Radio spectrum monitoring at Ny-Ålesund, Spitsbergen (https://doi.org/10.5880/GFZ.1.2.2024.003)

Carsten Falck[1], Sven Reißland[1]

1. *GFZ German Research Centre for Geosciences, Potsdam, Germany*

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3. Data Description

The published data sets are derived from radio spectrum measurements at GFZ's Satellite Receiving Station at Ny-Ålesund, Spitsbergen (station described in Falck et al., 2020). The engaged radio spectrum monitoring system was designed and installed by GFZ to support analysis, assessments and discussions on local usage of radio system, radio interference issues and radio silence. Radio silence is an important topic at Ny-Ålesund (https://nyalesundresearch.no/research-and-monitoring/researchers-guide/using-radio-frequences/), in order to support and protect the operation of sensible instruments, especially the antennas at the local VLBI station (Very Long Baseline Interferometry). Transmissions at frequencies between 2 and 32 GHz are generally prohibited by Norwegian regulations in a 20 km radius around Ny-Ålesund (with exemptions for safety-relevant applications). This includes all kinds of Wifi/WLAN- and Bluetooth transmissions (2.4 GHz and 5.7 GHz band), both, from consumer electronics and scientific instruments.

GFZ's radio spectrum measurements started mid of September 2023 (commissioning phase) and entered full functionality on 11. October 2023. The monitoring system includes an easy-to-handle, graphical user interface (**https://rsm.gfz-potsdam.de**, online since 1st October 2024) to display graphics from the measurement data, as processed by GFZ. Also, daily plots and raw data are available from the website for user-selectable days and antennas (Fig. 1). We recommend to visit the website to become acquainted with the published data. This publication covers raw data (numerical, full resolution) and data processed by GFZ (graphical, lower resolution). The main components of the measurement system, the measurement procedures and the file structures of the published data are described below.

