RF – interference mitigation process

How to handle external radar interference sources?

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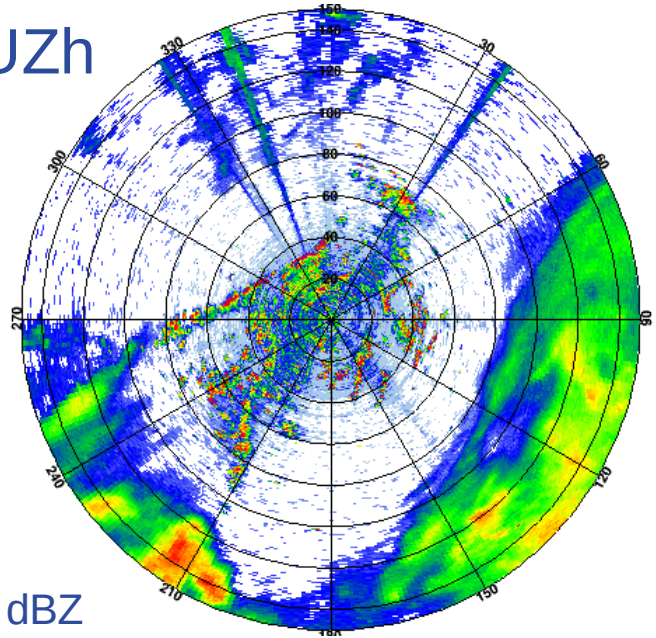
Date: 17.11.2021

Motivation

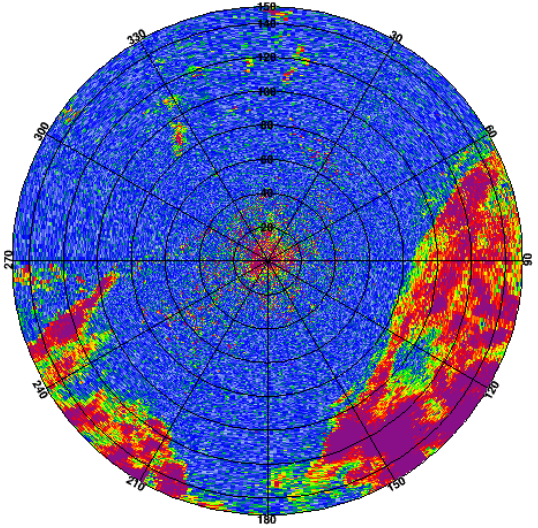
UZh



dBZ

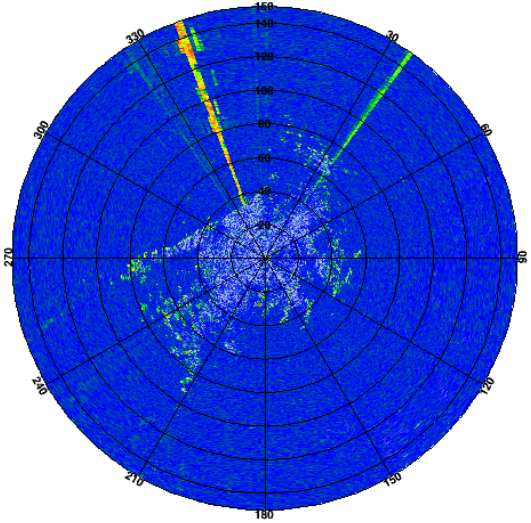
-10 0 10 20 30 40

SQIh – no reflection



0 0.35 0.7

STDh – pulsed signal



0.3 0.65 1

source: OFT 19.10.2019

RFI detection (WXRCalMon2019)

- Detecting „disturbed“ rays via ray based criteria
- Identifying RF-interference (RFI) sources
  - Collecting rays for 24h
  - Applying thresholds to identify „strong“ and „persistent“ RFIs

„persistent“	RFI:	SNRh > 0dB	&	disturbance fraction > 10%
„strong“	RFI:	SNRh > 20dB	&	disturbance fraction > 1%

