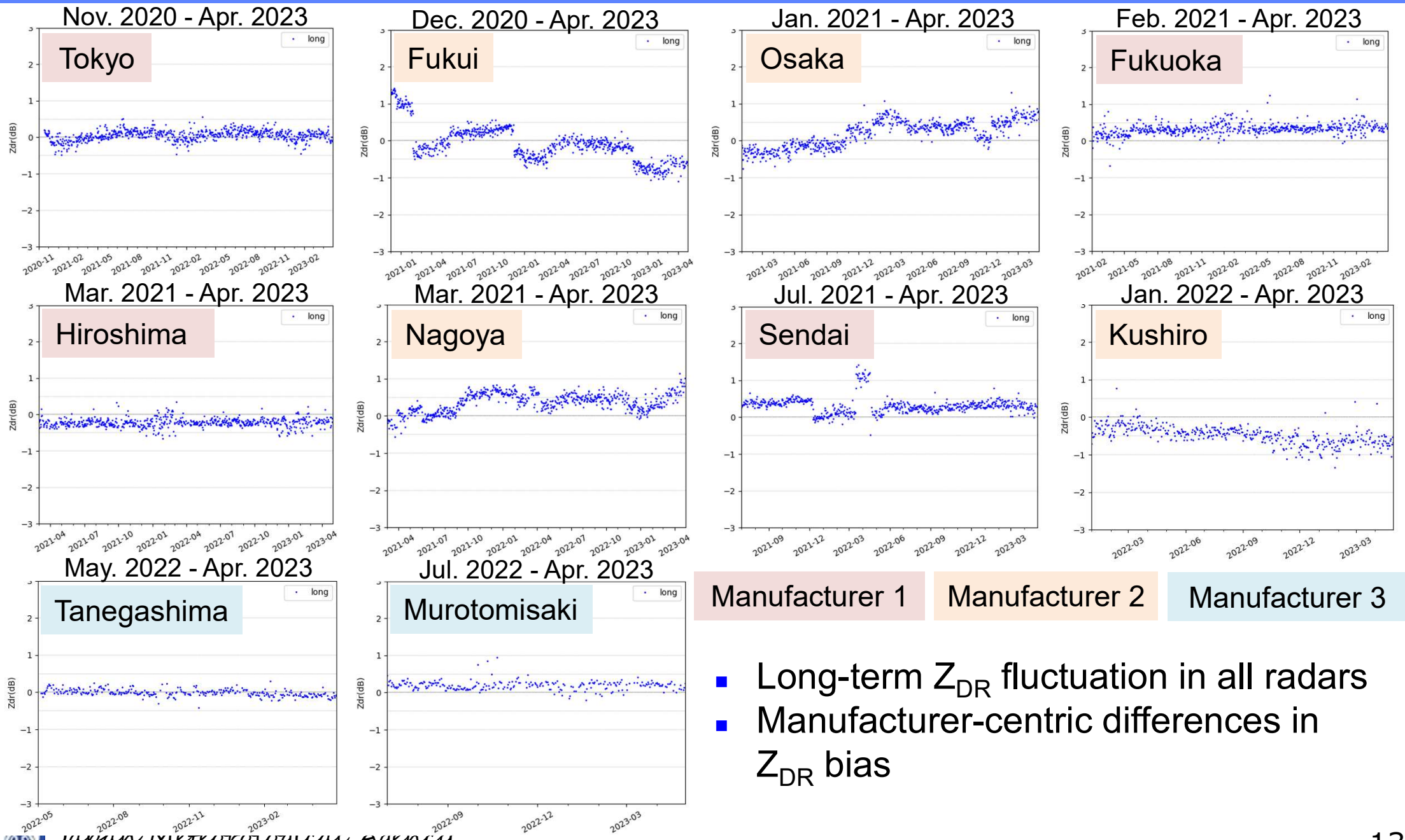




Comparison of short pulse region daily average

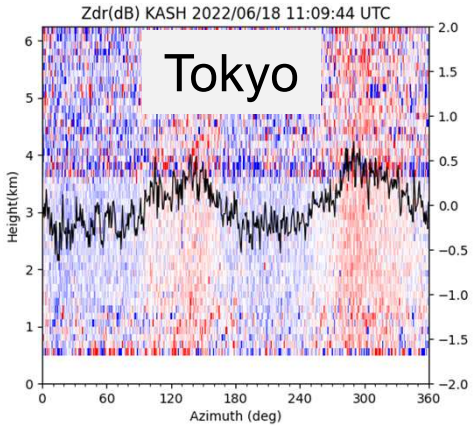
- Z_{DR}: 0.24 dB (low-elevation > bird-bath)
- Consistent Z_{DR} fluctuation trend