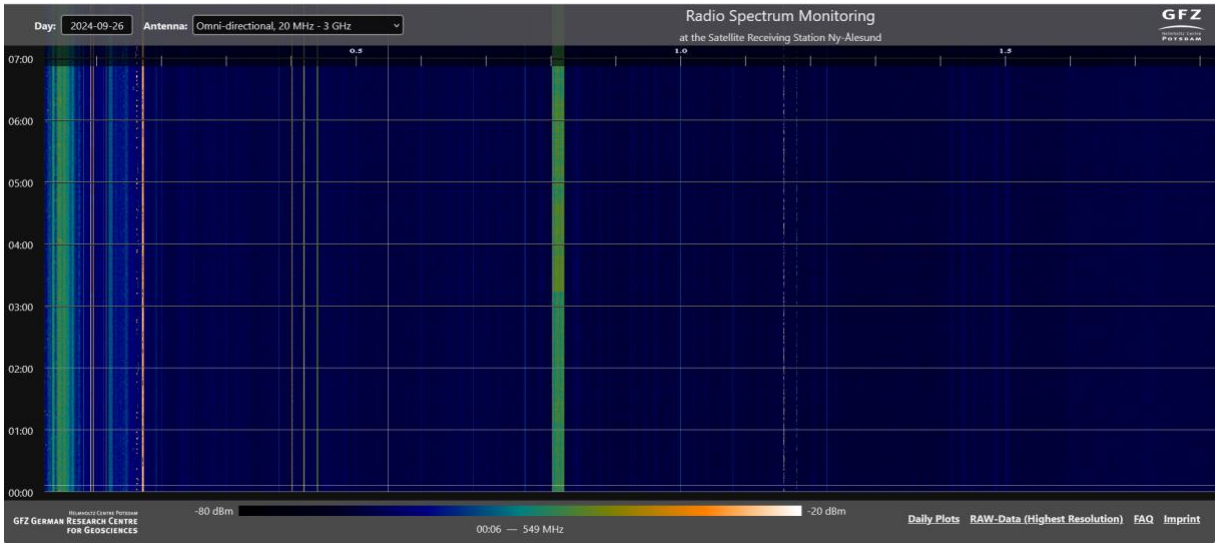

*Figure 1: Screenshot from website **rsm.gfz-potsdam.de***

3.1. Sampling method

The radio spectrum monitoring system uses 3 vertically polarized antennas at different installation points and with different orientations (Fig. 2). An omni-directional active broadband antenna (low noise amplifier integrated) with moderate sensitivity is mounted at the GFZ Satellite Receiving Station cabin. It receives signals almost equally from all directions at frequencies from 20 MHz to 3 GHz. The other two antennas, referred to as 2.4 GHz antennas, are directional by design (higher gain/sensitivity in installation direction), equipped with external low noise amplifiers, and receive frequencies

between 2.2 GHz and 2.5 GHz. This frequency range covers the S-band satellite downlink frequencies, as used onsite by GFZ, Andøya Space and NASA, the 2.4 GHz Wifi/WLAN/Bluetooth-band (used e.g., by consumer electronics and drones) and the nominal frequency of microwave ovens (2.45 GHz). One of these directional 2.4 GHz antennas is installed in the eastward GFZ antenna radome and points to the village of Ny-Ålesund (bearing about 105º, distance about 1 km). The other directional 2.4 GHz antenna is installed in the westward GFZ antenna radome and points to the airport parking area (bearing about 285º, distance about 150 m).

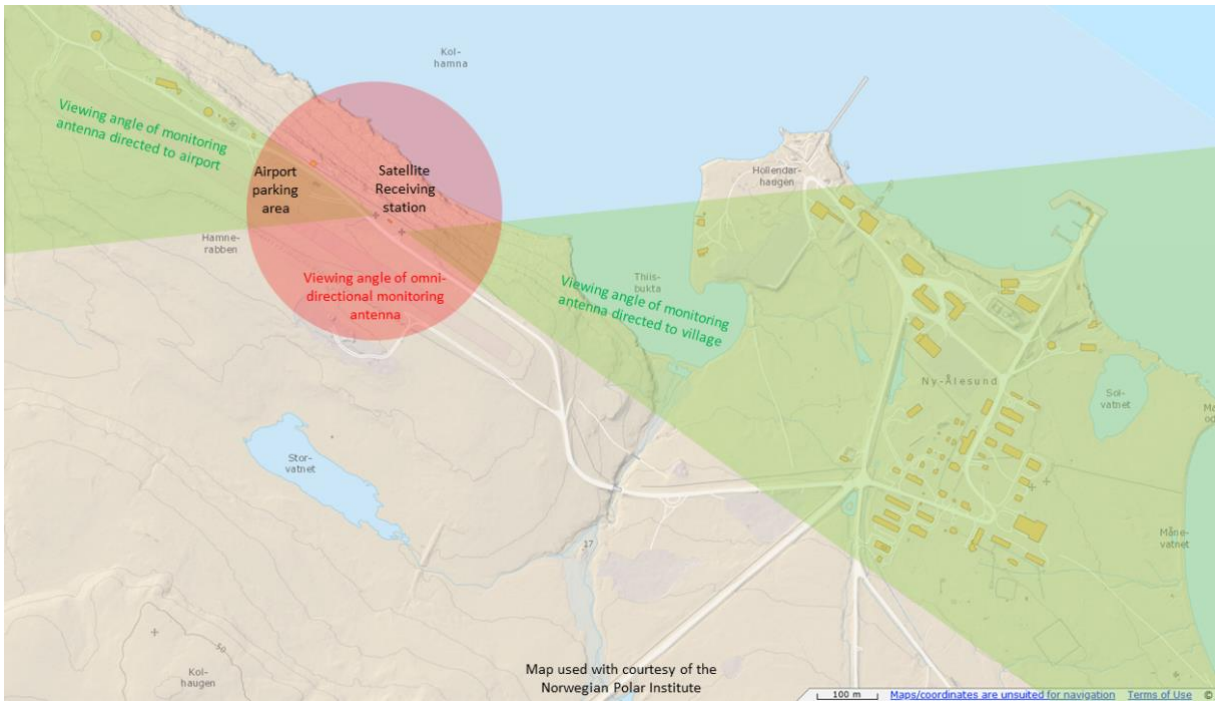

Figure 2: Locations and viewing angles of radio spectrum monitoring antennas at Ny-Ålesund