RFI detection visualisation

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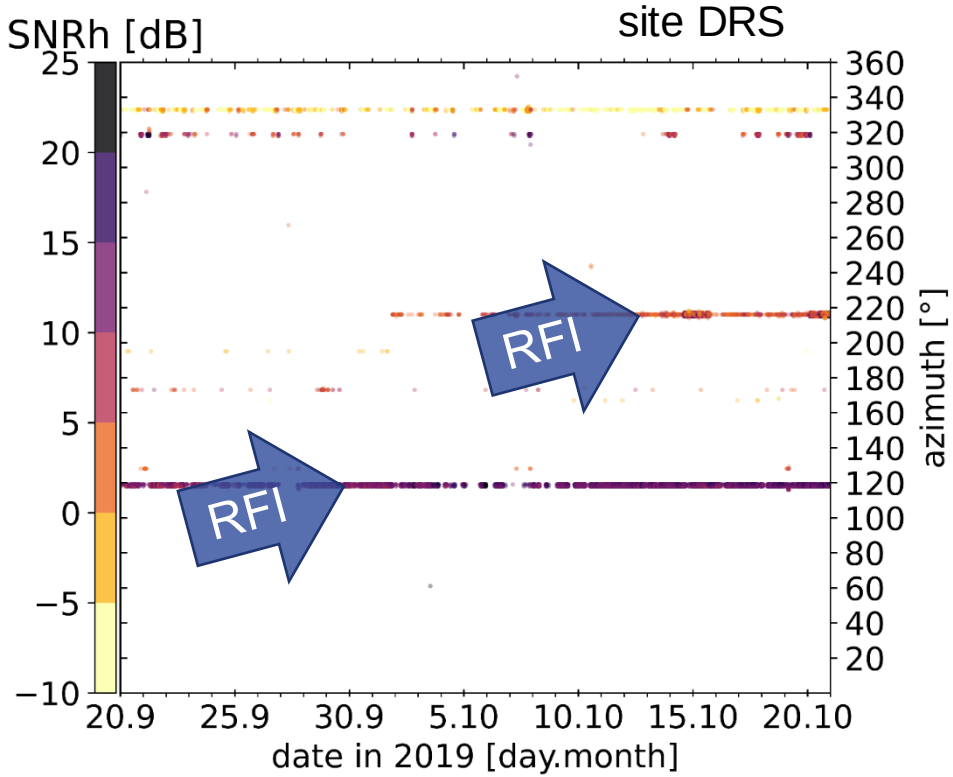
- Disturbed rays with mean SNRh
- …over 30 days
- 2 regions pass the RFI thresholds



Content

- Communicating detected interferences
- Independent verification method
  - „RHunt“ – hardware
  - comparison to operational data
- Mitigation experience over 5 years of data collection

Communicating detected RFIs

How to provide and forward the detection results?

Communicating detected interferences

- operational procedure in place since 2020

- detection results aggregated in HTML-table (and additional PNGs)
  - daily aggragation of the RFIs within the last 7 days
  - manual verification and further actions

- communication towards the NRA (BNetzA)
  - reporting evaluated interference via an email – which results in a BNetzA-Ticket
    - on site visits with DWD technicans to identify sources
  - monthly report of interferences via an aggragated table
    - to keep track of short term interferences which would go unnoticed otherwise

HTML-table of RFIs in last 7 days

➔ One row corresponds to: 1 RFI + 1 site + 1 day

loc	date	width	min az	mean az	max az	mean el	n-rays	%-rays	int. limit	median int.	qty3 int.	max int.	DB az	BNetzA
FLD	09.11.2021	0.0°	190.0°	190.0°	190.0°	0.5°	5.0	1.7%	20.0dB	20.3dB	21.0dB	22.3dB		
FLD	12.11.2021	0.0°	190.0°	190.0°	190.0°	0.6°	7.0	2.4%	20.0dB	21.6dB	23.6dB	27.5dB		
ASB	08.11.2021	1.0°	228.0°	228.7°	229.0°	0.6°	56.5	19.6%	0.0dB	8.0dB	11.1dB	17dB	228.1°	C441/01002/21
ASB	09.11.2021	1.0°	228.0°	228.7°	229.0°	0.6°	65.0	22.6%	0.0dB	8.2dB	11.1dB		228.1°	C441/01002/21
ASB	10.11.2021	0.0°	229.0°	229.0°	229.0°	0.6°	52.0	18.1%	0.0dB				1°	C441/01002/21
ASB	11.11.2021	1.0°	228.0°	228.7°	229.0°	0.5°	50.0	17.4%	0.0dB					C441/01002/21
ASB	12.11.2021	1.0°	228.0°	228.7°	229.0°	0.5°	45.5	15.8%	0.0dB				1°	C441/01002/21
ASB	13.11.2021	1.0°	228.0°	228.7°	229.0°	0.6°	36.5	12.7%	0.0dB	9.9dB	12.6dB		228.1°	C441/01002/21
ASB	14.11.2021	1.0°	228.0°	228.7°	229.0°	0.6°	58.5	20.3%	0.0dB	8.9dB	11.7dB	dB	228.1°	C441/01002/21
DRS	14.11.2021	0.0°	119.0°	119.0°	119.0°	0.5°	44.0	15.3%	0.0dB	2.4dB	3.1dB	6.3dB		
DRS	11.11.2021	1.0°	340.0°	340.4°	341.0°	0.6°	76.0	26.4%	0.0dB	8.3dB	11.1dB	17.9dB		

Strong RFIs with high SNRh

Persistent RFIs with high number of rays

Already reported to NRA

Independent verification method

How to independently verify the detection results?