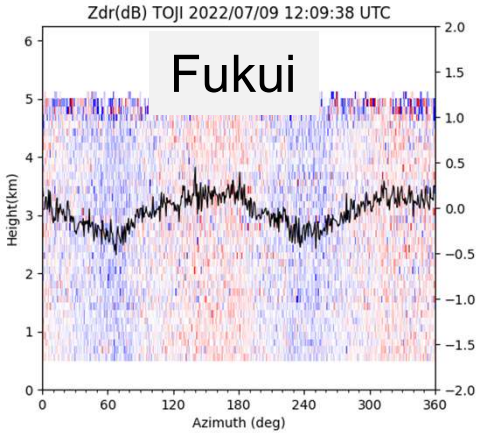
Long-term Z_{DR} bias trend (low-elevation scans)

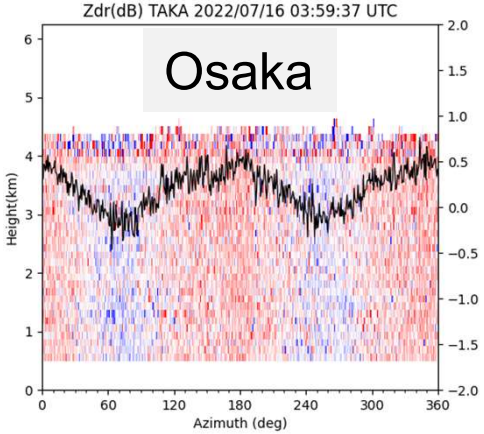


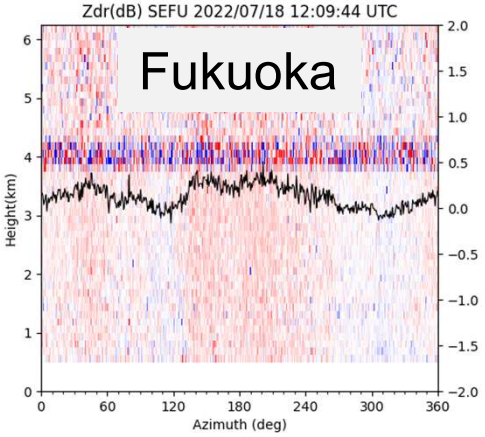
- Long-term Z_{DR} fluctuation in all radars
- Manufacturer-centric differences in Z_{DR} bias

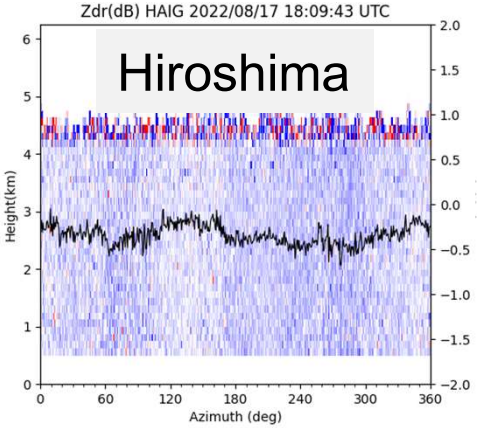
Cyclically changed Z_{DR} in bird-bath scans

