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Update on Monitoring and Calibration of Slovak Weather Radar Network

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Introduction of Slovak Weather Radar Network *

Basic facts:

- network consists of 4 C-band dual-pol radars METEOR 735 CDP by Leonardo (Fig. 1):
  - **Malý Javorník** (replaced in 2015)
  - **Kojšovská hoľa** (replaced in 2015)
  - **Španí laz** (new site since 2016)
  - **Kubínska hoľa** (new site since 2016)

Fig. 1: Position of radars in Slovak network.
Black – original radar sites, blue – radar sites since 2016.

- central processing system at headquarters comprises of two identical HPE ProLiant DL360 Gen9 interchangeable servers: one for controlling operation and data processing of Slovak radars, another for processing data from 9 foreign radars (3 from Poland, 4 from Hungary, 2 from Czech Republic)
- radar sites are equipped with: UPS ensuring at least 1 hour radar operation, diesel-generator (at Španí laz and Kubínska hoľa with GSM module sending SMS in case of electricity outages or problems), primary and backup broadband internet connection, air-conditioner; new unmanned sites Španí laz and Kubínska hoľa are also equipped with automatic fire suppression system and intrusion alarm system

Transmitter	
Frequency band	C (5430 - 5800 MHz)
Peak power	400 kW
Power supply	~220V-240V/50Hz; 3 phase; nominal input power 8 kW
Type	magnetron
Operating conditions	Temperature: 0 – 50°C Humidity: 10 – 90%
Pulse length	0.5 – 0.83 – 2.0 – 3.3 μs
PRF	200 – 2400 Hz
Dual PRF	2:3 – 3:4 – 4:5
Dual polarization	simultaneous
Waveguide filters	Band pass filter, harmonic filter
Receiver	
Type	Digital GDRX 5
Number of channels	4 (2 per each polarization)
Resolution	16 bit
MDS	≤-120 dBm
Dynamic range	≥130 dB
Noise number	≤2.5 dB
Max. number of bins per channel	≥8000
Intermediate frequency	60 MHz
Sampling frequency	180 MHz
Antenna	
Type	Parabolic with feedhorn
Diameter	4.3 m
Gain	45 dB (nom.)
Beam width	<1.0° (-3dB)
Polarization	Horizontal & vertical
Side lobes	28 dB (min.) below main lobe
Cross-polarization	-32dB
Radome	
Material	Quasi-random sandwich fiber glass panels
Diameter	6.5 m
One-way loss in dry conditions	≤ 0.3 dB
Colour	White
Max. wind	≥200 km/h
Accessories	ICAO obstruction light, dehumidifier

Major technical issues in the network:
Since installation of the new network in 2015-16, we have encountered the following severe and/or repeating issues or failures of the radars components:

- 1 magnetron broken (arcing) in spring 2021, replaced with magnetron from another radar with lower priority. Also other magnetrons show signs of degradation (public procurement for new magnetons in progress)
- Front-end failure on 1 radar shortly after installation (in-warranty repair)
- On all radars repeating measurement outages at midnight due to loss of synchronization between GDRX5 and signal processor – resolved by Leonardo
- On one radar, the Antenna Control Unit (ACU) occasionally cannot be turn on after being put into standby mode from the RCP touchscreen (RCP restart necessary to recover)
- Repeating elevation grease pump failures on 2 radars (stop working then recover after some time), 1 pump set replaced
- Problems with waveguide dehydrators on 3 radars – replaced leaking compressor membranes and 1 whole compressor set
- Azimuth servo drive and motor brake resistor replaced on 1 radar
- Failure of the GDRX5 power supply on 2 radars in 2020 and 2021
- An ACU error disabling antenna movement at higher temperatures in the radome occurring at 1 radar (lost signal from the elevation encoder)
- TR limiters already degraded (increased insertion loss) on 1 radar
- Decrease of magnetron filament voltage below critical level on 1 radar – partially resolved by editing the conversion constant for the filament voltage
- The GDRX-SP failed to boot once on 1 radar due to disk errors
- Leaking waveguide dummy load since installation on 1 radar – replaced by new piece (in-warranty repair)
- Leaking SF6 gas from waveguide filter due to hole in pressure window on 1 radar – replaced pressure window (in-warranty repair)
- 1 rotary joint changed due to high VSWR (in-warranty repair)
- Malfunction of the waveguide switch remote control on 1 radar – resolved by the waveguide switch replacement (in-warranty repair)
- Damaged SD card in the GDRX-SP on 1 radar after power down (diesel generator failed to start)

Overview of current calibration and monitoring techniques at SHMU

Online procedures:

24/7 radar network supervision

- monitoring of basic radars status and products generation by SHMU staff using Rainbow5 software tools (RainVIEW and RainDART)

Detailed radars status check

- check of detailed radars status using Ravis maintenance software and RainLOG tool from Rainbow5 (not all warnings and errors are shown in the RainVIEW tool)

Periodic noise level sampling *

- automatic noise level measurement by means of built-in Zero Check procedure performed every hour
- SHMU modified the Zero Check script to throw away noise samples significantly affected by RLAN interference that produced ray-shaped artifacts in the data. New noise samples are accepted only if their magnitude do no exceed previous sample by more than 25%.