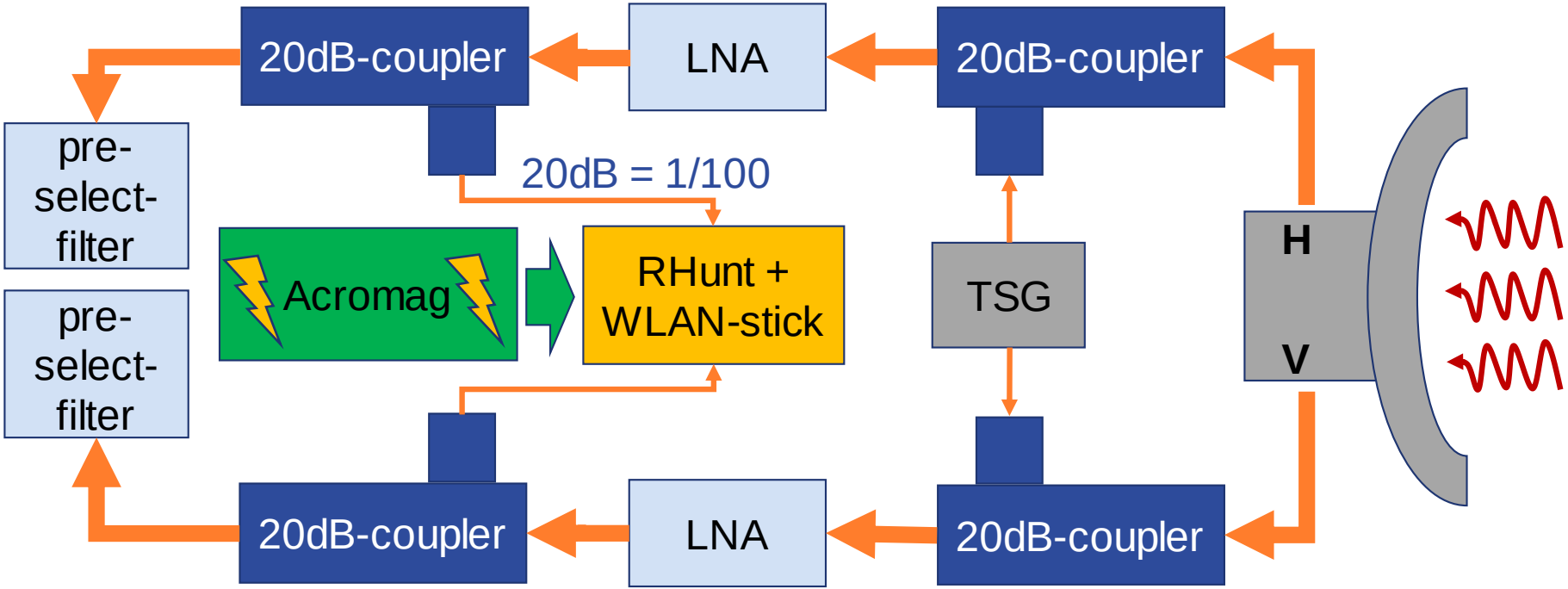
RFI detection verification method

- current RFI detection is based on received and processed radar pulses
- reliable verification is only possible with an independent measurement
  - BUT from 2 years of experience – RFI detection does not have false positives

- Goal:
  detect WLANs as independent as possible from the radar HW and processing

- Approach: verification has to use the same signal that the radar receives

Receiver setup for independent verification



Rhunt result – MHP 22.09.2021

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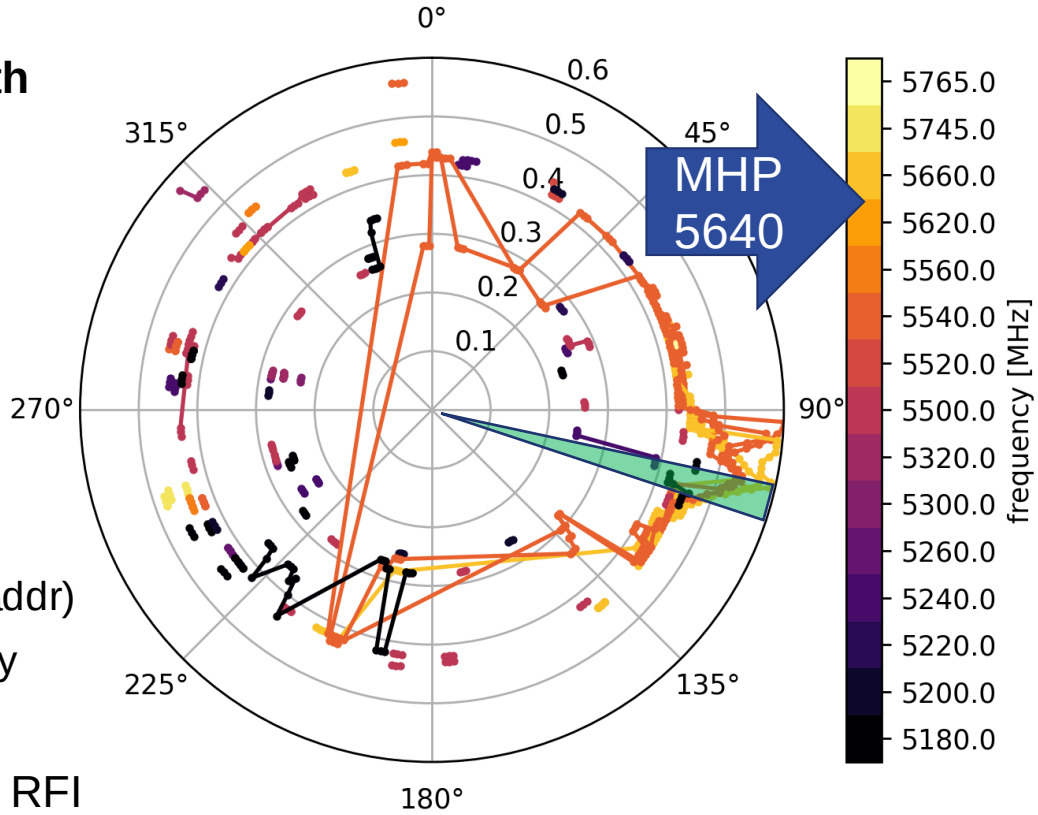
- **Signal level [%] over azimuth**
- Scanning…
  - in 1° az steps
  - with fixed antenna position
  - 360° requires over 1h
- WLAN bandwidth 20-80 MHz
  - 127 detected WLANs (MAC-addr)
  - 5 in 80MHz to radar frequency
- Green region shows detected RFI



Rhunt result – PRO 27.10.2021

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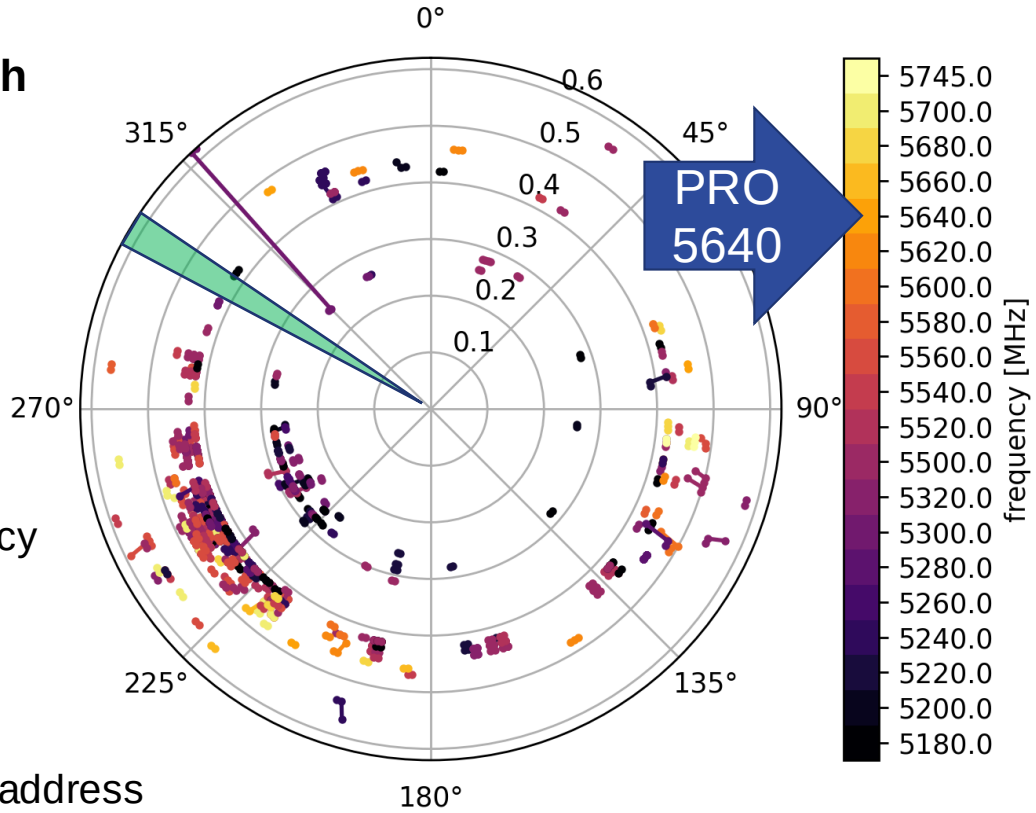
- **Signal level [%] over azimuth**
- Green region
  > strong RFI detected
- Detected WLANs:
  - 726 unique MAC-addr.
  - 79 in 80MHz to radar frequency
- Only WLANs which can be identified as such show up
  - At least with detectable MAC-address