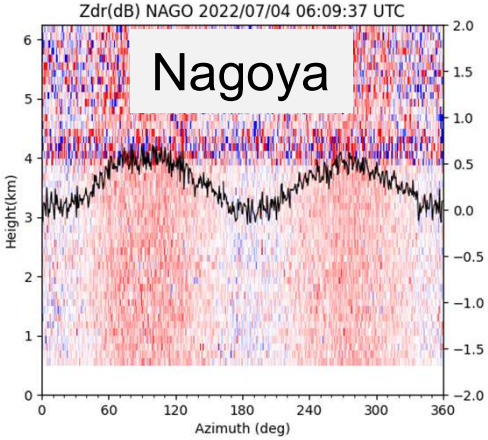


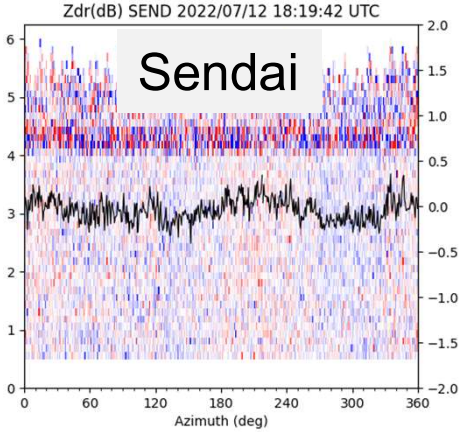


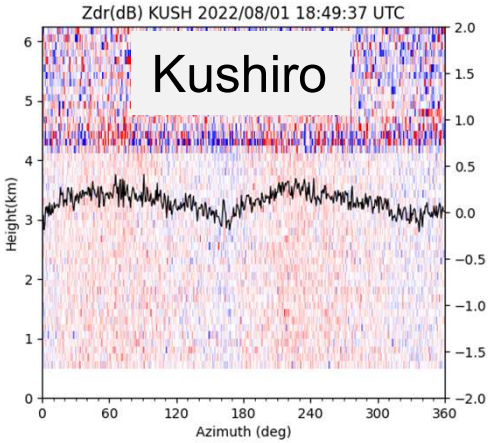


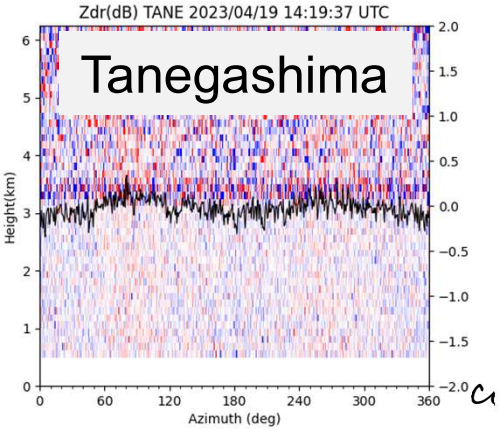


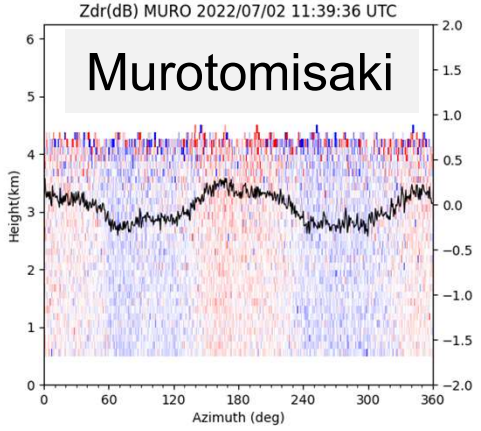


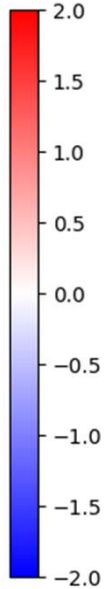










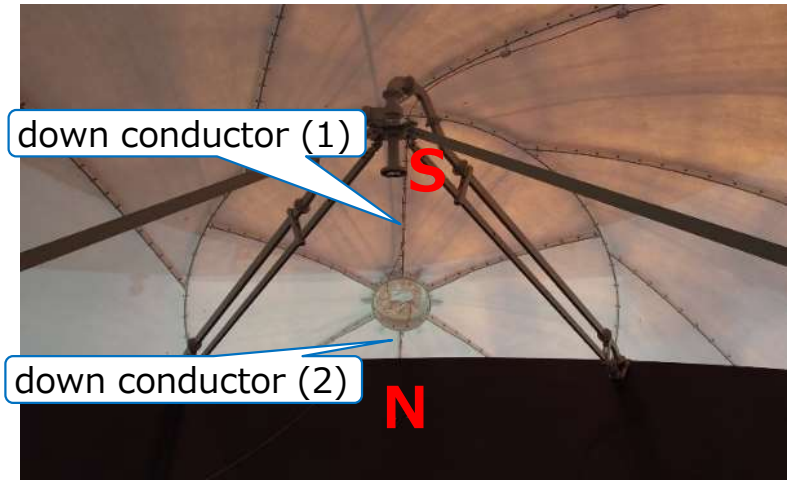


- Cyclically changed Z_{DR} in bird-bath scans for certain radars
- Changes at 7 out of 10 sites

