COMBIT

SIMon International System

Technical specification

Created by

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SIMon International System

1. Design goals and feature overview of the SIMon system

Equipment vendor independence

During the development of the SIMon system, the most important design goal was to deliver a measurement system that is capable of uniform, full-scale integration of new measurement devices from independent equipment vendors into the system by implementing a device's drivers based on a common SIMon driver development SDK.

Web-based user interface

We decided that the system's user interface must run in all major Web browsers (Google Chrome, Mozilla Firefox, Microsoft Edge) and should not require other installation on the client-side. To develop the user interface, we chose a commercially supported, professionally maintained JavaScript framework (Sencha Ext JS) that allows the developers to build a browser-independent Web application. The Sencha Ext JS framework accelerates web application development with an enterprise-ready framework, an extensive, pre-built UI component library, and tools built to work together seamlessly.

Because the most important task of the user interface is to support the display and analysis of large (even up to 200 million data points) measurement results, we decided that the integrated Spectrum and Signal Analyzer must use the parallel processing capabilities of the GPU on the client to handle huge amounts of data efficiently. Based on this requirement, we implemented the Spectrum and Signal Analyzer component using the standard WebGL v2.0 library. The Web Graphics Library version 2.0 is a JavaScript API for rendering high-performance interactive 3D and 2D graphics within any compatible web browser without the use of plug-ins.

Fixed and mobile stations with offline measurement support

We designed the SIMon system in such a way that it can integrate and supervise a measurement network consisting of fixed and mobile measurement stations with the help of a ***Central controller*** module and ***Station controller*** modules.

The ***Station controller*** module installed on-site at the measurement station guarantees the full use of all integrated measurement devices and controlling devices (like antenna switch/rotator) even if the measurement station is in offline mode (cannot access the central controller software). The ***Station controller*** module can also be installed in a remote location (for compact measurement stations without a local PC) and provides the same measurement and control capabilities, but it requires an online connection with the measurement station.

Device integration

The integration of new devices (whether coming from a different manufacturer or a new device by an already-supported manufacturer) to the system should not require the modification of the basic system (the ***SIMon measurement controller***), only the development of a new driver based on existing drivers and or using the SIMon driver development SDK.

With the help of the SIMon device drivers, the ***SIMon measurement controller*** can cooperate with the following device families:

- Measuring receivers,
- Antenna switches and antenna rotators,
- Direction-finders,
- Digital broadcasting transmission monitors (e.g., DVB-T/T2),

- GPS devices,
- Devices providing meteorological data.

Currently, we have integrated and developed drivers for the following devices:

- **NARDA**: SignalShark 3310, 3320, 3330,
- **Rohde & Schwarz**: DDF-550, DDF-255, EB-500, EM-550, EM-100, ESMB, GB-127, GB-127M, RD-127, ZS-127,
- **IZT**: R3000 series,
- **CRFS**: RFeye Node 20-6, 50-8, 100-8, 100-18,
- **CommsAudit**: Spectra SRDF, CA4909-1,
- **STMM**: KM44 and KM88 switch, RK3 rotator,
- **Compu-Consult**: TELE-OPERATOR UTS v.16 DVB-T/T2 Dual LAN monitor,
- **Boreas**: Weather station.

Measurement modes and data storage

The ***SIMon measurement controller*** supports the issuing and execution of direct measurement tasks at the integrated measuring stations and measuring devices. In the case of direct measurement, the operator can access the devices and their settings via the user interface and can receive "real-time" feedback on setting changes by the resulting measured data.

The ***SIMon measurement controller*** also supports the issuing and the execution of automated, scheduled measurement tasks at the integrated measurement stations and measurement devices. The integrated scheduler supports:

- The execution of measurement tasks at the specified time/times based on task definitions devised in advance, without operator interference,
- Parallel task execution,
- Parallel resource usage (if the devices used for the tasks support it),
- Prioritized task execution.

The data generated during measurements is stored in uniform data format, regardless of which manufacturer's device was used for the measurement. The measurement data is stored at the measurement station, but the system also provides the option for on-demand automatic synchronization of the results to the central server.

Real-time measurements

The SIMon system is designed from the ground up to deliver the measurement results from the equipment to the user interface with optimal throughput and minimal latency. This design allows for “real-time” measurements.

During the system development we used the Akka toolkit which allows building highly concurrent, distributed, and resilient message-driven applications. Using the Akka toolkit we can use multiple threads in the driver development, to receive, decode, postprocess the measurement results from the receivers.

We also optimized the connection between the measurement stations and the user interface, to compress the data transmitted (lossless compression) and we are sending multiple packets of data simultaneously to reduce latency.

The user interface is also optimized for fast data processing and display, we use the GPU to parallelly process huge amounts of data.

Based on this design decisions and the optimized implementation we feel confident that our software does can handle the data acquisition speed of modern receivers.

The “real-time” operation is only limited by the used hardware, like switches, routers, network speed and latency…

User workflow

The starting page of the user interface is the integrated map (Google Maps or OpenStreetMap) which displays the integrated measurement stations. The main work processes of the system are initiated from the map:

- All integrated measurement stations are be displayed on the map, colour-coded for current status.
- Measurement locations and licensed and coordinated transmitters are displayable on the map.
- When selecting a measurement station, the system displays a window containing the available antennas and measurement devices, their current connections, and the list of scheduled and direct measurement tasks running on the selected station.

After selecting a measurement station, the user can perform the following task:

- Initiate a new measurement with the selected antenna and measurement device,
- Connect directly to the ***Station controller*** and configure the Station in a new window,
- View the measurement results.

Configuration

The system provides a uniform, centralized solution for the management of configuration data:

- System parameters,
- Central configuration data:
    - Measurement stations,
    - Places of measurement,
    - Transmitter data,
    - Measurement bands.
- Measurement station configuration data:
    - Antennas,
    - Devices,
    - Signal paths (valid antenna and device connections).

User identification and authorization

The system's functions are accessible only to identified users who must be identified with a username and password pair. Users and their authorizations are recorded and managed centrally.

The authorization system is role-based. During development, we define a set of basic rights or entitlements that secure the menu functions of the user interfaces and also the rights for calling functions or editing privileges. These privileges can be grouped into user-configurable roles, and the roles are assigned to the users.

Authentication of users logging in from the user interface and authorization at the start of each subprogram or function call is performed by the ***Central- or Station controller*** (based on the entitlements, rights derived from the roles assigned to users) depending on whether the user connects to the URL of the ***Central controller*** or the specified ***Station controller***.

For the sake of autonomous (offline) operation, the ***Station controller*** has a synchronized, encrypted local copy of the central user and authorization records.

The user authentication in the SIMon system can be integrated with an existing Active Directory (AD) server or other LDAP servers (e.g., Open LDAP).

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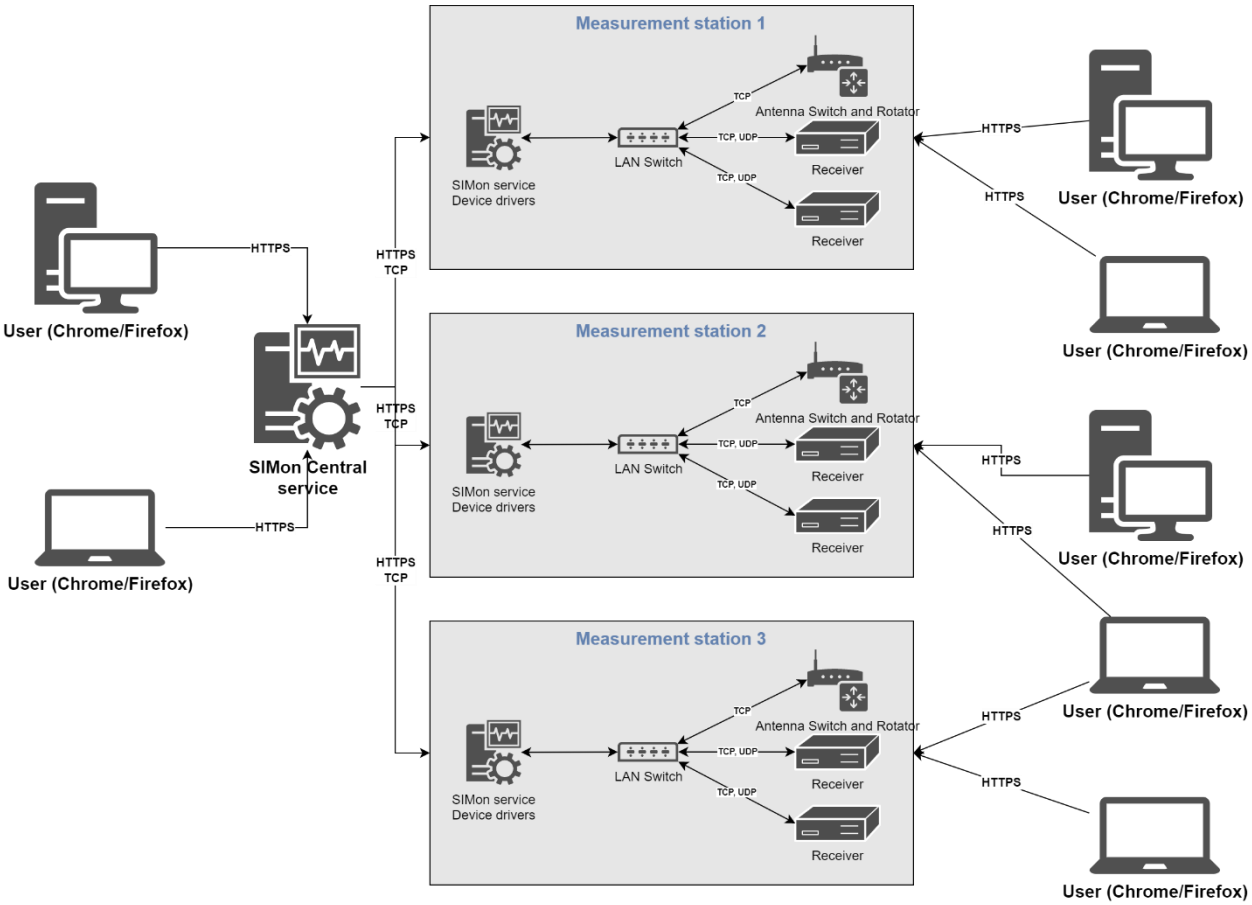
2. Logical operation model, system architecture

The SIMon system is designed in such a way that it can integrate and supervise a measurement network consisting of fixed and mobile measurement stations with the help of a module acting as a ***Central controller***.

The ***Central controller*** can perform the following tasks with the integrated fixed and mobile measuring stations managed by their own ***Station controller***:

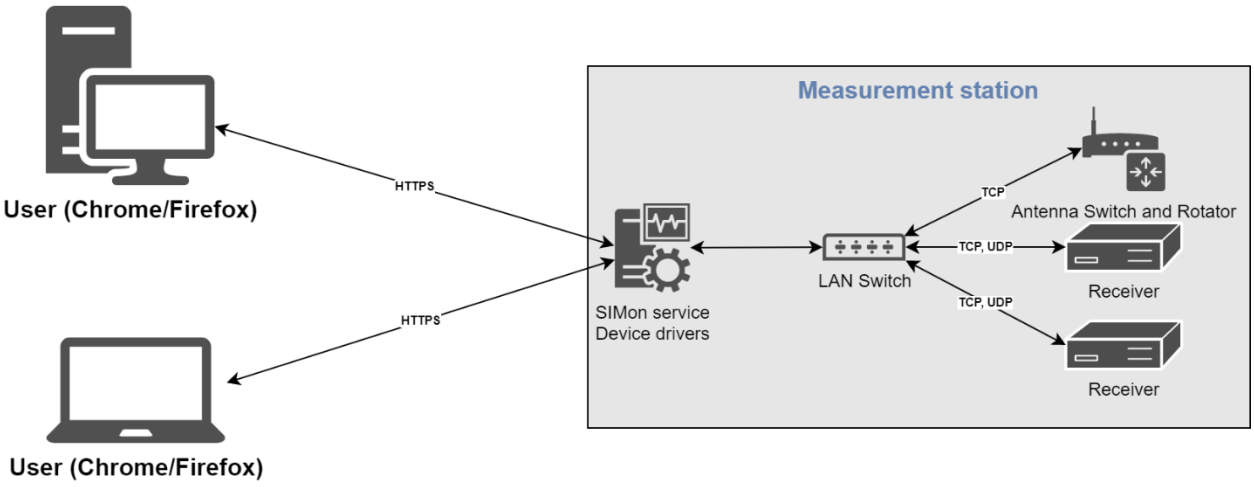
- Automatic registration of the newly installed measuring stations and storage of the configuration of the measuring stations in the Central system.
- Supervision of the measuring stations by scheduled (at least every 3 minutes) status information exchange provides an overview of the status of the stations and measuring devices.
- Synchronization of scheduled measurement tasks and the measured data.



The ***Station controller*** can:

- Manage and supervise the devices installed at the measuring Station:
  - Antennas,
  - Antenna switches and rotators,
  - Monitoring measurement receivers,
  - Direction finders.
- Connect automatically to the ***Central controller*** and reconnect in case of an error, and send the current measuring station configuration and status information,
- Support the execution of direct and automated (scheduled) measurements, even if the central Station is not available (is offline),

- Store and process the measurement results even if the central Station is not available (is offline),
- Provide offline map data and services (based on locally stored OpenStreetMap data).



The ***Central controller*** and the ***Station controllers*** running on the measuring stations provide a separate, standalone user interface accessible by a browser, which allows the complete management of the measurement system.

Using the user interface provided by the ***Central controller***, all online measuring stations can be fully controlled.

The user interface provided by the ***Station controller*** supports the following tasks also in offline mode (without connection to the ***Central controller***):

- The management of all integrated devices at the Station,
- The execution of direct and scheduled measurements,
- The graphical display and analysis of the measurement results.

3. Features in detail

Internationalization and localization

The user interface elements, the notifications /message texts are translated to English, French, Dutch and Hungarian.

Authorization

The system's user interface pages and functions are accessible only to authenticated users, who have the **basic right** to use the selected user interface or functionality.

Users and their authorizations are recorded and managed centrally.

The authorization system is role-based. During development, we define a set of **basic rights** or **entitlements** that secure the menu functions of the user interfaces and also the rights for calling functions or editing privileges. These privileges can be grouped into user-configurable **roles**, and the **roles** are assigned to the users.

At the start of each subprogram or function call, an authorization check is performed by the ***Central- or Station controller*** (based on the **basic rights/entitlements** derived from the **roles** assigned to users).