The three monitoring antennas share one software designed radio (SDR), operated as monitoring receiver, with a dedicated time schedule. The time sharing is realized by a software-controlled antenna switch which connects the receiver to one antenna for 20 seconds, before it is connected to the next antenna, again for 20 seconds, then the third antenna and so on. In consequence all minutes of a day are probed with the same receiver and all antennas, but in different time slots of 20 seconds each.

Within a 20 seconds time slot the receiver repeatedly scans the full frequency range according to the currently connected antenna and records the strength of radio signals over frequency. The scanning is controlled by software which tunes the receiver to probe the currently required frequency range step by step. The step size, respectively the frequency scan interval, is determined by the receiver bandwidth, which is also controlled by software. More than 50 scans per 20 seconds are executed for the 20 MHz – 3 GHz range, with a nominal receiver bandwidth of 100 KHz, and more than 300 scans per 20 seconds for 2.2 GHz – 2.5 GHz, with a nominal receiver bandwidth of 10 KHz. “Nominal bandwidth” refers to the commanded bandwidth, which is not perfectly adjusted in praxis. The real bandwidth, as executed by the receiver, is usually some Khz smaller than the commanded bandwidth, but known (detected) and recorded in the measurement raw data files. These files list the detected signal strength maxima in the scanned frequency range, but not their duration or exact time of occurrence within a 20 seconds slot. At this point the measurement strategy is equivalent to the “max-hold function” of commercial spectrum-analyzers. In consequence singular short pulses might produce

the same measurement data as longer or permanent signals, at least within a 20 seconds time slot, provided that the signals have the same signal strength. It is also possible that temporary or short signals are not detected at all, depending on the currently connected antenna and momentary probed frequency interval.

The radio signal strength values in the raw data files are given on a relative and not calibrated logarithmic scale. They may be used best to monitor and compare the signal strengths of detected signals, while further going conclusion, e.g., on transmission field intensities, may not be derivable directly.

3.2. Data processing

The radio spectrum monitoring system produces great data volumes, which are not easy to examine. Thus, GFZ produces graphical "lookup" files, which are used for the publicly usable web-interface (Fig. 1) and provided for download.

The processed data files (format described in 4.2) are color-coded images (3000 x 120 pixels) in the Portable Network Graphics format (png-files) with a reduced resolution (compared to raw data). About 10 neighbored frequency scan measurements are represented by one graphical data point (1 pixel wide and 2 pixels high). The graphical data points show the maximum measurement values as found in the combined scan intervals. Also, the scale range (dynamic range) of the graphics was limited according to the system's mean noise floor and the maximum strength of signals that were detected during an initial system test-phase. The graphical scale limits were set to -80 dBm and -20 dBm for the broadband measurements between 20 MHz and 3 GHz, and to -75 dBm and -55 dBm for the measurements between 2.2 GHz and 2.5 GHz. Black or white pixels in the processed data graphics may indicate a possible under- or overshooting of these fixed color scales. However, the raw data files contain the full frequency resolution and range of signal strength, as described above, and may be used for more detailed analysis.

3.3. Main components of the radio spectrum monitoring system

The radio spectrum monitoring system was constructed with the components as listed below. None of the components or the complete system setup were calibrated. Antenna characteristics, e.g., antenna factors from data sheets, are not considered to correct measurements or data.

A "HackRF One" software defined radio (SDR) with attached "Opera Cake" antenna switch, both distributed by "Great Scott Gadgets", is operated as monitoring receiver and controlled by software developed at GFZ (as explained above).

One "HE500" active antenna from "Rohde & Schwarz" is used for the broadband measurements (20 MHz-3 GHz).