Reflectivity cross-comparison *

- online comparison of reflectivity values between SHMU radars and between SHMU and foreign radars
- monthly scatterplots of reflectivities and 15-day running averages of reflectivity differences are calculated
- in addition to corrected reflectivities also uncorrected (if available) are compared in order to exclude effect of radar beam attenuation correction applied to corrected SHMU data
- for the scatterplots, linear fit equations are calculated from points of maximum frequency of occurrence (instead of complete dataset in which case outliers could shift the results)
- based on the comparison results, an offline harmonization of reflectivity values from SHMU radars was performed in 2018

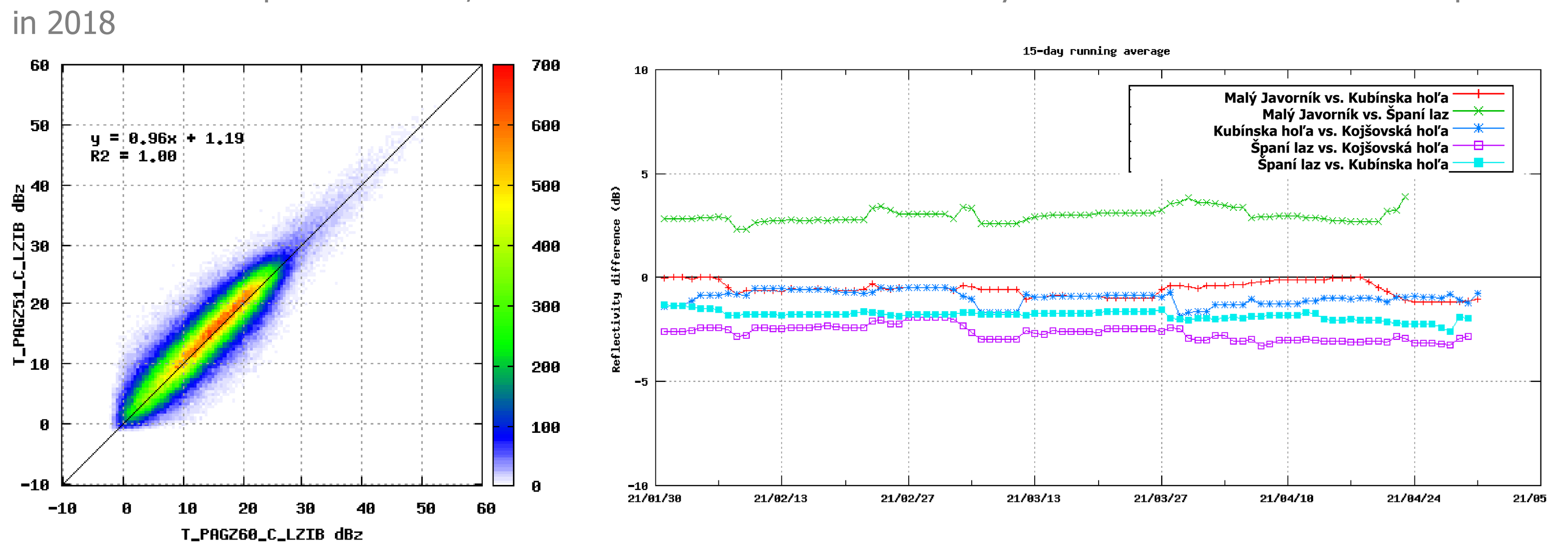

Fig. 2: Example of monthly scatterplot of Z_H values from two SHMU radars Kojšovská hoľa and Kubínska hoľa (left) and 15-day running average of Z_H differences between SHMU radars (right)

- NEW: Added monthly archiving of the plots and history browsing on the monitoring page

OPERA Solar Monitoring

- we use the monthly Solar hits monitoring results provided by OPERA to monitor the antenna pointing accuracy and the RX calibration of our radars

ZDR offset monitoring & correction

- online monitoring of ZDR offset using bird-bath scan performed every 1 hour
- NEW: since June 2020, all 4 SHMU radars are monitored (first 2 radars since 2018 and 2019, respectively)
- bird-bath scan parameters and processing algorithm taken from the Leonardo procedure and slightly modified:
  - bins close to radar antenna are removed from processing so that the results are not influenced by problems with TR limiter (increased recovery time). NEW: The starting range had to be increased from 1.5 km to 2 km and even 3 km for radar Kojšovská hoľa to take into account the TR limiters degradation.
- NEW: offline correction of the system ZDR offset is now performed in case the offset exceeds 0.25 dB for "sufficient" number of bird-bath scans with valid data (exact criteria still to be defined). Results for radar Malý Javorník are shown on Fig. 3. The corrections of the system ZDR offset (marked by green lines) are usually needed after the radar calibration (blue lines in Fig. 3).