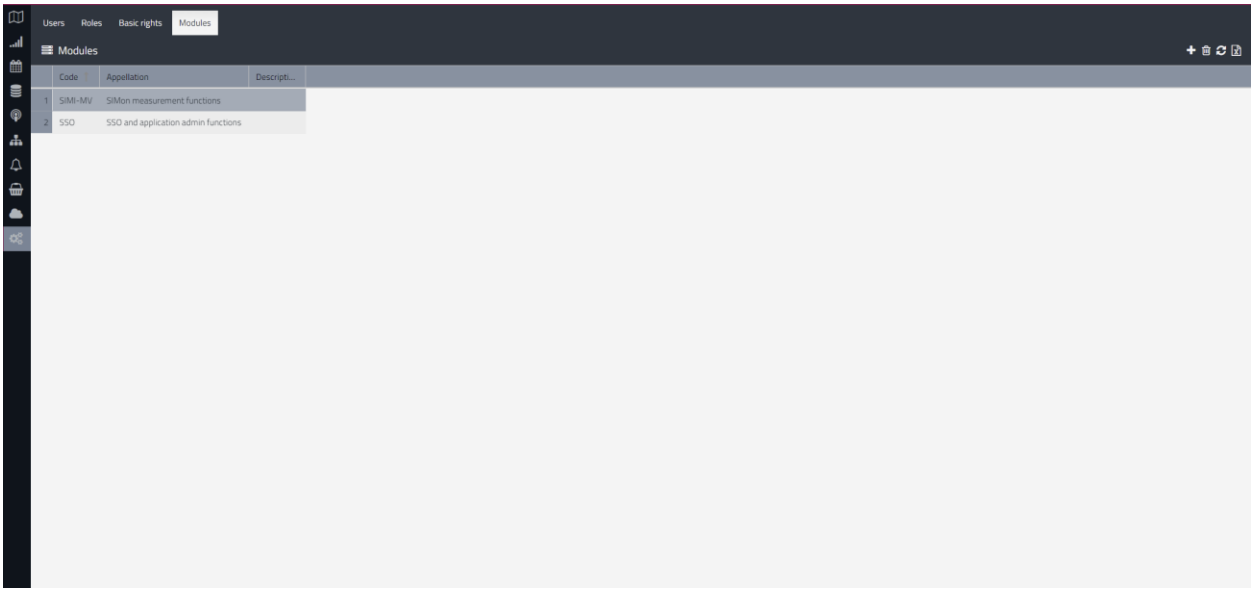
If the user doesn't have the proper **basic rights/entitlements** necessary to access the desired user interface or function, then the function menu/button is greyed out.

Entitlement management

The user interface for the Entitlement management is accessible only to the users with the "SSO and application admin functions - System administrator (SSO)" role.

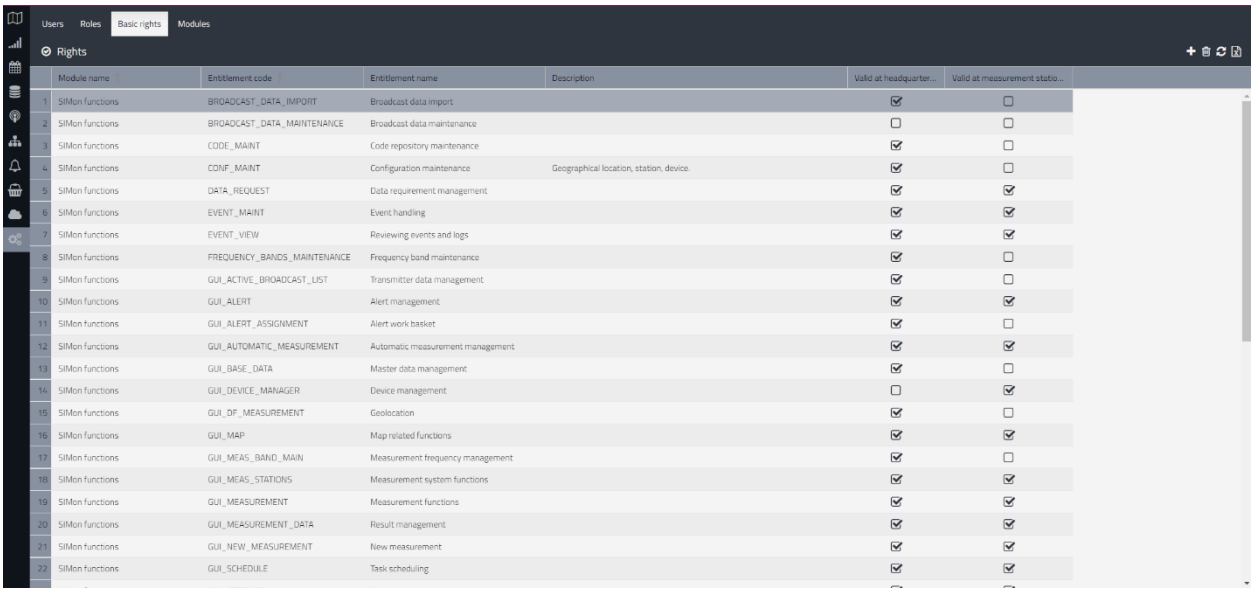
The entitlement management user interface contains the following tab pages:

Modules



The modules are used to separate the authentication/authorization components from the measurement components.

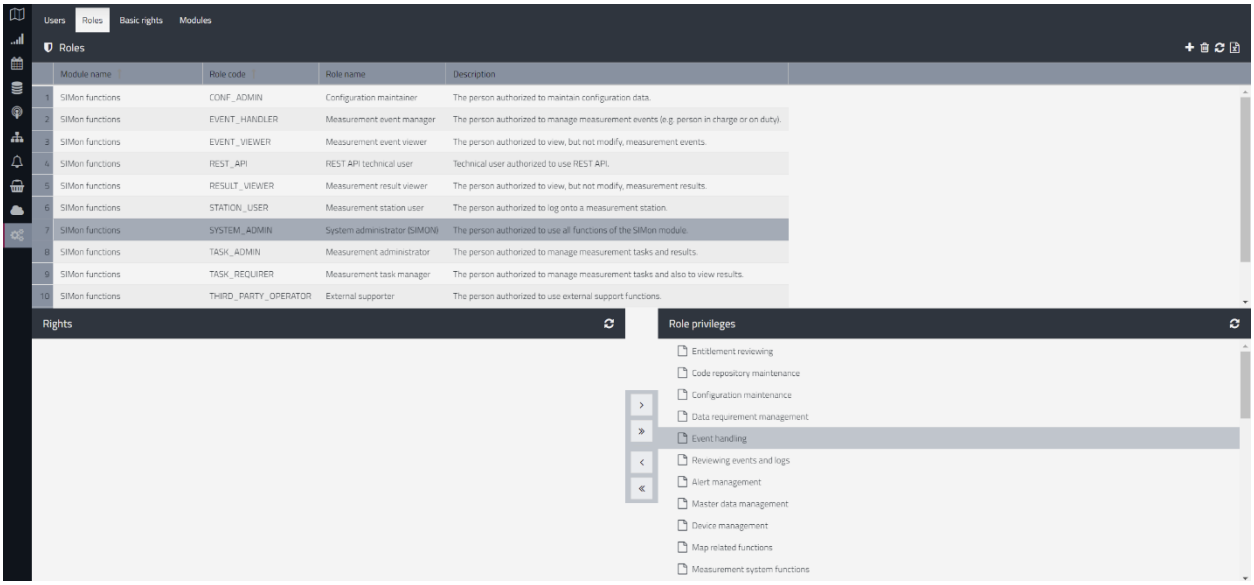
Basic rights



The basic rights page contains all the rights/entitlements associated with the system functions.

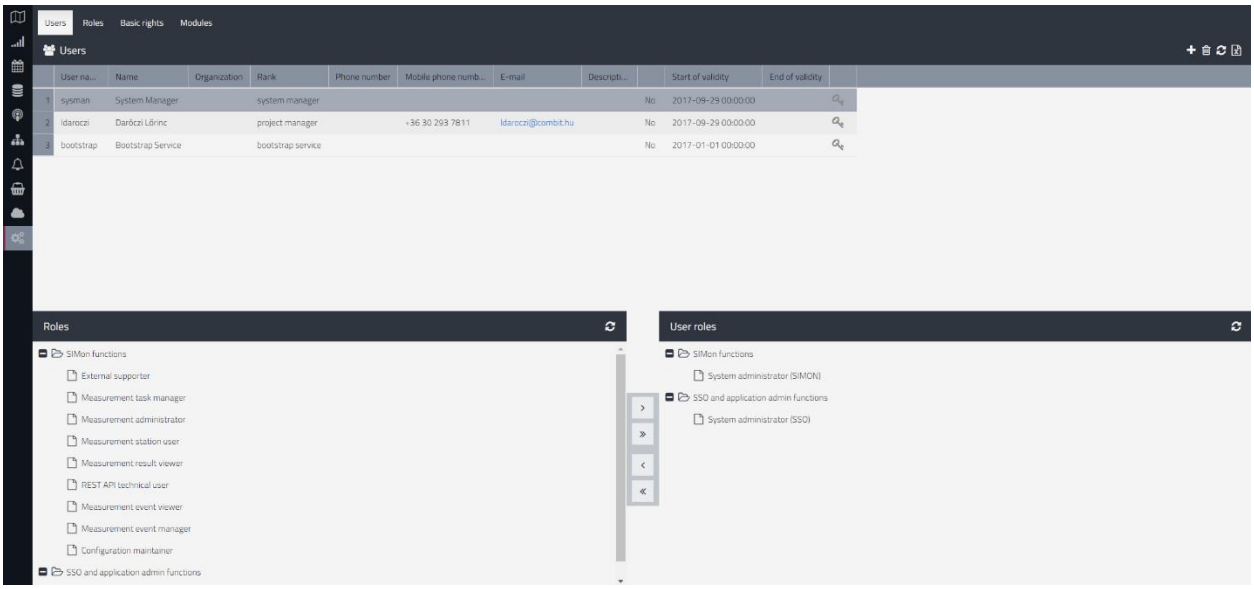
For example, if the user wants to configure the measurement station settings, then he must have access to the **CONF_MAINT** right/entitlement. The **CONF_MAINT** right/entitlement is assigned to the “SIMon measurement functions - System administrator (SIMON)” role.

Roles



From the basic rights/entitlements the admin users can create new roles or reconfigure existing roles to create a security policy specific to their organization.

Users



The Users page is used to manage the users who can access the system.

Each user can have multiple roles which determine the users access to the SIMon system functions.

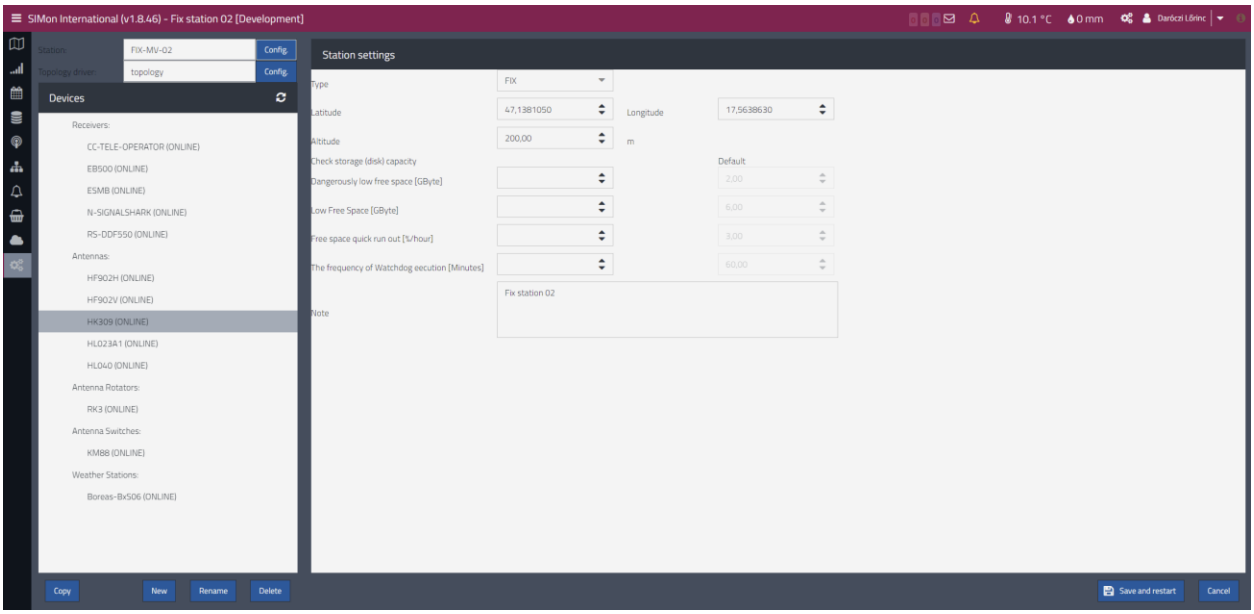
The SIMon system ships with some predefined users and roles, but they can be customized by our customers. The predefined access policies only allow administrators the options to configure the system settings, measurement station configuration, equipment configuration, ….

Station configuration

A measurement station can be configured by a user with “SIMon measurement functions - System administrator (SIMON)” role.

The station configuration interface supports the following settings:

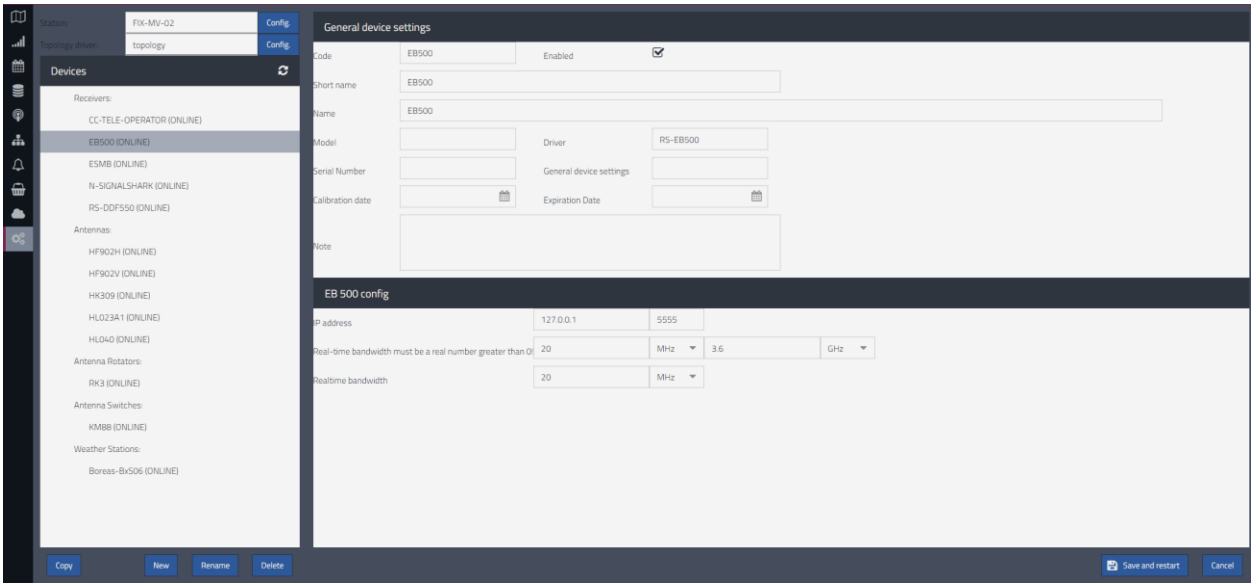
Station configuration panel



The station configuration panel contains the general configuration of the station, as seen on the screen above.