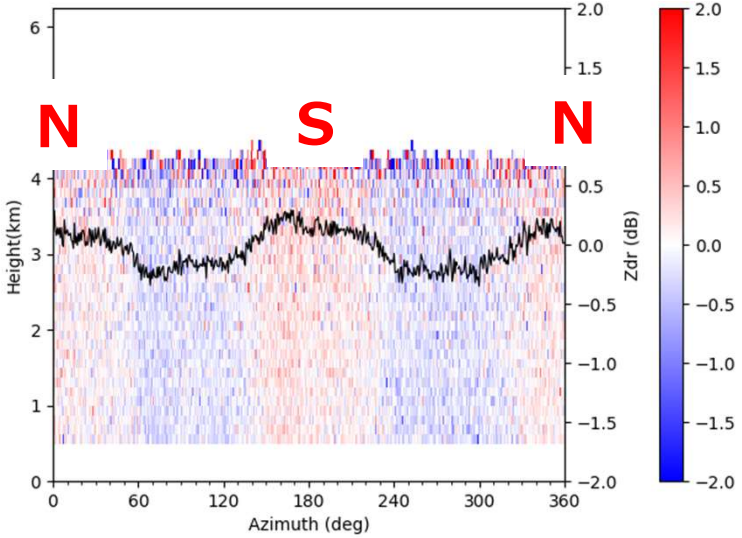
Investigation of causes

Investigating causes of Z_{DR} bias

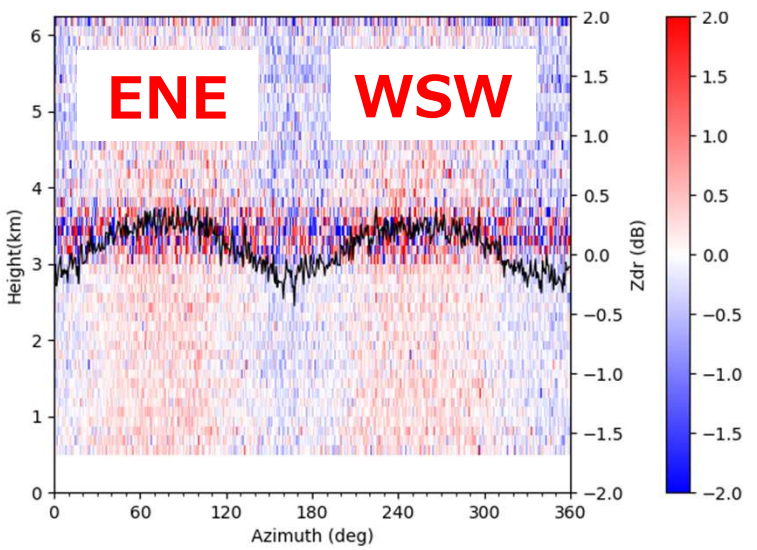
① Down conductors (Murotomisaki)

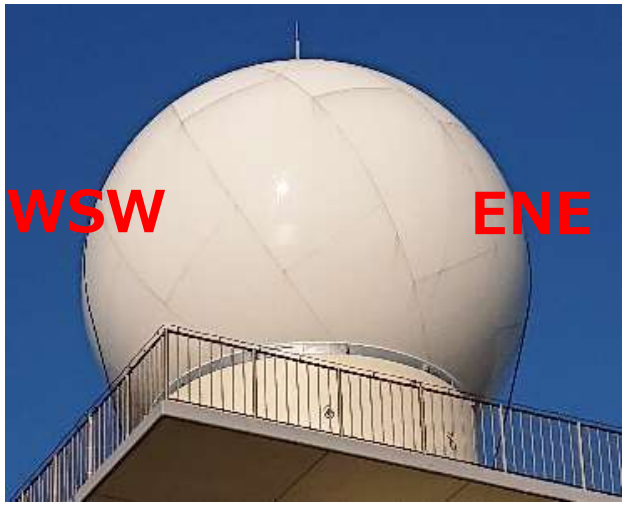


Note: South-facing antenna



② Maintenance ropes (Kushiro)





Do the directions match?

① Positive bias of Z_{DR} ≒ Down conductors

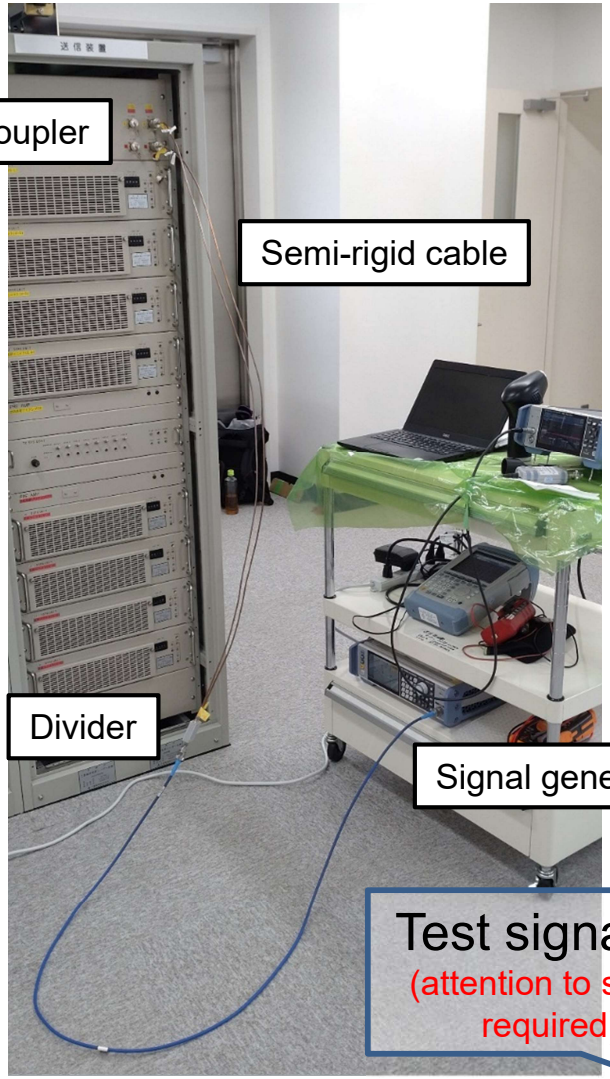
② Positive bias of Z_{DR} ≒ Maintenance ropes

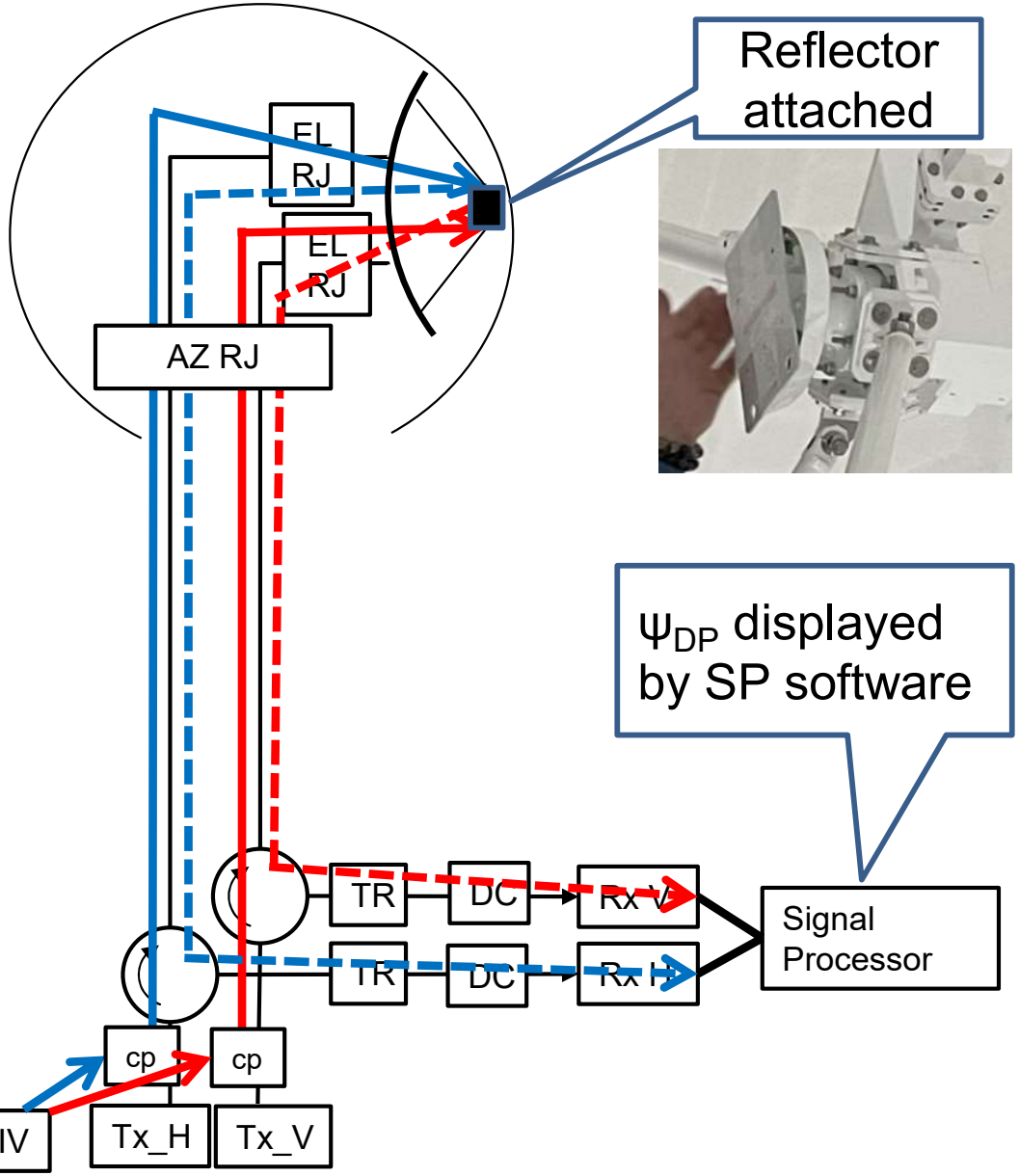
We should investigate causes in other radars.

Manufacturer inspection of ψ_{DP}

ψ_{DP} is checked semiannually by manufacturer for inspection.