Two "SPA-2400/75/9/0/V" directional passive antennas from "Huber and Suhner" are operated between 2.2 and 2.5 GHz. The specified viewing angels (3dB beamwidth) for this antenna type are 75º horizontal and 60º vertical. Each of the antennas is directly connected to a LNA (low noise amplifier) "Modell 2223 AH" manufactured by the company "Kuhne electronic GmbH" (NF: 0,5 dB or better, gain: 30 dB).

About 8 m coaxial cable were used to connect the broadband antenna and about 30 m coaxial cable for each of the both 2.4 GHz antennas (cable type "Ecoflex 10").

4. File description

Raw data sets are sorted into yearly subfolders. Processed data sets are sorted into subfolders for years and antennas respectively frequency ranges.

4.1. Raw data structure and naming convention

Folder structure of daily raw data files (explained below):

```
2023
2024
└── gfz-nya-rsm_2024-03-17.zip
    ├── 0_20_3000_100000_40_0
    │   ├── freq
    │   ├── 00.zip
    │   │   ├── 2024-03-17T00-00-28Z_2024-03-17T00-00-47Z_52_30396
    │   │   ├── ...
    │   │   └── 2024-03-17T00-59-16Z_2024-03-17T00-59-36Z_52_30396
    │   ├── 01.zip
    │   │   ├── 2024-03-17T01-00-18Z_2024-03-17T01-00-37Z_52_30396
    │   │   ├── ...
    │   │   └── 2024-03-17T01-59-06Z_2024-03-17T01-59-25Z_52_30396
    │   ├── 02.zip
    │   │   ├── 2024-03-17T02-00-08Z_2024-03-17T02-00-27Z_52_30396
    │   │   ├── ...
    │   │   └── 2024-03-17T02-59-57Z_2024-03-17T03-00-17Z_52_30396
    │   ├── 03.zip
    │   │   ├── 2024-03-17T03-00-59Z_2024-03-17T03-01-19Z_52_30396
    │   │   ├── ...
    │   │   └── 2024-03-17T03-59-48Z_2024-03-17T04-00-07Z_52_30396
    │   ├── 04.zip
    │   │   └── ...
    │   ├── ...
    │   └── 23.zip
    │       └── ...
    ├── 1_2200_2500_10000_40_0
    │   ├── freq
    │   ├── 00.zip
    │   │   ├── 2024-03-17T00-00-48Z_2024-03-17T00-01-08Z_343_30060
    │   │   ├── ...
    │   │   └── 2024-03-17T00-59-36Z_2024-03-17T00-59-57Z_335_30060
    │   ├── 01.zip
    │   │   └── ...
    │   ├── ...
    │   └── 23.zip
    │       └── ...
    └── 2_2200_2500_10000_40_0
        ├── freq
        ├── 00.zip
        │   ├── 2024-03-17T00-00-07Z_2024-03-17T00-00-27Z_331_30060
        │   ├── ...
        │   └── 2024-03-17T00-59-57Z_2024-03-17T01-00-17Z_331_30060
        ├── 01.zip
        │   └── ...
        ├── ..
        └── 23.zip
            └── ...
```

All raw data of a day are sorted into zip-compressed daily files which are named with “gfz-nya-rsm” (GFZ radio spectrum monitoring at Ny-Ålesund) followed by the date of the measurements.

```
gfz-nya-rsm_yyyy-mm-dd.zip

yyyy = year
mm = month
dd = day
```

Example: gfz-nya-rsm_2024-03-17.zip

The daily raw data files contain one folder for each antenna. The antennas (code numbers given below) are operated in different frequency-ranges which are scanned with different sample intervals. These parameters are part of the folder names, as well as the “HackRF” receiver settings (described at **https://hackrf.readthedocs.io/en/latest/faq.html#what-gain-controls-are-provided-by-hackrf**, last accessed on 24.4.2024).

```
Antenna code numbers:

0 = omni-directional antenna
1 = directional antenna directed to airport
2 = directional antenna directed to village

Example:

0_20_3000_100000_40_0_amp

^                              omni-directional antenna
  ^                            frequency scan starts at 20 MHz
     ^                         frequency scan stops at 3000 MHz
          ^                    scan range is scanned in 100000 Hz intervals
                ^              receiver intermediate frequency gain (dB)
                   ^           receiver VGA baseband gain (dB)
                     ^         receiver internal amplifier on (RF gain)
```

Each folder for one antenna contains 24 zip-files for all hours of a day and one file with a list of scanned frequencies, which applies to all measurement data files in that folder. The first value in each measurement file refers to the first frequency value in the freq-file, and so on, until the last measurement value. The frequencies are listed as 64-bit big-endian integers and indicate the lower edge frequencies of scanned frequency intervals.

Individual data files in the hourly zip-files contain the recorded radio signal maxima (one 32-bit big-endian float value per frequency scan interval) as detected between the start- and stop-times of the measurement (nominally 20 second intervals) in which a certain number of scans were executed (e.g., 52) over a certain number of discrete frequencies (e.g., 30396). The data files are named according to the described parameters.

Example:

2024-03-17T00-00-28Z_2024-03-17T00-00-47Z_52_30396:

```
^                                                  scan start time (UTC)
                    ^                              scan stop time (UTC)
                                          ^        number of scans
                                             ^     scanned frequencies
```

4.2. Processed data structure and naming convention

Raw data is processed by GFZ to graphic files in the Portable Network Graphics format (png-files). Each png-file covers the measurements of one antenna over one day with a resolution and range as described in 3.2 and is named to the day of measurements accordingly (yyyy-mm-dd). All daily png-files are sorted in yearly folders which are named accordingly to the year and the used antenna and scan settings.

Folder structure of daily raw data files:

```
├── 2024-0_80_3000_100000_40_0
│   ├── 2024-01-01.png
│   ├── 2024-01-02.png
│   ├── 2024-01-03.png
│   ├── …
│   ├── 2024-01-30.png
│   ├── 2024-01-31.png
├── 2024-1_2200_2500_10000_40_0
│   ├── 2024-01-01.png
│   ├── 2024-01-02.png
│   ├── 2024-01-03.png
│   ├── …
│   ├── 2024-01-30.png
│   ├── 2024-01-31.png
└── 2024-2_2220_2500_10000_40_0
    ├── 2024-01-01.png
    ├── 2024-01-02.png
    ├── 2024-01-03.png
    ├── …
    ├── 2024-01-30.png
    └── 2024-01-31.png
```

Example for naming of folders:

```
2024-0_20_3000_100000_40_0_amp
^                            year of measurements
     ^                       omni-directional antenna (antenna code = 0)
       ^                     frequency scan starts at 20 MHz
          ^                  frequency scan stops at 3000 MHz
               ^             scan range is scanned in 100000 Hz intervals
                     ^       receiver intermediate frequency gain (dB)
                        ^    receiver VGA baseband gain (dB)
                          ^  receiver internal amplifier on (RF gain)
```

5. References

Radio spectrum monitoring system user interface and data access point

https://rsm.gfz-potsdam.de

Restrictions on the use of radio transmitters at Ny-Ålesund

https://nyalesundresearch.no/research-and-monitoring/researchers-guide/using-radio-frequences/

List of frequencies used at Ny-Ålesund

https://nyalesundresearch.no/wp-content/uploads/2024/04/frekvensoversikt-nya.pdf

Documentation for "HackRF" software defined radio

https://hackrf.readthedocs.io/en/latest/index.html

Homepage of Satellite Receiving Station Ny-Ålesund

https://www.gfz-potsdam.de/srs-nya

Description of satellite data reception at GFZ's ground station at Ny-Ålesund

Falck, C., Reißland, S., Snopek, K., Massmann, F.-H. (2020): Satellite data reception at Ny-Ålesund, Spitsbergen: From CHAMP to GRACE Follow-On. - ZfV: Zeitschrift für Geodäsie, Geoinformation und Landmanagement, 145, 2, 111-117. https://geodaesie.info/images/zfv/145-jahrgang-2020/downloads/zfv_2020_2_Falck_et-al.pdf, https://doi.org/10.12902/zfv-0290-2020