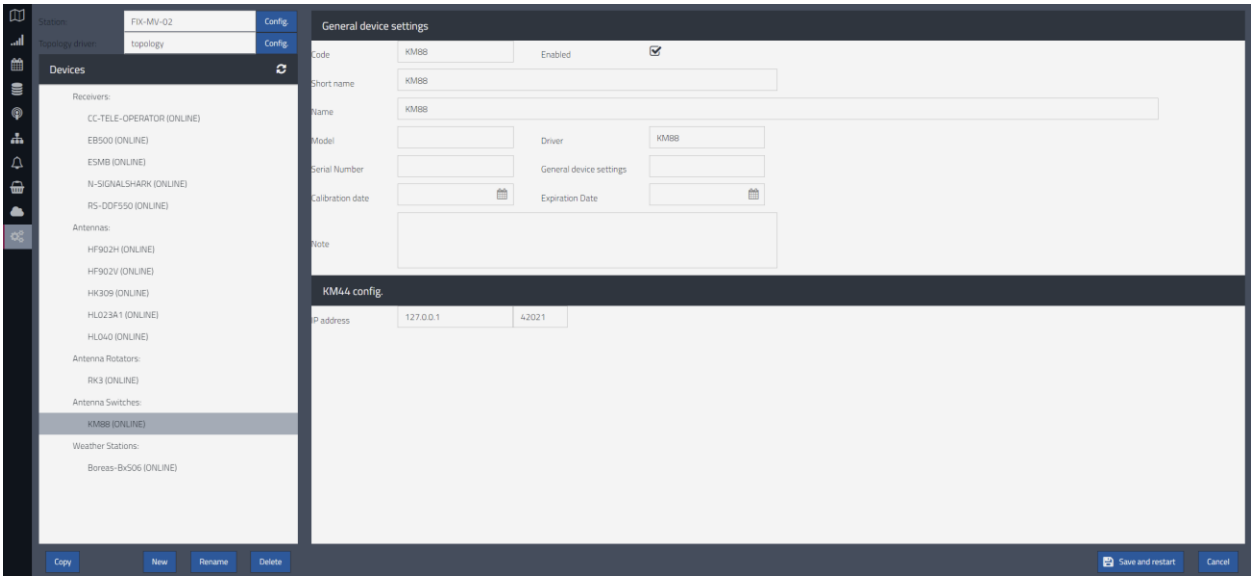
Device configuration panel

Receivers

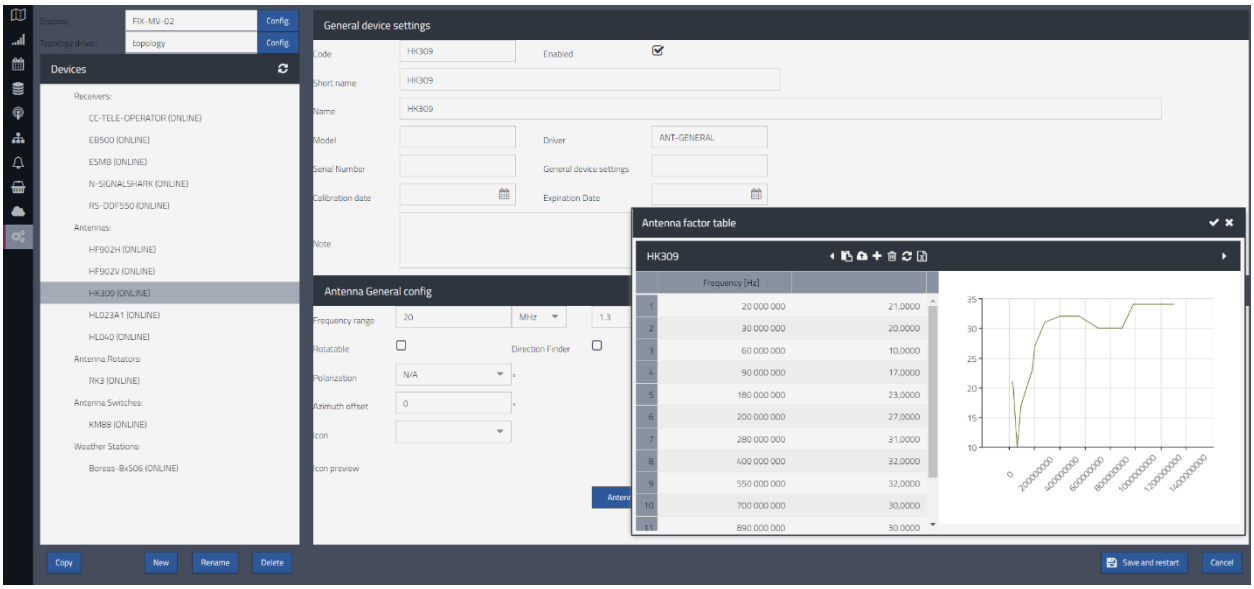


The receivers available on the station can be configured by using the devices panel.

Antenna switches and rotators



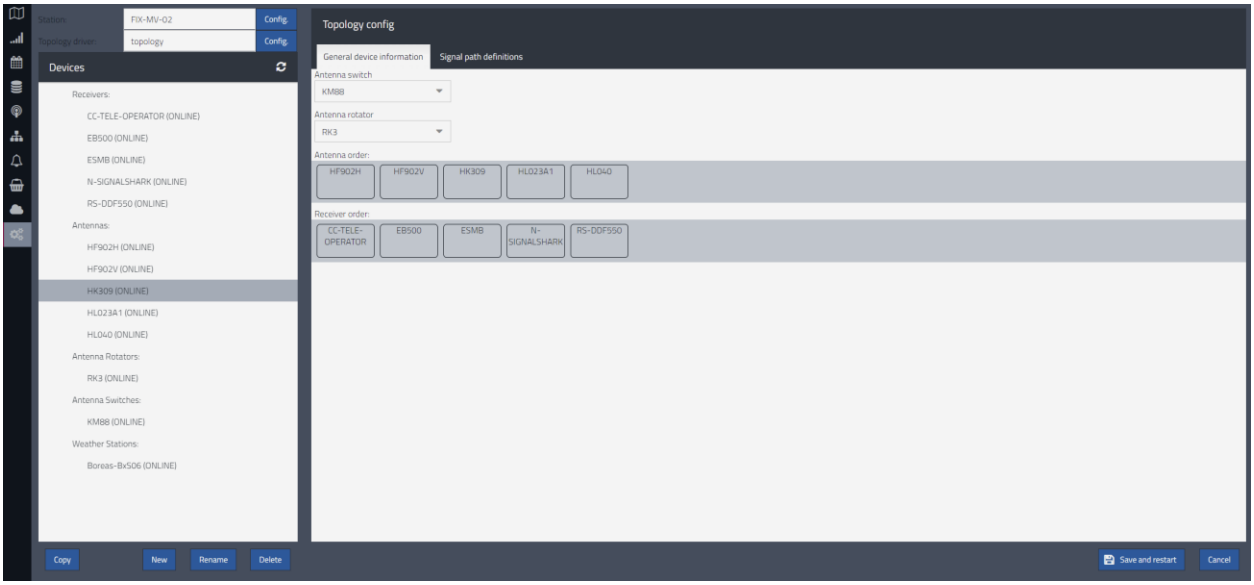
Antennas



The antenna configuration options allow the configuration of the antennas available on the station with their frequency range and the antenna correction factor table.

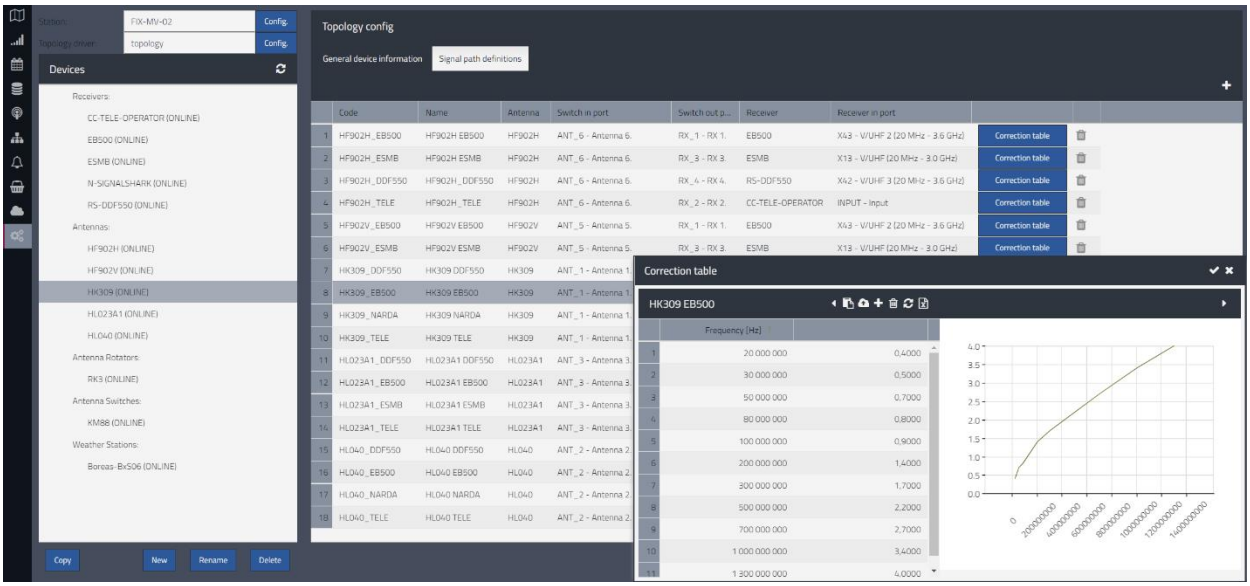
Topology configuration panel

General configuration



The general configuration panel allows the configuration of the antenna switch and the display order of antennas and receivers on the signal path selection panel.

Signal path definitions



The signal path definitions panel allows the configuration of the connections between the antennas, the signal path switch input and output and the receiver input.

For each signal path it is possible to provide a correction table.

The antenna and the signal path correction tables are taken into account when displaying the spectrum data using the dBµV/m measurement unit.

The SIMon system automatically saves the station configuration to the central server, so in case of failure/data loss, during the reinstallation of the software on the station it can be copied back.

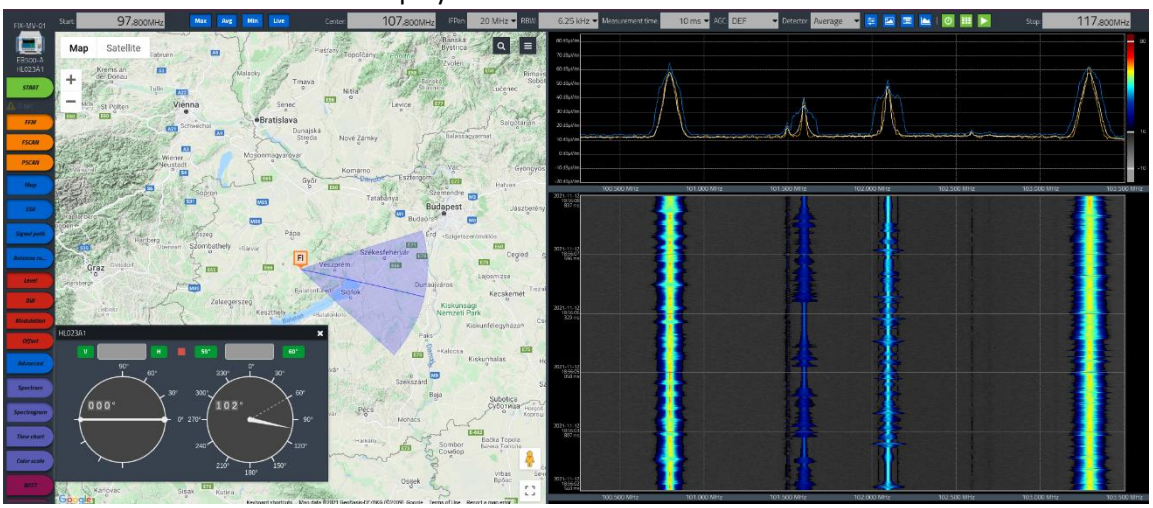
The installation image of the SIMon system contains all the device drivers supported by the system, and it will automatically configure them according to the station configuration files which can be restored manually form the central server.

Measurement execution

The ***SIMon measurement controller*** provides the following measurement execution modes:

- Direct measurement: when device selection (including the antenna rotator and signal path switch) and measurement configuration take place in "real-time" through the user interface,

and the measured data is also displayed in "real-time."



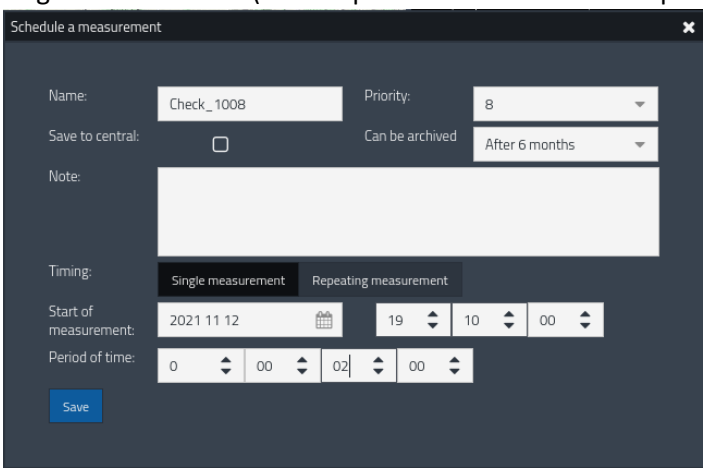
- Automatic and scheduled monitoring measurement: when the execution of a pre-assembled and queued (scheduled) measurement task takes place in the background (without a connected user interface), and the measured data is continuously stored.