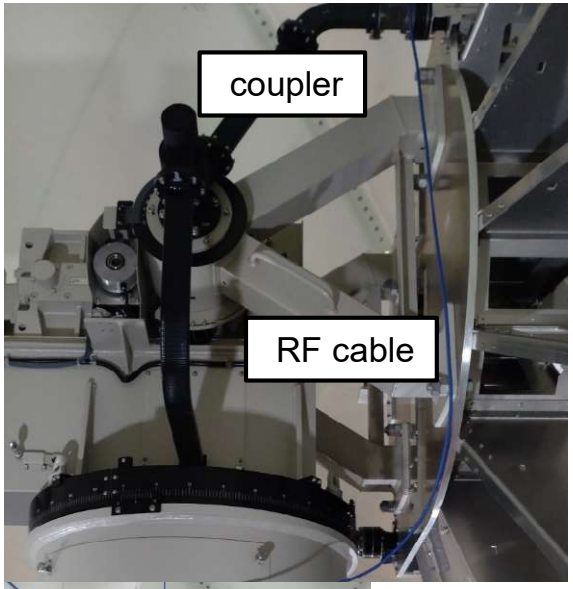
First ψ_{DP} measurement

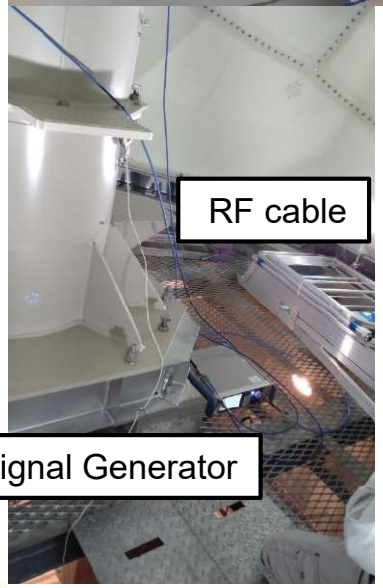


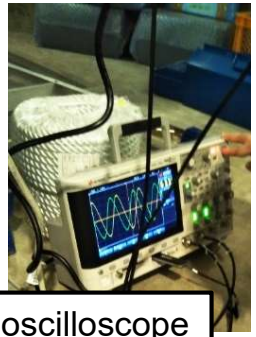


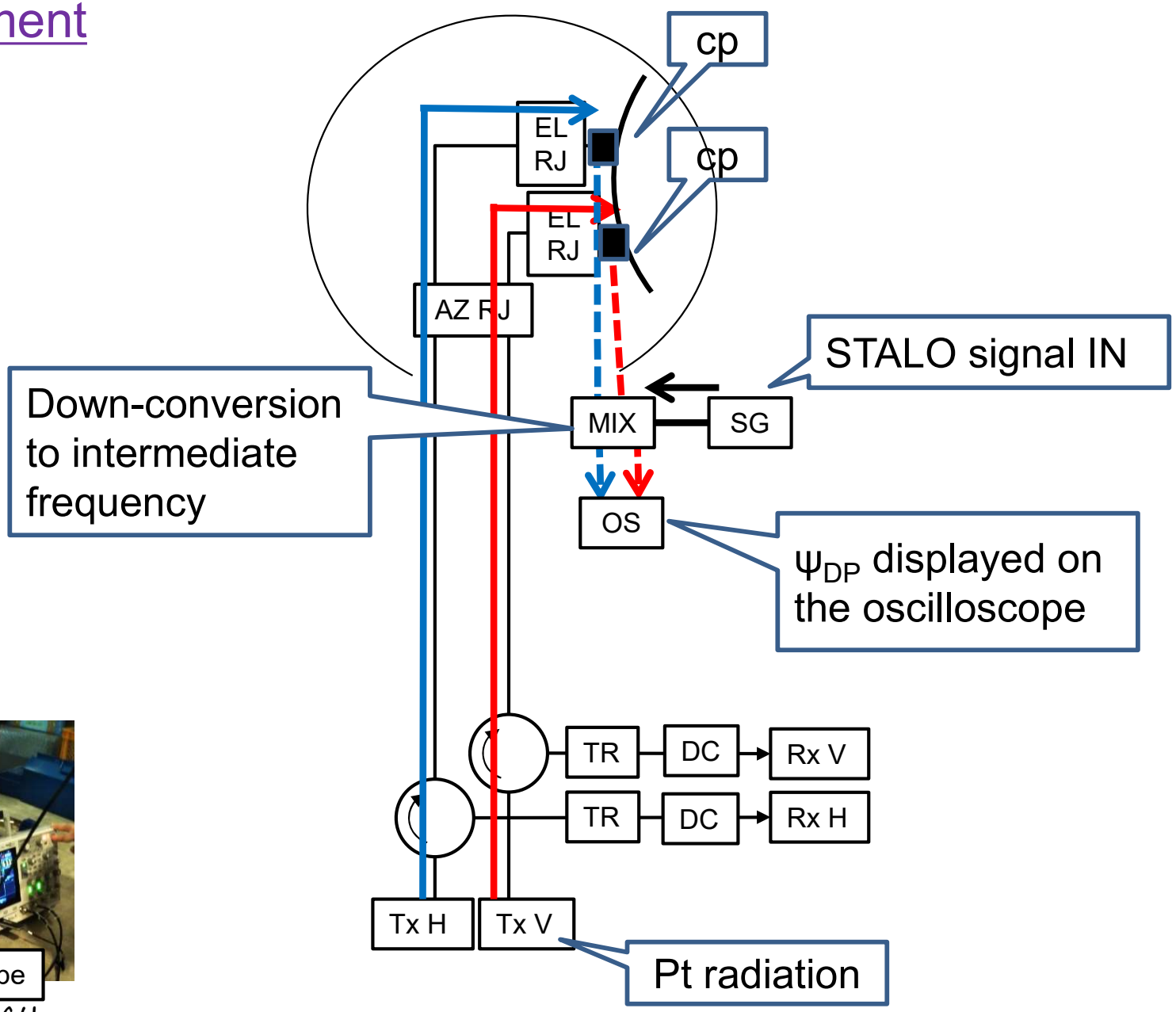
Manufacturer inspection of ψ_{DP}

Second ψ_{DP} measurement



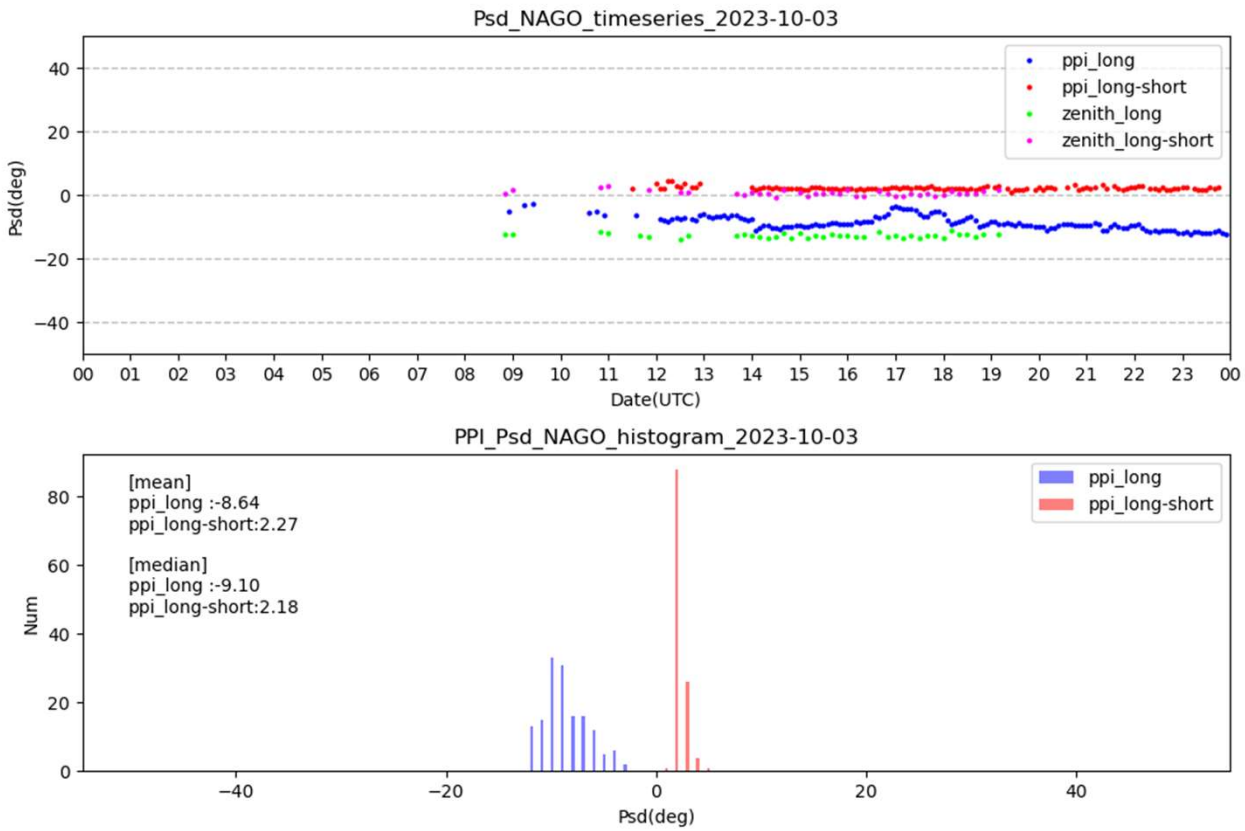


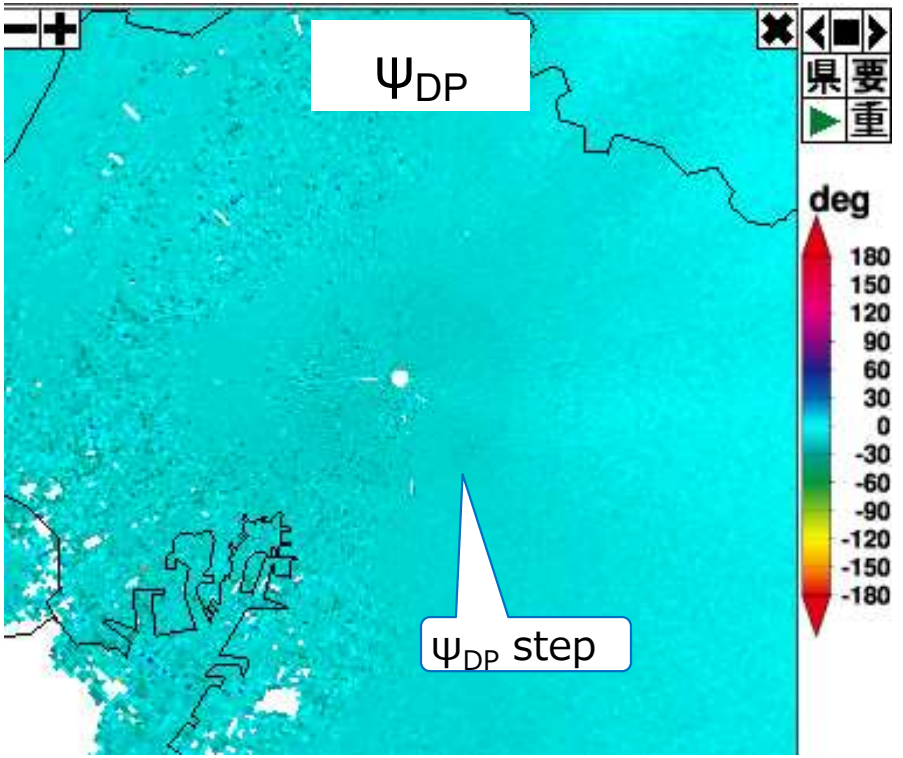




Contents

ψ_{DP} step generation



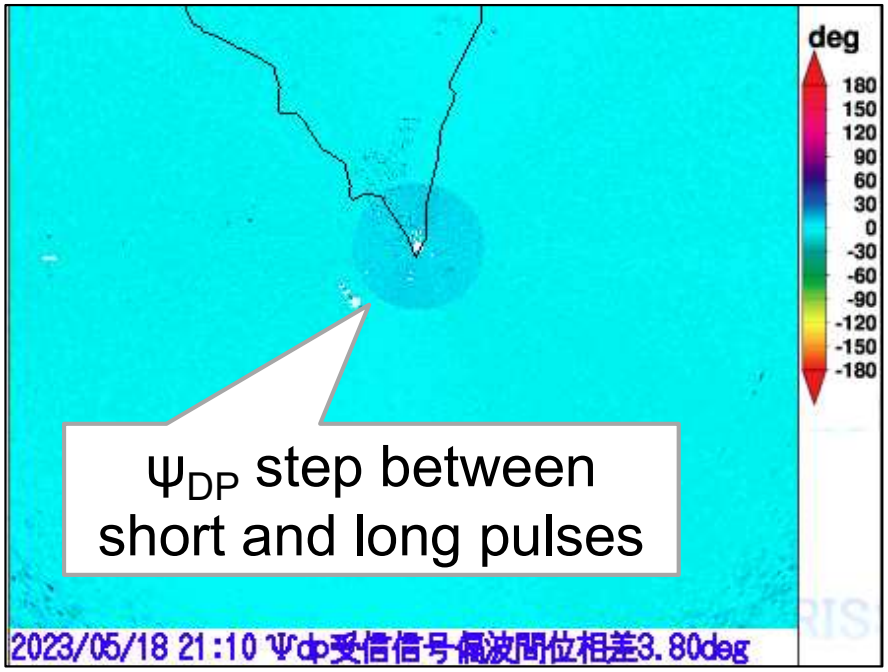