Improving the independet verification

- Using a more suitable detection device wich can…
  - report the actual power measurement
  - analyze the received spectrum – detect unidentifiable RFI sources
- While trying to keep the signal processing step to a minimum

Mitigation experience over 5 years

What can be achived using the current mitigation process?

Historic overview of detected RFIs

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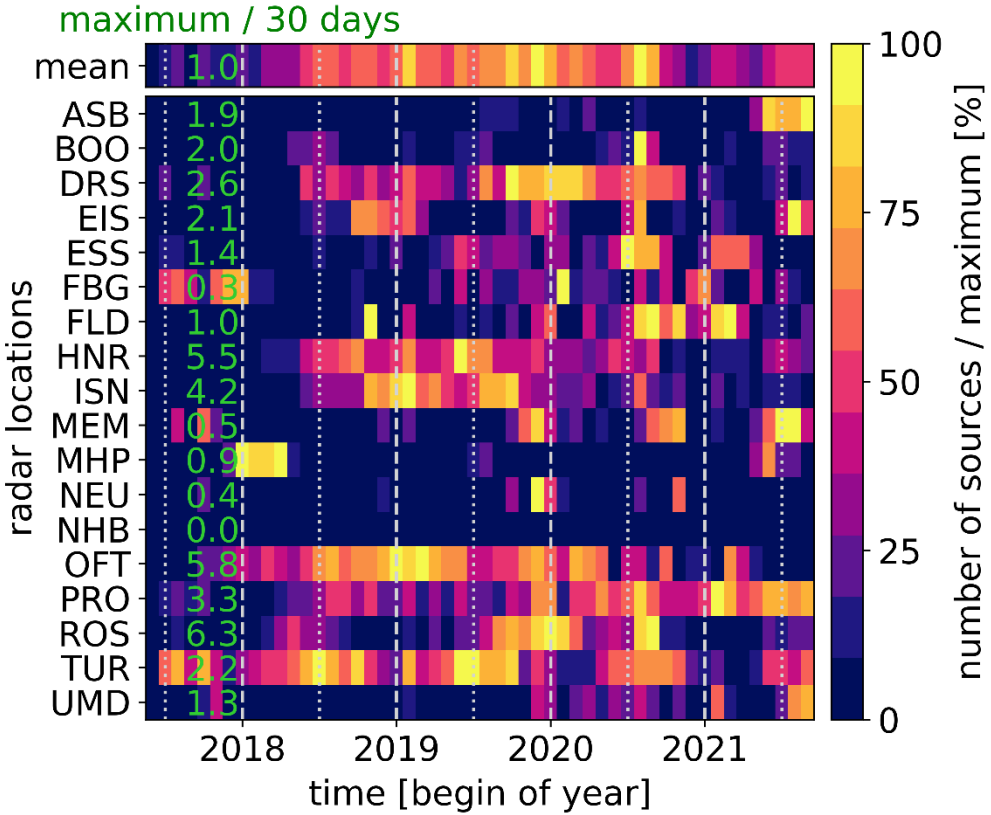
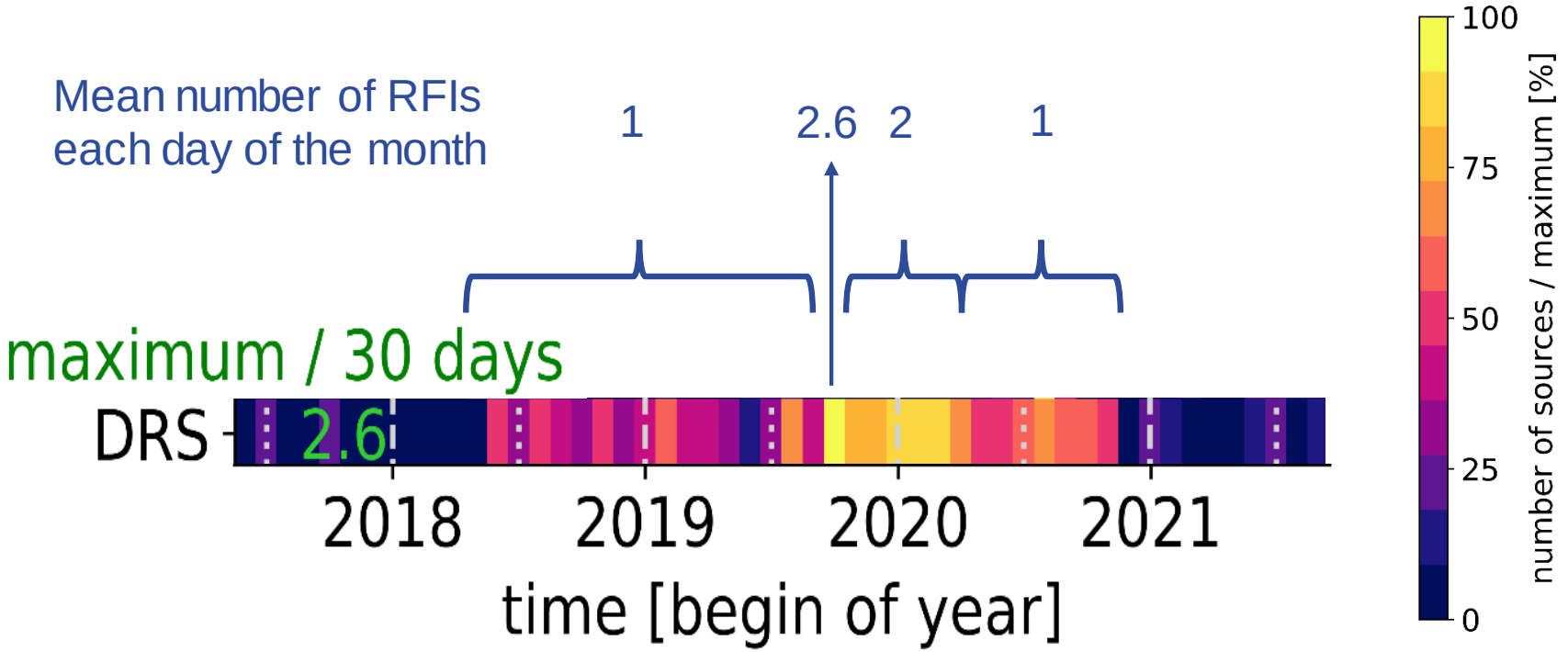
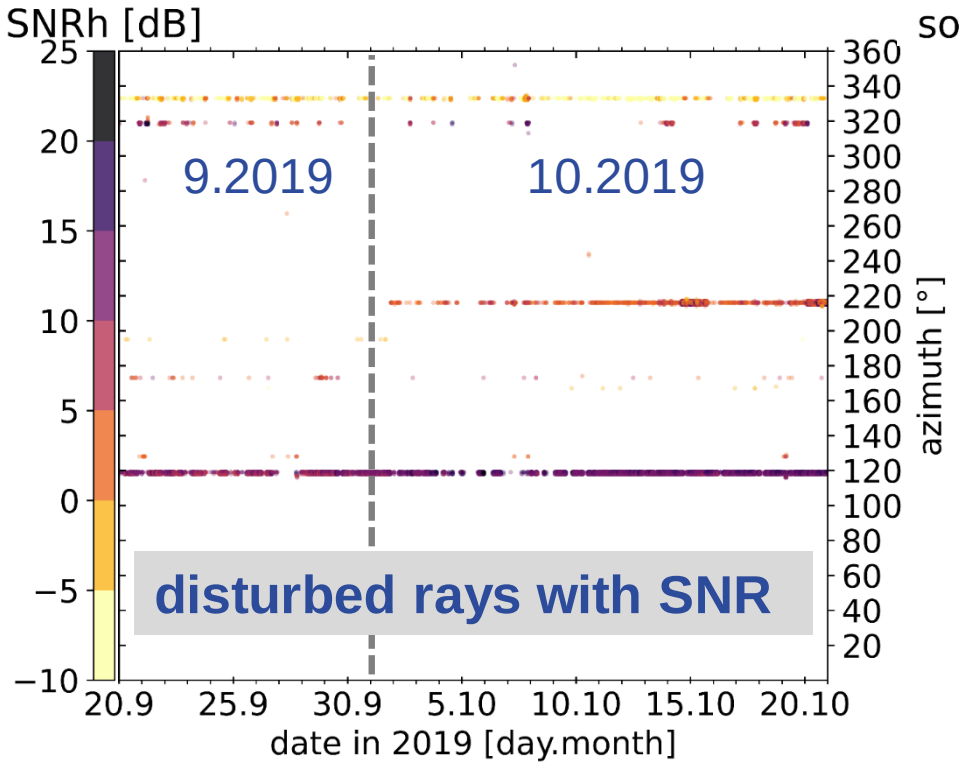
- Heatmap of monthly „RF-interference sources“ for each radar site