Scheduled and active measurements

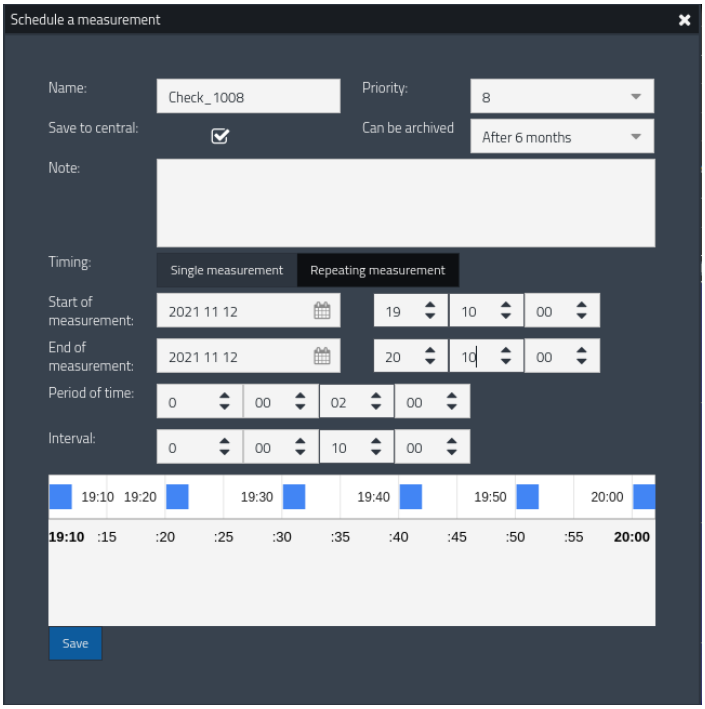
	Type	Task name	Start	Finish	State	Period of time	Device
1		107 800 kHz	2021.11.12 19:08:25				DDF255-A HK309
2		Check_1008	2021.11.12 19:10:00	2021.11.12 19:12:00	✔	00:02:00	EB500-A HL023A1
3		Check_1008	2021.11.12 19:20:00	2021.11.12 19:22:00	✔	00:02:00	EB500-A HL023A1
4		Check_1008	2021.11.12 19:30:00	2021.11.12 19:32:00		00:02:00	EB500-A HL023A1
5		Check_1008	2021.11.12 19:40:00	2021.11.12 19:42:00		00:02:00	EB500-A HL023A1
6		Check_1008	2021.11.12 19:50:00	2021.11.12 19:52:00		00:02:00	EB500-A HL023A1
7		Check_1008	2021.11.12 20:00:00	2021.11.12 20:02:00		00:02:00	EB500-A HL023A1

Automatic measurements can be scheduled like a:

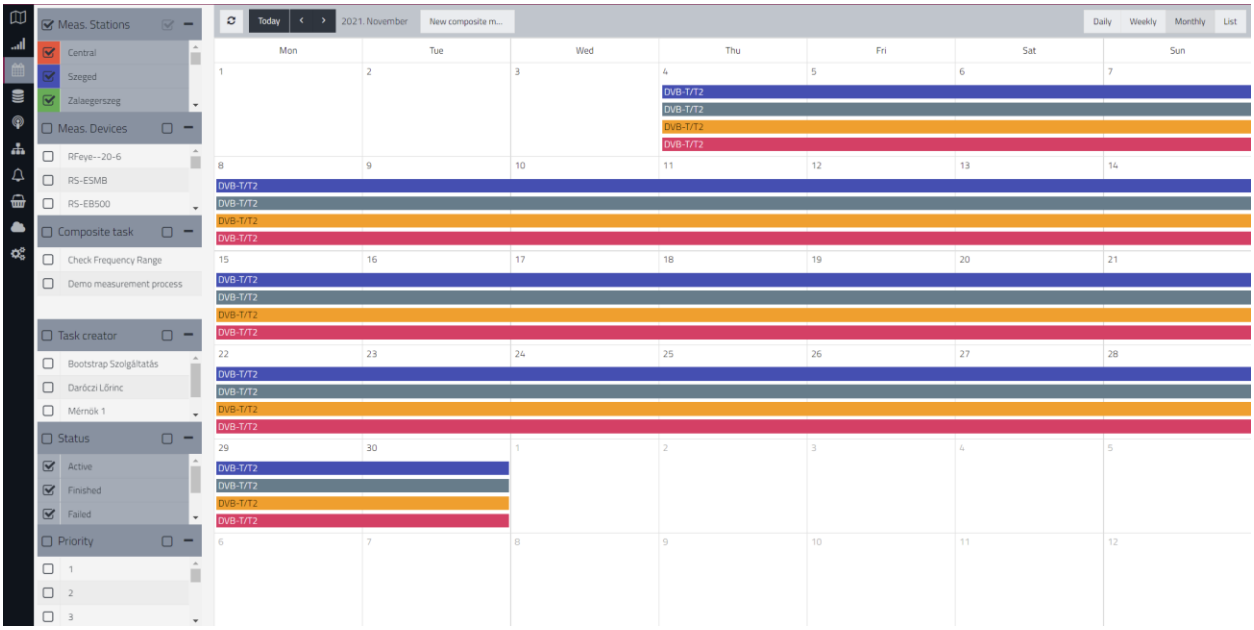
- single measurement (with a specified start time and a specified duration),



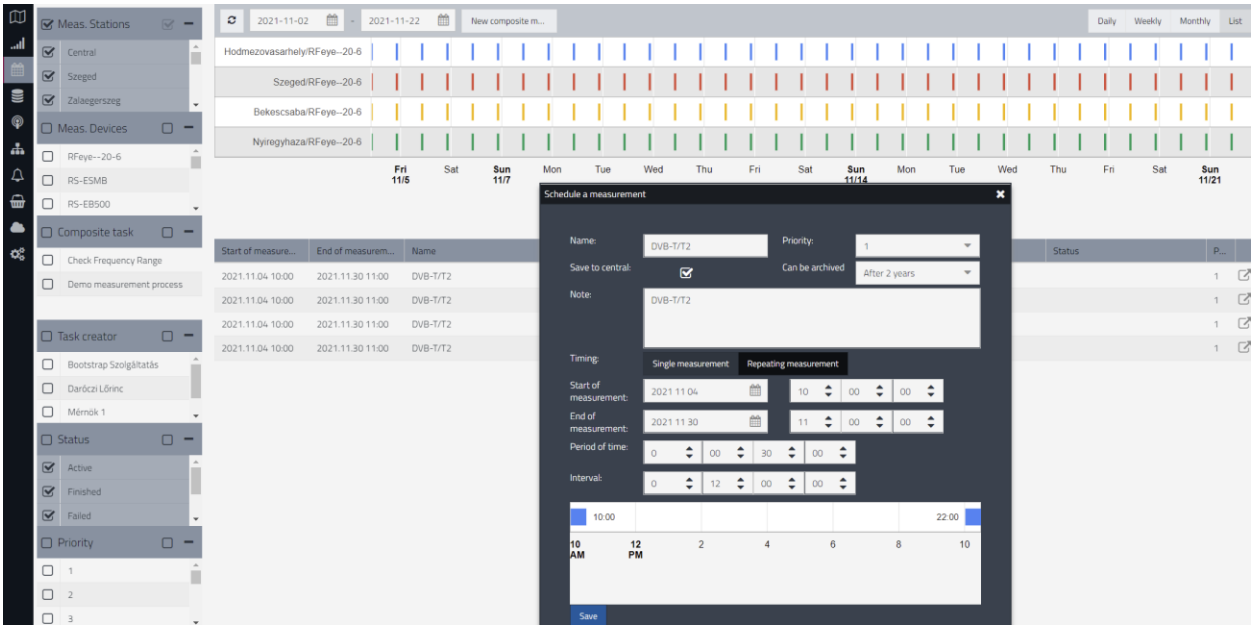
- repeating measurement (measured during a specified time range, with a specified duration, repeated at specified intervals).



The scheduled measurement tasks can be viewed and managed using the embedded calendar view:



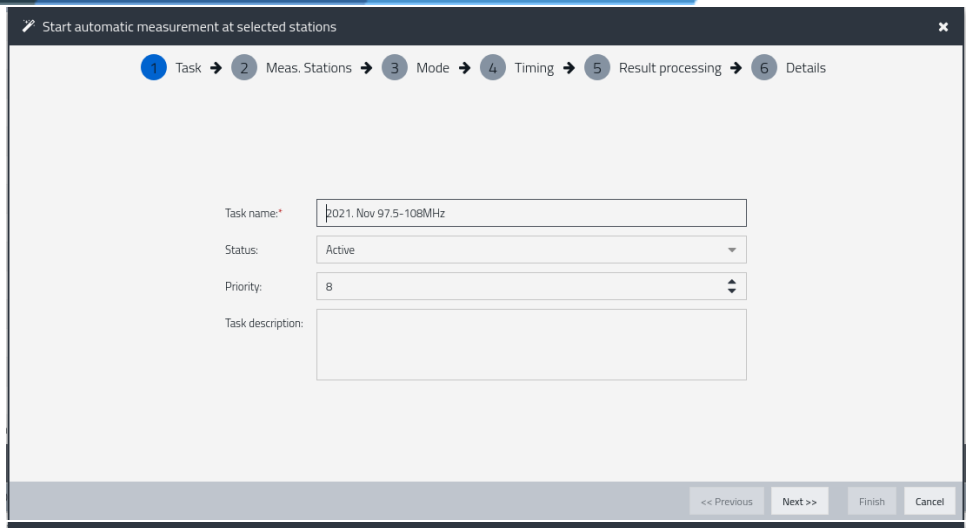
The scheduled repeating measurements can be viewed and managed using the embedded list view:

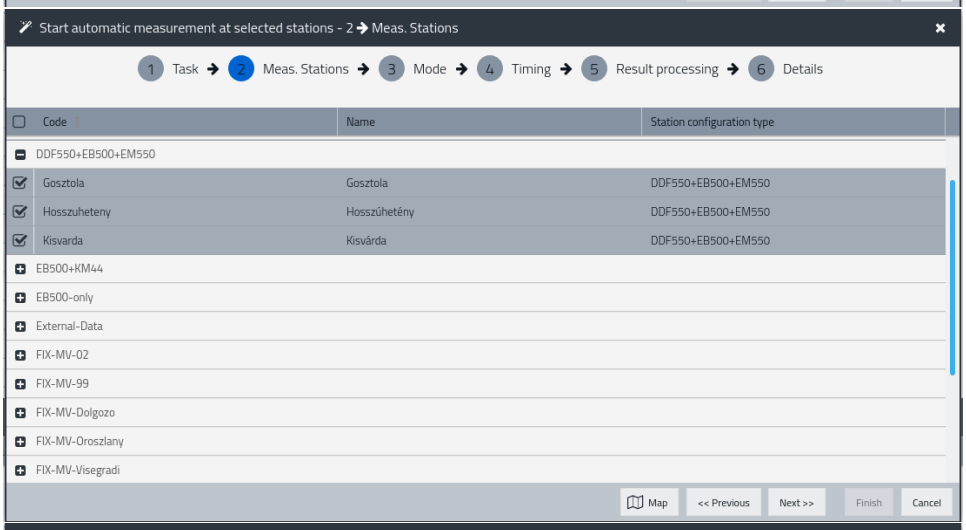


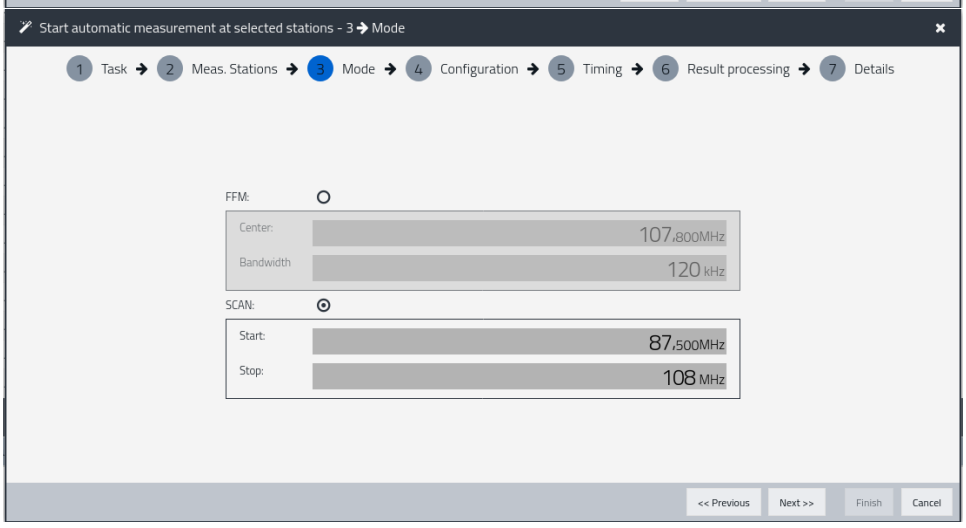
Automated missions

Measurement Wizard

The ***SIMon measurement controller*** also provides the possibility to schedule the same measurement at the same time on multiple measuring stations, having the same device and antenna configuration.







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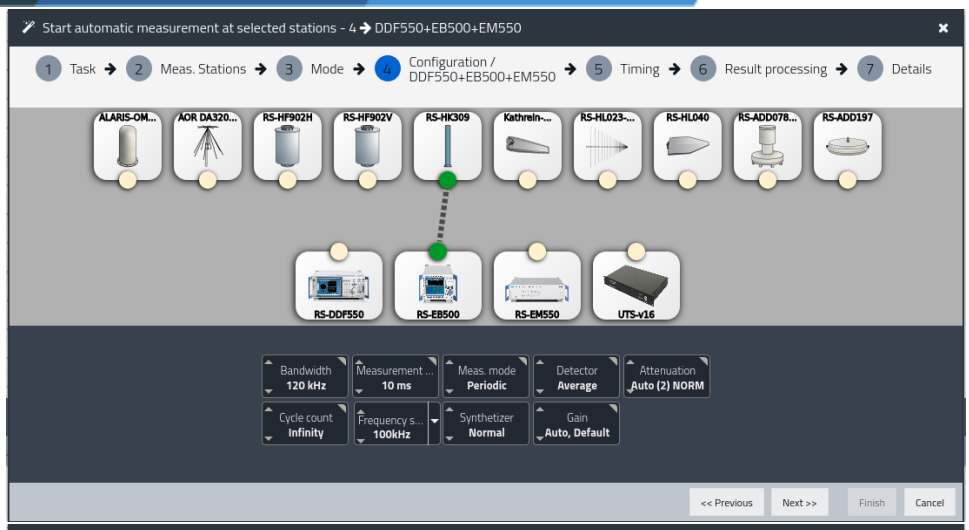

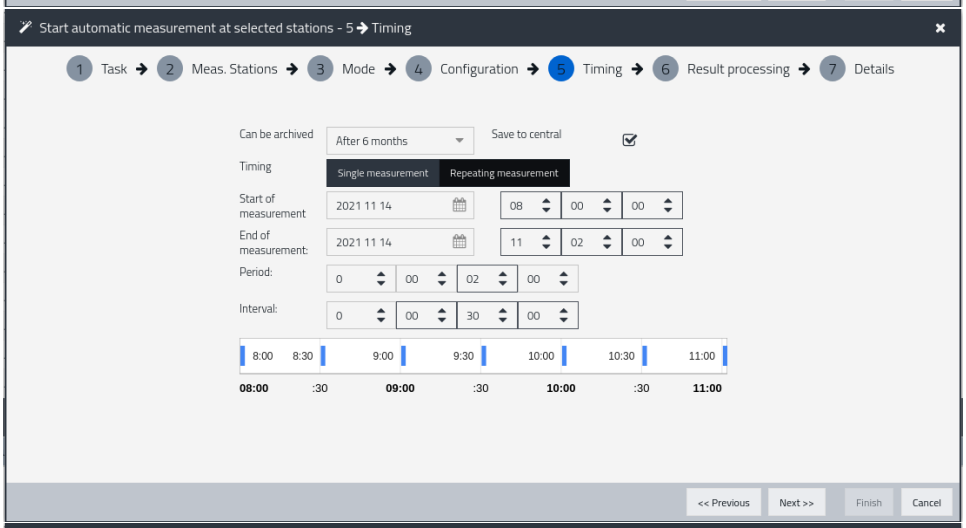

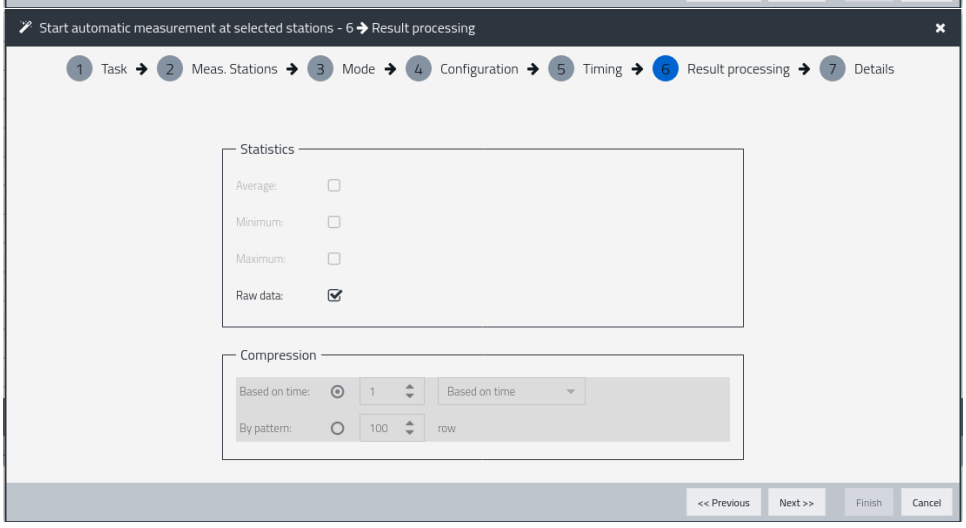

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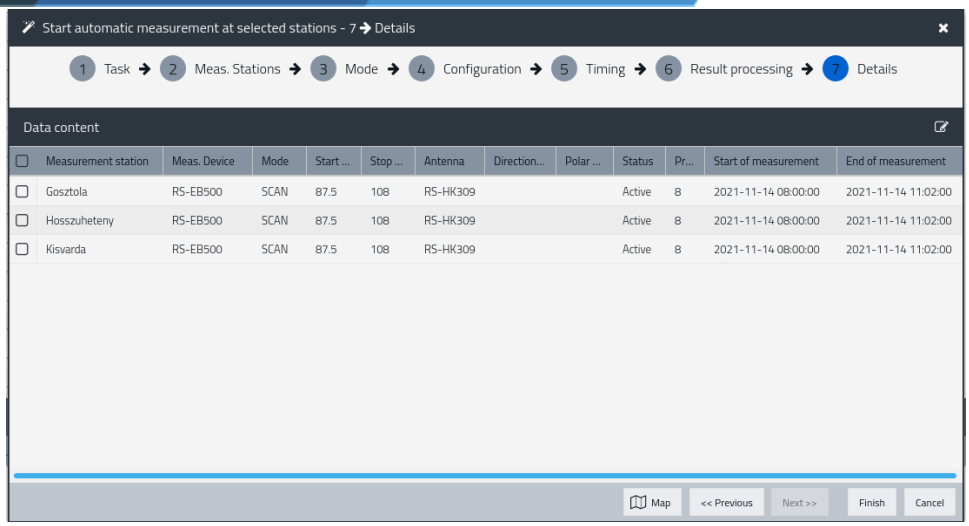

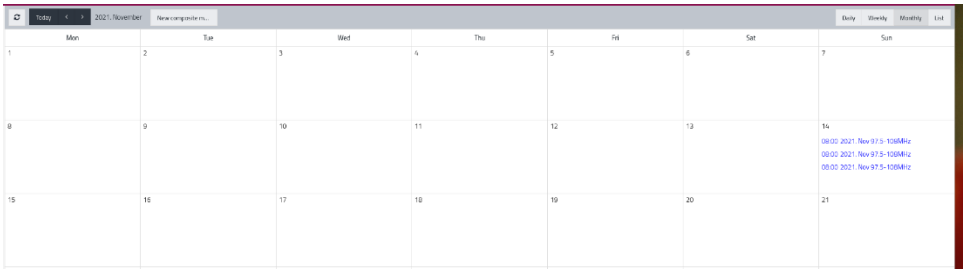

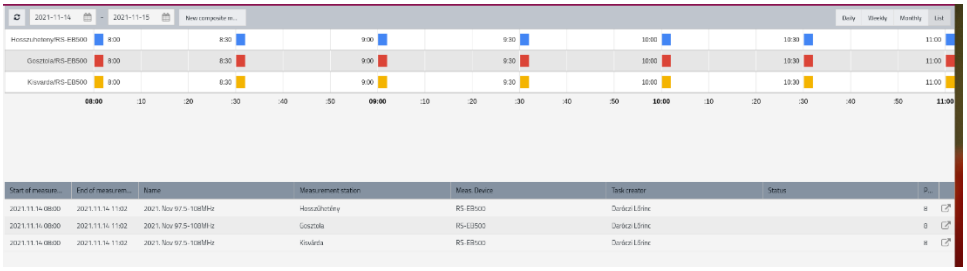

Mask/List definitions

Masks are named collections of expected values by frequencies/channels.

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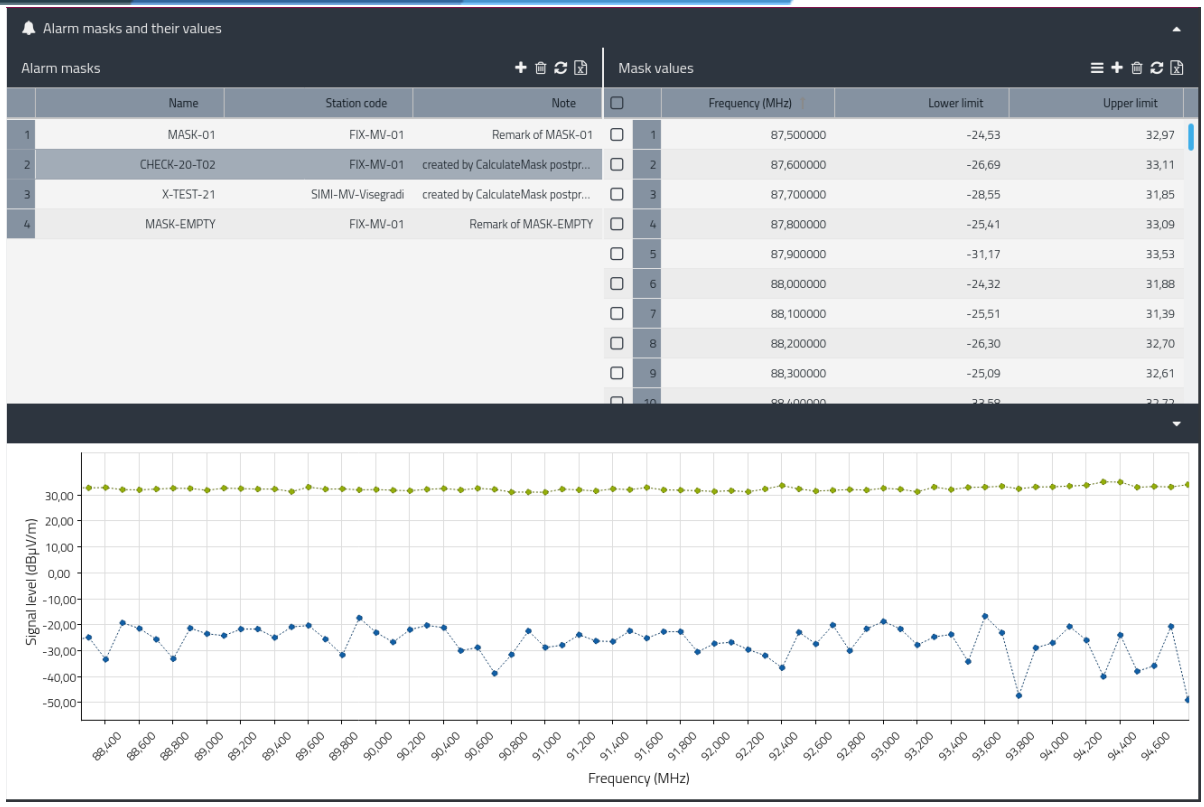
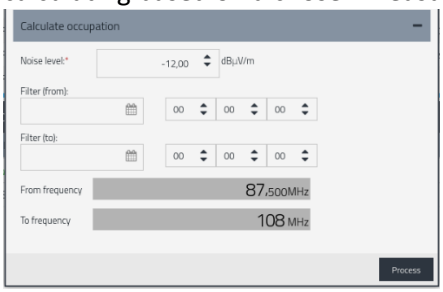


It currently supports only level range (lower limit and upper limit).

It can be created:

- enter manually (from scratch)
- loading from Excel
- calculating based on a chosen measurement result and the given parameters:



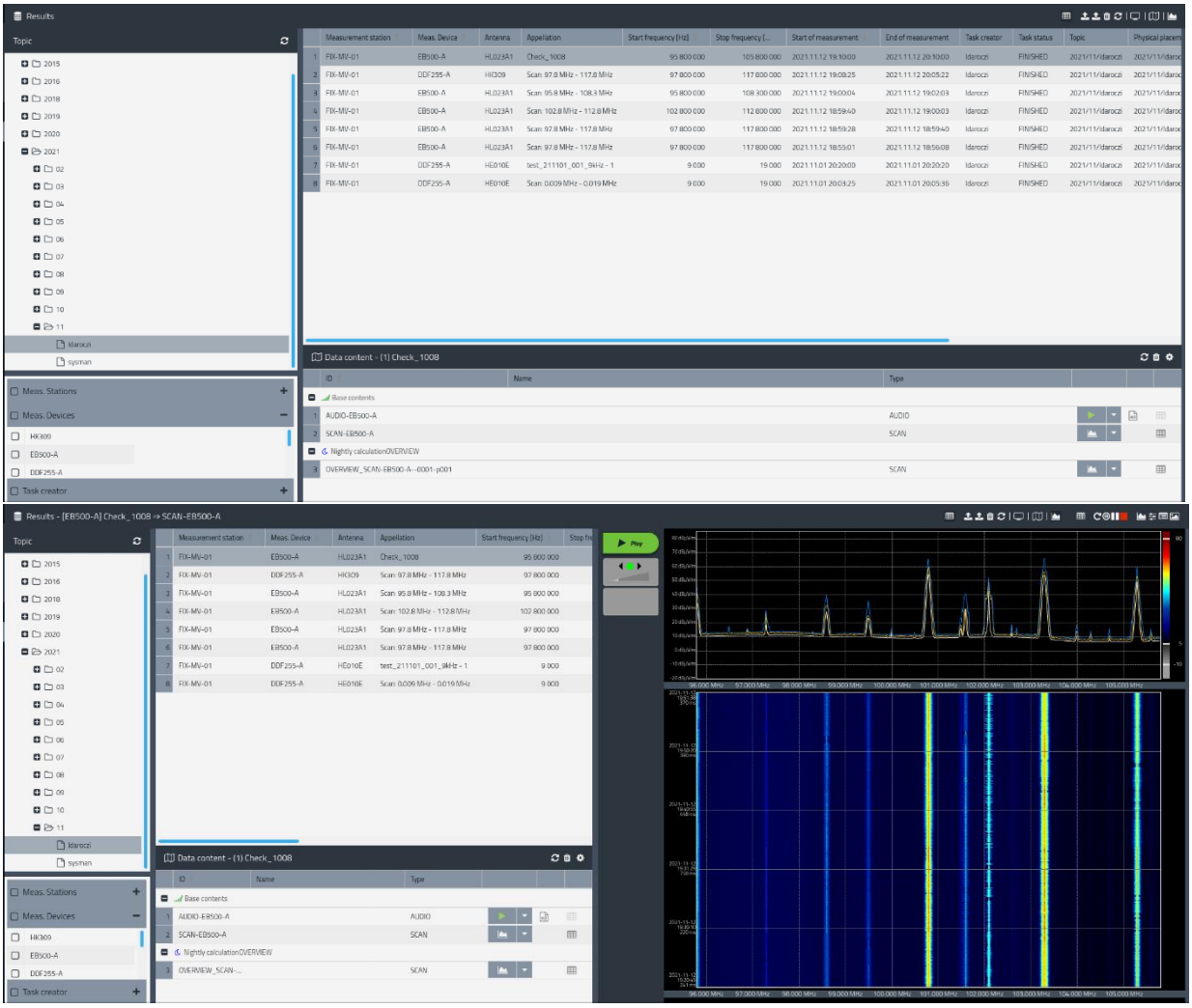
Alerts

A scheduled measurement running on the station can generate alerts based on mask violations.

The station saves the alert and transfer it to the Central controller. The system notifies the users with a bell sign at the top corner of the main window:

The alerts can be shown in the detailed view:

Result management, post-processing



The measured data is stored in a uniform data format, regardless of which manufacturer's device was used for the measurement. This way, it can be ensured that data measured by different devices can be compared and processed with uniform algorithms. The system manages the following data types:

- Spectrum data (signal level data measured in the specified frequency range, at the specified time range),
- Audio data,
- Direction finding data,
- DVB-T/T2 data,

- I/Q data,
- Weather data.

The system supports the automated uploading of measurement results stored at the measuring stations to the ***Central controller***. The following use cases are supported:

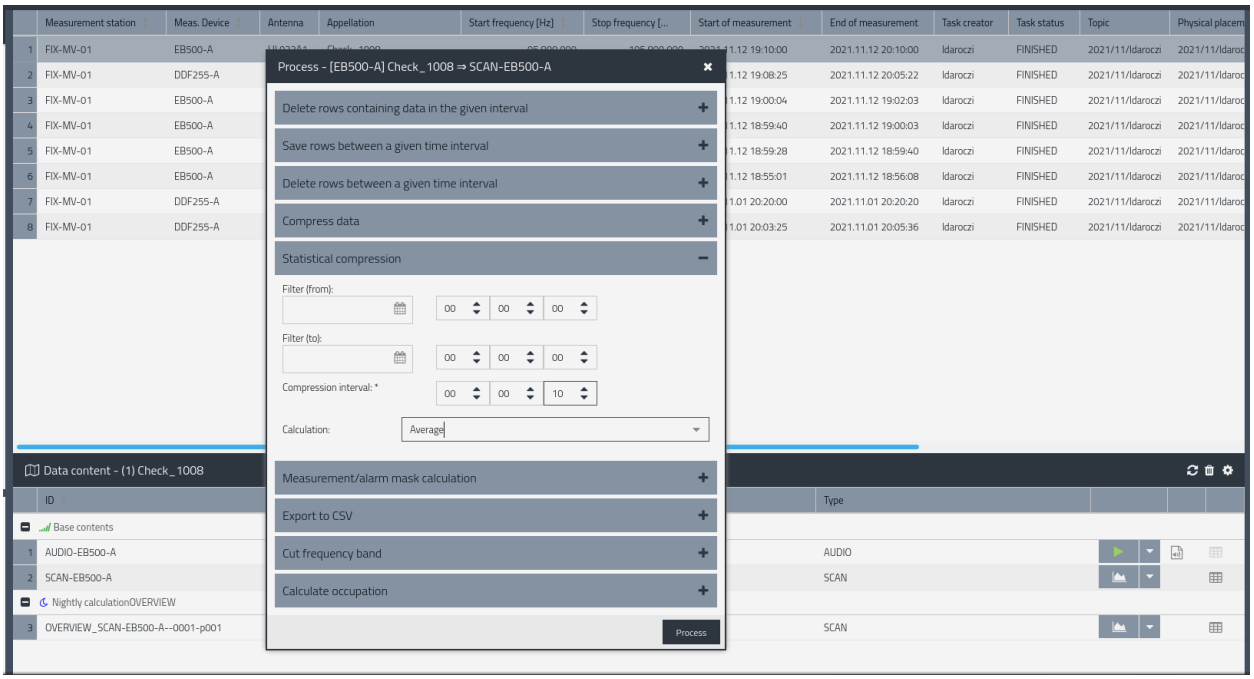
- The automated upload to the central storage can be requested at the time of the measurement task creation,
- The automated upload to the central storage can be requested after the execution of the measurement task,
- Manual upload to the central storage, with the help of a USB drive, in the case of offline measuring stations.

"Real-time" processing of measurement data

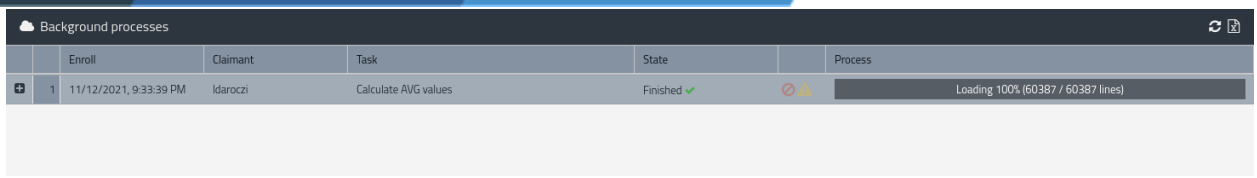
- channel occupation %

Post-processing of measurement results is supported with the following features:

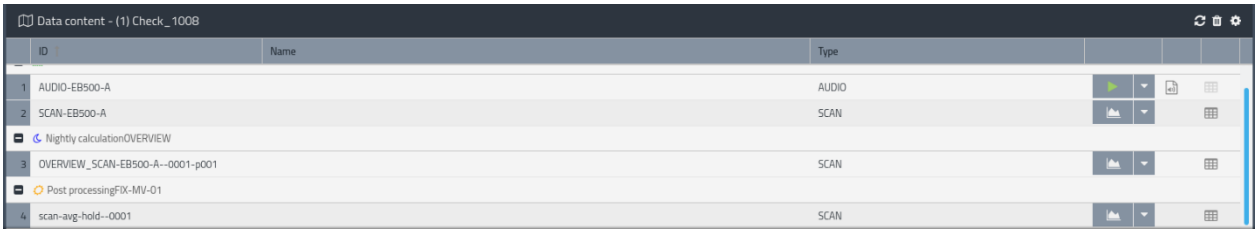
- Spectrum data:
  - Deleting rows between given signal level and/or frequency interval,
  - Saving rows between given time interval,
  - Saving rows between given time and frequency interval,
  - Deleting rows between given time intervals,
  - Statistical compression of data (maximum, average, minimum), for the given time interval, with the given compression interval,
  - Occupancy calculation based on a given noise level,
  - Export of data in CSV (Comma-Separated Values) format.
- Audio data:
  - Conversion to WAV (Waveform Audio File) format.



It runs on the server as a background process:



The output of the processing is stored as the part of the result:

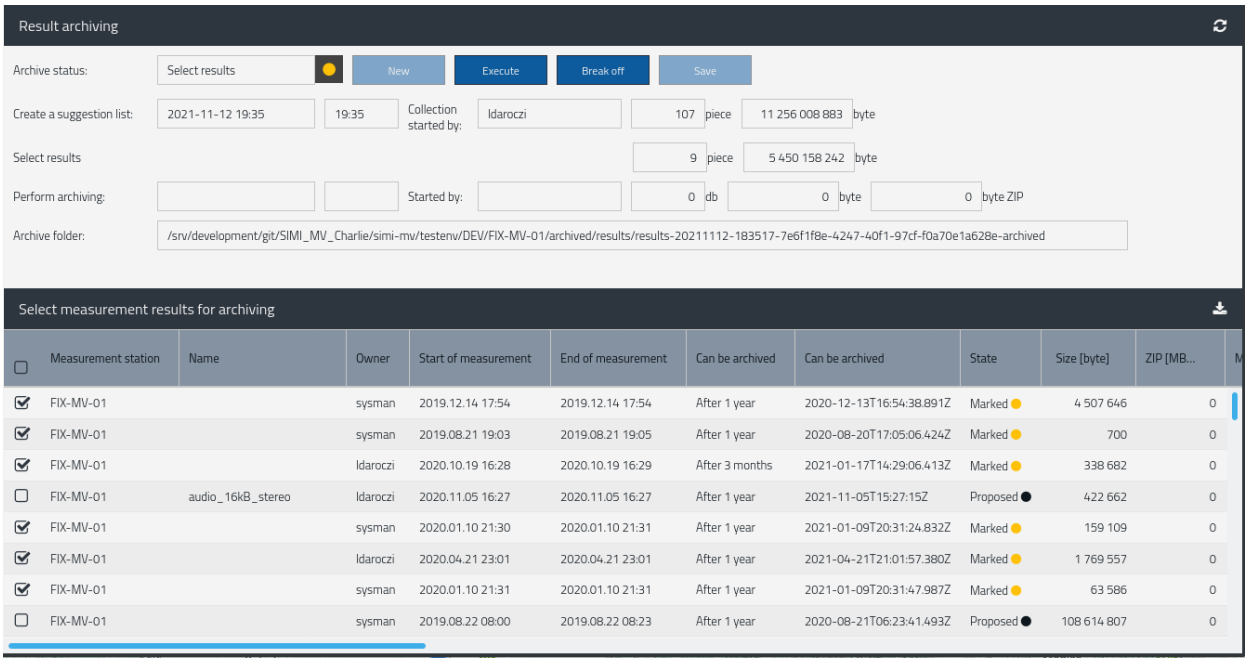


Archiving

The system also supports archiving old measurement data. Measurement results can be categorized in the following archival categories:

- test data (no need to keep, can be deleted at any time),
- can be archived after 3 months,
- can be archived after 6 months,
- can be archived after 1 year,
- can be archived after 2 years,
- can be archived after 5 years.

At the start of the archiving process, the system prepares the list of measurement results to be archived based on the archival categories. After the user's consent, it stores them compressed in the archive folder, which can be moved to an external drive. The restoration of individual archived measurement results is supported (simply by decompression and copying it back to the results folder).



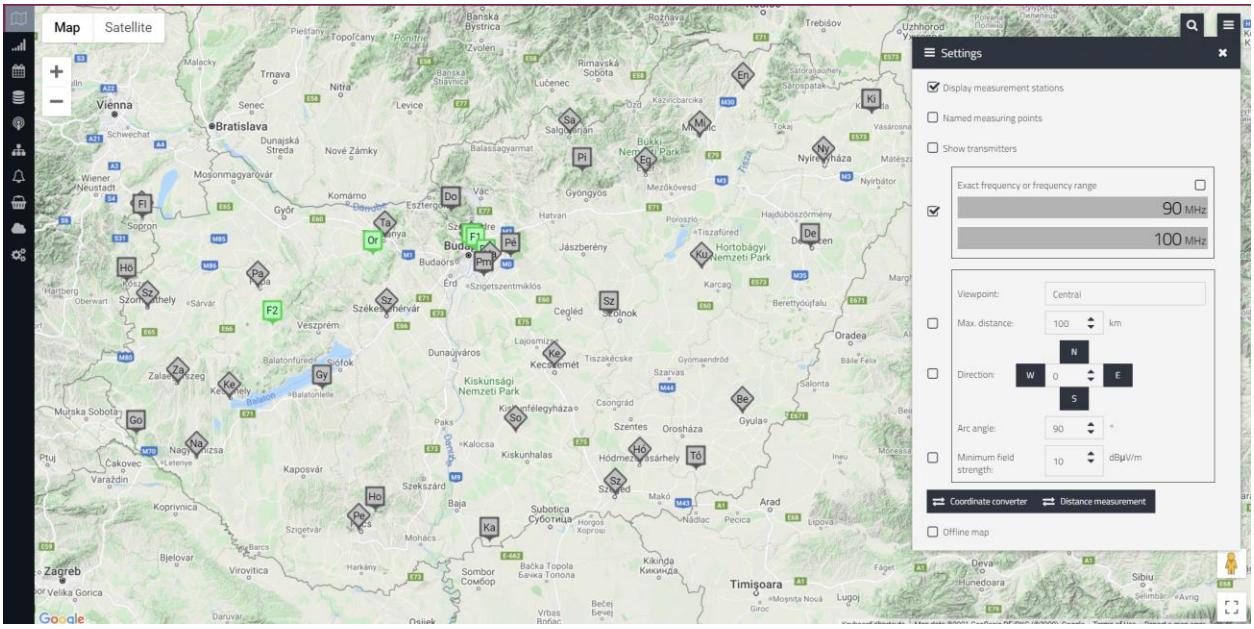
Map

The central element of the user interface is the map, which functions as a starting point for everyday activities, like initiating measurements, displaying the transmitters, etc.

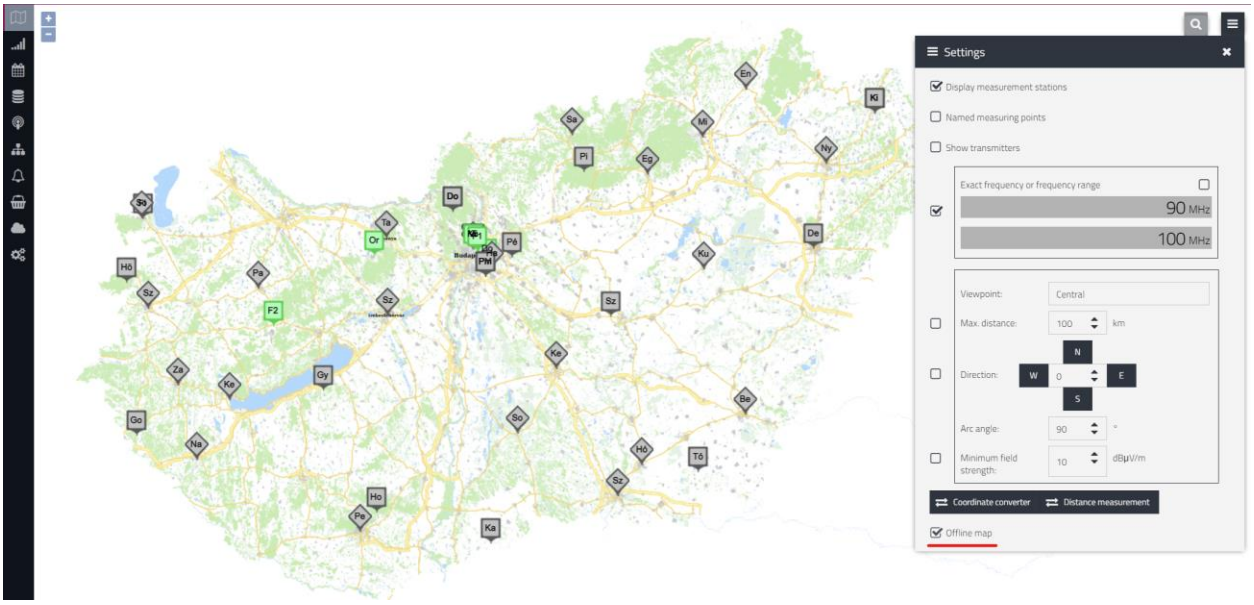
The map-based home screen provides a comprehensive picture of the measuring stations integrated into the system. It displays them at their current location and shows their current status (offline, online, free to use, executing a measurement, or in an error state if a device is malfunctioning).

The map-based home screen supports the following technology types, between which the user can switch freely:

- Google Maps,



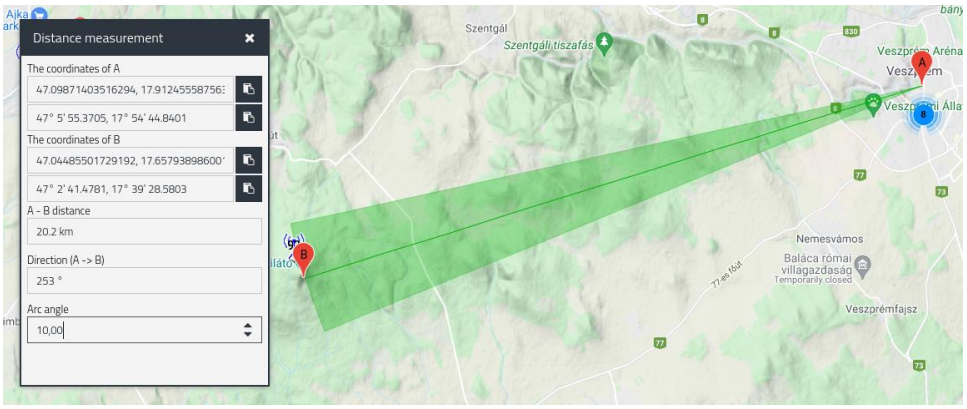
- OpenStreetMap-based offline data.



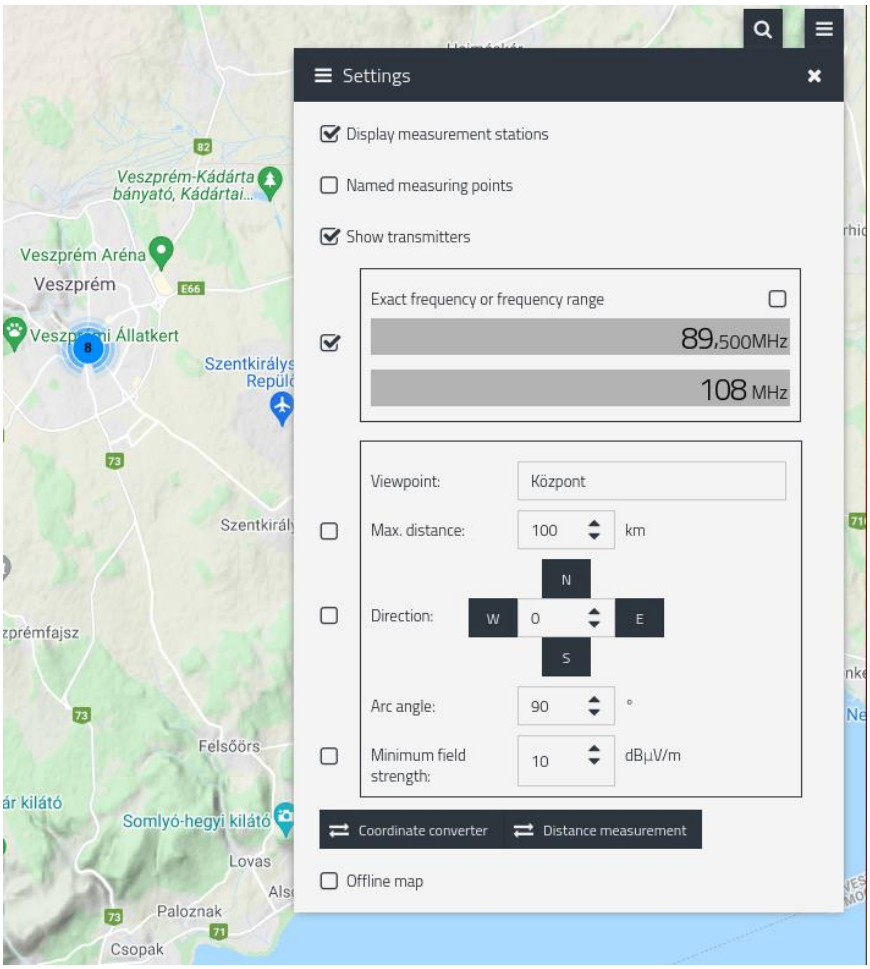
The default map display is based on Google Maps and supports its special functions (like terrain display, satellite view, street view, search based on address).

Map display based on the data from OpenStreetMap plays a role in offline scenarios when the Google Map service is not accessible, e.g., at a remote location with a mobile station. The necessary infrastructure to support offline maps is part of the system.

The integrated mapping services support the calculation of distance and direction between two arbitrarily selected points.