- ψ_{DP} step between short and long pulses: approx. 2 degrees
- Negative ψ_{DP} bias with long pulses: approx. 10 degrees

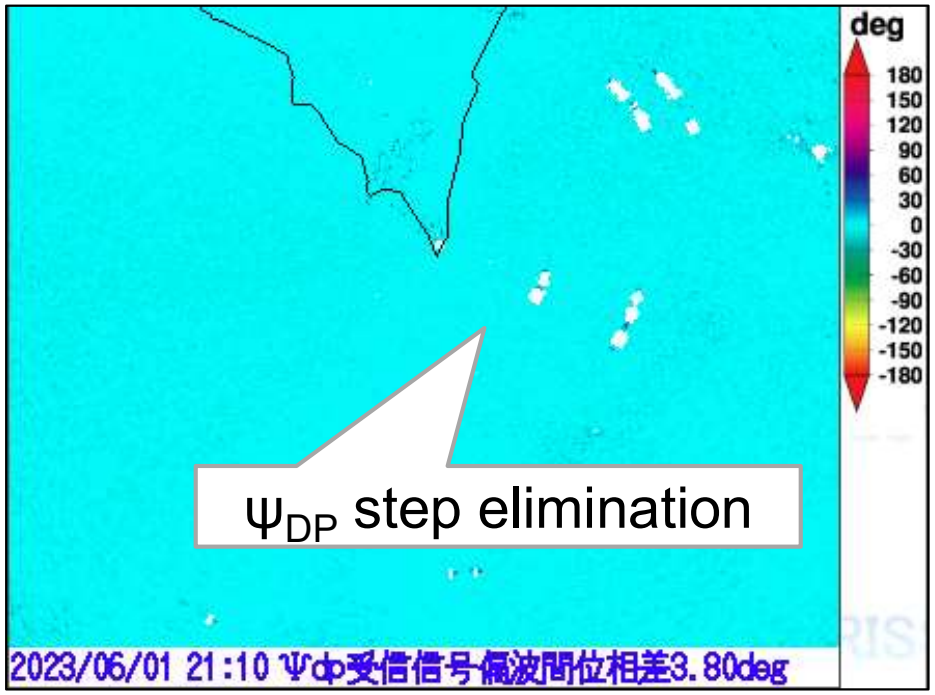
ψ_{DP} step adjustment

- GUI-based adjustment of parameter in the radar system
- Possible to change parameters for in-service operation

Before adjustment (ψ_{DP})



After adjustment (ψ_{DP})



Instant polarimetric parameter calibration is important for accurate observation.

Summary

- SSPA radars have more inspection and monitoring items for use of four pulse types.
  - Peak power sensor can be used to efficiently analyze pulse width and transmitted power.
- Polarimetric parameter monitoring is important.
  - Checking of ZDR bias for short and long pulses
  - Checking of ψDP discontinuity between short and long pulses
  - Use of low-elevation and bird-bath scan data for long pulses monitoring

Thank you for your attention.