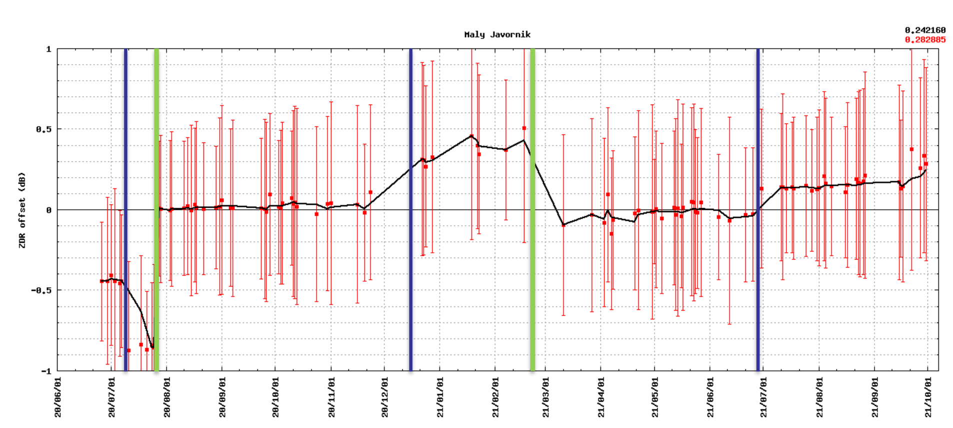

Fig. 3: Daily averaged ZDR offset of radar Malý Javorník obtained from the bird-bath scans. Green lines: offline correction of system ZDR offset, blue lines: radar calibration

- NEW: Added yearly archiving of the plots and history browsing on the monitoring page

Antenna stability monitoring *

- online monitoring of antenna stability based on information stored in volumes
- monitoring of actual antenna elevation angle and start time of each scan is currently performed
- increased scan start times may indicate problems with antenna movement in azimuthal direction (though can be also due to other reasons like signal processor or communication line overload)

TR limiters monitoring (NEW)

- Based on the concept by KNMI presented at WXRCalMon 2019
- Monitoring of daily azimuth averaged TH (ground clutter) reflectivity in the vicinity of the radars
- First 8 range bins (up to 2 km from radar) monitored separately in H and V polarization channels
- Precipitation and wet radome not taken into account
- Example of the output for H channel on radar Kojšovská hoľa is shown in Fig. 4. A decrease of the reflectivity in bins 3-8 was observed in the beggining of May 2020. It was not confirmed, however, that the TH drop was actually associated with the TR limiter degradation.

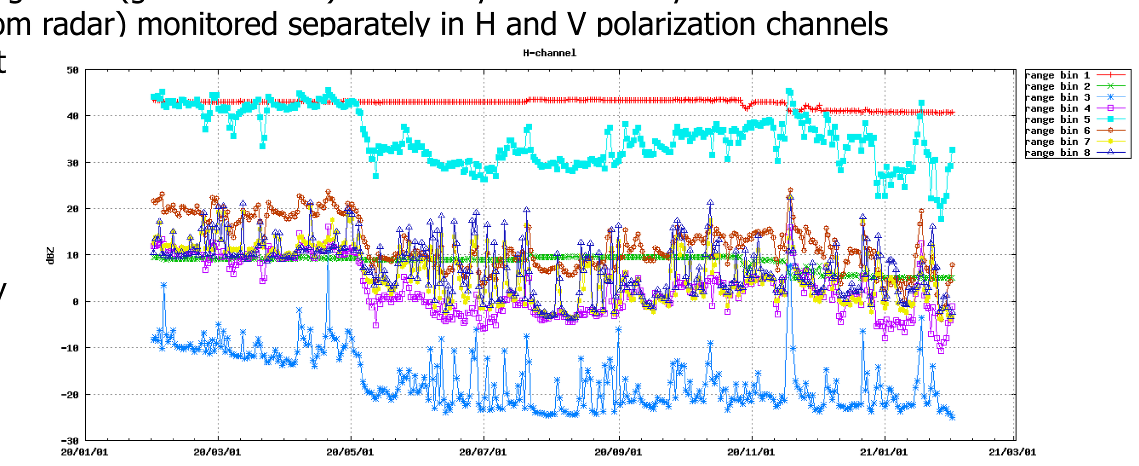

Fig. 4: Output of the TR limiter monitoring of radar Kojšovská hoľa (H channel)