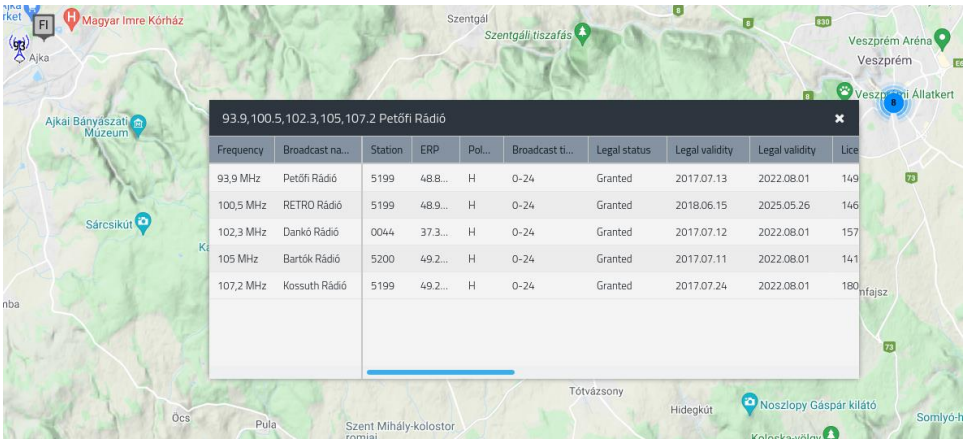
On the map, the following data is displayed in a filterable way:



- Measuring stations,
- The named measuring points (which are frequent sites for on-field measurements with mobile stations),
- The transmitters from the licensing database, with filtering option relative to the selected measurement station, based on:
    - maximum distance,
    - direction and arc angle

- minimum field strength calculated by free space attenuation, and frequency range.

For the selected (clicked) transmitter on the map, the system can display the detailed transmitter.



For the selected (clicked) Station on the map, the system displays its detailed data, including:

- antenna types and measurement limits,
- measuring device types and measurement limits,
- the data from the ongoing measurements (who started it and when, on which devices, etc.).

Direct- and scheduled measurements can be started by selecting a station on the map.

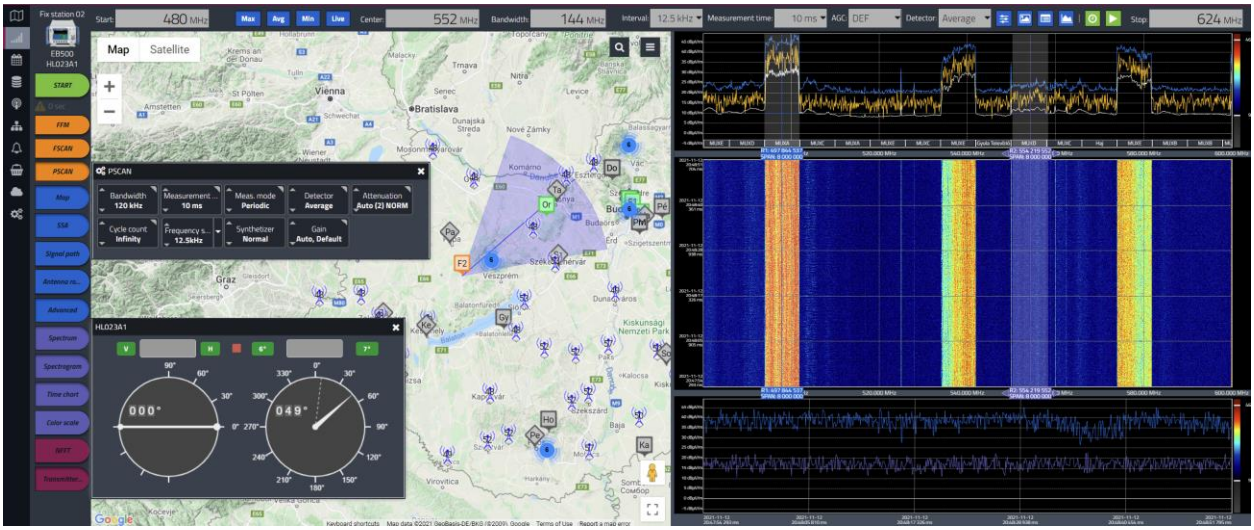
An intuitive graphical interface supports the selection of the signal path to be used during the measurement (the user connects the desired antenna and measurement receiver using the mouse).

Measurement control interface

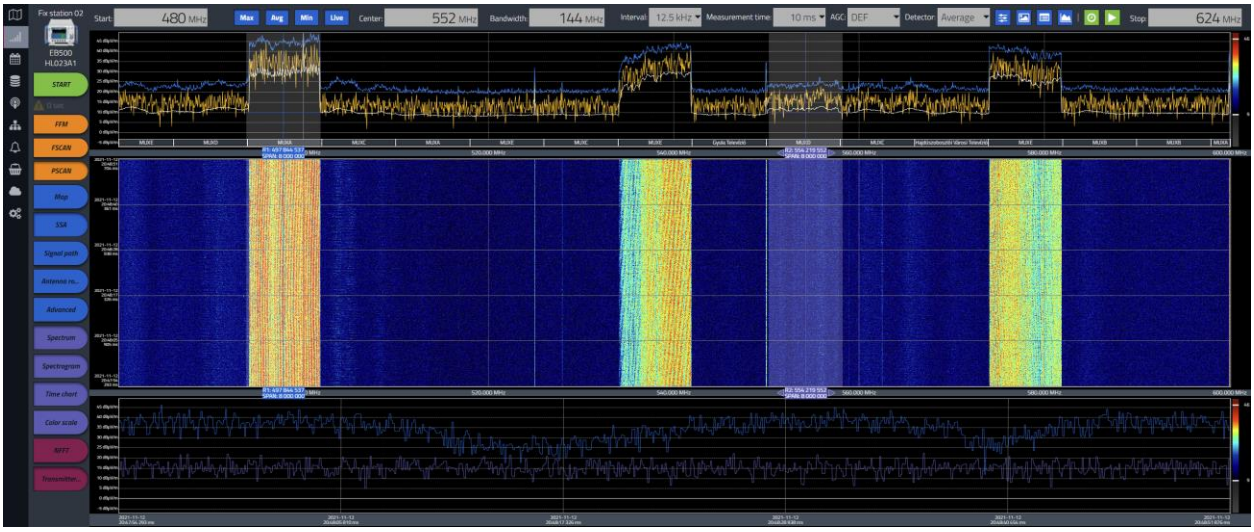
The measurement control interface is designed with the following features:

- The configuration options of the selected device are displayed (frequencies, bandwidth, measurement time, detector etc.) according to the device type,
- During the configuration, the UI validates the settings and also checks the correlations between the configuration options.
- For a directional antenna, the UI displays a graphical antenna rotation control screen which allows the user to select the desired antenna direction and polarity and provides continuous, real-time feedback on the current position of the antenna.

- For a given measurement, the UI provides an integrated map panel, which displays:
  - the environment of the given measuring station (with the Station in the middle),
  - based on the measured frequency/frequency range, the relevant transmitters from the licensing database,
  - for a directional antenna, the current direction of the antenna and its direction cone is based on the arc angle.
- This integrated map panel also provides all the features of the home screen map (e.g., switch between Google Map with satellite, street view and offline map, distance measuring, filtering the transmitters).



The measurement control screen is designed in such a way that the spectrum analysis interface is given the most possible space so that the graphic display of the measurement data can be as detailed as possible.

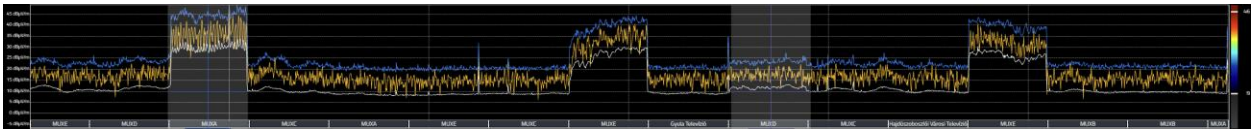


Spectrum and Signal Analyzer

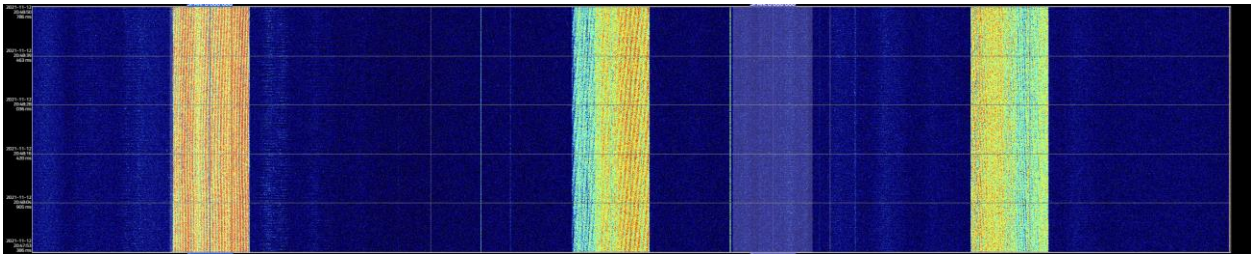
The Spectrum and Signal Analyzer interface displays the scan (IF panorama, panorama scan, frequency scan) measurement data on three interconnected types of diagrams:

- Spectrum diagram:
  - X-axis: frequency

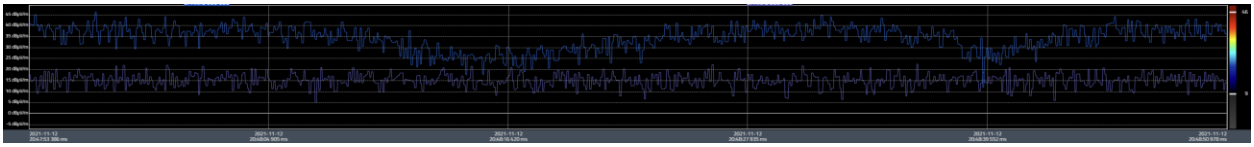
- Y-axis: field strength



- Spectrogram (waterfall diagram):
  - X-axis: frequency
  - Y-axis: time



- Time–field strength diagram:
  - X-axis: time
  - Y-axis: field strength

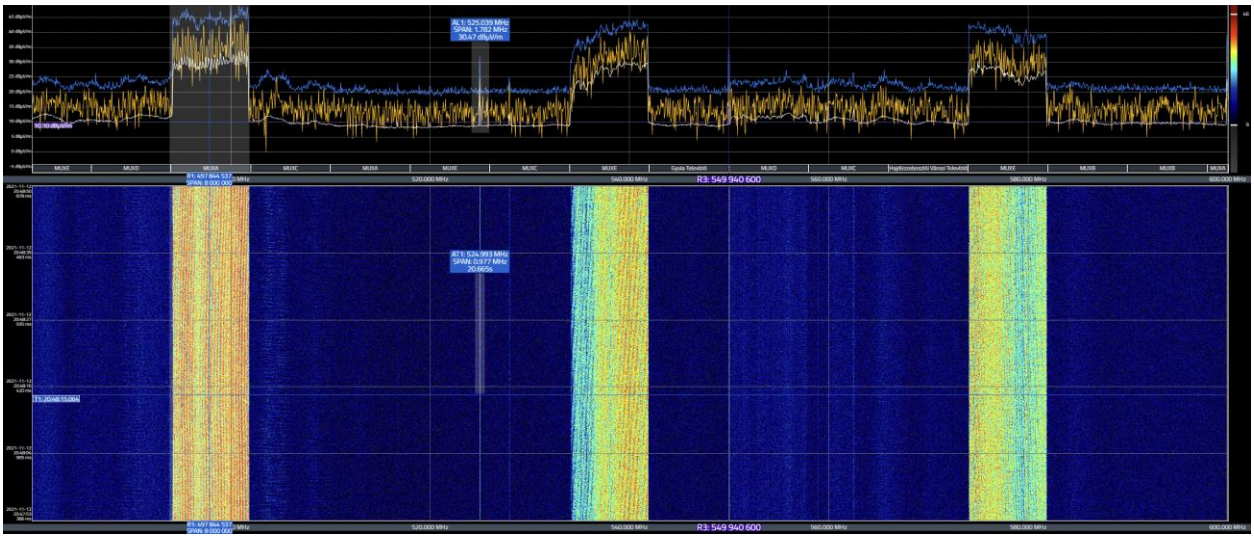


The diagrams are resizable, and their display can be turned on and off.

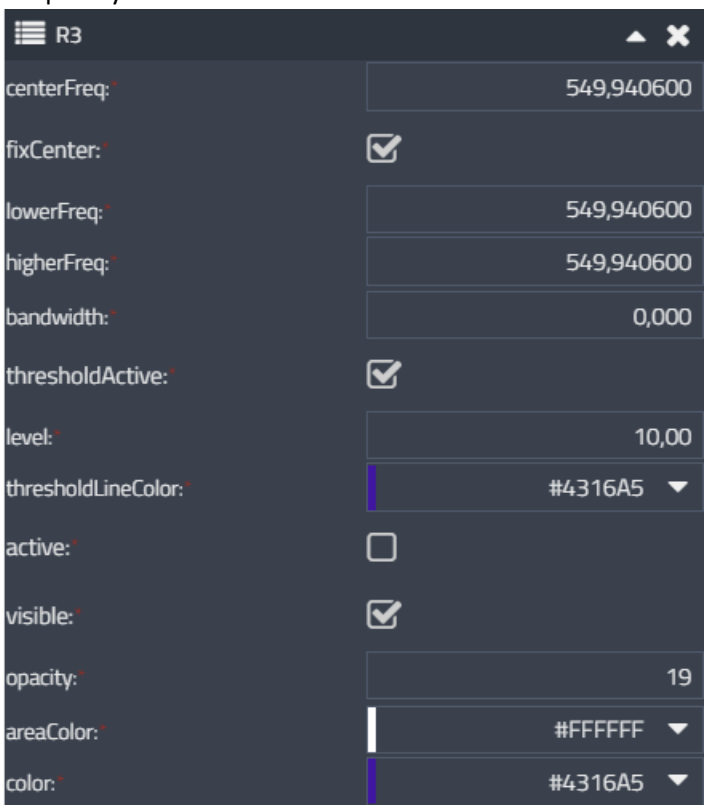
In the spectrum diagram, the minimum, average, maximum values are calculated by the GPU, and the live (last) measured values can be displayed. The display of the minimum, average, maximum, and live values can be turned on and off.

On the waterfall diagram, the measured values can be displayed coloured according to the measured signal level. If necessary, multiple values can be compressed during zoom operation according to the chosen minimum, maximum or average value compression mode. By default, two colour schemes are used for colouring, a grey colour scheme for values below the noise level and a coloured transition for values above the noise level. The (bi-graded) colour scheme used for colouring is also displayed on the screen.

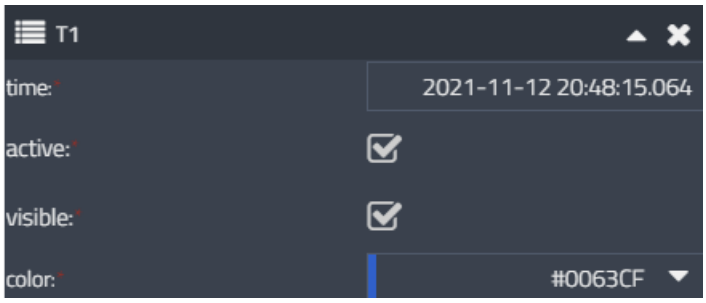
The spectrum analyser supports the placement of markers to allow the reading of exact measurement values and selecting relevant, significant data regions. The following markers are supported:



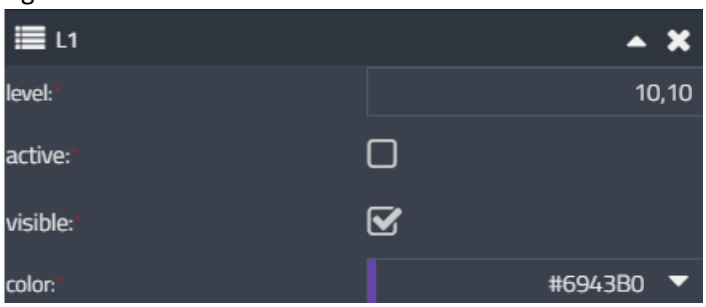
- Line markers:
  - frequency marker



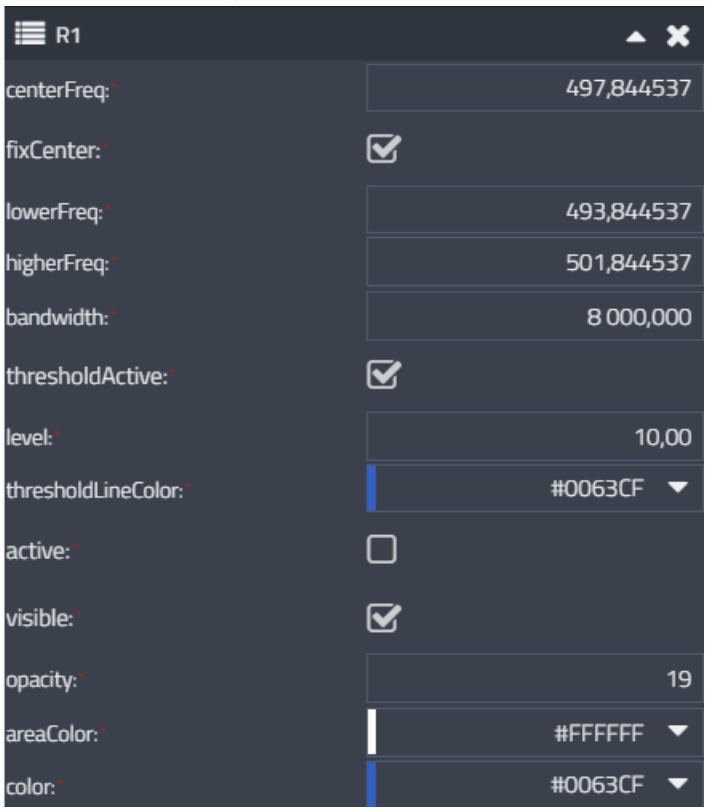
- time marker



- signal level marker

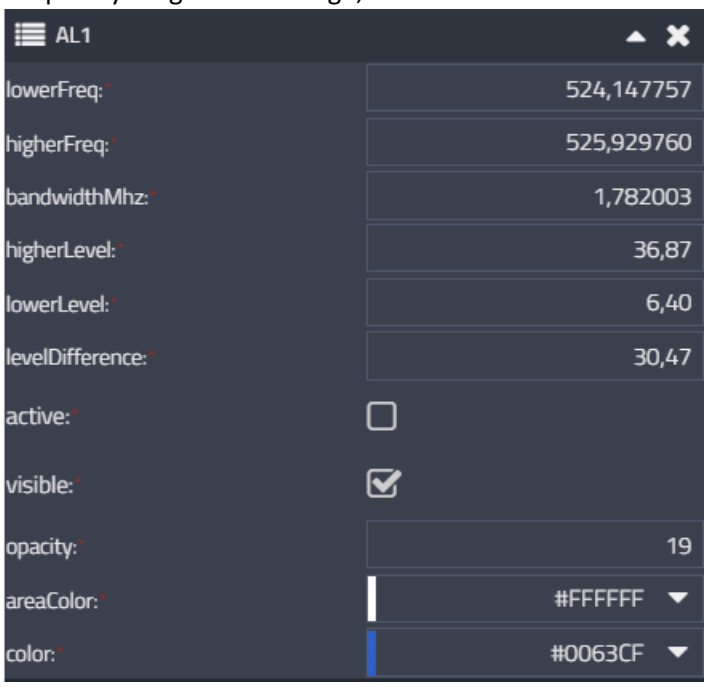


- Bandwidth markers,

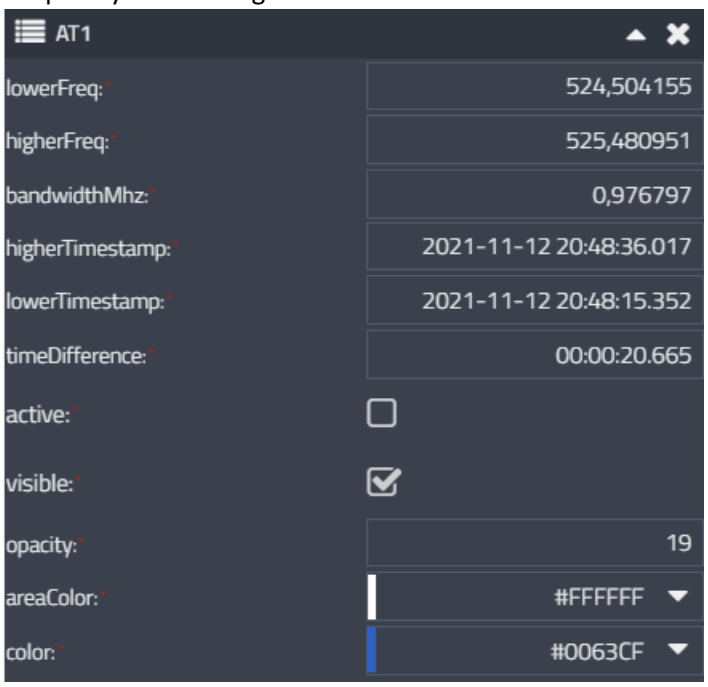


- Area markers – marking a rectangle area on a given diagram:

- frequency – signal level range,



- frequency – time range.



The Time–field strength diagram displays the change in signal levels over time for the frequencies selected by the frequency markers.

The frequency marker provides a "peak search" function that allows moving the marker to the previous/next "peak" value according to a set threshold.

All three diagrams provide synchronized zoom functions accessible by the mouse scroll wheel:

- Zoom-in: enlargement can be increased up to the measured elemental data,
- Zoom-out: the measured values are displayed compressed. This way, the total amount of measurement data (in the buffer) can be displayed on a single screen.

The diagrams are created, and the data in them is processed and displayed in the browser using WebGL 2.0 technology, taking advantage of the graphics card's power on the client computer. During measurement, the measured values are displayed continuously and can reach an image refresh rate of 60 FPS (depending on the GPU of the computer).

The analyser was designed with the goal to ensure that as many data rows as possible can be reviewed on the waterfall diagram by buffering the incoming data rows.

For example, the spectrum analyser can:

- display data of at least a 120-minute time period, in case of measurement with start=87.5 MHz, stop=107.5 MHz, step=6.25 kHz, measurement time=100 ms,
- display data of at least a 12-minute time period, in case of measurement with start=87.5 MHz, stop=107.5 MHz, step=6.25 kHz, measurement time =10 ms,

Measurements with high column numbers (containing many frequencies) must also be displayed. For example:

- in case of a start=20 MHz, stop=3.6 GHz, step=250 Hz measurement, 14.320.000 frequencies
- in case of a start=20 MHz, stop=6.0 GHz, step=250 Hz measurement, 23.920.000 frequencies

The spectrum analyser can help the identification of the measured signals by the switchable display of possible transmitters on the spectrum diagram, based on the licensing database. On click, it should display the details of the relevant entries from the licensing database.

In a switchable mode, it can also display the national and international frequency allocation ranges on the spectrum diagram. On click, it should provide information for the given range (service, usage guidelines, and recommendations).

Direction finding and geolocation

The ***SIMon measurement controller*** provides support for integrating direction finders based on Angle of Arrival (AoA) technology.

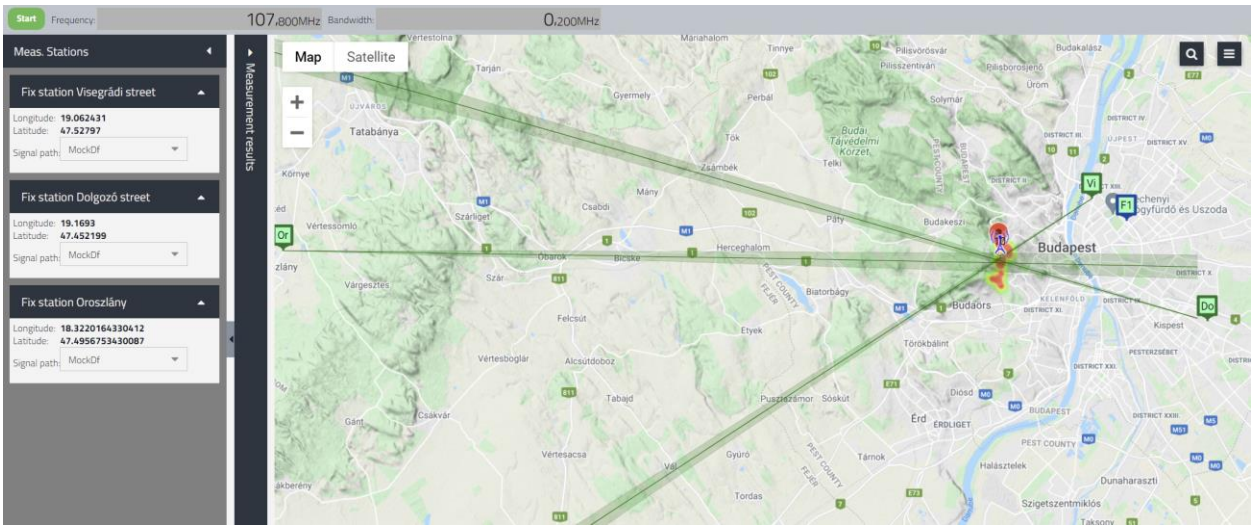
We have implemented drivers for equipment which supports AoA direction finding measurements. The following drivers support this feature:

- **Rohde & Schwarz**: DDF-550, DDF-255,
- **NARDA**: SignalShark 3320, 3330,
- **CRFS**: RFeye Node,
- **CommsAudit**: Spectra SRDF, CA4909-1.

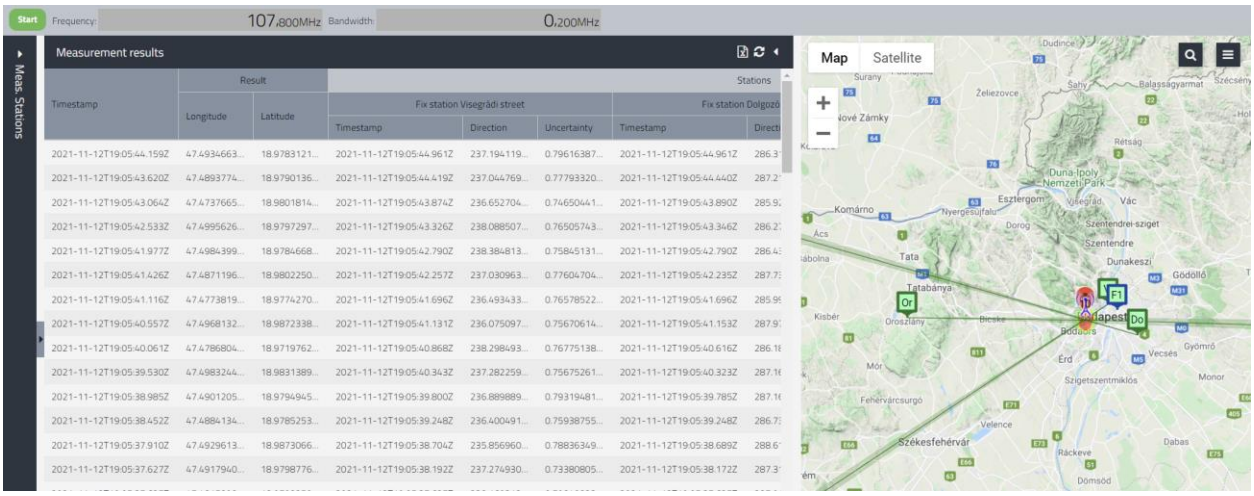
These drivers provide the measurement results in a unified data format which includes:

- Timestamp,
- Location of the receiver,
- Signal level,
- Azimuth,
- Azimuth confidence,
- Elevation,
- Elevation confidence.

Based on this data the user interface can display the measurement results on the map, using a direction cone, where the aperture of the cone represents the confidence in the results provided by measurement equipment. The system aggregates the previous N direction finding results to also provide statistics about the number of directions from which the signal is received. This allows for detecting peer to peer communication or interference signals.



By using a unified data format for handling the direction-finding results, the system also allows for using this data to calculate the location of a transmitter using multiple sites. The measurement results from multiple locations are corelated using the timestamp. The correlated results are used by our geolocation algorithm which takes in account the azimuth and the azimuth confidence, to calculate the possible location of the transmitter. During the calculation based on the azimuth confidence data, the algorithm also calculates a probable location ellipse centred around the most probable location.



The accuracy of the results depends on the equipment and the DF antennas used.

4. Hardware requirements

- Measurement stations (recommended configuration):
  - CPU: minimum 6 core, 12 thread, minimum 3 GHz,
  - RAM: 32 GB,
  - SSD: NVMe, PCI-E Gen 3, 1 TB
  - Storage (for measurement data): minimum 2 TB,
  - GPU: Nvidia GeForce GTX 1050 4GB RAM,
  - OS: Custom Linux to support the drivers,
- Central server (recommended configuration):
  - CPU: minimum 8 core, 16 thread, minimum 3 GHz,
  - RAM: 64 GB,
  - SSD: NVMe, PCI-E Gen 3, 1 TB,
  - Storage (for measurement data): minimum 8 TB,
  - OS: Ubuntu 20.04 x64,
- Client PC-s or Laptops (recommended configuration):
  - CPU: minimum 4 core, 8 thread, minimum 3 GHz,
  - RAM: 16 GB,
  - GPU: Nvidia GeForce GTX 1050 4GB RAM,
  - Operating system: Windows 10 x64,
  - Browser: Google Chrome 64-bit v95.0, Mozilla Firefox 64-bit v94.0, Microsoft Edge 64-bit v95.0.

5. Network requirements

Connection types supported:

- Wired (Copper, Fibre optic),
- Wireless (3G HSPA+, 4G LTE, 5G, P2P microwave).

Security:

- Secure VPN connection between the Central server, the Stations and Client PC-s or Laptops.

Connection Speed for a station:

- Minimum: ~1 Mbit/s download and upload speed (in this case the “real-time” measurement options are severely limited),
- Typical: 30 Mbit/s download and upload speed,
- Recommended: 80 Mbit/s download and upload speed.

The upload speed is the more important, because the station uploads the measurement results to the central server or the client in “real-time”.

The upload speed should be even higher if the upload in “real-time” of I-Q data or DVB transport streams is required.