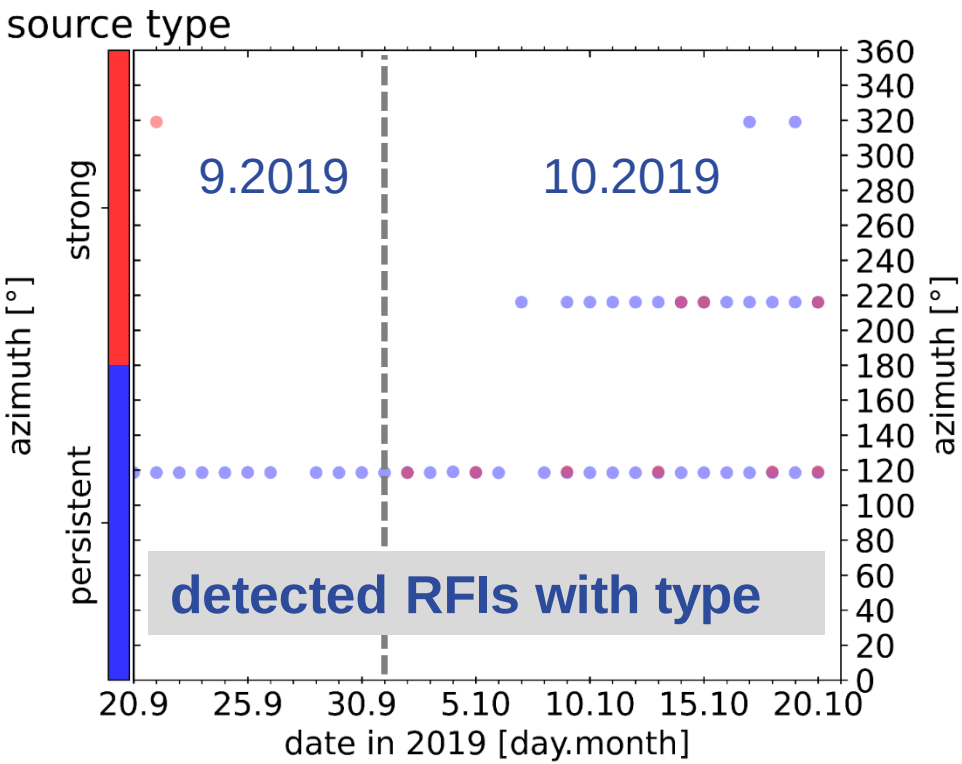


Historic overview of detected RFIs

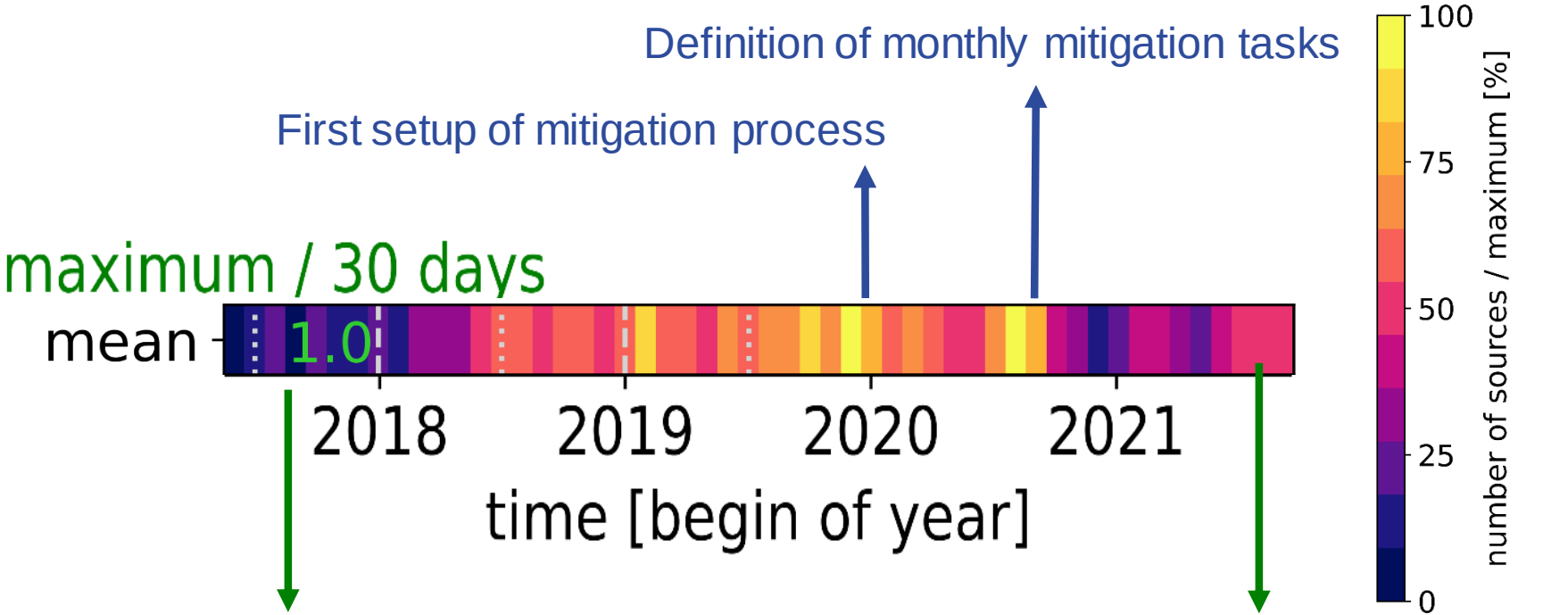


What do 2.6 RFIs look like?





Historic overview of detected RFIs



1.0 == one RFI on average at each of the 18 radar sites

currently ~ 9 RFIs

Conclusion

- We setup a versatile software framework (Python)
  - RHunt control SW can be used as command line tool to aid technicians on site
- Experience with operational mitigation process over 1.5 years is very positive
  - There is always a RFI source to be found if one was detected
  - Persistent RFIs can be removed very effectively
  - But a continuous effort is still mandatory
- Outlook:
  - Test more capable RHunt hardware (power spectrum analysis)
  - Setup a robust analysis of short term RFIs
    - They can **not** be tracked down by NRA, but reporting there existance is important

RFI detection algorithm (1/2)

- detecting „disturbed“ rays
  - „disturbance“ criteria:

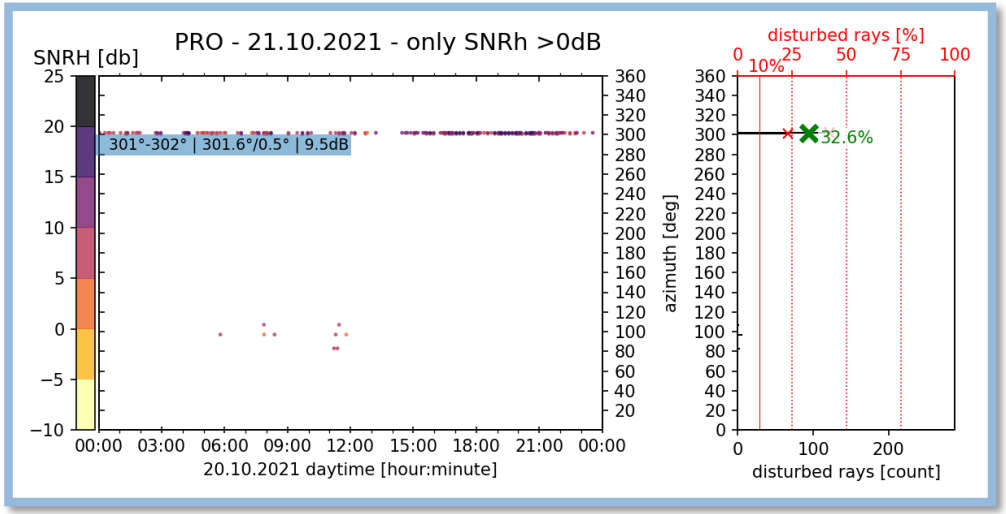
mean $SQI_h < 0.6$	detects non-coherent signals (not reflected - external)
mean $STD_h > 0.6$	detects short pulsed signals (RLAN communication)

  - STD_h => standard deviation of received power within a range gate between single pulses

- NOTE: based on interference detection approach used in the GAMIC signalprocessor „Enigma3p“

RFI detection algorithm (2/2) – Details in Anhang

- identifying interference sources
  - collecting disturbed rays for 24h
  - selecting rays based on SNR_h
  - binning rays based on azimuth
  - grouping neighboring bins above predefined disturbance threshold



- Thresholds:

„persistent“	RFI:	SNRh > 0dB	&	disturbance fraction > 10%
„strong“	RFI:	SNRh > 20dB	&	disturbance fraction > 1%