Log files archiving

- Archiving of radar log files from Rainbow on magnetic tapes
- archived messages can be easily viewed in RainLOG utility (Leonardo) after retrieving the log files into dedicated Rainbow subdirectory

RLAN interference monitoring (NEW)

- In August 2020, SHMU started to monitor occurrence of RLAN interference in the operational volumetric data. The RLAN signals are searched in the 5 lowest elevation scans of TH reflectivity according to ray shape similarity criteria. Mean TH reflectivity differences in consecutive rays are calculated for this purpose. The sectors of rays with mean TH gradients exceeding defined threshold and minimum sector width and minimum fraction of ray filled with echo are considered as RLAN signals. Only the bins far enough from the radar are examined to avoid false detection due to ground clutter. No filtering of the Sun signal nor precipitation similar to RLAN signal is performed, so far. Example of the RLAN monitoring output for radar Kubínska hoľa with corresponding unfiltered MAX dBZ image is shown in Fig. 5.

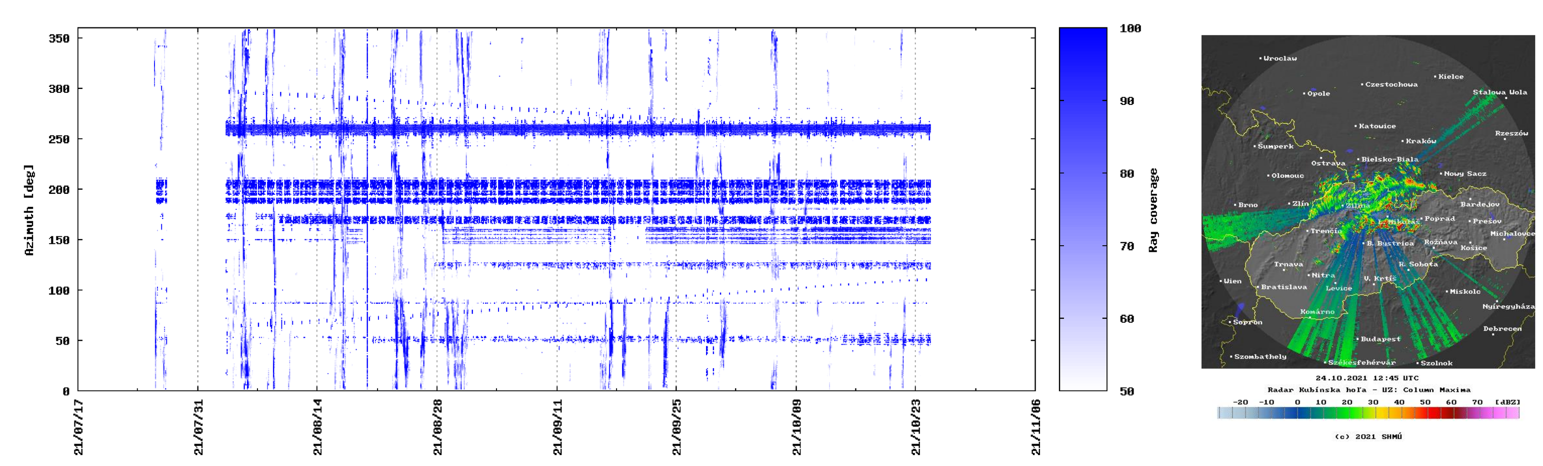

Fig. 5: Left: Output of the RLAN monitoring for radar Kubínska hoľa. The plot represents time series of radar ray coverage with RLAN signal for each azimuth. Right: Example of unfiltered MAX dBZ image from the same radar

- Results of the RLAN monitoring at SHMU are very similar to those provided by OPERA

Offline procedures:

Regular radar maintenance

- preventive technical maintenance including TX and RX calibration is performed by internal technicians every 6 months in accordance with Leonardo manual
- the RX calibration comprises of calibration of the receiver channel difference between high and low sensitive channels and the Single point calibration determining the relationship between power level at reference point (RF frontend input) and ADU value detected by the signal processor
- in addition to prescribed RX calibrations, the linearity and continuity of transfer characteristics of high and low sensitive receiver channels are regularly checked using external signal generator

Solar Raster Scan

- Sun antenna pointing and RX calibration checks by means of built-in Solar Raster Scan procedure in Ravis

RLAN interference measurement

- offline detection of interfering RLAN devices using wi-fi router Mikrotik RB911-5HacD connected to the radar waveguide output
- The process of RLAN detection is partially automated using a script on GDRX5 that reads in the azimuth angles with interference, moves the antenna to the corresponding positions and runs the scan command on the router with output to a file. Another script is used to process all the output files (one per azimuth) and list devices potentially interfering with the radar
- the list of detected devices is reported to the NRA

* more details at: