



USER MANUAL

v.4.7.3 20.08.2024

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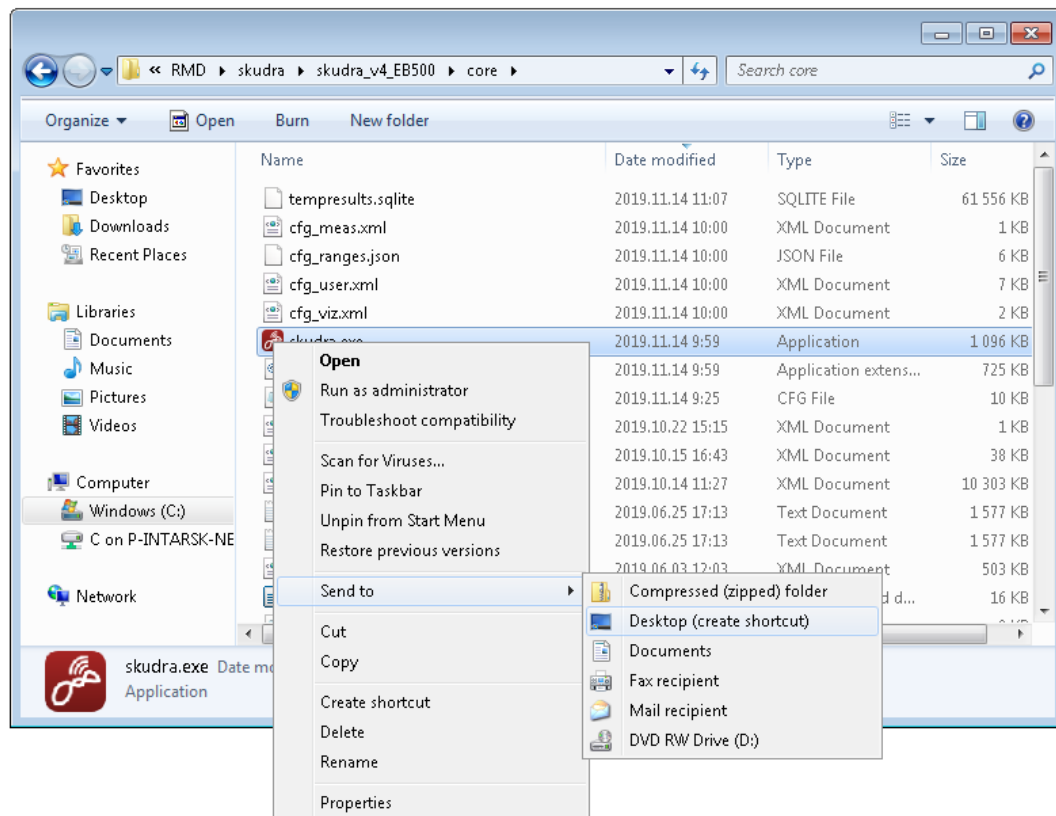
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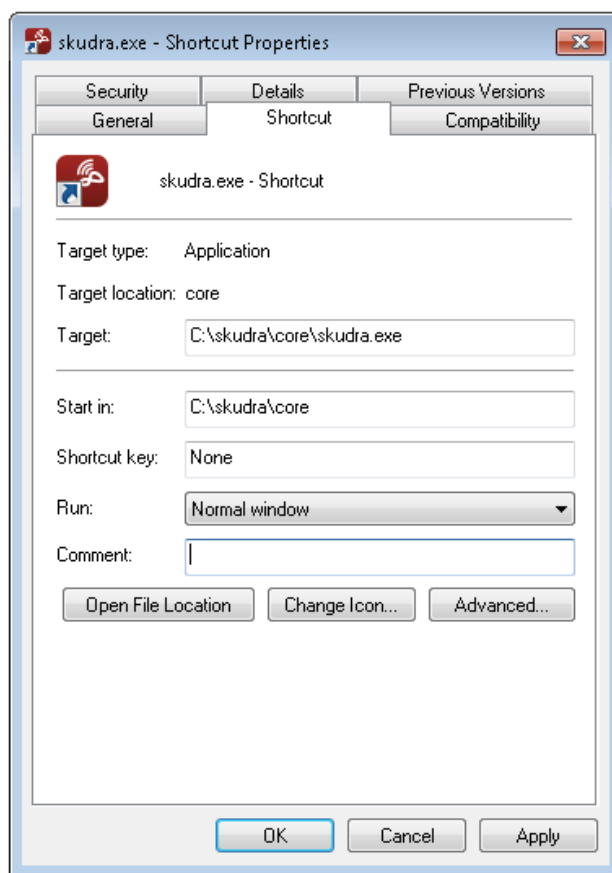
1 Initial Setup

1.1 Setting up the software

No installation is necessary for the software Skudra - just copy the software folder from the USB stick to the desired folder in the computer. For user convenience a shortcut may be created.



It is important to designate the correct value of start in. By default start in should be correct, but in the event of copying the shortcut from another computer it may occur that the start in value should be corrected.



1.1.1 Computer configuration requirements

Technical requirements for the running the software:

- OS: Microsoft Windows 7, 10, 11 with Microsoft.NET Framework 4.7.2 or later;
- CPU: Intel Core i5;
- RAM: 4GB;
- HDD: 100GB;
- Screen resolution: 1280 x 720 px;

1.1.2 Supported receivers

R&S EB200; R&S ESMB; R&S EB500; R&S ESMD; R&S DDF255; R&S PR100; R&S EM100; R&S EB510; Narda SignalShark; R&S DDF107; R&S DD205; R&S EM550; R&S UMS100; R&S PR200; R&S EM200; R&S DDF550 (and derived devices e.g. R&S UMS300 and UMS400).

1.1.3 UMS100 support

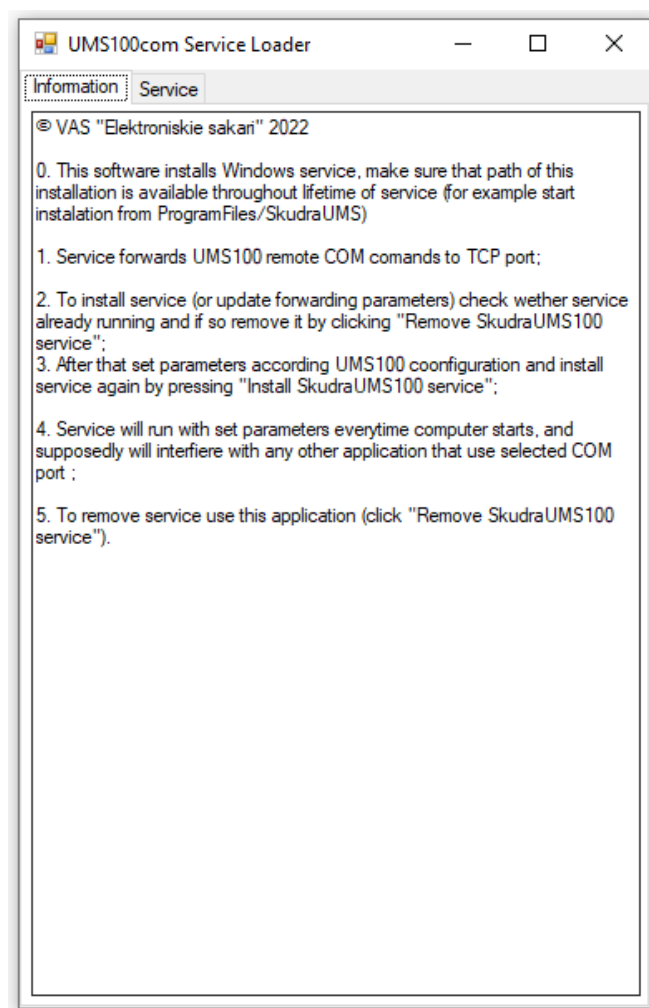
R&S UMS100 support is provided through SkudraUMS100 windows service installed on UMS100 embedded computer. Installation files are provided with copy of Skudra Patrol. SkudraUMS100 requires Microsoft.NET Framework 2.0 to be installed on UMS100 embedded computer.

SkudraUMS100 service forwards commands sent to and received from embedded UMS100 receiver to external TCP connection, that is accessible on UMS100 IP address and port set in during installation of service. Thus, when configuring Skudra Patrol, external IP address of R&S UMS100 and port set during the installation of service has to set as receiver IP (port) in settings panel.

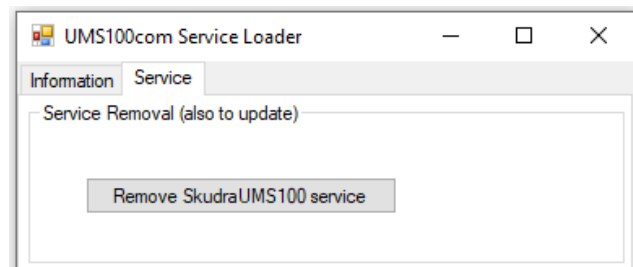
As Skudra Patrol requires OS and Microsoft.NET framework far newer than that achievable on UMS100 system, only way to run Skudra Patrol with UMS100 is using Skudra Patrol on remote computer with SkudraUMS100 service installed on UMS100.

1.1.3.1 Installation of SkudraUMS100 service

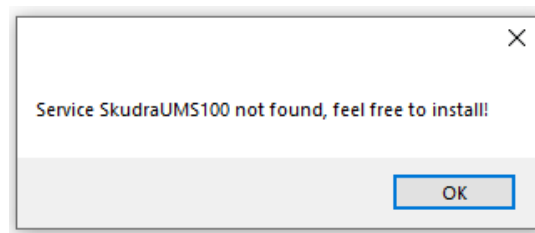
- Installation of SkudraUMS100 service has to be done on R&S embedded computer;
- As later possible configuration or removal of service is possible only with same application that installs service, it is advisable to run installation (*SkudraUMS100comLoader.exe*) from folder that will be accessible throughout the lifetime of service;
- Installation of SkudraUMS100 service is started with running the file *SkudraUMS100comLoader.exe*. After that following screen appears:



- Functionality to install service is provided in tab “Service”;



- To install SkudraUMS100 service, it is first necessary to press “Remove SkudraUMS100 service”. Doing that performs check whether service is installed and if installed uninstalls service;



- After ensuring that service is not installed, Install SkudraUMS100 service is enabled:

The screenshot shows a window titled "UMS100com Service Loader" with two tabs: "Information" and "Service". The "Service" tab is active. It contains two main sections: "Service Removal (also to update)" and "Install service with set configuration".

Service Removal (also to update)

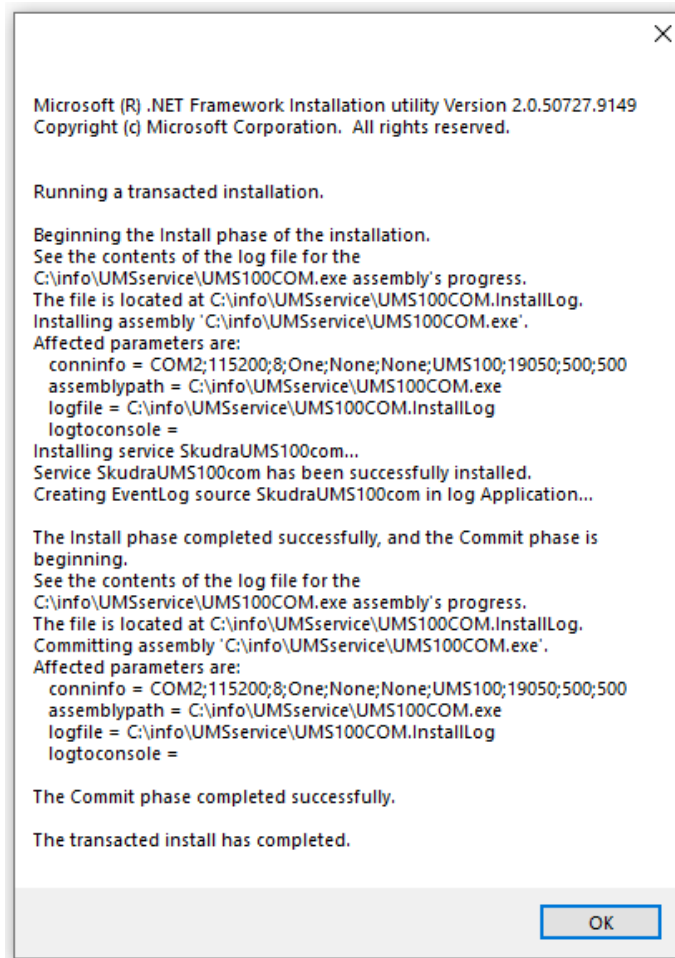
Remove SkudraUMS100 service

Install service with set configuration

COM port	COM3
Baud rate	115200
Data bits	8
Stop bits	One
Parity	None
Handshake	None
Device name (required)	UMS100
TCP port	19050
Read timeout (ms)	100
Write timeout (ms)	100

Install SkudraUMS100 service

- By pressing “Install Skudra UMS100 service” service will install with defined settings. After successful installation following message box will be displayed:



- After service is installed it will start every time as the system starts and block use of set Serial (COM) port by any other application. To unblock serial port to be used by another application, Skudra Service has to be uninstalled or stopped (temporarily) using Windows services functionality.

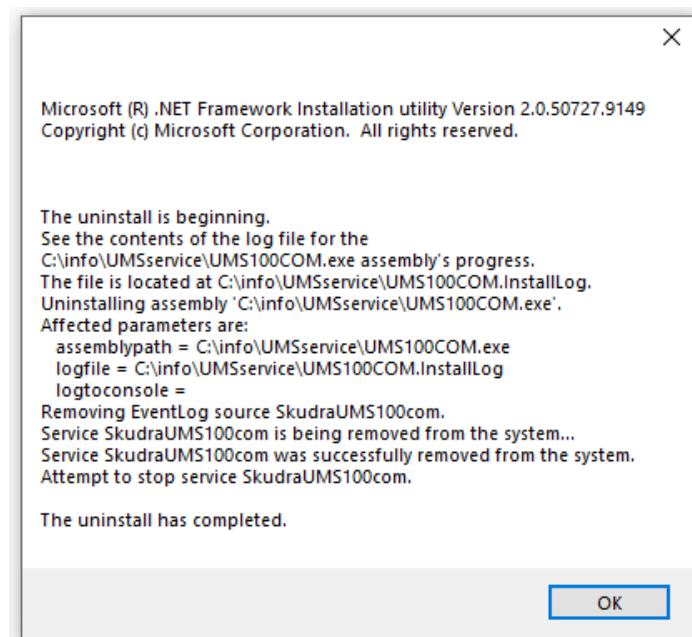
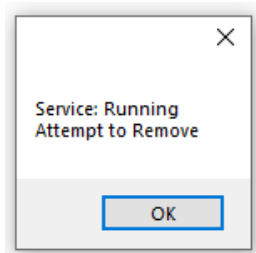
1.1.3.2 Settings of SkudraUMS100 service

- Serial (COM) port related settings is dependant of actual internal configuration of UMS100, however settings shown in this manual may be considered as default;
- As used serial (COM) port may not be visible in UMS100 device manager, it can be found using Serial port communications software (like PuTTY) by checking which port responds to connection requests;
- After restart of receiver Baud rate is set to 19200 (and such must be used when communicating through PuTTY), however SkudraUMS100 service sets Baud rate to selected in settings. Value of 115200 is recommended, as it provides faster data connection;
- For Skudra Patrol to recognize SkudraUMS100 service as UMS100 receiver, it is required to set Device name to "UMS100";

- TCP port has to be set to free port. Generally Skudra software uses ports in range 19005 to 19100, therefore it may be practical to use port in this range, as use of them already may be allowed by network administrator. However it is possible to use any free port of UMS100 computer, provided that network is configured to allow communication on selected port;
- Read and Write timeouts defines time how long service waits before request from Skudra Patrol is considered unsuccessful. Setting High values (in range of 1000 ms) is only necessary if network between Skudra Patrol and UMS100 frequently experiences comparable delays. High timeout values comes with drawback of longer communication retry times. However setting small (in range of tens of ms) response timeout maybe too short for receiver to perform sweep and return results.

1.1.3.3 Removal and update of SkudraUMS100 service

- Removal of SkudraUMS100 service can be done by installation (SkudraUMS100comLoader.exe);
- To stop and remove SkudraUMS100 service from UMS100 user has to press “Remove SkudraUMS100 service”. After following message boxes will be displayed:



- After SkudraUMS100 service is uninstalled, it can be updated (installed again with different settings). See 1.1.3.1

1.1.4 Supported direction finders

R&S DDF255, R&S DD205; R&S EB500; R&S ESMD; R&S PR200; Narda SignalShark

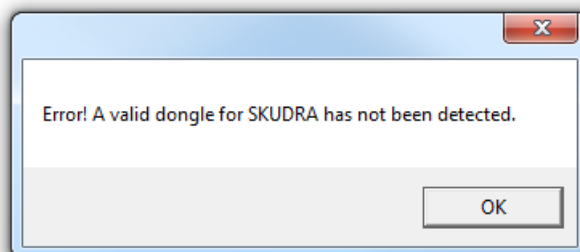
1.1.5 Licence protection

The software is protected from unlicensed use by a USB dongle. To start and use the software Skudra, the dongle accompanying the software licence agreement must be plugged into a USB port.



No manual driver installation is necessary for the dongle. The driver is installed by the *Windows* operating system when the dongle is first plugged in.

If the software is started without the dongle a warning message appears.



One dongle licenses three instances of Skudra running simultaneously.

1.2 Network configuration

The software Skudra uses the Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) to communicate with the receiver or Skudra Server Database.

Thus typically (however receiver can be configured to use different ports), Skudra should be allowed appropriate access to:

- Outgoing connection (from Skudra to receiver) on ports:

- 5555 (TCP) for all supported receivers except SignalShark and UMS100
- 5300 (TCP) for Narda SignalShark receivers
- 19050 (TCP) or other for UMS100 service (see. 1.1.3)
- 5563 (TCP) for R&S DDF550 in addition to 5555 (TCP)
- Outgoing connection (from Skudra to receiver) for TCP streaming on ports:
 - 5565 for receivers R&S EB500, ESMD, DDF255, R&S EB510, EM550, PR200, EM200, DDF550 (and derived devices e.g. R&S UMS300 and UMS400)
- Incoming connection (from receiver to Skudra) for UDP streaming on ports:
 - 19005 - 19100 (UDP) for R&S EB200, PR100; R&S EM100, DDF107, EM550 only. Often this functionality is firewall-blocked by default, and must be manually allowed. In case UDP packets are blocked, the connected receiver model may be determined, but monitoring spectrum is not acquired.
- In order to save monitoring results, as well as upload and save spectrum samples and spectrum usage statistics in the Skudra Server Database, a TCP connection is necessary (port 80 or 443).

Connecting via VPN and tunnelling, etc. is supported, but the delay involved may slow down the speed of scanning.

1.2.1 Firewall settings

Following is relevant to R&S EB200, PR100; R&S EM100, DDF107 and EM550 only.

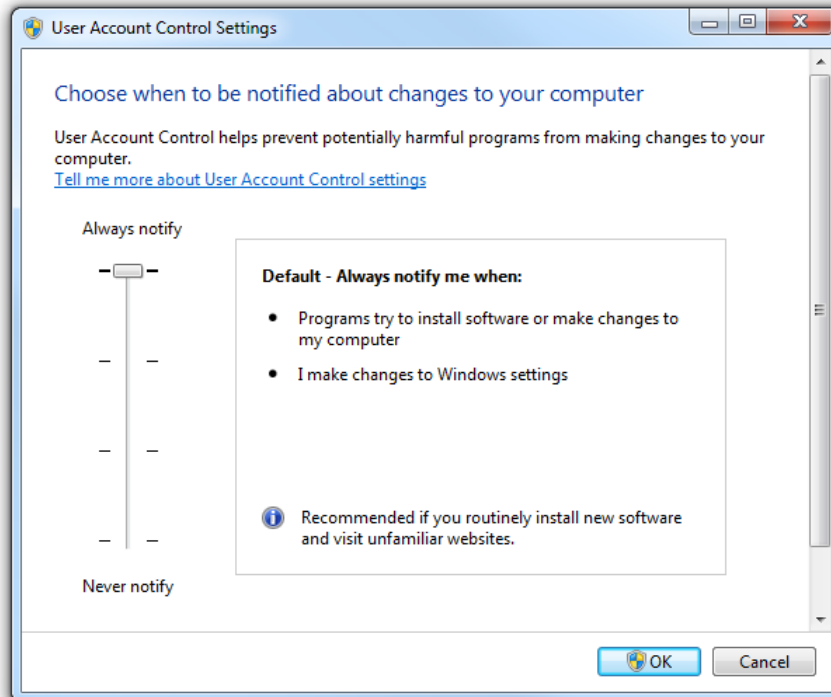
Initial use of Skudra software, depending on the computer configuration, may require unblocking Skudra access to arriving receiver UDP data.



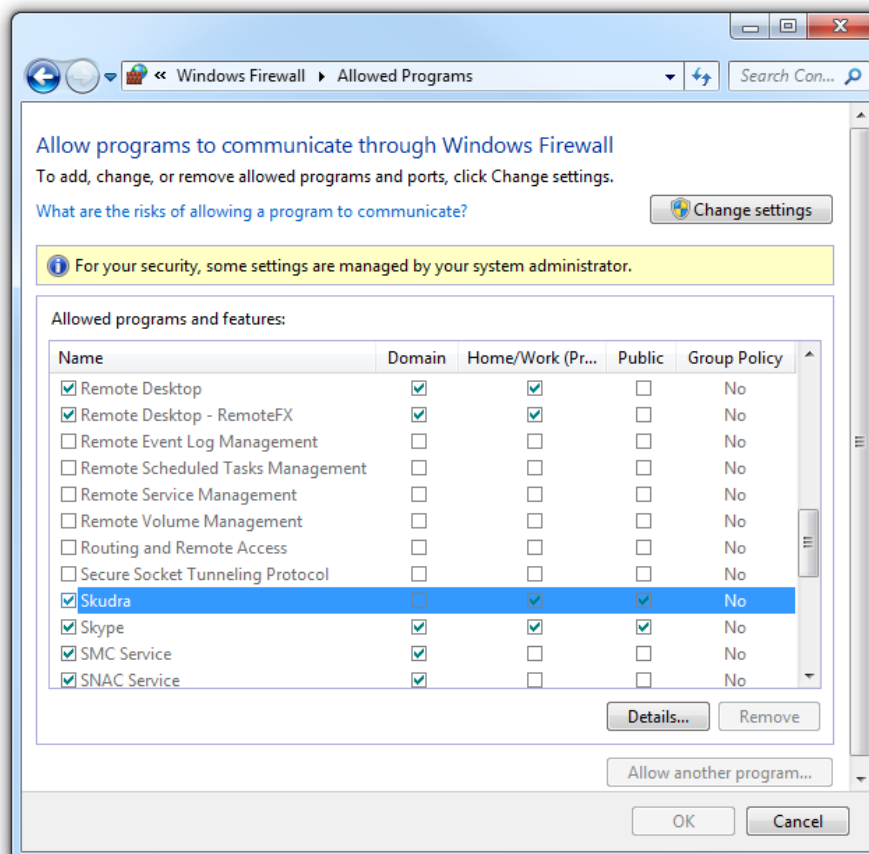
To allow access, it is necessary to define in which networks access to receiver data is licensed - work/home, public (sometimes, domain). The choice must be made according to the network connection indicator.



If there is no pop-up message concerning blocking of the software, you may need to check if *Windows* is set up to alert on the change of settings:

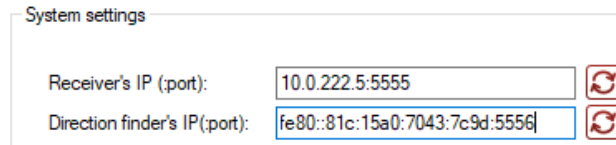


An alternative method is adding Skudra to the programs allowed to communicate through the *Windows* firewall or to alter the Skudra entry according to the used network.



1.2.2 IPv6 support

Skudra Patrol supports IPv6 addressing. IPv6 address can be provided in formats [2001:db8:85a3:8d3:1319:8a2e:370:7348]:443 or 2001:db8:85a3:8d3:1319:8a2e:370:7348:443. However, for address IPv6 to work it is necessary that receiver supports IPv6 also.



System settings

Receiver's IP (port): 10.0.222.5:5555

Direction finder's IP (port): fe80::81c:15a0:7043:7c9d:5556

1.3 Software update

Most often software updates are done by substituting the files in the *core* folder of Skudra with the updated ones. In special cases, when noted in the information accompanying the update, it may be necessary to change all the content of the core folder as explained in the next section.

After such updates the software will keep the setup intact and it will be possible to open earlier saved result files.

If old result files are not needed any more, their support may be terminated to make the software operation more effective.

1.3.1 Software update in special cases

If the description of the software update states that all of the *core* folder files should be changed, in order not to lose the software settings, prior to the change the following *core* files should be saved in a temporary folder of the user's choice:

- cfg_applications.xml
- cfg_licence_db.xml
- cfg_licence_spec.xml
- cfg_meas.xml
- cfg_paraugspektri.xml
- cfg_ranges.json
- cfg_user.xml
- cfg_viz.xml
- karte (folder)

The file "cfg_paraugspektri.xml" contains sample spectra. If the user has never appended the sample spectra, using "cfg_paraugspektri.xml" from the update should be considered, as this already contains sample spectra that enable optimal signal determination in the software developer's measurement environment. Similarly the

folder *karte* (map) update should be considered, because it contains the current map of Latvia, the update of which by software tools is time consuming.

Continuing the update, all content of the *core* folder should be deleted. If the old files remain, the software may not work properly. Further, all *core* files from the update should be copied to the computer's Skudra *core* folder and the earlier saved configuration files in the temporary folder should also be copied back to the computer's Skudra *core* folder.

! This special update procedure should also be used updating from a version earlier than 4.0.9 to 4.1.0 and higher.

1.3.2 Insignificant software updates

Doing insignificant software updates, if the accompanying information does not require otherwise, it suffices to substitute the computer Skudra *core* files with the ones in the update.

Most often updated are the files “skudra.exe”, “skudra.exe.dp64.dll” and “language.cfg”. Prior to substituting these the software should be closed.

2 Short Tutorial

2.1 Commencing measurements

To begin measurements, start the software either from the shortcut (1) or directly from the folder “\core\skudra.exe”.

The software Skudra will start with last session’s settings.

If no changes are needed in the measurement settings, monitoring can be commenced immediately by clicking the measurement start button (A.1). If changes are necessary, they should be applied in the settings section (0).

To start the software for the first time it is necessary to define at least the receiver’s IP address and port (5555) in the appropriate window (3.3).

Parameters most often changed in day-to-day operations:

- Geographical coordinates of the monitoring site (**Error! Reference source not found.** and **Error! Reference source not found.**);
- Monitoring range (D.1);
- Licence database file download (**Error! Reference source not found.** and **REF _Ref508629959 \r \hError! Reference source not found.**);
- Skudra Server authorisation (**Error! Reference source not found.** un **Error! Reference source not found.**)

2.2 Measurement process control

An ongoing measurement can be paused by clicking the button “PAUSE” (A.1) or completely stopped by clicking the button “STOP” (A.2).



Settings can not be changed during an ongoing measurement.

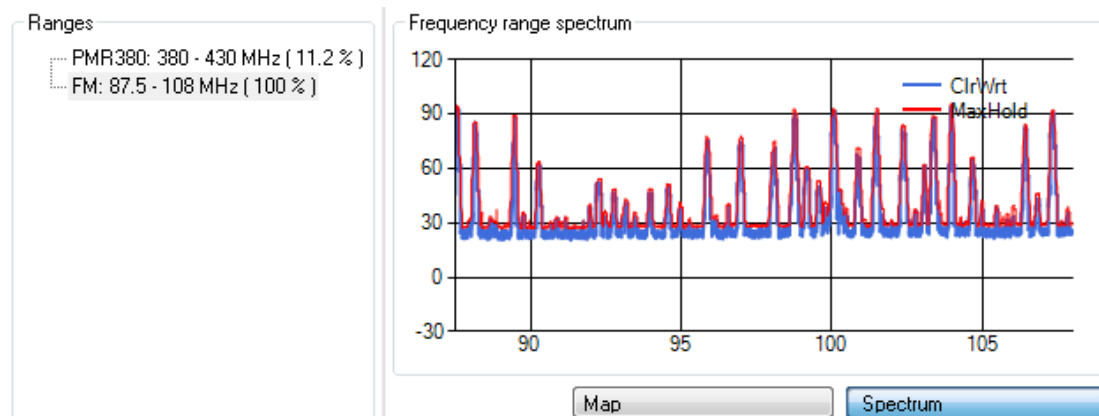
2.3 Measurement result analysis

The software constantly visualizes the measurement process regardless if the measurement is underway, paused or stopped completely, thus the user can observe ongoing events as they develop.

During measurement, bands checked in the settings section are scanned. Bands are scanned consecutively and cyclically. The progress of each range scan is displayed in parentheses after the range. By clicking the name of the range, the spectrum of the

respective range is visualized. It should be taken in account that, to see the spectrum ,the button “Spectrum” should be clicked.

The bands spectrum graph can be zoomed in by drawing the frame over the part of interest. The displayed spectrum central frequency can be changed (to sequently review the spectrum) by clicking the graph with the left mouse button. Zooming out to see the complete spectrum is done by clicking the graph with the right-hand mouse button.



Signal detection results from all scanned ranges are presented in the list of results. The results are aggregated by frequency channel and monitoring range. Each entry can have multiple parameters, which may be revealed or hidden by clicking the right-hand mouse button on the column title.

Frequency	Range	Corr.	Lev.	Diff.	Dist.	BW	%	Count	Em.class	Licence	Lic.Nr.	Application	Notes
87.6	FM	0.917	94.6	-5.6	2.3	95	100	749	300KF8...	Latvijas Valst...	BC-FM-148 - ...	TV analoque...	
88.2	FM	0.921	85.7	-2.3	2	122.5	100	749	300KF8...	SUPER FM I...	BC-FM-269 - ...	TV analoque...	
89.5	FM	0.919	89.1	-11.2	2.3	112.5	100	749	300KF8...	Latvijas Valst...	BC-FM-309 - ...	TV analoque...	
90.3	FM	0.923	63.6	2.4	23.1	130	100	749	300KF8...	SUPER FM I...	BC-FM-336 - ...	TV analoque...	
92	FM	0.835	40	-2.5	46.3	92.5	37.7	282	300KF8...	STAR FM	BC-FM-202 - ...	TV analoque...	
92.3	FM	0.895	53.9	9.4	31.4	155	100	749	300KF8...	SUPER FM I...	BC-FM-238 - ...	TV analoque...	
92.8	FM	0.883	48.5	4.1	42	140	100	749	300KF8...	RADIO VIDZ...	BC-FM-249 - ...	TV analoque...	
93.2	FM	0.759	42.9	-3.2	33.6	182.5	85.4	639	300KF8...	QBS	BC-FM-377 - ...	TV analoque...	
94	FM	0.869	48.8	-2.9	33.6	145	100	749	300KF8...	Radio TEV	BC-FM-273 - ...	TV analoque...	
94.6	FM	0.887	51.1	-0.7	33.6	150	100	749	300KF8...	RADIO VIDZ...	BC-FM-218 - ...	TV analoque...	

Explanation of signal detection result values:

Frequency - The frequency channel (MHz), where the signal was found. Depending on the range set, the channel step may be 100 kHz or 6.25 kHz;

Range - The name of the user-determined measurement range where the signals were detected;

Corr. - Average correlation value (see section □) of all signal events in the frequency channel;

Lev. - Field strength dBμV/m (see section □);

Diff. - The difference between the theoretically calculated and the measured field strength. Positive values are assigned to field strength that exceeds theoretically calculated, but negative - strength that is less than theoretically

calculated. Zero is displayed when the measurement is equal to the theoretical value or theoretical calculations show there should not be any signals at the monitoring site;

Dist. - Distance in kilometres from the monitoring site to the possible licence coordinates. Zero is displayed if by theoretical calculations the transmitter should not be received;

BW - the emission's bandwidth in kHz (see section 4.1.8);

% - Frequency occupancy (%) as the number of instances of signals determined over the number of scans, expressed in percent;

Count - Number of instances of signals determined;

Em. class - The class of emission most often determined, found by comparing the received signal with the sample spectra;

Licence - most probable licence (it's holder);

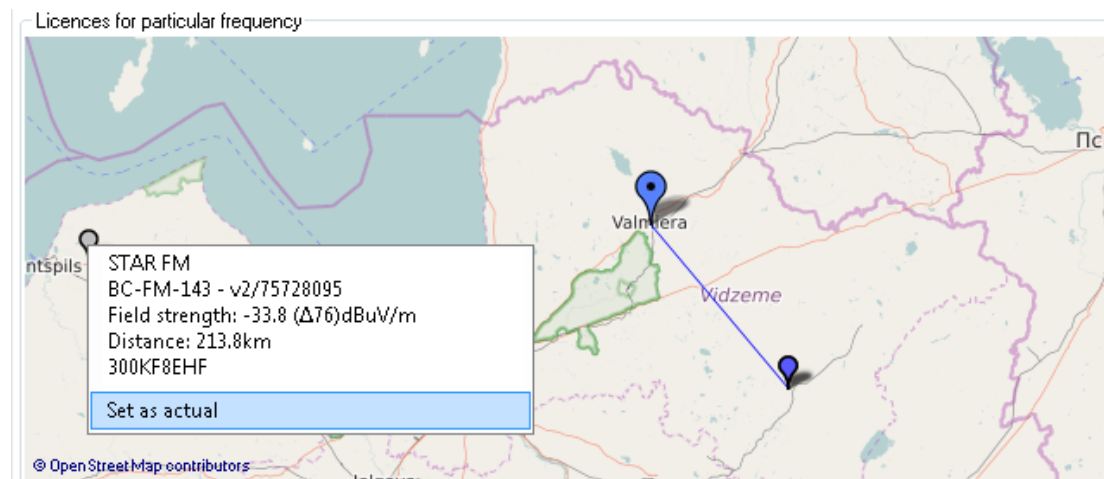
Lic.Nr - The number of the most probable licence;

Application - Radiofrequency application according to EFIS;

Notes - User added comment. Text input in this field will be linked to the saved entry in the Skudra file as well as the Skudra database.

By highlighting an entry in the signal determination result list, it is possible to show the corresponding licence on the map, the cumulated spectrum of the frequency channel, bandwidth breakdown and the time-level or occupancy graph of signals determined in the frequency channel.

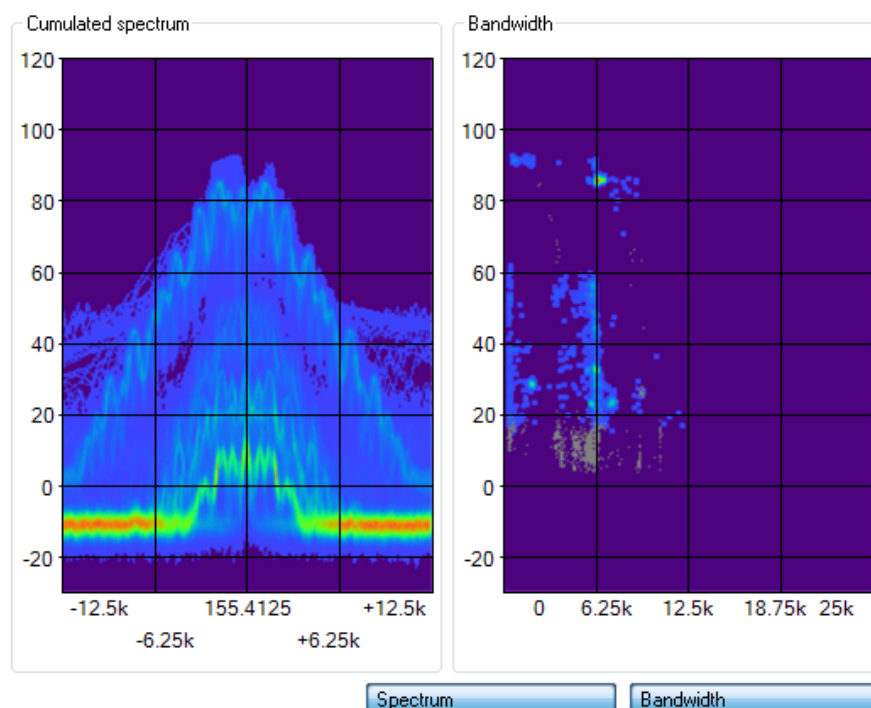
Click the button “map” to display the map.



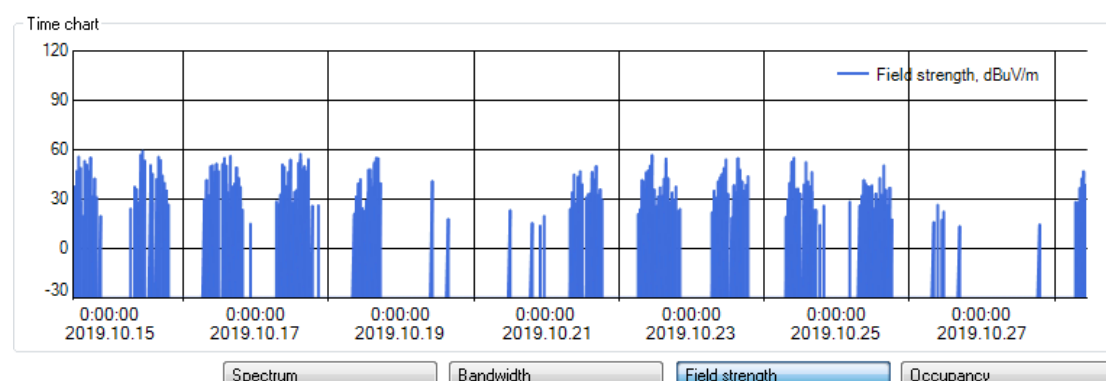
The map shows licences corresponding the frequency channel. The large blue marker shows the monitoring site. A small blue marker shows the most probable licence at the monitoring site, other licences are shown by grey markers. Clicking on the marker, a menu opens with licence owner and number, theoretically calculated level

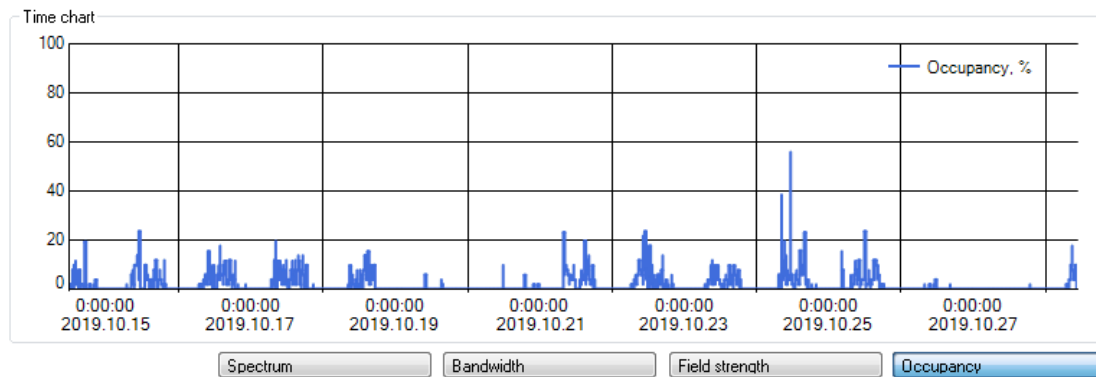
and its difference with the measurement result, distance to the monitoring site, emission class and the option to mark the licence as most probable. On the monitoring site marker it is possible to mark the most probable licence (owner) without linking coordinates.

To visualize the observed signal's cumulated spectrum and bandwidth breakdown in the frequency channel, the buttons "Spectrum" and "Bandwidth" should be pressed accordingly. The graphs show most often observed frequency - level pairs (or correspondingly, bandwidth - level pairs) with a hue that is closer to red. Less often observed values are shown with a hue closer to blue.



To view the detected signal field strength/time or occupancy/time graphs of the frequency channel the buttons "Field strength" or "Occupancy" should be correspondingly clicked. The graphs are shown alternatively - opening one, the second is closed. The occupancy graph shows the number of signal detections in 15 minute intervals.





Both the field strength and occupancy graphs may be zoomed into by drawing the frame over the spot of interest and zoomed out by right-click of the mouse on the graph.

2.4 Editing Measurement Results

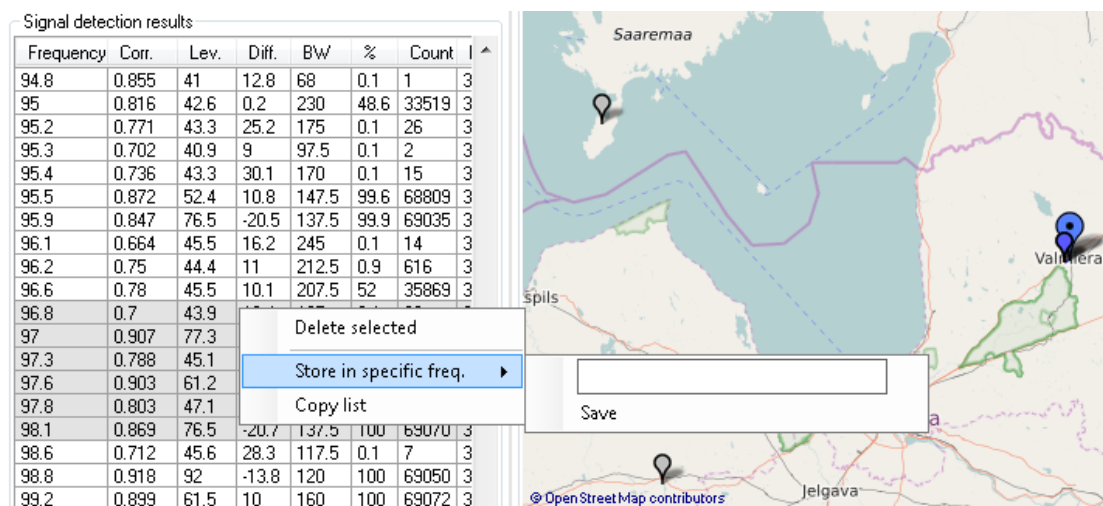
Results may be edited during measurements, after measurements have stopped, or opening an earlier saved result file.

The following editing actions are possible:

- Delete entries (frequency channels);
- Change licences designated as most probable;
- Recalculate most probable licences for all the signal determination result list, using modified monitoring site coordinates, updated licence database and other frequency licence input and range settings.

No other edits are foreseen, e.g., bandwidth or level time graph.

Signal detection result list entries may be deleted highlighting the entry and choosing “*Delete selected*” (delete highlighted) from the mouse right-click menu. Alternatively “*delete*” may be pressed on the keyboard. Entries may be deleted one by one or several at a time by highlighting them pressing and holding the keys “*Shift*” or “*Ctrl*”.



Licences found as most probable, can be changed only one by one. Licences included in the licence database or the list of specific frequencies can be chosen on the map, and on the marker menu clicking “set as actual”. In cases when the licence will not be listed in the database, the corresponding frequency/user pair can be saved to the specific frequency file, opening the mouse context menu by right-click, choosing “Store in specific freq.” (to the specific frequency list), inputting the user information and clicking “Save”.

Complete recalculation of the most probable licence, radio communication system, difference between theoretical and measured level of the signal determination list can be done by clicking the button “Recalculate results” in the “Stored measurement settings” section (B.4).

The results will be updated according to the current settings: “Coordinates”, “Rec. antenna height”, “Environment”, “Licence database file”, “Specific frequencies’ file” and it’s changes, “Application file”, as well as the newly set “Min. field strength” and “Guaranteed distance”.

2.5 Actions with the Receiver during monitoring

While the software Skudra is carrying out measurements, the receiver may be disconnected from the software. In this case the software will stand by until the receiver is reconnected or the measurement is manually stopped.

On disconnecting the receiver from the software it is safe to change any receiver settings (except the IP address and port). Upon reconnecting the receiver with the software, all settings necessary for the functioning of the software will restore their correct value.

Correction of software settings necessary for the operation of the software is not done constantly, but in specific moments (e.g., upon losing connection). Therefore, while the receiver allows it, parameter change during the operation of the software may give unforeseen results. The following settings have direct impact on the measurement results and software operation: IP configuration, IF spectrum display, duration of measurement, IF Span, IF spectrum accumulation mode, IF spectrum width - SPAN, RF attenuation, IF mode (Lowdist/Normal/LowNoise) and for individual receivers spectrum point width (Sharp/Narrow/Normal).

2.6 Stopping measurements, saving results and storing them in the database

Measurement may be stopped by clicking the “STOP” button (A.2).

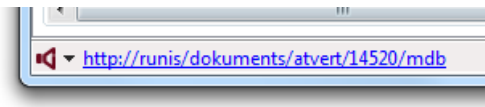


After interrupting the measurement, buttons will be shown to erase the active results from the software memory, saving and sending them to the database.



By clicking the save button (A.4), the results will be saved in the result folder indicated in the settings section (**Error! Reference source not found.**). The result file will be named automatically. The name will consist of the start date of monitoring, name of the measurement session, start and stop frequencies, a serial number based on the previous criteria and a version serial number in the sequence hereby listed.

Upon clicking the upload to database button (A.5), the results will be uploaded to Skudra Server. If successful, a link to the saved result will be shown in the measurement sections lower left corner, but in the case of failure a pop-up error message will be displayed.



User authorization is required for any interaction with Skudra Server. Authorization is done by entering the user's name and password and clicking "accept" button below password box or just pressing "Enter" key in password box.

Skudra SERVER paths

Skudra SERVER name:

Server authorisation:

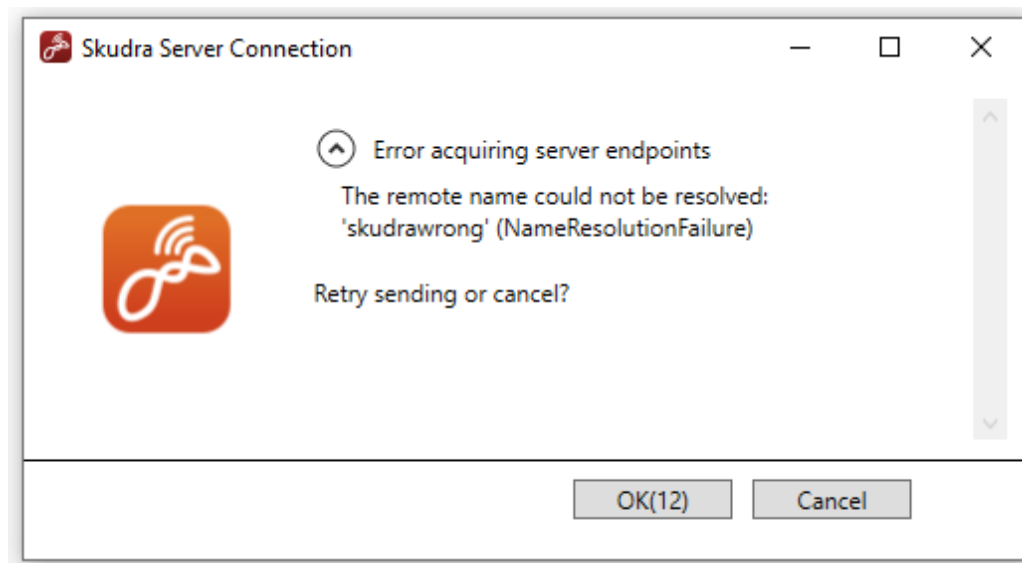
Skudra Server user:

Password:

☐ ☐

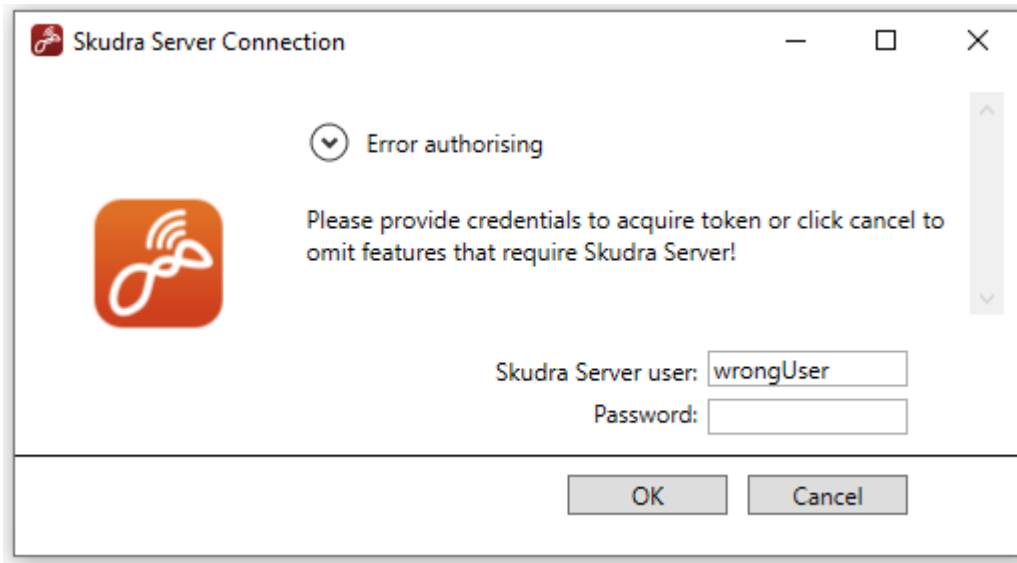
Access tokens received after successful authorisation are stored in Windows credential manager for each instance (separate executable file) of Skudra Patrol separately.

Normally continuous access to Skudra is maintained (if requested) by automatically retrying every 30 seconds.



Expander in the middle of the message box contains additional information about connection error.

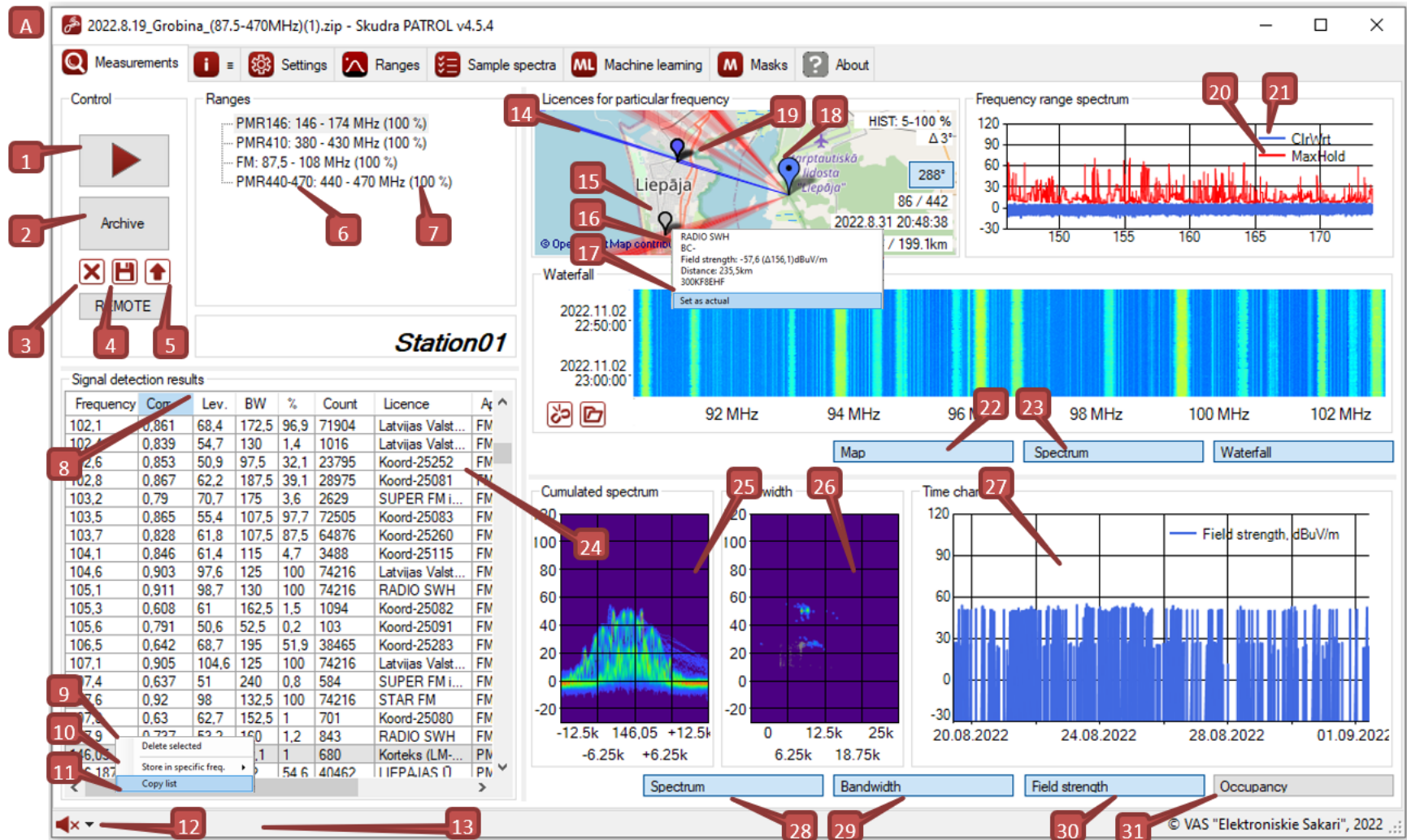
However in cases when connection is refused because of invalid or non-existent access token user is prompted for username and password.



The saved token may be deleted clicking the button with the cross in the group “Skudra SERVER paths”.

3 Description of the Software User Interface

3.1 Measurement section



- A.1. Combined functionality measurement start and measurement pause button;
- A.2. Combined functionality measurement interrupting and saved measurement opening button;
- A.3. Button to close current (indicated) measurement results;
- A.4. Button to save current (indicated) measurement results;
- A.5. Button to upload the current (indicated) measurement results to the database (*Skudra Server*);
- A.6. Bands in which monitoring will be done;
- A.7. Measurement cycle range scan progress;
- A.8. Signal detection results column title, that may comprise Frequency, Range name, Correlation, Level, theoretical level Difference, Distance to transmitter, emission occupied Bandwidth, how often the signal is detected (%), Number of emissions detected, Owner of the licence, Number of the licence, Radio communication application and user Notes;
- A.9. Menu to delete the highlighted entry from the list of signal detection results;
- A.10. Menu to add the highlighted entry to the list of specific frequencies;
- A.11. Menu to copy the list of signal detection results to the clipboard;
- A.12. Menu to adjust the receiver's volume while Paused;
- A.13. Area to display information on the working of the software;
- A.14. Map showing licences corresponding to the frequency;
- A.15. Marker showing licences assumed less possible;
- A.16. Menu showing information corresponding to the marker;
- A.17. Menu to change the highlighted licence as most probably corresponding to the signal;
- A.18. Blue marker showing most probable licences;
- A.19. Light blue marker showing the monitoring site;
- A.20. Selected range's spectrum maximum value curve (*MaxHold*);
- A.21. Selected range's spectrum instantaneous value curve (*ClrWrt*);
- A.22. Button to display and hide the map of licences corresponding to the frequency;
- A.23. Button to display and hide the range spectrum graph;
- A.24. List of signal detection results;
- A.25. Cumulated signal spectrum for an entry chosen from the list of signal detection results;
- A.26. Bandwidth/level two dimensional breakdown for an entry chosen from the list of signal detection results;
- A.27. Frequency time/level occupancy graph for an entry chosen from the list of signal detection results;
- A.28. Button to display and hide the cumulated spectrum;
- A.29. Button to display and hide the signal bandwidth/level two dimensional diagram;
- A.30. Button to display the level/time graph;
- A.31. Button to display the occupancy/time graph.

3.2 Stored measurements settings

B 2022.10.7_Grobina_(87.5-950MHz)(1).zip - Skudra PATROL v4.5.9

Measurements **i** = Settings **R** Ranges **S** Sample spectra **ML** Machine learning **M** Masks **?** About **2**

1 Settings

- File name
 - Measurement session
 - Measurement session title
 - Session type
 - Measurement time
 - Measurement coordinates
 - Result link
 - Antenna/receiver tract
 - Receiver type
 - Receiver IP address
 - Antenna information
 - Antenna file
 - Antenna factor
 - Cable information
 - Cable file
 - Cable attenuation
 - Measurement ranges
 - Measurement range list
 - Measurement ranges' directory
 - Receiver
 - Server ranges references
 - Licence database information
 - Licence database file
 - Specific frequencies' file
 - Application file
 - Rec. antenna height
 - Environment
 - Links information
 - Results folder
 - Results database link
 - Sample spectra database link
 - Username

Values of current/stored measurement session settings

	Name	Frequencies	Step	Attenuation	Licence det.	Narrowband det.	Mask detection	Broadband det.	Spectrogram	Statistics	DF
<input checked="" type="checkbox"/>	PMR146	146 MHz 174 MHz	6.25kHz/25kHz	RF input 1 5 dB LowDistortio	10 dBuVm 30 km	0.65 10 dB	OFF	OFF	ON Skudra Server	OFF	1x >0 dBuVm Any 5 s ,80%
<input checked="" type="checkbox"/>	PMR410	380 MHz 430 MHz	6.25kHz/25kHz	RF input 1 5 dB Normal	10 dBuVm 30 km	0.5 15 dB	OFF	OFF	ON Skudra Server	OFF	1x >0 dBuVm Any 1 s ,80%, server
<input type="checkbox"/>	Macibas	30 MHz 80 MHz	6.25kHz/25kHz	RF input 1 0 dB LowDistortio	10 dBuVm 30 km	0.6 15 dB	OFF	OFF	ON Locally	OFF	5x >5 dBuVm Any 1 s ,70%
<input type="checkbox"/>	870-874.4	870 MHz 874.4 MHz	6.25kHz/25kHz	RF input 1 0 dB LowDistortio	0 dBuVm 30 km	0.6 10 dB	OFF	OFF	ON Skudra Server Locally	OFF	OFF
<input type="checkbox"/>	1609-1676	1600 MHz 1680 MHz	1MHz/25MHz	RF input 1 0 dB LowDistortio	10 dBuVm 30 km	OFF	OFF	15 dB 0.5 prob. upperPAMR	ON Locally	OFF	OFF
<input checked="" type="checkbox"/>	FM	87.5 MHz 108 MHz	100kHz/200kHz	RF input 1 25 dB Normal	10 dBuVm 50 km	0.5 20 dB	OFF	OFF	ON Skudra Server	OFF	5x >30 dBuVm Any 10 s ,80%
<input checked="" type="checkbox"/>	PMR440-470	440 MHz 470 MHz	6.25kHz/25kHz	RF input 1 5 dB Normal	0 dBuVm 30 km	0.5 10 dB	OFF	OFF	ON Skudra Server	OFF	1x >0 dBuVm Any 1 s ,80%
<input checked="" type="checkbox"/>	GSM 900	850 MHz 950 MHz	1MHz/25MHz	RF input 1 10 dB LowDistortio	10 dBuVm 30 km	OFF	OFF	15 dB 0.5 prob. dvb+lte+low	ON Skudra Server Locally	OFF	1x >5 dBuVm Any 1 s ,80%

Edit licence detection settings

Min. field strength **3**

Guaranteed distance **4**

5 Recalculate results

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- B.1. Treeview to select stored or ongoing measurement session settings to be view in field on right;
- B.2. Display of measurement ranges list (choise selected in treeview on the left) of current or stored measurement session;
- B.3. Licence detection's minumum field strength input field to be used for Recalculation of results;
- B.4. Licence detection's guaranteed distance input field to be used for Recalculation of results
- B.5. Button for recalculation of the signal detection result list for an updated theoretically possible detectable transmitter list at the monitoring site

3.3 Settings section

PR200 - Skudra PATROL 4.7.0

Measurements **Settings** Ranges Sample spectra ML Machine learning Masks About

1 System settings

Usage of equipment: Sequential scanning and DF with same receiver

Receiver (IP port): 10.0.50.46:5555

DF (IP port): 10.0.50.46:5555 DF duration between scans (s): 15

Azimuth and location: Fixed azimuth correction without GNSS location

Additional azimuth correction (°): 0

Results' folder: C:\skudra_testu_results

Measurement session: Skudra v4.7.0 Type: fix

Antenna factor: 2.15dbi (30 - 3000 MHz)

Cable attenuation: generic_cable (30 - 3000 MHz)

2 Map cache

Language: ENG

Prefetch

Clear map

Offline

Map size: 514 MB

3 Specific frequency list

Frequency(Hz)	User	Em.class	Span(kHz)
156025000	Jūras mobilais dienests		0
156525000	Jūras mobilais dienests		0
156800000	Jūras mobilais dienests		0
156400000	Jūras mobilais dienests		0
156750000	Jūras mobilais dienests		0
446006250	PMR446		0
446018750	PMR446		0
446031250	PMR446		0
446056250	PMR446		0
446068750	PMR446		0
446081250	PMR446		0
446043750	PMR446		0
446093750	PMR446		0
457525000	Jūras mobilais		0
457575000	Jūras mobilais		0
467525000	Jūras mobilais		0
467550000	Jūras mobilais		0
467550000	Jūras mobilais dienests		0
381743750	Kabeļu TV		0
389743750	Kabeļu TV		0
397750000	Kabeļu TV		0
413750000	Kabeļu TV		0
421756250	Kabeļu TV		0
391250000	Kabeļu TV		0
399250000	Kabeļu TV		0
405750000	Kabeļu TV		0
407250000	Kabeļu TV		0
415256250	Kabeļu TV		0
429750000	Kabeļu TV		0
423250000	Kabeļu TV		0
446131250	PMR446		0

4 Import of licence database

Licence database file: final

Licence database download range (MHz): 80 500

Specific frequencies' file: db_specifikas

Application file: Allocation Compare-2024-04-11

Coordinates (decimal N/E): 56.96059722222 24.02814166666

Rec. antenna height (1-10m): 10

Environment: Small/medium city

5 Skudra SERVER paths

Skudra SERVER name: https://skudra

Server authorisation:

Skudra Server user: user

Password:

Skudra SERVER subpaths:

- ⊕ Authorisation subpath:
- ⊕ Results upload subpath:
- ⊕ Measurement event view subpath:
- ⊕ Licence download subpath:
- ⊕ Selected frequency view subpath:
- ⊕ Sample spectra subpath:
- ⊕ Remote control subpath:

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- C.1. System settings(4.2.2)
- C.2. Map storage settings(4.2.8)
- C.3. List of frequencies specific to monitoring site(4.2.6)
- C.4. Licence database configuration(4.2.4)
- C.5. Interaction with Skudra server(4.2.7)

3.4 Range definition section

PR200 - Skudra PATROL 4.7.0

Measurements **i** Settings **Ranges** Sample spectra Machine learning Masks About

Measurement range list

Receiver type: PR200 DF type: PR200

Name	Frequencies	Step	Attenuation	Licence det.	Narrowband det.	Mask detection	Broadband det.	Jammer det.	Spectrogram	Statistics	DF	DF settings
<input checked="" type="checkbox"/> FM	87.5 MHz 108 MHz	100kHz/200kHz	0 dB/Normal VERT/Active	10 dBuVm 30 km	0.6 15 dB	90 % > FM_MAX Min. Mask OFF 100 (100) kHz	OFF	OFF	OFF	ON 5 minutes	1x >30 dBuVm Any 1 s ,95%	DF thr.: 5 dBuV Vertical / Active 0 / Normal
<input checked="" type="checkbox"/> smd380	380 MHz 430 MHz	6.25kHz/25kHzIQ	0 dB/LowNoise VERT/Passive	10 dBuVm 30 km	0.6 15 dB	OFF	OFF	OFF	OFF	OFF	5x >30 dBuVm NRS 10 s ,80%	DF thr.: 0 dBuV
<input type="checkbox"/> cellular	700 MHz 900 MHz	1MHz/25MHz	30 dB/LowDistortion	10 dBuVm 30 km	OFF	OFF	15 dB 0.5 prob. drone	3 dB 20 - 29: 31 - 44: 46 - 500 kHz	ON Skudra Server Locally	OFF	OFF	OFF

Frequency range name: FM

Receiver settings

Start/end frequency: 87.5 108

Channel step: 100kHz/200kHz

RF input: -

Attenuator(dB): 0

IF Attenuator: Normal

Antenna ctrl.: VERT/Active

Licence detection

Min. field strength: 10

Guaranteed distance: 30

☒ Narrowband detection

Correlation squelch: 0.6

Noise squelch(dB): 15

☒ Mask detection

Max. mask: FM_MAX 90 %

Min. mask: OFF 90 %

Step(kHz): 100 / 1 BW: 100

☐ Jammer detection

Noise squelch(dB): 3

Carrier spacing(from to, kHz): 30 - 180

Car. specificity: 1

Exclude: GSM LTE 5G

☐ Broadband detection

Noise squelch(dB): 15

Prob. squelch: 0.5

ML model: drone

☒ Report statistics

Reporting interval: 5

Spectrogram storage

☐ Locally

☐ Skudra Server

☒ Triggered DF

Dwell time(s): 1 Quality(%): 95

Trigger conditions (Field str., count, freq.): 30 >dBuVm 1x Any

DF list(MHz):

☐ Report DF to Skudra Server

DF equipment settings

Threshold (dBuV): 5

DF polarisation: Vertical

DF amplification: Active

DF antenna input:

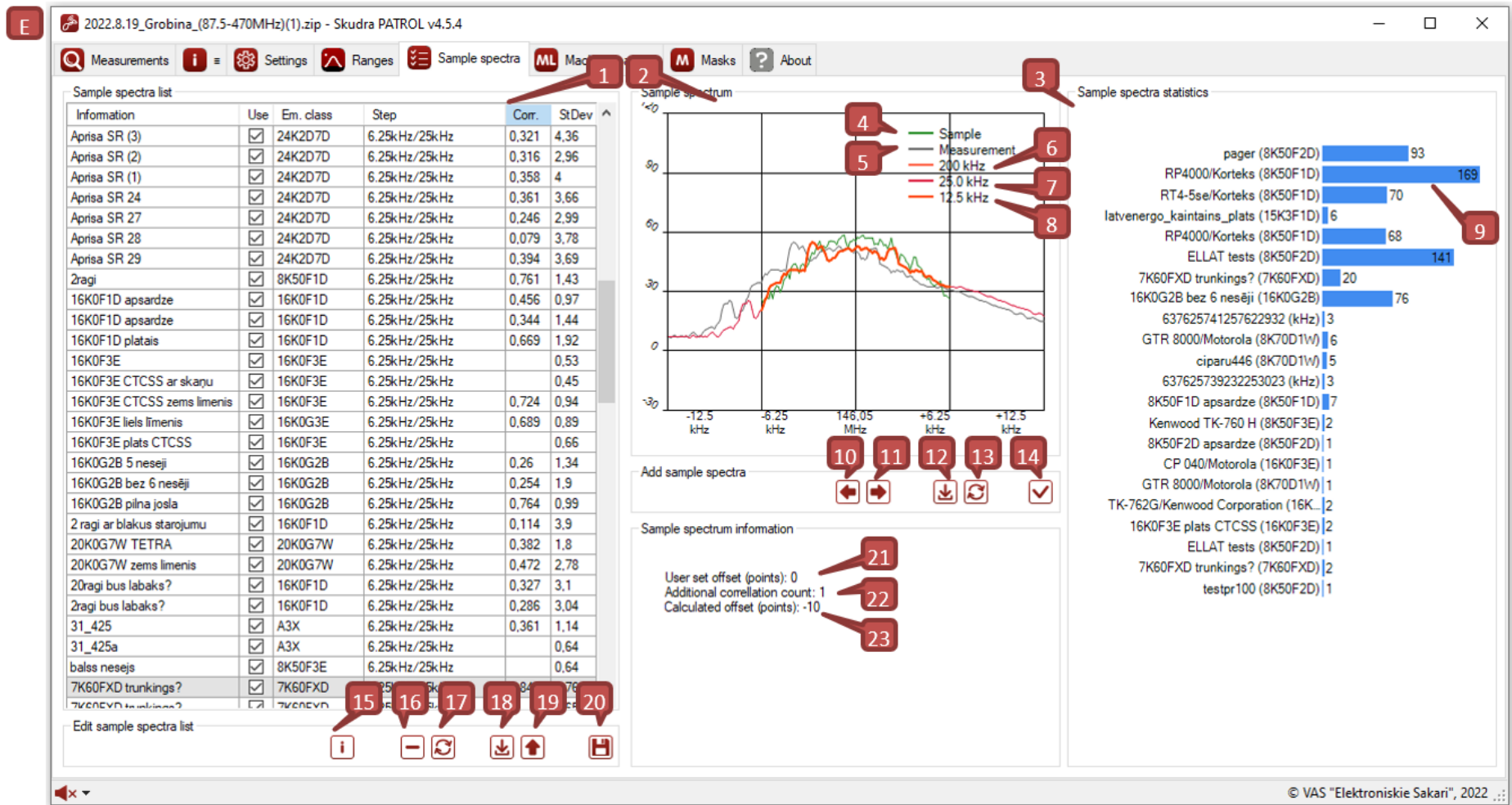
DF attenuator: 0

DF IF attenuator: Normal

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- D.1. Measurement ranges editing list (4.3.11)
- D.2. Range receiver settings(4.3.1)
- D.3. Range licence detection settings(4.3.2)
- D.4. Range narrowband (correlation) detection settings(4.3.3)
- D.5. Range mask detection settings(4.3.4)
- D.6. Range jammer detection settings(4.3.5)
- D.7. Range broadband (machine learning) detection settings(4.3.6)
- D.8. Range statistics and spectrogram settings(4.3.7)
- D.9. Range direction finding triggering settings(4.3.9)
- D.10. Range direction finder's settings(4.3.10)

3.5 Sample spectra section



- E.1. Sample spectra list;
- E.2. Sample spectra display and defining graph;
- E.3. Sample spectra usage statistics graph;
- E.4. Sample spectrum highlighted in the list;
- E.5. The highlighted entry's (in the signal detection list) cumulated spectrum quasi mode value;
- E.6. A potential sample curve of values of 200 kHz wide spectrum;
- E.7. A potential sample curve of values of 25 kHz wide spectrum;
- E.8. A potential sample curve of values of 12.5 kHz wide spectrum;
- E.9. Sample spectra which have been determined as closest to the highlighted entry in the signal determination result list and how often they have been observed;
- E.10. Button for manual fine tuning of the middle frequency of the highlighted potential sample spectrum to a lower value;
- E.11. Button for manual fine tuning of the middle frequency of the highlighted potential sample spectrum to a higher value;
- E.12. Button to obtain quasi-mode spectrum and potential sample spectrum from the highlighted entry in the signal detection result list;
- E.13. Button to cancel the manual changes to potential sample spectra;
- E.14. Button to add the highlighted potential sample spectrum to the sample spectra list;
- E.15. Button to visualize the statistics of all frequencies where the signal was determined to be close to the selected sample spectrum including number of occurrences;
- E.16. Button to delete the highlighted sample from the software's list of sample spectra;
- E.17. Button to erase all unsaved changes to the list of sample spectra;
- E.18. Button to add remotely stored (Skudra Server) sample spectra to the local sample spectra list;
- E.19. Button to upload the highlighted entry in the list of sample spectra to Skudra Server;
- E.20. Button to save changes to the list of the local sample spectra;
- E.21. Information on the deviation of the user added frequency offset points of the potential sample spectrum from the sample spectrum middle frequency;
- E.22. Information on the additional number of necessary correlations to the potential sample spectrum (each with an additional frequency deviation of one point);
- E.23. Information on the number of offset points of the automatically determined potential sample spectra central frequency.

3.6 Machine learning section

2022.8.19_Grobina_(87.5-470MHz)(1).zip - Skudra PATROL v4.5.4

Measurements **i** Settings Ranges Sample spectra **ML** Machine learning **M** Masks ? About

Machine learning source data preparation

1. Selection of spectrogram data

Locating files...
20232-0-256.zip (460 MHz - 980 MHz):
1MHz / 25 MHz: 126720 samples
Completed
Total: 126720

2. Identify samples with range above (dB):

126720 samples mapped for identification
Checked: 126720 , above squelch: 33455

3. Reduce amount of samples to :

10000 samples selected for Machine learning
10000 samples processed
populating list...completed

4. Labeling of samples

Time	Frequency	BW	offset	Label
20232	937000000	25000000	0,56071...	<input type="checkbox"/>
20232	938000000	25000000	-0,4194...	<input checked="" type="checkbox"/>
20232	939000000	25000000	0,02816...	<input type="checkbox"/>
20232	940000000	25000000	0,07884...	<input type="checkbox"/>
20232	941000000	25000000	-0,2205...	<input type="checkbox"/>
20232	942000000	25000000	0,01948...	<input type="checkbox"/>
20232	943000000	25000000	0,14246...	<input type="checkbox"/>
20232	944000000	25000000	0,03266...	<input type="checkbox"/>
20232	945000000	25000000	0,01555...	<input type="checkbox"/>
20232	946000000	25000000	-0,1246...	<input type="checkbox"/>
20232	947000000	25000000	-0,0186...	<input type="checkbox"/>
20232	948000000	25000000	-0,2493...	<input type="checkbox"/>
20232	949000000	25000000	0	<input type="checkbox"/>
20232	950000000	25000000	0,01290...	<input type="checkbox"/>
20232	951000000	25000000	-0,0275...	<input type="checkbox"/>
20232	952000000	25000000	0	<input type="checkbox"/>
20232	953000000	25000000	0,03857...	<input type="checkbox"/>
20232	954000000	25000000	-0,0851...	<input type="checkbox"/>
20232	955000000	25000000	0,00588...	<input type="checkbox"/>
20232	956000000	25000000	0	<input type="checkbox"/>
20232	957000000	25000000	0	<input type="checkbox"/>
20232	958000000	25000000	0	<input checked="" type="checkbox"/>
20232	959000000	25000000	0,28	<input type="checkbox"/>

5. Fitting the model

0,0884 (84,0/(84,0+866,0))
Confusion table

	positive	negative	Recall
PREDICTED			
TRUTH			
positive	84	0	1,0000
negative	0	866	1,0000
Precision	1,0000	1,0000	

Spectrum of sample

Management of spectrum samples

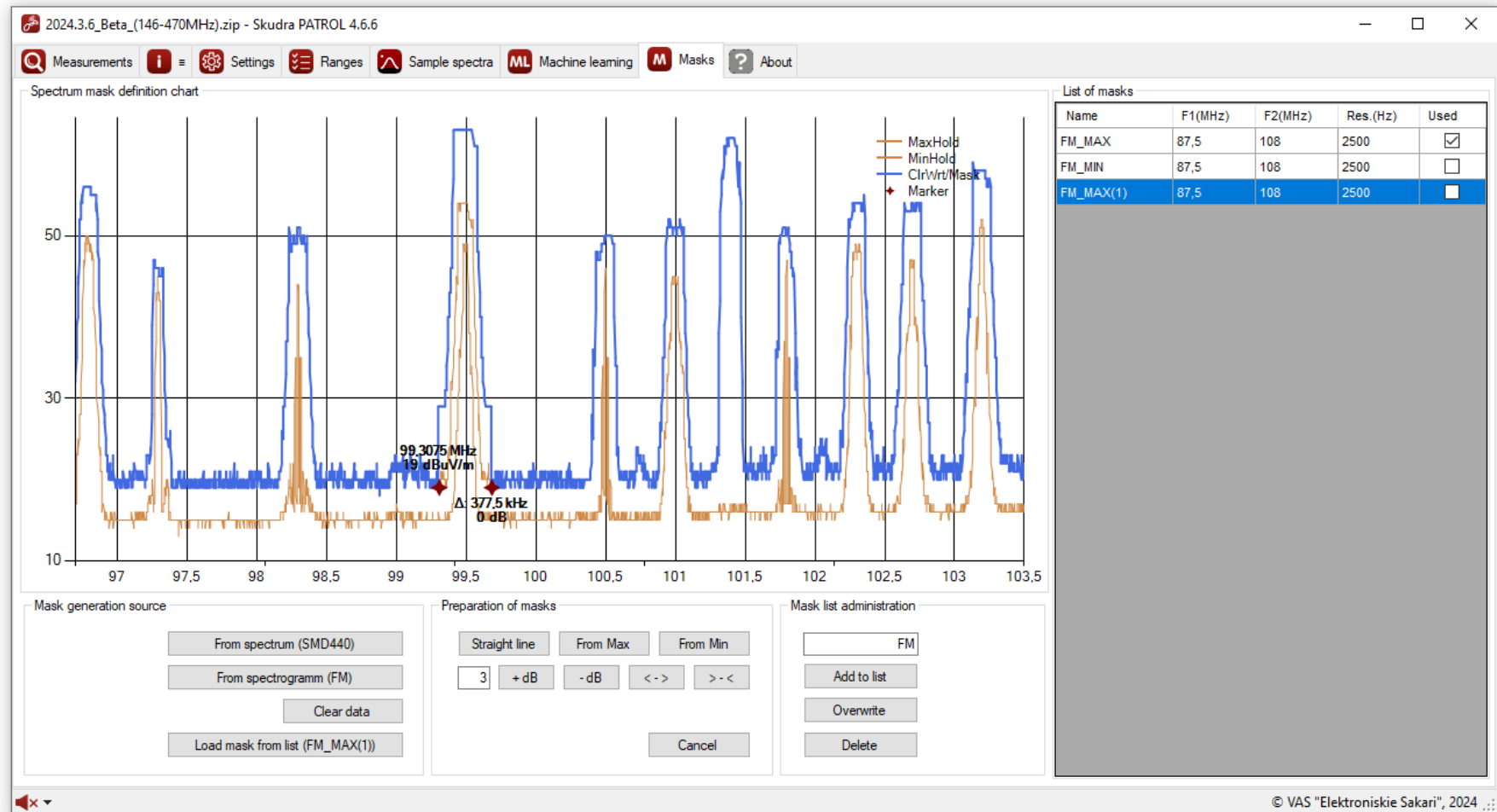
saved to: test_grobina.json

Import of fitted models for broadband detection

Loading models..
test_grobina.. Loaded
Models stored successfully / ready for use

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3.7 Masks section

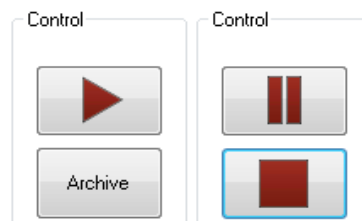


4 Description of Complete Functionality

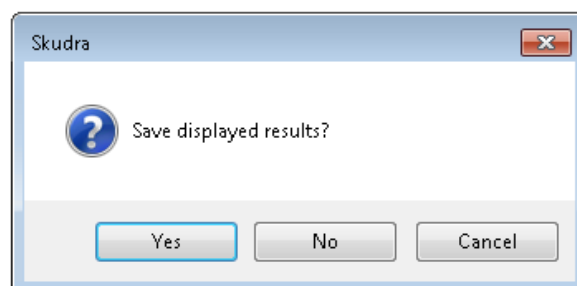
4.1 Measurement control and visualization

4.1.1 Starting, stopping and interrupting measurements

- To start measurements click the typical multimedia design button “Play” (A.1), to stop - “Stop”(A.2);

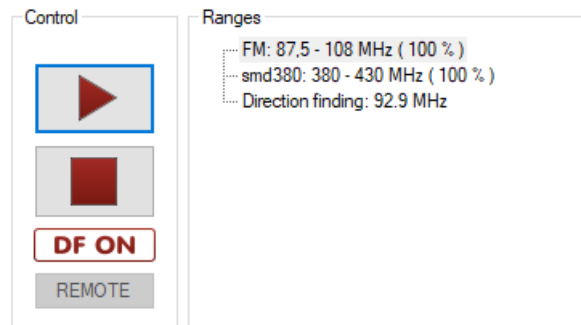


- It is possible to pause the measurement by clicking the button “Pause” (A.1), and restart by clicking the button “Play”. During the paused measurement the receiver may be used for aural monitoring, and other purposes, including disconnecting from the software. After clicking the button “Play” monitoring will resume and the results will not be fragmented.
- If prior to commencing measurements the software contains unsaved measurement data or unsaved open measurement results, the software will offer to save the existing results, not save/discard changes or cancel opening of the result file.

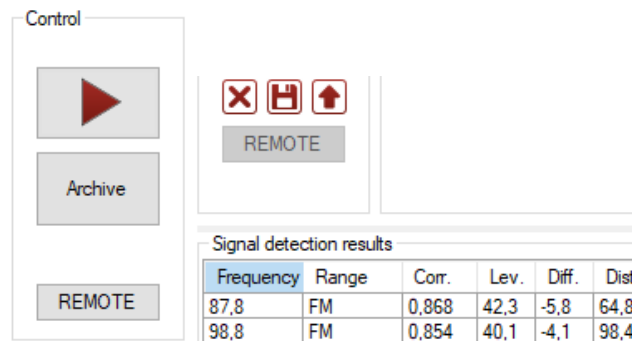


- If any active (set as used) measurement range has DF triggering enabled (4.3.9), “DF ON” / ”DF OFF” button is visible in “Control” group. Also Direction finding record together with currently active DF-ied frequency is shown in “Ranges” group.
- When starting measurement session button is in “DF ON” state, indicating that direction finding is in progress. Direction finding can be interrupted by setting (clicking) button to “DF OFF” state, and continued by setting (clicking) to “DF ON” state. During the interruption direction finder can be used for any other task. However, by interrupting DF process, all DF requests

enqueued (5.3), yet not DFied will be lost. DF requests completed are not influenced;



- “Direction finding: On hold” message is displayed in “Ranges” group if direction finding is not performed by several reasons:
 - User has pressed “DF OFF” button,
 - Receiver is being used for frequency scanning, when same equipment is used as receiver and direction finder,
 - All frequencies on direction finding queue have been DF-ied.
- It is possible to run Skudra Patrol in remote control mode (4.8), when measurement ranges are configured, measurements started and stopped, and results saved automatically by Skudra Server. This mode is enabled and disabled by toggling “REMOTE” button;

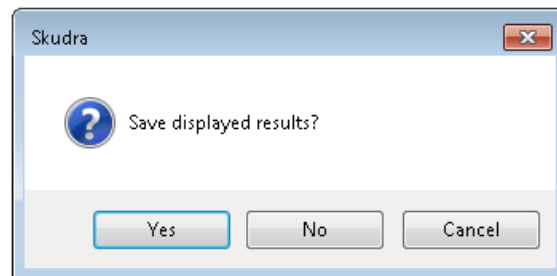


- Remote control mode can be enabled only if no measurements are active and Signal detection results are cleared.

4.1.2 Saving and opening the results

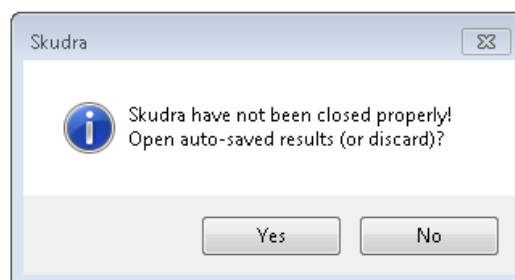
- Upon stopping the measurements the result may be saved in a file by clicking the button “Save” (A.4);
- The result will be saved together with the setting information in a “zip” file which is automatically named by a sequence of the monitoring start date, measurement session name, start and stop frequencies, a serial number based on the previous criteria and a version serial number in the sequence hereby listed. The result file will be saved in the folder specified in the settings section (Error! Reference source not found.);

- The result file may be opened clicking the button “Archive” (A.2) and selecting the appropriate file. Opening the file, full functionality is restored as it was after stopping the measurement;
- If prior to opening a result file the software already contains unsaved measurement results or unsaved changes of open measurement results, prior to opening the new file the software will offer to save the existing results, not save/discard changes or cancel opening of the result file.



4.1.3 Automatic saving of results

- During measurement and introducing changes to either earlier saved or unsaved results, results are automatically saved in an internal software file. The goal for this automatic saving is to prevent loss of the results in case of incorrect closure of the software, e.g., unforeseen shutdown of the computer;
- In cases of it's incorrect closure, the software will inform the user and offer to save the automatically saved results;



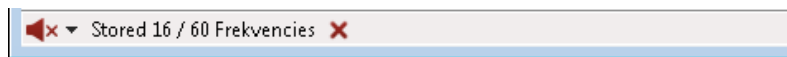
- If the software was closed correctly, it is not possible to restore unsaved results.

4.1.4 Upload results to Skudra Server

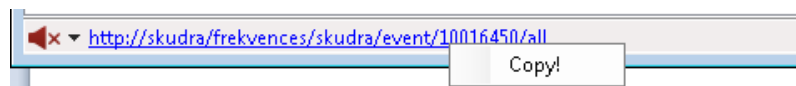
- After stopping measurements, the signal detection results may be uploaded to Skudra Server by clicking the button “upload” (A.5) in the measurement section;



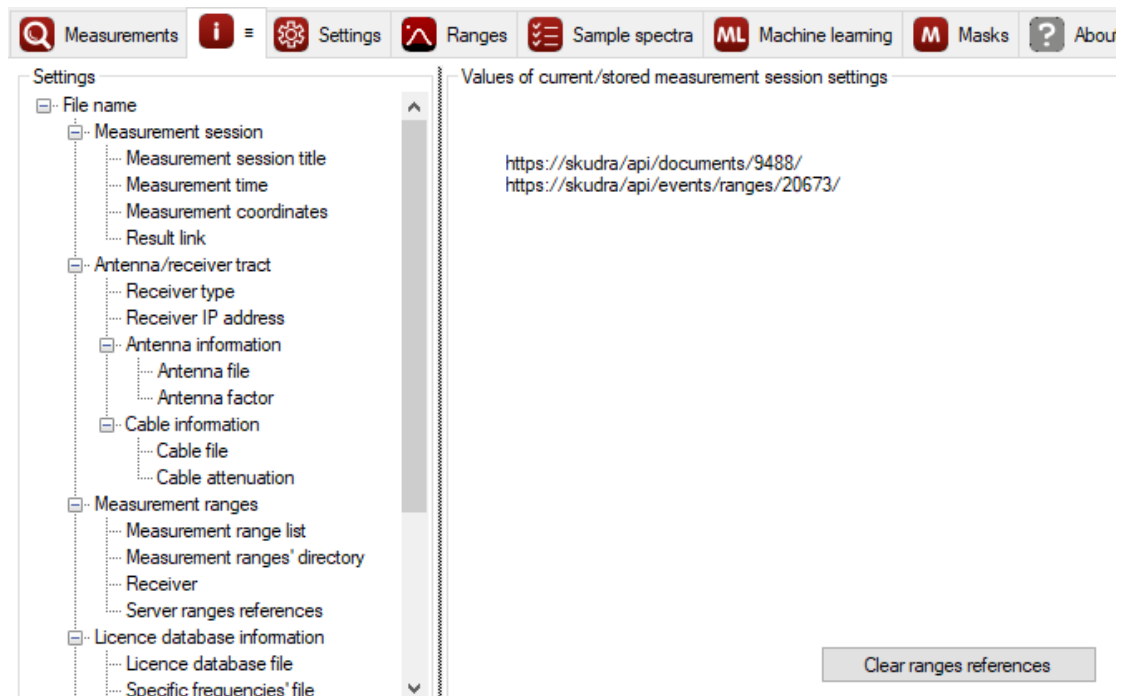
- To enable uploading the results, the software must have access to the Skudra Server access key (see section 4.2.7);
- The following information is sent to Skudra Server: monitoring coordinates, time of monitoring, measurement session type, measurement range limits, the contents of the signal search result list (all columns), the cumulated spectra of each entry, bandwidth breakdown, signal level change with time, DF results (if available);
- The upload progress during uploading the results is shown in the bottom left corner of the software window;



- When upload is complete a link to the saved result is displayed in the bottom left corner of the software window. It is possible to copy the link to the uploaded result to the clipboard by right-clicking the link and choosing “copy”.



- If measurement has been set-up, with options that performs periodic updates to Skudra (DF reporting to Skudra server, statistics, waterfall spectrogram storage to server) and corresponding measurement has been deleted from Skudra server, measurement upload to server will result in error “*Storing to Skudra Server not complete The remote server returned an error: (500) Internal Server Error. DoesNotExist at /api/events/ranges/...*”. To avoid that Skudra server measurement reference at Skudra Patrol has to be cleared at “Stored measurement settings” panel’s (3.2) “Server ranges reference” selection by clicking “Clear ranges refences”.

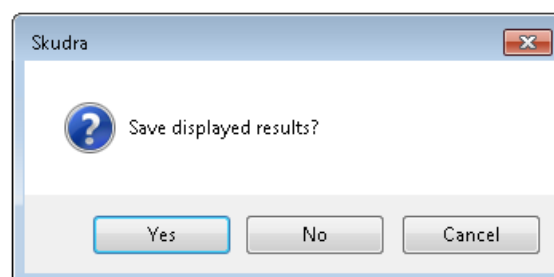


4.1.5 Closing measurements results and the software

- The results displayed by the software may be closed clicking the button “X” (A.3) in the group of control buttons;



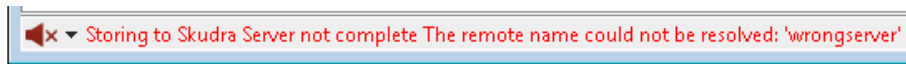
- The software may be closed by clicking the button “X” in the software window’s upper right corner;
- If there remains unsaved measurement data or unsaved open measurement results when closing the data file or the software, the software will offer to save the existing results, not save/discard changes or cancel closing of the result file or software.



- If there is no warning displayed, there have been no unsaved results in the software.

4.1.6 Informative messages

- Most error messages and other information that will occur while running the software will appear in the area for informative messages (A.13) at the lower left of the software window;



- These messages may be copied to the clipboard or cleared by clicking the right mouse button and choosing “copy” or “clear” respectively.

4.1.7 Measurement ranges

- By clicking the measurement start button (A.1) measurements are started in the ranges (A.6) that are displayed in the group “Ranges”. Measurement ranges and parameters should be defined in the measurement range list in the settings section (D.1);
- If any of measurement ranges is set up to trigger direction finding, currently active direction finding task or direction finding status will be shown as last record in “Ranges” group.



- At each range the appropriate scanning progress of the measurement cycle is shown (A.7);
- During measurements or while reviewing earlier measurement results, by clicking the left mouse button over the range, the appropriate range’s spectrum will be displayed.

4.1.8 Signal detection result list

- The signal search result list (A.24) shows entries of all frequency channels where signals were observed;

Signal detection results

Frequency	Range	Corr.	Lev.	BW	%	Count	DF cnt.	Em.class	Licence	Lic.Nr.	Application	Notes
101	FM	0.92	97.6	137.5	100	3	1	300KF8...	LIE		FM sound an...	
104.6	FM	0.933	95.1	87.5	100	3	1	300KF8...	LIE		FM sound an...	
103.5	FM	0.863	51.5	50	100	3	1	300KF8...	SK		FM sound an...	
107.6	FM	0.924	90.4	130	100	3	1	300KF8...	LIE		FM sound an...	
89.5	FM	0.878	52.2	105	100	3	1	300KF8...	AIZ		FM sound an...	
103.7	FM	0.826	44.8	215	100	3	1	300KF8...	KL		FM sound an...	
106.5	FM	0.683	47.5	187.5	66.7	2	1	300KF8...	KL		FM sound an...	
91.4	FM	0.665	38	55	33.4	1	0	300KF8...	KL		FM sound an...	
91.6	FM	0.779	48.2	212.5	100	3	0	300KF8...	SK		FM sound an...	
91.8	FM	0.826	38.4	85	33.4	1	0	300KF8...	"."		FM sound an...	
92.3	FM	0.914	85.2	152.5	100	3	0	300KF8...	LIE		FM sound an...	
92.9	FM	0.897	83.3	112.5	100	3	0	300KF8...	LIE		FM sound an...	
93.5	FM	0.909	87.1	147.5	100	3	0	300KF8...	LIE		FM sound an...	
94.6	FM	0.903	60.2	147.5	100	3	0	300KF8...	LIE		FM sound an...	
94.9	FM	0.829	45.2	180	100	3	0	300KF8...	KL		FM sound an...	
95.2	FM	0.892	89.4	157.5	100	3	0	300KF8...	LIE		FM sound an...	
95.6	FM	0.915	64.3	127.5	100	3	0	300KF8...	LIE		FM sound an...	
96.1	FM	0.918	88.2	147.5	100	3	0	300KF8...	LIE		FM sound an...	
96.6	FM	0.826	47.7	120	100	3	0	300KF8...	AIZ		FM sound an...	
97.1	FM	0.818	87.9	20	100	3	0	300KF8...	LIE		FM sound an...	
97.5	FM	0.912	76.1	132.5	100	3	0	300KF8...	LIE		FM sound an...	
97.9	FM	0.915	96.3	75	100	3	0	300KF8...	LIE		FM sound an...	

- Detecting a signal in a frequency channel where previously no signal was detected (no entry in the list), a new entry appears top of the list. If the signal is detected repeatedly, content of the entry is appended;
- The result list may be arranged in an ascending or descending order for every shown value by clicking the left mouse button on the columns title (A.8);
- The result list's columns may be displayed or hidden by clicking the columns title (A.8) with the right mouse button and choosing the appropriate columns out of the context menu appearing;
- Highlighting an entry to the result list, the appropriate cumulated spectrum (A.25), bandwidth breakdown (A.26), licences corresponding to the frequency including map coordinates (A.14) and the time or occupancy graph (A.27) is displayed. Highlighting several entries, information will be displayed for the last highlighted entry.
- Introduced changes to the signal determination list can be saved to new result file or uploaded to the database. Already saved result files and database entries will not be edited.
- The size of the signal search result list may be changed by dragging the lists top and right-hand borders. Column size (respecting the system design minimum) may be changed by dragging the column title borderlines.

4.1.9 Explanation of Signal Determination Result Parameters

Frequency - The frequency channel (MHz), where the signal was found. Depending on the range setting (D.1), the channel step may be 100 kHz or 6.25 kHz;

Range - The name of the user determined measurement range where the signals were found;

Corr. - Average value of detection quality of all registered signal events in the frequency channel. However, different signal detection types have different meaning for this parameter:

- For narrow band detection - maximum Pearson correlation coefficient squared (determination coefficient) among correlations of all sample spectra;
- For broadband detection - Selected ML model output from 0 to 1;
- For jammer detection - Maximum of Carrier specificity in dB, in specified spacing range;
- For mask detection - maximum mask overshoot/undershoot value in dB;

Lev. - Maximum electromagnetic field strength db μ V/m exceeding 2% of events of signal detection. The field strength is calculated by adding the antenna factor and cable attenuation (see 4.2.2) to the signal level. The signal level of each detection is calculated as the maximal value of spectrum in the signal bandwidth. The 100 kHz channel step FFT resolution is 2.5 kHz, 6.25 kHz - 125 Hz, *Blackman* windowing.;

Diff. - The difference between the theoretically calculated and the measured field strength. Positive values are assigned to field strength that exceeds theoretically calculated, but negative - field strength that is less than theoretically calculated. Zero is displayed when the measurement is equal to the theoretical value or theoretical calculations show there should not be any signals at the monitoring site;

Dist. - Distance in kilometres from the monitoring site to the possible licence coordinates. Zero is displayed if by theoretical calculations the transmitter should not be received;

BW - the emission's maximum bandwidth in kHz exceeded in 5% of signal detections at a signal to noise ratio at least 30 dB. If the signal to noise ratio has never exceeded 30 dB, the bandwidth is calculated as maximum of unique bandwidth level combination pairs exceeding 5% of signal observations. The signal bandwidth in each detection event is determined by the 1% B (99% power in bandwidth) method, and by the mid-level between the maximum level and noise level if the signal to noise ratio does not exceed 30 dB;

Count - Number of instances of signals detected;

DF cnt. - Number of direction finding attempts that successfully returned direction

Em. class - For narrowband detection the class of emission of the sample spectrum that most often correlates most with the signal in the specific frequency channel. For broadband, jammer and mask detection field is always filled with "broadband", "jammer" and "mask" respectively;

Licence - The holder of the most probable licence of the signal received at the monitoring site. The addressees or users that are not linked to coordinates are shown in parantheses;

Lic. Nr. - The number of most probable licence of the signal received at the monitoring site;

Application - Radiofrequency application relevant to frequency in the EFIS classifier according to the downloadable file from www.efis.dk which has been set in the settings section as radiofrequency application file (6.1.5);

Notes - User added comment. Text input in this field will be linked to the entry in the signal determination result file.

Frequency	Range	Corr.	Lev.	Diff.	Dist.	BW	%	Count	DF cnt.	Em.class	Licence	Lic.Nr.	Application	Notes
87.7	FM	0.902	87.7	1.9	4.7	160	100	18	0	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	
88.1	FM	0.819	40	5.6	42.4	227.5	100	18	2	300KF8...	SKRUNDA	KOORD/120...	FM sound an...	
88.4	FM	0.923	90	9.6	4.7	122.5	100	18	3	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	
88.7	FM	0.725	37	11.1	62.7	220	27.8	5	0	300KF8...	PALANGA	KOORD/102...	FM sound an...	
88.9	FM	0.9	57.7	-8.8	4.8	117.5	100	18	0	300KF8...	LIEPAJA	KOORD/115...	FM sound an...	
89.5	FM	0.872	52.2	4.1	38.5	117.5	100	18	3	300KF8...	AIZPUTE	KOORD/104...	FM sound an...	
91	FM	0.927	89.2	3.5	4.7	125	100	18	0	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	
91.4	FM	0.631	38.2	24.9	91.8	255	16.7	3	0	300KF8...	KLAIPEDA	KOORD/102...	FM sound an...	
91.6	FM	0.783	48.4	5.3	38.6	220	100	18	0	300KF8...	SKUODAS	KOORD/102...	FM sound an...	

4.1.9.1 Notification of unauthorised emissions

Signal detection result(4.1.8) list contains information, whether detected signal is authorised according to frequency assignment database (4.5,) filtered by set licence detection parameters (4.3.2), and whether emissions on particular frequency overshoot set spectrum mask(4.3.3).

- In all detection modes, if, for particular frequency channel, frequency assignment in particular monitoring site is considered invalid or there is no assignment for frequency at all, Licence field for related record in signal detection results list contains key “-” - no assignment;

Frequency	Range	Corr.	Lev.	%	Count	Em.class	Licence	Application	Notes
108	FM	0.804	50.8	100	2	200K8E	"-"	FM sound an...	
107.7	FM	0.886	60.7	100	2	300KF8...	Latvijas Valst...	FM sound an...	
107.2	FM	0.903	56.6	100	2	300KF8...	RADIO SKO...	FM sound an...	
106.8	FM	0.828	49.1	100	2	300KF8...	Radio TEV	FM sound an...	
106.2	FM	0.818	55.7	100	2	300KF8...	STAR FM	FM sound an...	
105.7	FM	0.662	49.4	100	2	300KF8...	RADIO SWH	FM sound an...	
105.2	FM	0.887	62.5	100	2	300KF8...	RADIO SWH	FM sound an...	
104.3	FM	0.902	52.9	100	2	300KF8...	SUPER FM i	FM sound an...	

- In mask detection mode, Emission class field contains keywords “mask+” or “mask-” - emission has overshoot or undershoot mask. Mask detection is independent of unauthorised signal detection, thus signal can be both - unauthorized and spectrum mask, just one or none.

Signal detection results									
Frequency	Range	Corr.	Lev.	%	Count	Em.class	Licence	Application	Notes
100.4	FM	0.5	47,1	4,6	1	mask	"."	FM sound an...	
101.6	FM	6,843	54,1	95,5	21	mask	"."	FM sound an...	
102.5	FM	3,681	46,2	95,5	21	mask	Latvijas Valst...	FM sound an...	
101.9	FM	4,755	60,7	100	22	mask	"."	FM sound an...	
101.7	FM	4,586	60,7	95,5	21	mask	"."	FM sound an...	
102	FM	8,727	58,2	100	22	mask	"."	FM sound an...	
102.4	FM	7,529	52,7	95,5	21	mask	"."	FM sound an...	
101.3	FM	0,45	49,3	18,2	4	mask	Latvijas Valst...	FM sound an...	
101.2	FM	2,76	51,5	91	20	mask	"."	FM sound an...	
102.1	FM	4,168	51,5	100	22	mask	"."	FM sound an...	
102.2	FM	2,05	51,5	91	20	mask	Latvijas Valst...	FM sound an...	
101.5	FM	4,719	47,3	95,5	21	mask	Latvijas Valst...	FM sound an...	
101.1	FM	0,65	41,6	18,2	4	mask	RADIO SWH	FM sound an...	
90.7	FM	0.842	57.1	100	22	300KF8	Latvijas Valst	TV analogue	

Licence (unauthorised emission) and mask detection (overshoot) events are sent to Skudra Server, if at least one of measurement options are enabled: Report statistics (4.1.22), Report DF to Skudra Server (5.4), Remote control with automatic upload to Skudra Server (4.8), or if results are manually uploaded to Skudra Server.

4.1.10 Signal Search Result List Context Menu

Right-clicking the mouse on an entry in the signal search result list opens a menu providing the following functionality:

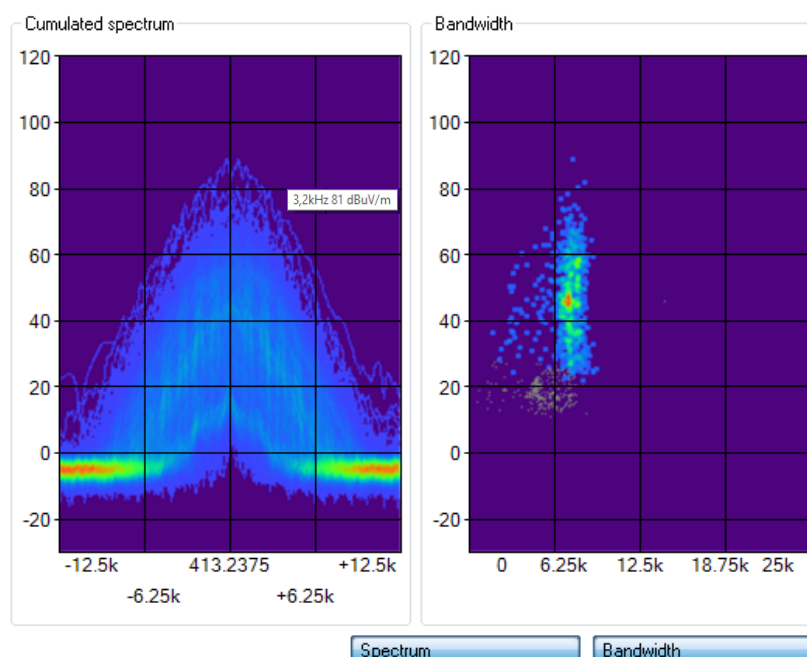
- “Delete selected” - the highlighted entry and all associated information about the signals observed on the frequency will be erased. The task may be carried out by clicking the key “delete”. If multiple entries are highlighted, all will be deleted;
- “Clear DF Results” - All direction finding results for highlighted entry(-ies) will be erased. If multiple entries are highlighted, DF results for each entry will be erased;
- “To specific list” - the highlighted entry’s frequency may be added to the list of specific frequencies (setting section, list of specific frequencies (**Error! Reference source not found.**)). The frequency user should be entered and confirmed by clicking the button “Save”;

Signal detection results												
Frequency	Range	Corr.	Lev.	BW	%	Count	DF cnt.	Em.class	Licence	Lic.Nr.	Application	Notes
87.7	FM	0.902	87.7	160	100	18	0	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	
88.1	FM	0.819	40	227.5	100	18	2	300KF8...	SKRUNDA	KOORD/120...	FM sound an...	
88.4	FM	0.822	40	122.5	100	18	3	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	
88.7	FM					5	0	300KF8...	PALANGA	KOORD/102...	FM sound an...	
88.9	FM					18	0	300KF8...	LIEPAJA	KOORD/115...	FM sound an...	
89.5	FM					18	3	300KF8...	AIZPUTE	KOORD/104...	FM sound an...	
91	FM					18	0	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	
91.4	FM									RD/102...	FM sound an...	
91.6	FM									RD/102...	FM sound an...	
91.8	FM	0.836	41	145	100						FM sound an...	
90.2	FM	0.888	55.2	162.5	100	18	0	300KF8...	LIEPAJA	KOORD/102...	FM sound an...	

- “Copy list” - All entries of the signal search result list are copied to the clipboard in “csv” format to be pasted in any word or spreadsheet processor.

4.1.11 Cumulated spectrum of signals

- The cumulated spectrum of signals corresponding to the highlighted entry in the signal detection result list is displayed to the right of list (A.25). If multiple entries are highlighted, the last cumulated spectrum will be displayed;
- The cumulated spectrum graph may be displayed or hidden by clicking the button (A.28) on the panel below the cumulated spectrum or the time graph, if the cumulated spectrum is hidden;
- In the cumulated spectrum, all observed signal spectra in the frequency channel are shown. Spectra containing no signal, only noise, are not included. All signal spectra are overlaid. The number of appearances of the relevant frequency-level pair is colour-coded from red (maximum, though often less than 100%) to green, to blue (once);
- The cumulated spectrum characterizes how often the signal is detected - whether on the frequency operates one or several transmitters, what the base station/repeater spectrum looks like.



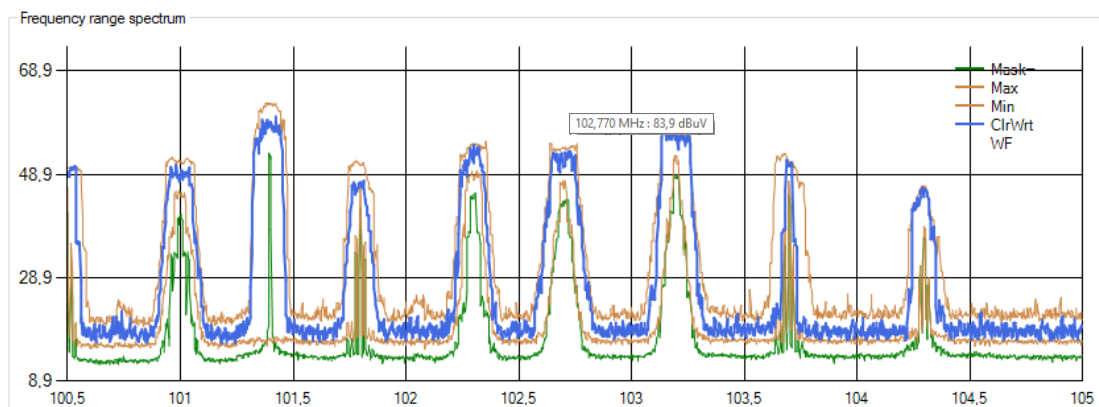
- The cumulated spectra at the channel step of 100 kHz are displayed in a band of 500 kHz, but at the step of 6.25 kHz in a 31.25 kHz range;
- The cumulated spectra graph can be resized by dragging the graph's top border. The cumulated spectra contains 200x300 values. When resizing, the aspect ratio 2:3 is kept unchanged;
- Marker of cumulative spectrum value, currently mouse hovering on, is displayed in mouse tooltip.

4.1.12 Bandwidth breakdown graph

- Right of the signal search list is the two dimensional display of the signal level/strength (A.26) relevant to the highlighted entry in the list. When multiple entries are marked, the cumulated spectrum of the last highlighted entry is displayed;
- The Bandwidth breakdown graph may be displayed or hidden by clicking the button “Bandwidth” (A.29) in the panel under the bandwidth breakdown graph or the time graph if the bandwidth breakdown is hidden;
- All combination pairs of signal bandwidth/level detected in a single frequency channel of a measurement range are displayed in the bandwidth breakdown graph. Bandwidth measurements with signal to noise ratios no less than 30 dB (measurements are done with the 1% B method - 99% power in the bandwidth) are displayed colour-coded from red (maximum) to green, to blue (a single event). Combination pairs with a signal to noise ratio less than 30 dB (by spectrum width in the middle between maximum and noise level) are displayed grey. The frequency of equal results are not cumulated for the latter;
- The bandwidth breakdown graph helps to determine the field strength of a specific bandwidth signal - what is the field strength of a repeater, what is the field strength of a base station;
- The bandwidth breakdown at the channel step of 100 kHz is displayed in a band up to 500 kHz, but at the step of 6.25 kHz - up to 31.25 kHz;
- The bandwidth breakdown graph can be resized by dragging the graph’s top border. The cumulated spectra contains 200x300 or 250x300 values. When resizing, the aspect ratio is kept unchanged.

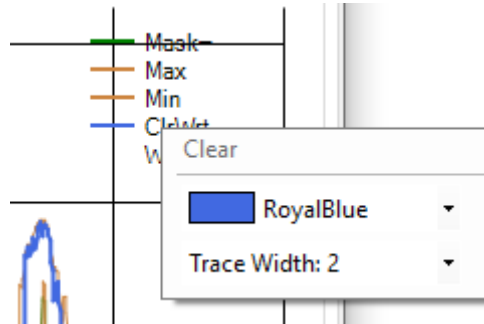
4.1.13 The frequency range’s spectrum

- The range’s spectrum graph is displayed on the right-hand side of the measurement panel. The graph shows spectrum of the range highlighted in the measurement panel’s list (A.6);



- Several spectrum traces are available at frequency range spectrum chart

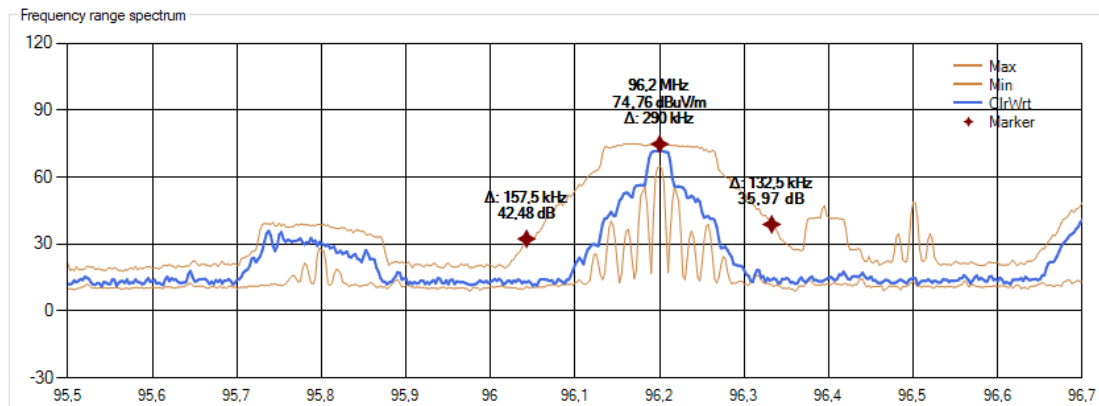
- Maximum Hold spectrum (Max), Minimum Hold (Min) and Current value (ClrWrt) - available for every measurement,
 - Spectrum mask above (Mask+) and/or spectrum mask below (Mask-) - available if corresponding detection is set for selected range,
 - Spectrum trace from spectrogram (WF) - available if selected from spectrogram (4.1.20)
- Colour and line width of each trace can be set by right click on legend's corresponding item. Selected values will be retained for every spectrum range, including mask definition chart (also after restart):



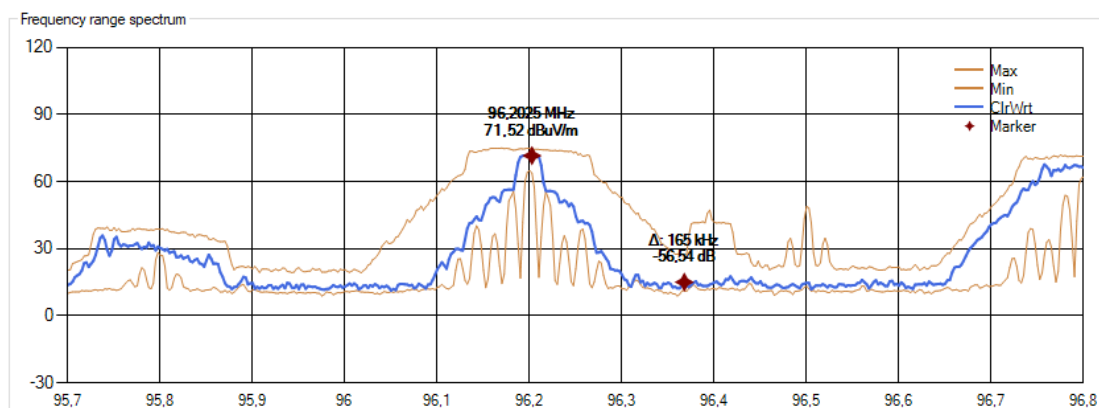
- Every spectrum trace available on frequency range spectrum chart can be temporally hidden, by right clicking on corresponding legends item.
- The bands spectrum graph may be zoomed in on the abscissa by left-mouse drag on the necessary limits. Right-click of the mouse, performs 4x zoom-out. By left-click of the mouse the central frequency may be set without changing the zoom, thus gradually reviewing all the spectrum under magnification;
- The bands spectrum graph may be zoomed in on the ordinate by left-mouse drag on the necessary limits while holding “shift” key. The maximum range may be restored by right-click of the mouse, while holding “shift” key;
- Maximum Hold spectrum (Max) can be cleared by selecting “Clear” in tooltip menu on graph's legend;
- The bands spectrum graph may be displayed or hidden clicking the button “Spectrum” (A.22) under the spectrum graph or the frequency's licence map if the band's spectrum graph is hidden;
- The bands spectrum graph may be resized by hiding or displaying the frequency's licence map, or dragging the bottom border under the button “Spectrum” (A.22);
- Spectrum trace value, currently mouse hovering on, is displayed in mouse tooltip.

4.1.14 The frequency range's spectrum: Markers

Marker functionality is added to frequency range spectrum to aid reading spectrum values.



- Markers can be added either by mouse left-click while holding “Ctrl” key or by holding mouse left-click for longer than 1 second;
- Markers can be removed either by mouse right-click while holding “Ctrl” key or by holding mouse right-click for longer than 1 second;
- In total 3 markers can be added. Adding 4-th marker, the marker will be set in place of marker which is closest to clicked position;
- When added, marker is set on spectrum trace with value closest to clicked position;
- All markers are always set on same spectrum trace. If new marker is added to trace another than that of previous markers, previous markers are set to trace of new marker;

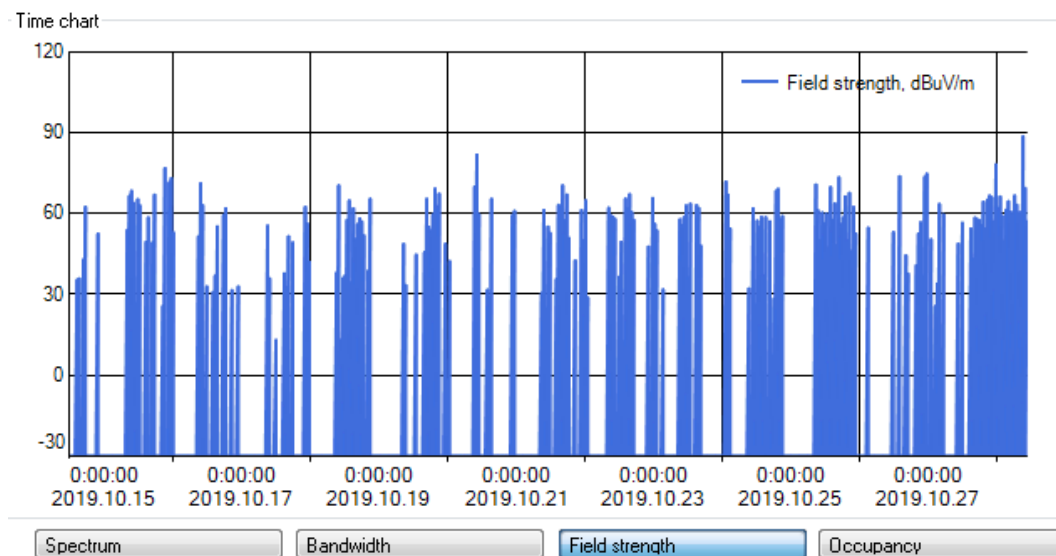


- If no more than 2 markers added:
 - first marker shows selected frequency and field strength value,
 - second marker shows frequency and level difference to first marker;
- If 3 markers added:
 - Third marker (e.g. last marker changed) shows frequency and field strength of marker and frequency difference between marker of highest frequency and marker of lowest frequency,

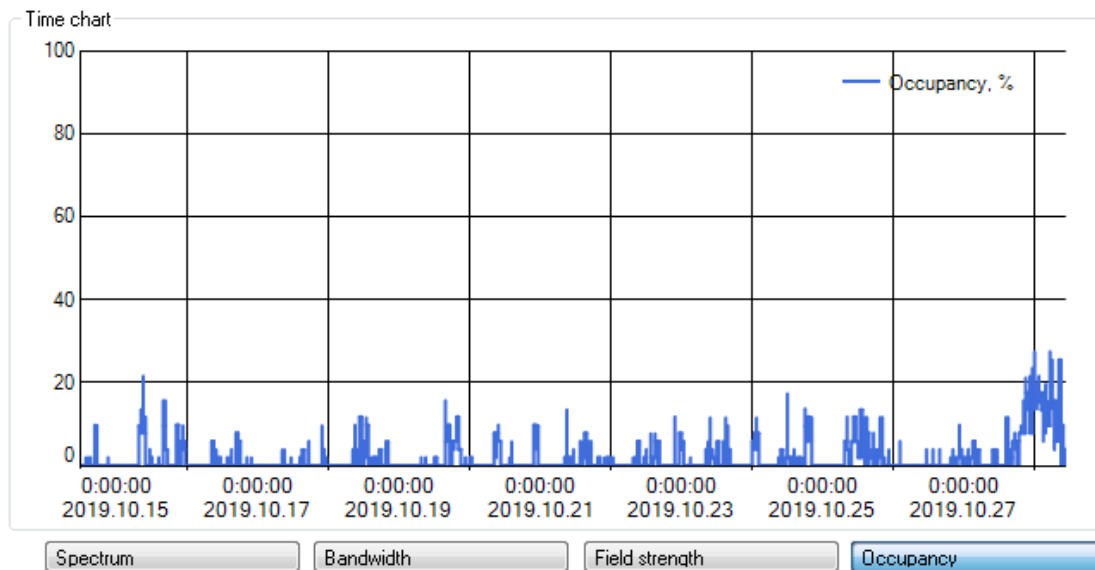
- First and second marker shows frequency and level difference to third marker (e.g. last marker added).

4.1.15 Field strength and occupancy time graph

- The field strength or frequency occupancy time graph is displayed in the measurement section's lower right corner. The displayed graph may be chosen by clicking the button "Field strength" (A.30) or "Occupancy" (A.1);
- The graph displays data of the highlighted entry in the signal determination list;
- The frequencies signal level is displayed as the ordinate, and the time is displayed as the abscissa. In the case no signal was observed during search, the ordinate displayed is minimal. If the process of measurement has been stopped or interrupted, the time graph will show a gap;



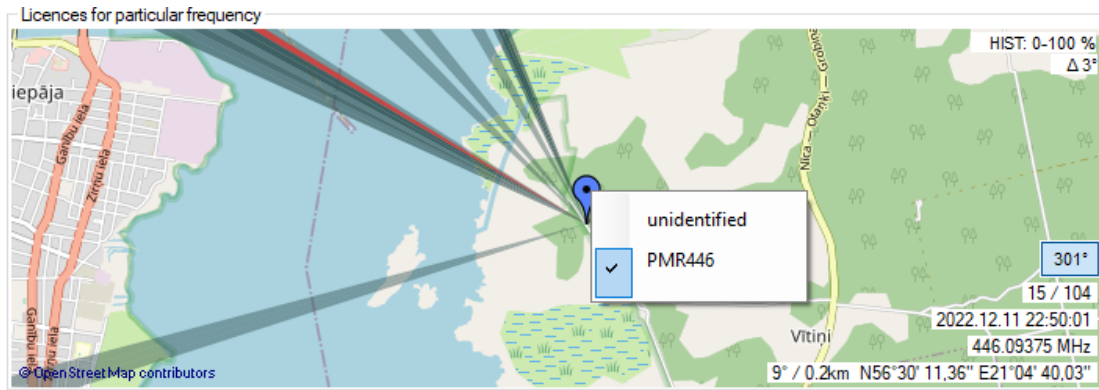
- If the occupancy graph option is chosen it is generated from the percentage how often the signal appears in 15 minute intervals according to Recommendation ITU-R SM.1880;



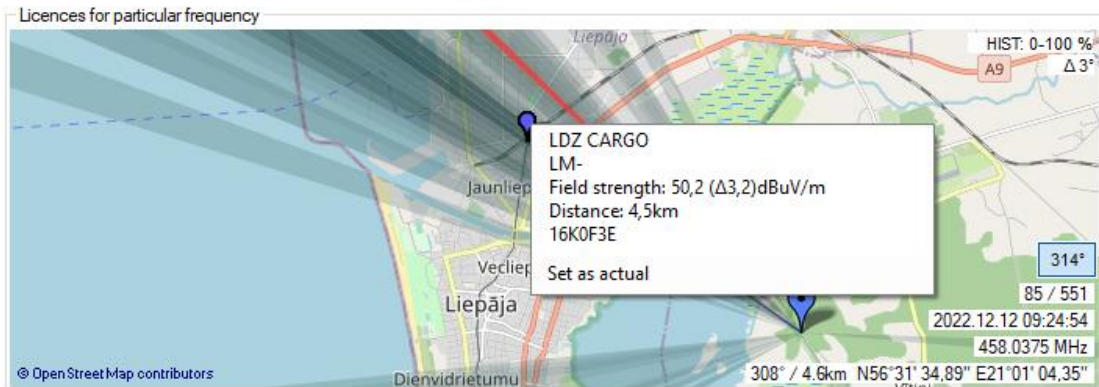
- Both the field strength graph and occupancy graph may be zoomed in on the abscissa by left-mouse drag the necessary time limits. Right-click of the mouse, performs 8x zoom-out.
- Both the field strength graph and occupancy graph may be zoomed in on the ordinate by left-mouse drag on the necessary limits while holding “shift” key. The maximum range may be restored by right-click of the mouse, while holding “shift” key;
- The graph may be resized displaying or hiding the cumulated spectrum and occupancy graphs, as well dragging the graphs top border.

4.1.16 Map: Frequency Assignments

- Map in measurement panel is used for two functionalities: display of frequency assignments and display of direction finding results;
- The frequency assignment map can be shown or hidden by toggling “Map” button in centre-right part of measurements tab;
- The frequency assignment map (A.14) displays all available licence information on the highlighted frequency in the signal detection list;
- Monitoring site location is displayed on map as large blue marker. Position of marker is updated as soon as coordinates for monitoring site are changed (4.2.2). If prior measurement results are shown, however, monitoring site’s position will be shown corresponding to measurement data;
- The licence assignment coordinates are displayed on the map by small markers. Small blue marker designates the coordinates of the most probable assignment. Other coordinates of the same frequency assignment are marked by small grey markers;



- The assignment map's coordinate context menu shows the frequency's licence owner, licence number, theoretically calculated field strength, the difference between calculated and measured field strength, distance from the monitoring site to the assignments coordinates and emission class according to licence as well as the option to mark the assignment as the most probably received;



- In the monitoring site's marker's context menu it possible to define an unknown spectrum (NRS) user as the most possible signal source, as well the option to mark as most possible an assignment without coordinates or an undefined user from the list of specific frequencies;
- The signal detection result list is also updated according to the change of assignment of the received signal;
- The map uses OSM maps offline or online (**Error! Reference source not found.**), according to the map settings in the settings section;
- The map may be resized displaying or hiding the range's spectrum graph or waterfall graph (by clicking "Spectrum" or "Waterfall" buttons respectively), as well as dragging the map's lower border.

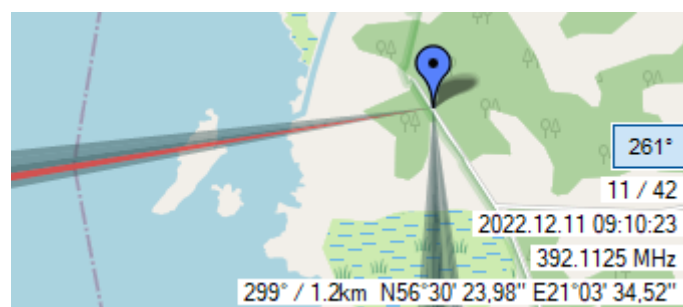
4.1.17 Map: Direction finding results

Map in measurement panel is used for two functionalities: display of frequency assignments and display of direction finding results;

- The frequency assignment map can be shown or hidden by toggling “Map” button in centre-right part of measurements tab;



- Direction finding results are displayed as histogram for currently selected record in signal detection result list (4.1.8). Direction finding results and corresponding functionality is only visible if the selected record has direction finding attempts associated;
- Histogram is displayed by dark grey beams, with various opacity ranging from minimum for single occurrences of particular bearing to full opacity for bearing measured most often;
- Opacity behaviour of histogram display can be altered by HIST text box in top-right corner of map in format “minimum visible recurrence - recurrence for maximum opacity”. By setting minimum above 0, it is possible to dismiss rare directions, by setting maximum bellow 100 it is possible to reduce impact of most frequent bearing;
- Width of each individual bearing can be set by Δ textbox in top-right corner of map;
- Red beam denotes last direction measured, it can be enabled or disabled by pressing button at bottom-right corner of map (“261°”), number represents last direction measured;

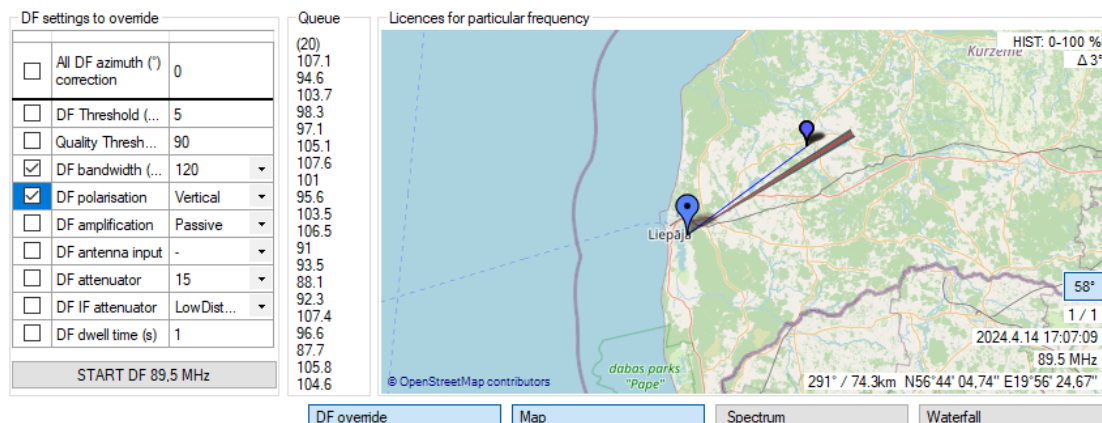


- First text box at bottom-right corner of map contains successful direction finding attempts versus all attempts;
- Second text box at bottom-right corner of map contains date and time of last direction measured;

- Third text box at bottom-right corner of map contains channel frequency of signal, direction finding results and licences are displayed for;
- Forth text box at bottom-right corner of map contains direction and distance from monitoring site location to mouse cursor as well as coordinates in DMS format. That can be used to readout bearing values from map.

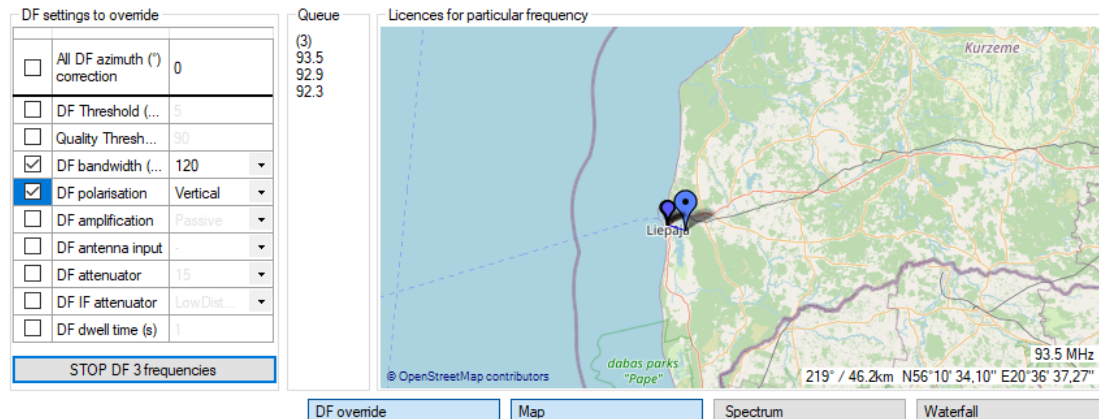
4.1.18 Direction finding override

If any active (set as used) measurement range has DF triggering enabled, “DF override” button is visible in centre of “Measurements” tab. By clicking “DF override” button “DF settings to override” and “DF queue” groups are shown.



User can manually set frequency to DF by selecting corresponding record in signal detection results list and clicking “START DF...”

- By selecting record in signal detection results list DF settings to override list filled with DF equipment settings that has been defined in “DF equipment settings” (4.3.10) for range on which signal was detected, except “DF bandwidth” row that is filled with value corresponding to measured bandwidth of signal.
- If more than one record is selected in signal detection results’ list, “DF settings to override table” won’t be filled with DF equipment settings that has been defined in “DF equipment settings” and rows without check mark for overriding will be disabled, however settings corresponding defined “DF equipment settings” still will be used for direction finding.



- If check box in first column of “DF settings to override” is checked, user set value will be used instead of automatically selected DF setting.

All settings to override except “All DF azimuth correction” are effective only for direction finding that user has requested manually by clicking “START DF...” button.

“All DF azimuth correction” setting (if checked) will be used for all DF results - for manually set frequencies and automatically set frequencies. However, bearing results that have been gathered prior to change of “All DF azimuth correction” are not changed.

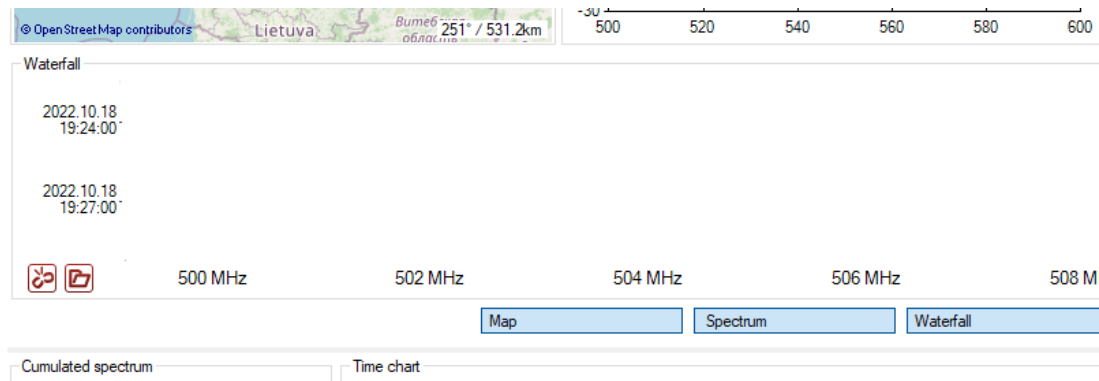
- After direction finding override is started, “DF queue” group shows list of frequencies manually set for direction finding. Direction finding queue of automatically selected frequencies is preserved and is shown and used after manually set direction finding is stopped by clicking “STOP DF” button.
- Contrary to automatically created “DF queue”, manually set frequencies are not removed from list after direction finding has been made and will continue endlessly or until “DF duration between scans” (4.2.2), if same receiver is used for scanning and direction finding.
- If same equipment is used for scanning and direction finding, during direction finding cycle scanning is paused (“Pause” button pressed), direction finding will continue until DF queue is empty or endlessly if manually set frequencies is being DF-ied.

4.1.19 Spectrogram (Spectrum Waterfall) graph

- To display actual spectrogram data, corresponding measurements have to be opted in Ranges section or measurements that includes spectrograms have to be stored before (See Ranges section for more information);
- Data displayed in Waterfall graph is generated every 256 scan cycles and after the measurement is stopped. After the same events it is possible to update spectrum waterfall;
- Zoom levels are generated sequentially after necessary scan data is acquired. Second zoom level is generated after first 512 scans, third after 1024 scans

and so on. That way it is ensured that access speed to measured spectrogram is similar to that of viewing map;

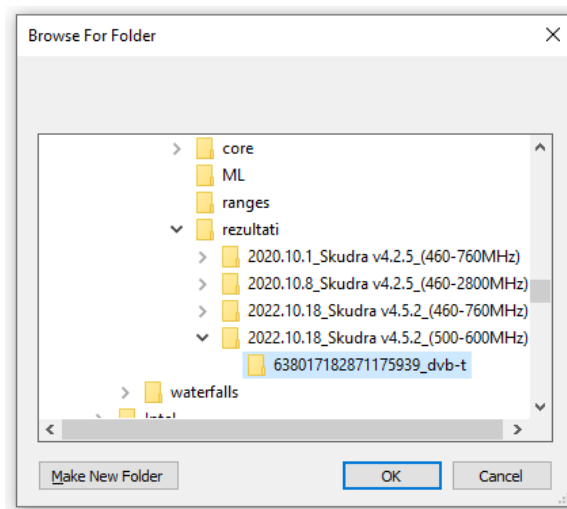
- Waterfall section is displayed above Time chart and Cumulated spectrum plot if Waterfall button is toggled on:



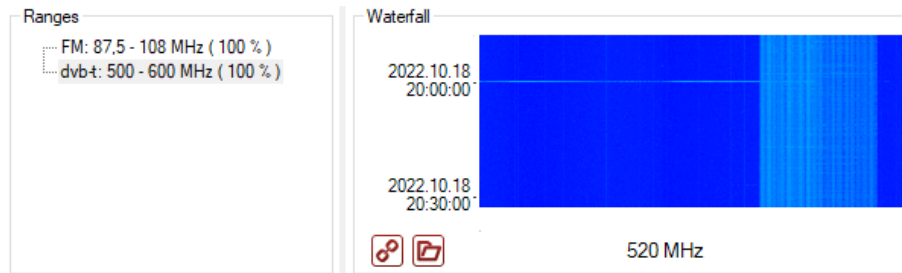
- User has to select spectrogram data to displayed in waterfall graph. There are two options provided for that. To show previously stored spectrogram user has to press “open folder” button. To show currently acquired spectrogram linked to selected frequency range user have to toggle on “chain” button:



- In process of selecting stored spectrogram for display user is provided with browse folder dialog. During measurement spectrograms are stored in results folder set in Settings section. Spectrograms for each measurement session is saved in subfolder with the name identical to one automatically given to zip file when saving measurement result. Further each measurement range in measurement session have subfolder named after range ID and range name. This folder has to be selected to display waterfall;



- If user has opted to show currently acquired spectrogram, spectrogram of currently selected range in Ranges group box (in Measurement section) will be displayed after clicking on corresponding range;

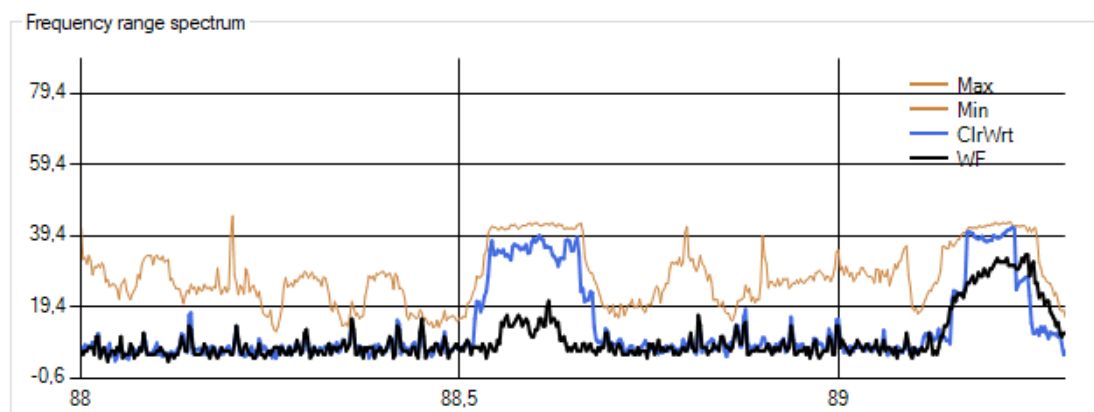


- To display spectrogram of currently selected range regardless of further selection of measurement ranges, user can toggle off “chain” button;
- Zooming in and out of spectrogram is done by mouse scroll. However, zooming is only available after corresponding zoom levels are generated as mentioned at the start of paragraph;
- Navigation on waterfall graph is possible with mouse drag, keyboard arrow keys, “Home” and “End” keys;
- F5 key forces to reload waterfall data. Similar effect can be achieved by zooming and panning waterfall graph.

4.1.20 Examining spectrum lines of spectrogram

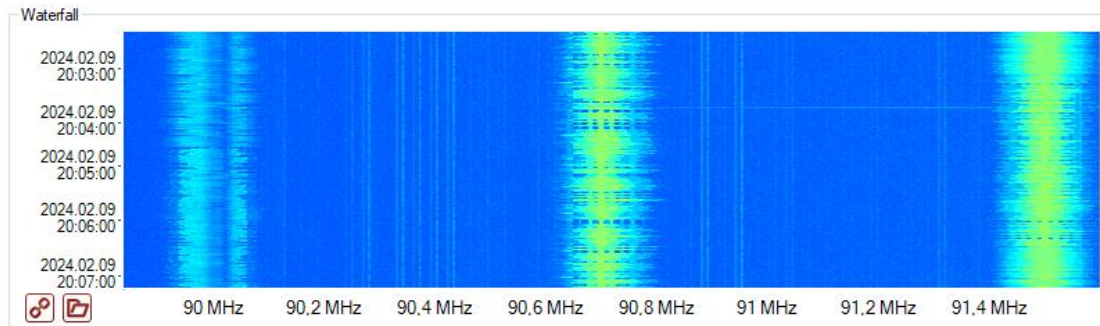
It is possible to view distinct spectrum trace from spectrogram in frequency range spectrum chart.

In following image spectrum trace from spectrogram is shown in black:



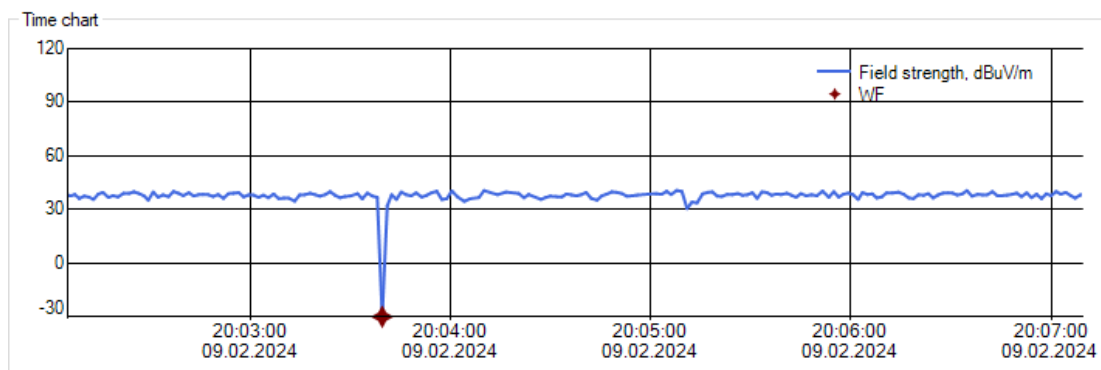
To view spectrum trace from spectrogram following conditions must be met:

- Spectrogram must be linked (“chained”) to frequency range spectrum (4.1.19)
- User must select spectrum trace of spectrogram to view. Initially it is done by double clicking on desired location of spectrogram.



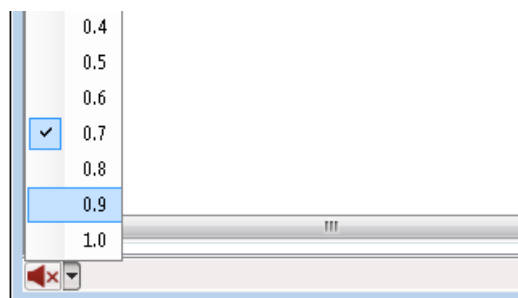
After initial spectrum trace selection, it is possible to move trace selection up or down in time domain by keys “Ctrl+Up” or “Ctrl+Down” when spectrogram window is selected.

Marker at time corresponding to selected trace is added to Field strength versus time chart:



4.1.21 Aural monitoring

- When measurements are paused, aural monitoring is possible. To enable it, the frequency detected during monitoring may be sent to the receiver together with the relevant receiver settings of the particular frequency. To do this, the entry in signal detection results list should be double-clicked or pressed on the “ENTER” key;

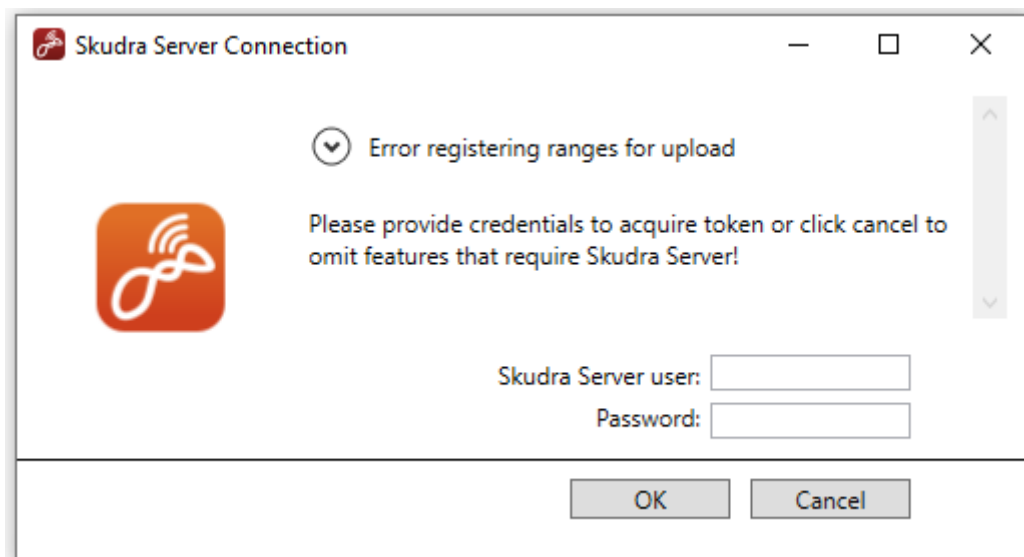


- The volume of the receiver speaker may be controlled by the context menu of the button (A.12) at the lower left of the software window. The default

volume may be set prior to measurements in the settings section (**Error! Reference source not found.** and **Error! Reference source not found.**).

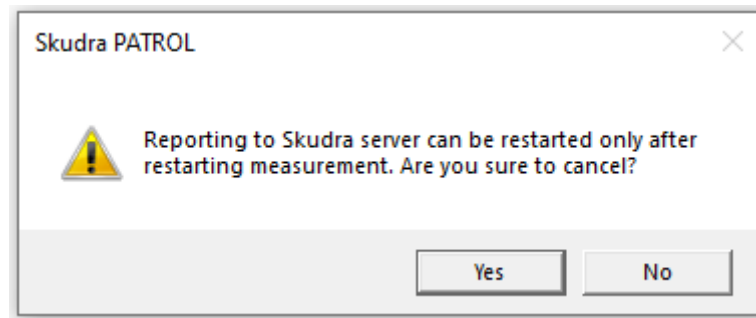
4.1.22 Reporting frequency usage statistics to Skudra Server

- Functionality of reporting frequency usage statistics is designed for periodic (in user set time intervals) storing of frequencies and count of detected signals into Skudra Server. Goal of such recording is to provide Skudra Server with immediate information about changes in spectrum usage;
- Frequency usage statistics are recorded in Skudra Server for selected ranges that have marked option “Report statistics” in Measurement range list (D.1);
- Each measurement range has statistics recorded separately, and for each range it is possible to set individual reporting;
- To perform reporting of statistics a valid Skudra server authorisation token is necessary;
- In order to get Skudra Server authorisation token it is necessary to set appropriate link in field “Skudra Server name”. Next it is necessary to fill fields “Skudra Server user” and “Password”, and confirm request of token by clicking “accept (See section 4.2.7);
- In case of commencing measurements set to include statistics reporting without a valid authorisation token, software will display authorisation window requesting to renew authorisation token by providing Skudra Server username and password;

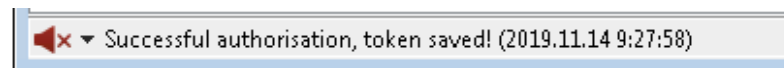
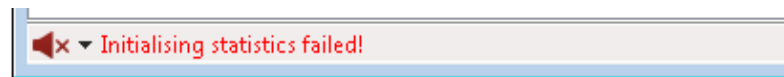


- By providing valid Skudra Server username and password and clicking “OK” new authorisation token will be obtained and stored in Skudra Patrol and measurements will be started. Providing invalid Skudra Server username and password user will be asked to enter credentials repeatedly. Choosing option

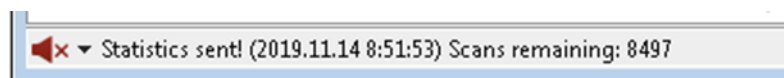
“Cancel” will display dialog to confirm cancelation, confirmation of which will cause measurement session not to start;



- According to result of authorisation Skudra Patrol information roll will show message either “Initialising statistics failed!” or “Successful authorisation, token saved”;



- If during the measurements authorisation token cease to be valid or expires, acquisition of new token is prompted, similarly as when commencing measurements, by authorisation window;
- Reporting statistics to Skudra Server without valid token is not possible. However, if authorisation token expires during the measurements, calculated statistics will be temporarily stored in Skudra Patrol until valid authorisation token is acquired and then reported to Skudra Server. The same is true if connection to Skudra Server has been lost;
- Reporting statistics stored temporarily in Skudra Patrol may take a while, therefore progress report will be indicated in Skudra Patrol information area (A.13);



- Choosing to cancel reporting statistics by clicking “Cancel” in authorisation window or closing Skudra Patrol software during reporting of temporarily stored statistics will cause loss of statistics that had not been reported by then;
- Calculation of frequency usage statistics from uploaded Skudra Patrol measurement results is foreseen in functionality of Skudra Server.







4.2 The Functionality of Settings

4.2.1 Saving settings

- Measurements are done with settings displayed at the start of measurements. During measurements settings can not be changed.
- Settings (with exceptions mentioned in the next clauses) are saved commencing measurements and closing the software;
- Frequency licences stored by the software, calculated taking into account the monitoring site's parameters, are stored immediately upon loading;
- Changes to the specific frequency file are saved immediately upon updating them from the signal determination result list (A.10) as well as clicking the save button in the list of specific frequencies group
- Changes to the range setting edit list (D.1) will be saved same as other settings upon commencing measurements and closing the software. The save button is provided to save the range settings in a separate file;
- The Skudra Server user password is not saved. The token acquired during authorisation will be saved with other settings upon commencing measurements and closing the software.

4.2.2 System Settings

System settings

Usage of equipment:	Sequential scanning and DF with same receiver		
Receiver (IP:port)	10.0.50.46:5555		
DF (IP:port):	10.0.50.46:5555		DF duration between scans (s): 15
Azimuth and location:	Fixed azimuth correction without GNSS location		
	Additional azimuth correction (°):		0
Results' folder:	C:\skudra_testu_results		
Measurement session:	Skudra v4.7.0		Type: fix
Antenna factor:	2.15dbi (30 - 3000 MHz)		
Cable attenuation:	generic_cable (30 - 3000 MHz)		

- Usage of equipment - Setting sets whether to use receiver and direction finder simultaneously (option “Simultaneous scanning and DF with separate receivers”), which implies that separate receiver and direction finder is available, or to use single receiver for scanning and direction finding (option

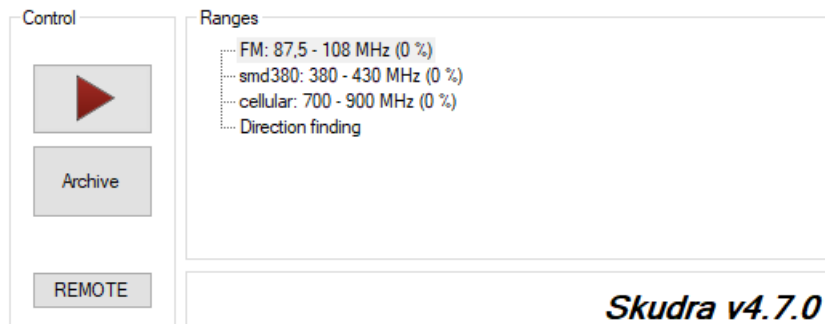
“Sequential scanning and DF with same receiver”). In later option DF (IP:port) will be used as scanning receiver’s IP address.

- Receiver (IP:port) - Receiver IP address and port for scanning should be entered in the format *IPv4address:Port* or *IPv6address:Port*. The port of currently supported receivers is either “5555” or “5300”. If the receiver’s IP address is not known, refer to the receiver’s user manual. Option is not available if “Sequential scanning and DF with same receiver” is selected, as then Direction finder is used as receiver.
- To check the connection to the IP address and determine the receiver’s model click the “*refresh*” button next to Receiver (IP:port). In case the IP address will correspond to a receiver supported by the software, the receiver model will be displayed, else, if the IP address will belong to a different equipment - “*receiver is not supported*”, but if the connection with the IP address will fail - “*connection failed*”. If “Sequential scanning and DF with same receiver” is selected, IP set in DF (IP:port) will be used.
- DF (IP:port) - The Direction finders IP address and port should be entered in the format *IPv4address:Port* or *IPv6address:Port*. Use of direction finder is not mandatory, it is required only if direction finding is enabled for measurement ranges (4.3.9) or sequential scanning and DF with same receiver is selected;
- To check the connection to the IP address and determine the direction finder’s model click the “*refresh*” button next to DF (IP:port). In case the IP address will correspond to a direction finder supported by the software, the DF antenna model and current settings (see 4.2.2.1) will be displayed, else, if the IP address will belong to a different equipment - “*Is not valid Direction finder!*”, but if the connection with the IP address will fail - “*connection failed*”;
- DF duration between scans (s) - If “Sequential scanning and DF with same receiver” is selected, it is necessary to set time window (seconds) for direction finding after each full scan of all measurement ranges is completed. If “Simultaneous scanning and DF with separate receivers” is selected, this setting has no effect and is disabled.
- Azimuth and location: Provides three options for azimuth correction and GNSS location usage. Receiver is configured with corresponding settings only when measurements are started. However, as settings are not changed back to previous state after measurements, that should be considered when using receiver with software other than Skudra.
 - Fixed azimuth correction without GNSS location - Fixed north correction as set manually on receiver is used. Coordinates set Skudra are used.

- Compass azimuth correction with GNSS location - Direction finding results are corrected with compass values internally by direction finder, compass magnetic declination is obtained by GNSS coordinates. If “Report DF to Skudra Server” is selected in “Triggered DF configuration” (4.3.9), direction finding results sent to Skudra server after each direction finding measurement are accompanied by current GNSS coordinates (For information in detail see 5.3.1).
- Course over ground azimuth correction with GNSS location - Direction finding results are corrected with GNSS course over ground values internally by direction finder. If “Report DF to Skudra Server” is selected in “Triggered DF configuration” (4.3.9), direction finding results sent to Skudra server after each direction finding measurement are accompanied by current GNSS coordinates (For information in detail see 5.3.1).

Direction finding results stored locally on Skudra Patrol and if necessary later uploaded to Skudra server are always referenced only to coordinates set on Skudra Patrol before start of measurements.

- Additional azimuth correction - All direction finding results gathered from direction finder are corrected by value set here, regardless of whether they have been already corrected internally in direction finder by fixed value, Compass or GNSS course over ground. Setting additional azimuth correction to zero degrees, effectively disables additional correction.
- The folder where results of measurements should be saved is indicated in the window “*result’s folder*”. If the folder turns out to be inaccessible a pop-up warning will appear. The results folder can be changed by clicking the “*open*” button at the folder window and choosing the desired folder;
- The measurement should distinctively named in the input field “*Measurement session*”. The name given will be used in the result file name, thus the symbols used are limited to the characters supported by the computer’s file system;
- The button “eye” is intended to display the contents of the window “Measurement session” in the software’s measurement section under the measurement range list.



- Type (Measurement session type) dropdown allows to set measurement session type by which measurement results can be filtered after uploaded to Skudra Server. Values available for selection (e.g. fixed, mobile, transportable) are fetched from Skudra server at updating server sites, and authorising and several other occasions. For saved measurements it is possible to change session type in information tab;
- The input field “Antenna factor” and “cable attenuation” accordingly show the antenna factor and cable attenuation files loaded into the software, and their covered frequency range;
- The antenna factor and cable attenuation files may be replaced clicking the button “open” next to the file window and choosing the necessary file. As soon as a new valid factor file is chosen it is saved to the software’s memory and it doesn’t have to be repeatedly read.

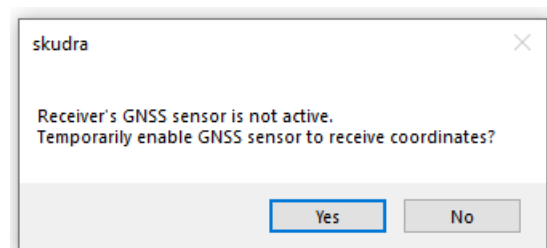
4.2.2.1 Current settings of DF equipment

By clicking “refresh” button by “DF IP(port)” textbox, device by set IP address will be identified.

DF (IP:port):  DF duration between scans (s):

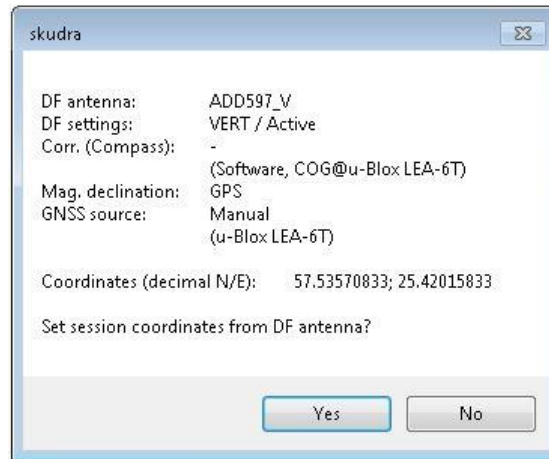
If device corresponds to supported direction finder DF antenna, Compass and GNSS configuration will be displayed. Configuration is shown as it is, and some (see 5.3.1) of settings may change after commencing direction finding.

If direction finder is currently set to fixed operation following message will be displayed:



By selecting “Yes” receivers location source will be temporarily set from fixed to GNSS and GNSS coordinates gathered, and location source returned to previous state. Previous message is shown only, if receiver has GNSS capability.

After that current settings of DF equipment will be shown:



- DF antenna - Currently connected main direction finding antenna;
- DF settings - Set polarisation and amplifier mode. Some direction finders allow setting polarisation and amplifier for antennas that do not support switching, therefore value may be incorrect;
- Corr.(Compass) - Compass currently used for north correction of bearing results. “-” value means that no compass is used.

Configuration when no compass is used means direction finder uses fixed DF correction set in GUI:

View

Special

ESC

APPL

MODE

SETUP

MENU

MEM

HELP

PANEL

CONN

FAIL

DEMOM BW [kHz] DETECT AFC ATT [dB] MGC [dBm] SQU [dBm]

DF Antenna Definition

Select Antenna 0 Refresh

	Name	Range Begin [MHz]	Range End [MHz]	North Corr.	Upside Down	GPS Enabled	Compass Used
0	ADD597_V	20	8500	29.0°	<input type="checkbox"/>	---	---
1	ADD597_H	20	7500	29.0°	<input type="checkbox"/>	<input type="checkbox"/>	---
2							
3							
4							
5							
6							

Use North Correction ☒ Use Compass ☐

North Correction 29.0° Select Compass HMC6343@ADD597_V

Upside Down ☐ Compass Value ---

Enable Antenna GPS ☐ Make fixed System

Reset North Correction Set North Correction

TABLE

It is important to note that “Use North Correction” for Skudra PATROL is effective only if use of compass is disabled (corresponds to “Use Compass” setting in eb500).

If checking direction finder when bearing is currently corrected by compass following message will be displayed:

skudra

DF antenna: ADD597_V

DF settings: VERT / Active

Corr. (Compass): COG@u-Blox LEA-6T
(Software, COG@u-Blox LEA-6T)

Mag. declination: GPS

GNSS source: u-Blox LEA-6T
(u-Blox LEA-6T)

Coordinates (decimal N/E): 57.535725; 25.42029722

Set session coordinates from DF antenna?



Yes No

- Corr.(Compass) - Compass currently used for north correction of bearing results. Selected compass is followed by available compasses in scopes. If physical compass is not available, direction finder can provide “Course over ground” (COG) compass, if there GNSS device available, or “Software”. “Software” option is available always, however is not used by Skudra PATROL;
- Mag.declination - Source for magnetic declination of compass values. (Always set by Skudra PATROL to GPS)

- GNSS source - Source for direction finder's coordinates. Options are manual (fixed coordinates set in direction finders's GUI), which are not used by Skudra PATROL in direction finding process, or physical GNSS devices connected to direction finder. Selected GNSS source are followed by available sources in scopes.

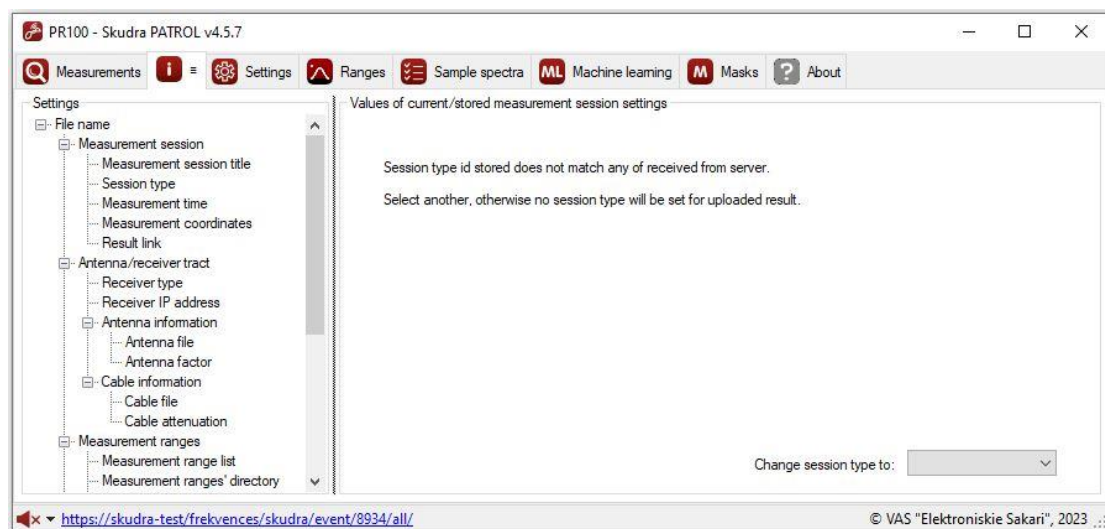
Regardless of whether direction finder has DF antenna connected or even DF option installed, coordinates (if available) of direction finder is read from direction finder:

- Coordinates (decimal N/E) - Coordinates available from direction finder, which can be set as measurement session coordinates, if accepted in user dialog.

Coordinates (decimal N/E):  

4.2.3 Editing of measurement session type for saved measurements

- Measurement results after uploaded to Skudra Server can be filtered by measurement session type;
- If measurement session type set for saved measurement are not supported by Skudra Server (e.g. at first use or recent server changes) uploaded measurements no session type will be set;



- However, for saved measurement, it is possible to change measurement session type in information tab/ Session type part in Settings treeview. Selection made in “change session type to” dropdown will be set as new measurement session type for saved measurement.

4.2.4 Configuration and import of licence database

The group of frequency licence loading comprises all functionality necessary to determine the theoretical field strength of the stations detectable at the monitoring site and their assignment's parameters, as well as to determine the radiofrequency application corresponding to the frequency channels. By the theoretical field strength it is determined whether it is possible to receive the emissions from assignments transmitter at the monitoring site;

The screenshot shows the 'Import of licence database' form with the following fields and values:

- Licence database file: 80-500 MHz (2024-08-20 - 2024-08-23)
- Licence database download period: 2024-08-20 to 2024-08-23
- Range (MHz): 80 to 500
- Specific frequencies' file: db_specifikas
- Application file: EFIS Application comparison 0.000 - 10000.000 MHz
- Coordinates (decimal N/E): 55.8789638889, 26.5552194444
- Rec. antenna height (1-10m): 10
- Environment: Small/medium city

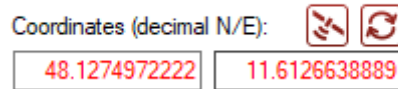
- Licence database information can imported through licence file of documented format (6.1.2), by clicking “folder open” button next to the “Licence database file” and selecting corresponding file. However, it easier to download database information directly;
- Authorised (4.2.7) user can download licence database information directly from Skudra Server in frequency range set in “Licence database download range” input field and validity period set in “Licence database download period” input fields by clicking download button next to it;

The screenshot shows the 'Import of licence database' form with the following fields and values:

- Licence database file: 3000 of 31419 downloaded
- Licence database download range (MHz): 30 to 500

- As download of licence database information can take some time, it is done in background and progress is reported in “Licence database file” input field;
- The theoretical field strength value of the assignment at the monitoring site is calculated by the Hata-Davidson method, using the monitoring site's coordinates, receiving antenna height, the monitoring environment characteristics. Licence selection is explained in detail in 4.5;
- In computers running *WINDOWS 10* or higher it is possible to get the monitoring site coordinates from the information stored in computer's operating system by clicking the button “satellite”;
- Changing the monitoring site's characteristics (i.e., everything except the licence database information) the site's characteristics will be changed temporally indicated by highlighting the parameter in red. To recalculate the theoretical field strength the button “refresh” should be clicked or the licence database file should be reloaded by clicking the button “open” or

“download”. If recalculation is not done, the changed settings will be lost next time the software restarts.



Coordinates (decimal N/E):

48.1274972222	11.6126638889
---------------	---------------

Clicking “Refresh” will also set monitoring site location on frequency assignment map in measurements tab, provided that no previously made measurement is open;

- In the window “*specific frequency file*” a file is indicated that contains information on assignments not linked to any particular frequency or do not require an individual licence. The specific frequency file may be changed clicking the button “*open*” and choosing the necessary file. After changing this file it is not necessary to recalculate the transmitters detectable at the monitoring site;
- Contents of the specific frequency file loaded to the software are displayed in the group “specific frequency list” (4.2.6);
- The file containing information on the radiofrequency applications appropriate to the frequency bands is displayed in the window “*Application file*”. The corresponding “*xlsx*” file of the necessary country may be downloaded from the web site www.efis.dk. Application search results exported to XLSX (country as columns) are supported (6.1.4). The radiofrequency application file may be changed clicking the button “*file open*” to the left from textbox and choosing the appropriate file; Additionally older EFIS “*csv*” format is supported
- The licence database file, specific frequency file and application file information may be deleted from the software by clicking the buttons “*delete*” to the right from the appropriate file text fields. After deletion of the file information, the recalculation of detectable transmitters at the monitoring site is not necessary.

4.2.5 Frequency use licence recalculation (update of results)

- During measurements, information about most probable licences, the theoretical signal field strength corresponding to licences, monitoring site coordinates, and other information shown in the group “*Configuration and import of licence database*” (see section 4.2.4), as well as values in the range settings list column “Licence detection” are linked to the signal detection results.
- In order to recalculate earlier results (e.g. with an updated licence database file) the button “*refresh results*” (B.5) should be clicked; To update the measurement results according to the newly loaded frequency licence

settings, the measurement results should be saved and opened as an archive file;

- If different licence detection thresholds are necessary, appropriate change have to be made in input fields “Min. field strength” and “Guaranteed distance” shown after selecting “Measurement range list” in “Settings” treeview (B.1). Changes will be indicated to the archived measurement range settings table (B.2) in red.

Values of current/stored measurement session settings

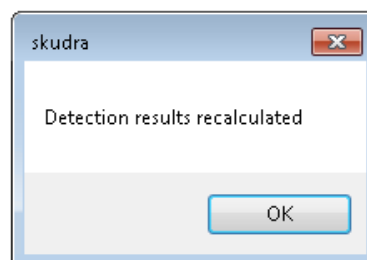
	Name	Frequencies	Step	Attenuation	Licence det.	Narrowband det	Statistics
<input checked="" type="checkbox"/>	FM	87.5 MHz 108 MHz	100kHz/200kHz	20 dB	10 dBuV/m 10 km	0.6 15 dB	ON 5 minutes
<input checked="" type="checkbox"/>	SMD146	146 MHz 174 MHz	6.25kHz/25kHz	0 dB	5 dBuV/m 30 km	0.6 15 dB	ON 10 minutes
<input type="checkbox"/>	SMD380	380 MHz 430 MHz	6.25kHz/25kHz	0 dB	10 dBuV/m 30 km	0.6 15 dB	OFF

Edit licence detection settings

Min. field strength

Guaranteed distance

- After implementing the necessary changes to the column “*Licence det.*”, and clicking button “*Recalculate results*” (B.5) - the results will be recalculated according to the updated licence information and settings. A pop-up message “*Detection results recalculated*” will appear;



4.2.6 The List of Specific Frequencies

- In the group “*Specific frequency list*”, it is possible to view and edit the contents of the of specific frequency list, i.e., frequencies of assignments, the licences of which are not linked to specific frequencies, or which do not require an individual licence;

- The list of specific frequencies may also be appended from the list of detected signals (A.24) by selecting the result's context menu *“to the specific frequency list”* (A.10);

Specific frequency list

Frequency(Hz)	User	Em.class	Span(kHz)
2315000000	LMT		20000
2345000000	Bite		20000
2530000000	Tele2 RX		5000
2550000000	Bite		20000
2585000000	LMT		20000
446056250	PMR446	F3E	0
446018750	PMR446	F3E	0
446006250	PMR446	F3E	0
446068750	PMR446	F3E	0
446043750	PMR446	F3E	0
446081250	PMR446	F3E	0
446093750	PMR446	F3E	0
446031250	PMR446	F3E	0

- The list of specific frequencies comprises three columns:
 - Frequency - the frequency of the channel (Hz),
 - User - the user operating the corresponding entry's frequency, the equipment, the radio communication service or other information,
 - Em. class - the class of emission corresponding to the frequency entry and user. Filling this column is not mandatory and it's contents are purely informative;
 - Span(kHz) - frequency span of assignment. Any frequency in set span is considered related to set user;
- The list of specific frequencies may be sorted by column, clicking the header;
- Changes to the list of specific frequencies may be done by direct editing of the entries. To save the changes and use them in measurements the button *“Save”* should be clicked;
- The list of specific frequencies may be appended or a highlighted entry deleted correspondingly clicking the buttons *“+”* and *“-”* . In order to apply the changes to measurements, they must be saved by clicking the button *“save”* .
- Clicking button *“save”* saves changes made to *“specific frequency list”* to the file that is loaded at *“Specific frequencies' file”* (4.2.4), therefore, to save previous edition of specific frequencies file, its copy have to be made manually.

4.2.7 Interaction with Skudra Server

To upload results, exchange sample spectra, download licence information, store waterfall spectrograms, report statistics, report DF results or register for remote control it is necessary to acquire an access key to Skudra Server;

- The Skudra Server access token may be acquired filling the windows “Skudra Server user” and “password” and confirming the key request by clicking the button “accept” or pressing “Enter” key on password box ;

Skudra SERVER paths

Skudra SERVER name:

Server authorisation:

Skudra Server user:

Password:

Skudra SERVER subpaths

- Authorisation subpath: ☐ `/api/o/token/`
- Results upload subpath: ☐ `/api/events/`
- Measurement event view subpath: ☐ `/frekvences/skudra/event/{0}/all/`
- Licence download subpath: ☐ `/api/licenses/export/`
- Selected frequency view subpath: ☐ `/frekvences/skudra/?freq={0}&zoom={1}&lat={2}&lng={3}`
- Sample spectra subpath: ☐ `/api/events/samplespectra/?limit=1000`
- Remote control subpath: ☐ `/api/scheduler/units/`

- The Skudra Server access token is stored in windows credential manager for each instance (executable file) separately. The key may be deleted by clicking the button “delete”;
- To be able to get the Skudra Server access token, valid Skudra SERVER name (path) must be available;
- There is possibility that due to changes in Skudra server configuration some of Skudra SERVER subpaths have been changed, they must be updated by clicking refresh button next to Skudra SERVER name input field;

4.2.8 Map storage

- OSM maps are used to display the licence information;

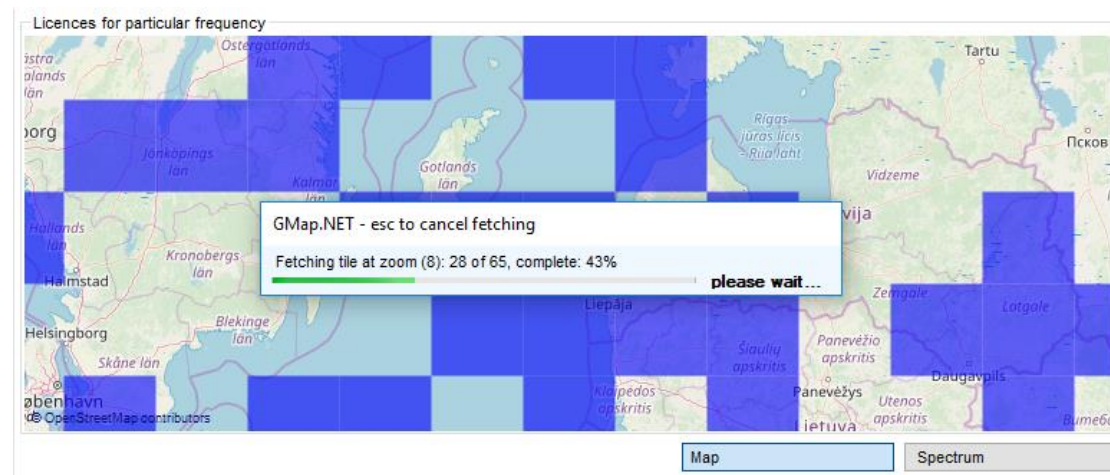
Map cache

Map size: 523 MB

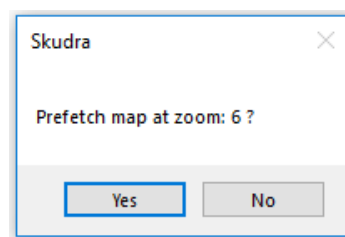
- Maps may be used offline, when the map saved by the software is used, or online when the map is acquired from OSM servers. Changing from offline mode to online mode and vice-versa is done clicking the button “Offline/Online” .
- Tiles of the map viewed online are saved in the software’s memory;

Preloaded maps are available at Skudra software download site as zip files. To use downloaded map user have to overwrite Skudra/Core/karte folder with one contained in downloaded zip file.

However, it is possible to create maps using Skudra Patrol functionality:



- In order to fetch the offline maps, click the button “Prefetch”. After clicking the appropriate button map fetching will begin within the borders of the current map displayed in the measurement section map “licences for particular frequency” (A.14),;
- A confirmation for each zoomed-in layer download will be asked, and download progress will be displayed;



- If the next zoomed-in layer’s download is not confirmed, the map’s download will stop. Each downloaded layer is saved before commencing the next download.

4.3 Measurement Ranges functionality

- The range settings define the bands that will be scanned during measurements, as well as their parameters;
- Summary of set measurement ranges is displayed in Measurement range list. List is not editable directly (except use check box), but selection of particular range in list provides editorial controls. It is possible to edit several ranges together by selecting more that one range;

Measurement range list								
								Receiver 1
	Name	Frequencies	Step	Attenuation	Licence det.	Narrowband det.	Mask detection	Broadbar
<input checked="" type="checkbox"/>	FM	87.5 MHz 108 MHz	100kHz/200kHz	0 dB/Normal VERT/Active	10 dBuVm 30 km	0.6 15 dB	90 % > FM_MAX Min. Mask OFF 100 (100) kHz	OFF
<input checked="" type="checkbox"/>	smd380	380 MHz 430 MHz	6.25kHz/25kHzIQ	RF input 0 0 dB/LowNoise VERT/Passive	10 dBuVm 30 km	0.6 15 dB	OFF	OFF
<input checked="" type="checkbox"/>	cellular	700 MHz 900 MHz	1MHz/25MHz	30 dB/LowDistortion	10 dBuVm 30 km	OFF	OFF	15 dB 0,5 prob. drone

Receiver type	EM200		DF type	PR200					
	Broadband det.	Jammer det.	Spectrogram	Statistics	DF	DF settings			
	OFF	OFF	OFF	ON 5 minutes	1x >30 dBuVm Any 1 s ,95%	DF thr.: 5 dBuV Vertical / Active 0 / Normal			
	OFF	OFF	OFF	OFF	5x >30 dBuVm NRS 10 s ,80%	DF thr.: 0 dBuV			
	15 dB 0,5 prob. drone	3 dB 20 - 29; 31 - 44; 46 - 500 kHz	ON Skudra Server Locally	OFF	OFF	OFF			

4.3.1 Receiver settings

Parameters available to set for each range:

- Use - does the range need to be scanned during measurements. This is only parameter settable in measurement range list;

Frequency range name

Receiver settings
Start/end frequency

Channel step
RF input
Attenuator(dB)
IF Attenuator
Antenna ctrl.

- Frequency range name - the range's name will be listed in the signal detection result list to distinguish frequency channels where measurements were done in the framework of different bands overlapping by frequency;
- Start/end frequency - The range edge frequencies in MHz. When choosing the start and end frequencies, range overlapping is allowed, even several identical bands are allowed. The software automatically will not allow the start frequency to exceed the end frequency;
- Channel step - four measurement frequency steps are available in the software:
 - 100kHz/200kHz - for signals containing their characteristic features in a range of 200 kHz and signals observed are aggregated in a step of 100 kHz (typically FM broadcasting)
 - 6.25kHz/25kHz - for signals containing their characteristic features in a bandwidth up to 31.25 kHz and signals observed are aggregated in a step of 6.25 kHz (typically private land mobile service)
 - 6.25kHz/25kHzIQ - identical to 6.25kHz/25kHz, except that spectrum is calculated on user computer from IQ data, which may greatly improve scanning speed, however that also requires high processing power and connection bandwidth (speed) between receiver and Skudra. Channel step is not available for SignalShark, ESMB, EB200 and EM550 receivers
 - 1MHz/25MHz - for broadband detection using machine learning (5.2.2), for signals containing their characteristic features in a range of 25 MHz and signals observed are aggregated in a step of 1 MHz, still channel frequency is specified in detection process to 250 kHz (typically used public mobile service and dvt-t)
 - 10MHz/100MHz - initially reserved for jammer detection (5.2.4), signals observed are aggregated in a step of 10MHz, and stored in 100MHz, 250 MHz or 500MHz bandwidth

However, jammer detection and mask detection options (but not narrowband detection, broadband detection) are available regardless of channel step;

- RF Input - Setting is valid for receivers which have multiple RF inputs available. Selected input (except “-”) is switched for each frequency range. When “-” option is selected, no action (switching) is taken. Only “-” option is available for receivers with single RF input. Value “0” is not the same as “-”! With “-” no switching will take place, but with “0” first RF input will be switched for R&S receiver.
- Attenuator - The setting of the receiver’s attenuator.
- IF attenuator - The setting of the receiver’s intermediate frequency attenuator.
- Antenna ctrl. - Antenna polarisation and amplification setting. When set to “-” value set previously will be used. However, if same receiver is used for direction finding and scanning, corresponding equipment value may be set by DF equipment settings.
- Available options for RF Input, Attenuator, IF attenuator and Antenna ctrl. depends on the receiver properties. The parameter’s menu shows values available to the receiver set in “Receiver type” menu in Ranges tab.

4.3.2 Licence detection configuration

Licence detection	
Min. field strength	<input type="text" value="10"/>
Guaranteed distance	<input type="text" value="30"/>

- Guaranteed distance - Distance in km from the monitoring site, where all assignments are considered valid. This parameter does not limit (filter) accessible assignments, it shows additional assignments, which in cases (e.g. FM broadcasting) when all transmitter parameters are known, are not necessary. At high values (>30km) this can introduce additional errors in determining the assignment. The value is practically applied to finding the mobile station assignment in a large territory (e.g. in a large city);
- Minimum level - theoretically calculated threshold of field strength (dBµV/m), exceeding which the assignment is considered detectable at the monitoring site. Adjustment of this parameter is foreseen in sites of unusually high or low noise level to refine the amount of assignments determined automatically;

4.3.3 Narrowband signal detection configuration

<input checked="" type="checkbox"/> Narrowband detection	
Correlation squelch	<input type="text" value="0.6"/>
Noise squelch(dB)	<input type="text" value="15"/>

- Narrow band detection is available only for 6.25kHz/25kHz, 6.25kHz/25kHzIQ and 100kHz/200kHz channel steps;
- Correlation squelch - The squelch value is from zero to one. To detect a signal the squelch value is compared to the maximum squared correlation coefficient achieved doing Pearson's correlation with sample spectra.
- Noise squelch - Squelch value in dB over noise. The noise squelch is used to determine the frequency channels where signals should be further detected using correlation;

4.3.4 Mask signal detection configuration

Mask detection configuration window showing the following settings:

- Mask detection: ☒
- Max. mask: Squelch(dB) [30]
- Min. mask: OFF [50 %]
- Step(kHz): 100 / 1 BW: 5

- Mask detection is available for any channel step;
- It is possible to use two masks: maximum mask for detection when signal overshoots mask and minimum mask when signal undershoots mask;
- For both maximum and minimum masks mask type can be set to “OFF”, fixed squelch “Squelch (dB)” and to user defined mask;
- If mask detection is set to fixed squelch, no user defined mask is necessary, and signal level is compared to value (in dBuV/m) set in textbox to the right of mask type dropdown;

Mask detection configuration window showing the following settings:

- Mask detection: ☒
- Max. mask: FM_MAX [50 %]
- Min. mask: FM_MIN [50 %]
- Step(kHz): 100 / 1 BW: 5

- To use mask detection with user defined mask, spectrum mask must be generated (5.2.3 and 4.7). List of user defined masks compatible to selected spectrum range (start frequency, stop frequency, channel step combination), if any, is shown in dropdown below options “OFF” and “Squelch(dB)”.
- Channel step for mask detection is independent for measurement range channel step and it will override signal aggregation channel step expected for measurement range channel step;
- Mask detection's channel step divisor enables non integer channel steps, for example $25\text{kHz}/3 = 8.333\text{ kHz}$;
- Mask detection bandwidth (BW) is set to compare signal against mask only in set bandwidth in the center of channel. For example, it can be used to compare mask to signal only at stable part of signal (carrier frequency).
- Practically spectrum in mask detection bandwidth contains more than single spectrum point. It may be relevant (for example spectrum changes due to

modulation) whether mask is overshoot by all spectrum points (100%) or just single point (0%). Overshoot/undershoot percentage can be set in textbox to the left of mask type dropdown, if user defined mask is selected;

4.3.5 Jammer detection configuration

☒ Jammer detection
 Noise squelch(dB)
 Carrier spacing(from-to, kHz)

 Car. specificity
 Exclude:

- Jammer detection is available for any channel step;
- In depth guidance selecting parameters for jammer detection is provided on 5.2.4;
- Noise squelch determines necessary interdecile range of emission's spectrum in 0.5 MHz, 2 MHz, 10 MHz or 20 MHz bands (respectively for 6.25kHz/25kHz, 10MHz/100MHz, 100kHz/200KHz and 1MHz/25MHz channel steps), to proceed to jammer detection;
- Carrier spacing determines ranges of carrier spacing (periods) to be considered related to jammer. Values are in format is "period1start - period1end; period2start - period2end;...". It is possible to add predefined carrier spacing exclusions for GSM, LTE, 5G by pressing respective buttons;
- Car. specificity determines how much more power must be concentrated in particular periodic carrier frequency, compared to average of other periodic components. Practical value for jammer detection may be 1 to 2;

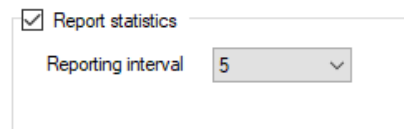
4.3.6 Broadband signal detection configuration

☒ Broadband detection
 Noise squelch(dB)
 Prob. squelch
 ML model

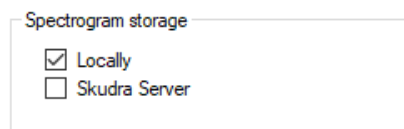
- Broadband detection is available only for 1MHz/25MHz channel step;
- In depth guidance selecting parameters for broadband detection is provided on 5.2.2 and 4.6;
- To use broadband detection ML model must be imported (4.6). Dropdown box provides list of currently imported ML models;

- Noise squelch determines level difference of spectrum sample to be used for broadband detection. Generally, it is appropriate to use value similar to one used when fitting model;
- Broadband detection provides probability value of signal being detected in range from 0 to 1. Probability squelch determines, whether emission to be regarded as signal depending on the probability value;

4.3.7 Statistics and spectrogram configuration



- Report statistics - enable functionality of reporting statistics to Skudra Server and set reporting interval (seconds).

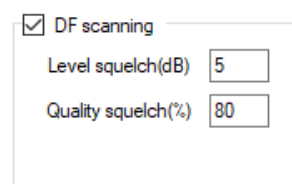


- Spectrogram storage enables recording (and display) of waterfall spectrogram. Spectrogram can be stored on local computer, on Skudra Server or both;

4.3.8 DF scanning configuration

“DF scanning” provides direction finding for all channels of spectrum currently scanned, with delay of only 50ms-150ms, or simultaneously for DDF550 direction finder.

- DF scanning requires that direction finder supports wideband DF, e.g. it is possible to direction find all frequency channels within receiver’s Realtime bandwidth simultaneously.
- Some direction finders (EB500, DDF205) require wideband DF option for DF scanning to provide direction finding results. Narda SignalShark does not support wideband DF scanning.



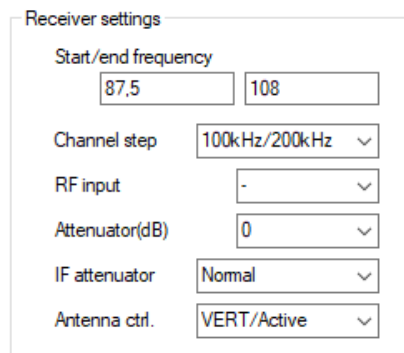
DF scanning has two configurable parameters: Level squelch and Quality squelch:

- Level squelch corresponds to value Threshold (dBUV) set in receiver's GUI in Normal DF mode. Value limits are -50 to +130.
- Quality squelch (%) configures threshold for bearing quality. Direction finding is successful and result is output only if direction measured, has quality higher or equal to that set in Quality squelch(%) textbox.

DF results gathered during DF scanning are added to signal detection results, provided that signal has been detected on particular frequency channel.

With DF scanning, to provide delay as short as possible between spectrum scanning and direction finding (if not simultaneous operation), spectrum scanning and direction finding use the same settings for both operations. Therefore:

- Parameters that influence spectrum scanning results, also influence direction finding results.



Receiver settings

Start/end frequency
87.5 108

Channel step 100kHz/200kHz

RF input -

Attenuator(dB) 0

IF attenuator Normal

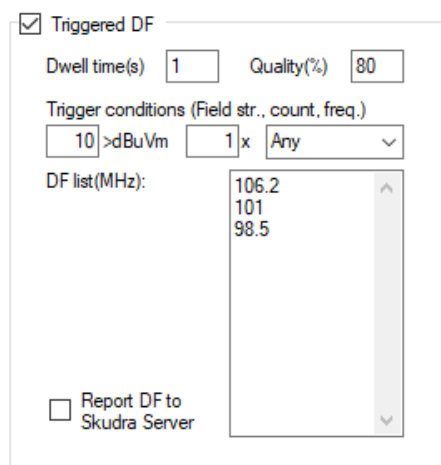
Antenna ctrl. VERT/Active

- DF equipment settings (4.3.10) has no effect on DF scanning results.

As Scanning DF is performed with low delay after scanning or even simultaneously, that is before signals have been detected:

- Triggered DF configuration (4.3.9) has no effect on DF scanning.

4.3.9 Triggered DF configuration



☒ Triggered DF

Dwell time(s) 1 Quality(%) 80

Trigger conditions (Field str., count, freq.)
10 >dBUV/m 1 x Any

DF list(MHz):
106.2
101
98.5

☐ Report DF to Skudra Server

- If enabled triggered DF, direction finding on each signal detection event that trigger conditions is requested (5.3);
- Trigger conditions are minimum field strength of aggregated signal, minimum count detections in particular frequency channel and frequency channel characteristics, which includes whether there is no licence associated to frequency (“NRS”), whether frequency is contained in DF list (“listed”), and no condition (“any”);
- DF list contains frequencies in MHz, for which only direction finding will be requested, if trigger condition “listed” is selected. Multiple frequencies can be added to DF list from clipboard, or added after keyboard shift-enter combination;
- Dwell time determines how long each DF request is carried out. During the dwell time many df measurements may be performed, in such case one most probably direction is output;
- Direction finding is successful and result is output only if at least one direction measured, has quality higher or equal to that set in quality(%) textbox. Also directions bellow quality(%) textbox value, are not included in calculation of most probable direction;
- It is possible to send each direction finding result in realtime to Skudra server by enabling Report DF to Skudra server (5.4). This functionality is separate from sending direction finding histogram as part measurement results.

4.3.10 DF equipment settings

Df equipment (Direction finder’s) settings are crucial to attain correct direction finding results. Therefore it Skudra provides functionality to DF equipment settings for each measurement range.

DF equipment settings is available if “DF type” in Measurement range list is set to value other than “-” and Triggered DF if enabled for selected range.

DF equipment settings

Threshold (dBuV)

5

DF polarisation

Vertical

DF amplification

Active

DF antenna input

-

DF attenuator

0

DF IF attenuator

Normal

- Values set in DF equipment settings are used direction finding signals found scanning corresponding range.
- For some settings “-” value is available, which means that value already set in direction finder by other means (e.g. GUI) will be used. However, when using same equipment for direction finding and scanning, settings relevant also to direction finding may be set during scanning by receiver settings (4.3.1)
- Settings not available for selected direction (regardless of antenna) finder are greyed-out.
- Threshold (dBuV) corresponds to value set in receiver’s GUI in Normal DF mode. Value limits are -50 to +130. In contrary to trigger conditions’ “field strength” this is value set directly to direction finder.

4.3.11 Editing the range setting list

- The range settings available depend on the receiver specification. The range editing list contains values available to the chosen receiver;
- If a different monitoring receiver is chosen in the menu the new receiver supports a parameter in the range list, the parameter is left unchanged. In the opposite case, the available value of the parameter closest to that previous one is set;



- By clicking the Receiver type “refresh” button, the receiver having the IP address set in “Receiver (IP:port)” will be automatically be chosen and set in the Receiver type menu. However, if “Sequential scanning and DF with same receiver” is opted, IP set in “DF (IP:port)” will be used;
- By clicking the DF type “refresh” button, the direction finder having the IP address set in “DF (IP:port)” will be automatically be chosen and set in the DF type menu.
- By clicking the button “add range” (“+”), the measurement range editing list will be appended by a new entry with default settings of the receiver chosen in menu.
- By clicking the button “delete range” (“-”), the highlighted entry will be deleted from the measurement range editing list.
- By clicking the button “open” (open folder icon) and selecting an earlier saved range setting file you may load this to the software.
- By clicking the button “save” (floppy disk icon) the software will offer to save the currently presented bands in a user named file for it’s future loading into the same or other instance of software by clicking the button “open”.

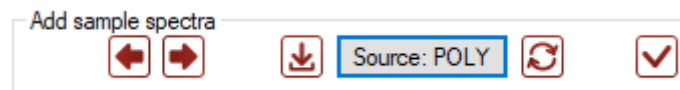
4.4 The Sample Spectra Functionality

To determine signals correctly, a sufficient stock of sample spectra is necessary. The majority of signal types need their own sample spectrum. The more sample spectra is available, the higher the correlation coefficient and the more it will differ from increased noise or out of range emissions, leading to better signal determination.

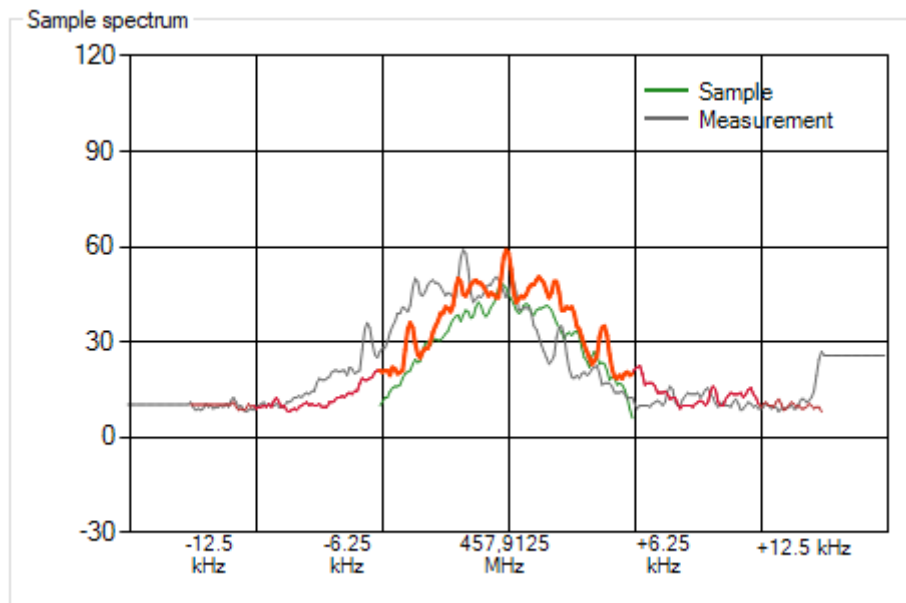
The collected sample spectra section is created for spectra sample analysis and creating new sample spectra.

4.4.1 Adding and Displaying Sample Spectra

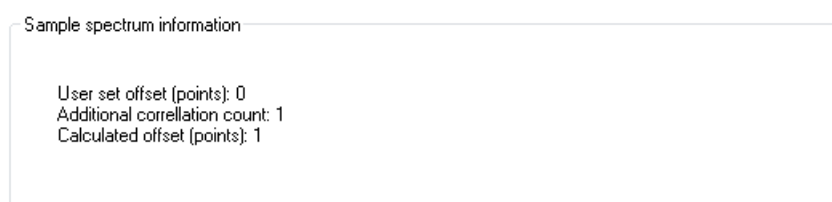
- Data defining new spectrum are taken either from the cumulated signal spectrum or spectrogram. Type selection for sample spectra source is made by toggling button “Source: POLY” or “Source: WF” respectively.



- If cumulated signal spectrum source is selected, then before defining a new sample spectrum it must be ensured that the corresponding record is highlighted in the signal detection result list;
- If spectrogram source is selected, refer to section 4.4.2 for details on setting frequency and time of sample source;
- To start a new sample spectrum project, the button “load” (E.12) should be clicked. The sample spectrum curve lies within the maximum values of each frequency component’s cumulated spectrum that falls within the 90% interval assuming that the dispersion of values follows a Gaussian distribution. (Inaccurately, but simpler - 90% of the maximum value);



- In the process of creating a sample spectrum project, several curves are plotted in the sample spectra display and defining graph (E.2), differing by frequency offset. The calculated sample spectrum “*measurement*” without frequency offset (E.5) is displayed, and, depending on the sample spectrum’s range’s step, sample spectrum with a frequency offset corresponding to the centring of the signal in the 200 kHz range (E.6) or two sample spectra with a frequency offset corresponding to the centring of the signal in the 31.25 kHz range (E.7) and 12.5 kHz (E.8);
- By selecting a sample spectrum on the graph with the left mouse button, it is possible to adjust the automatically determined frequency offset with the buttons “*left*” (E.10) and “*right*” (E.11);



- The automatic and manual sample spectrum offsets are shown in the group “*Sample spectrum information*”, respectively, “*Central frequency offset*” and “*User set offset (points)*” (E.21);
- The group “*Sample spectrum information*” also displays the information “*Additional correlation count*” (E.22), which characterizes the number of correlations necessary to the project (value exceeds 1 for most spectra containing multiple carriers);
- The manually corrected offset may be reset by clicking “*refresh*” (E.13);

- When creating a sample spectrum project, the sample spectrum usage statistics chart (E.3) of the closest signals to the source of the new sample are also shown. Only those sample spectra are shown in the chart rows that were detected as the closest signals, including occurrence count (E.9). The chart can also display how often a particular sample spectrum is used in various frequencies. To repeatedly view the source sample spectrum source spectra statistics, the button “*refresh*” (E.13) should be clicked;
- In order to add the sample spectra project to the list of sample spectra, the button “*confirm*” (E.14) should be clicked, and the columns “*information*”, “*Use*” and “*Em. Class*” should be filled-in directly in the list of sample spectra (E.1).

4.4.2 Sample spectra source: Spectrogram

It is possible to define new sample spectra either from cumulated spectra or spectrogram. Spectrogram source provides advantage that sample spectrum can be selected from single signal spectra contained in long term measurements. For example, it is possible to select the single spectrum in days’ worth of scanning, that was not correctly detected as signal, and use it to fine tune the sample spectra database.

To be able to set sample spectra source from spectrogram it necessary to:

- Create new or open stored measurement result, that is measured with spectrogram storage “Locally” enabled (4.3.7),
- Select and show in frequency range spectrum chart particular spectrum trace from spectrogram (4.1.20),
- Select frequency (signal) of interest in frequency range spectrum chart by zooming and centring on respective frequency.
- Spectrum at center of frequency range spectrum chart will be used as sample source, when user clicks button “*load*” (E.12) at sample spectrum generation process (4.4.1)

4.4.3 The list of sample spectra

- The available sample spectra with their parameters are displayed in the list (E.1) in columns:
 - Information - A description of the sample spectrum, e.g., the model of the emitting equipment, radiofrequency application or spectrum description. A unique identifier is allocated to each sample spectrum, thus several sample spectra may have the same description.
 - Use - A checkmark indicating the particular sample spectra is in use by the software to determine signals. Unchecking this parameter

enables temporary disabling the particular sample spectra without deleting it;

- Em. class - The class of emission associated with the sample spectrum is used to predict the measured signal's class of emission. The class of emission in the signal determination results corresponds to the most often observed sample spectrum most closely resembling the signal;
- Step - sample spectra differ significantly depending on the frequency channel step (thereby of frequency ranges and the typical signals in the range). To efficiently use the computer's processing power two groups of sample spectra are used - one for frequency ranges with a channel step 6,25 kHz and the other for frequency ranges with a channel step 100 kHz.
- Corr. - Correlation (coefficient of determination) between the cumulated sample spectrum and the spectrum project created from measurement results. The correlation column's entry is blank when no sample spectra project was acquired, when the sample spectrum project was acquired at a frequency channel step not conforming to the sample spectrum, as well as if the ratio of the standard deviation between the level values of the sample spectrum project and cumulated spectrum is less than 0.67;
- StDev - The standard deviation ratio of the level values of the sample spectrum project and cumulated sample spectrum. The column's entry is blank when no sample spectra project was acquired and when the sample spectrum project was acquired at a frequency channel step not conforming to the sample spectrum;

Information	Use	Em. class ▲	Step	Corr.	StDev ▲
Motorola GM300	<input checked="" type="checkbox"/>	8K50F2D	6.25kHz/25kHz	0.844	0.73
testpr100	<input checked="" type="checkbox"/>	8K50F2D	6.25kHz/25kHz	0.798	1.17
Unknown	<input checked="" type="checkbox"/>	8K50F2D	6.25kHz/25kHz	0.461	2.97
8K50F3E CTCSS	<input checked="" type="checkbox"/>	8K50F3E	6.25kHz/25kHz	0.335	0.72
8K50F3E CTCSS ar skanju	<input checked="" type="checkbox"/>	8K50F3E	6.25kHz/25kHz		0.64
8K50F3E CTCSS full	<input checked="" type="checkbox"/>	8K50F3E	6.25kHz/25kHz	0.743	0.9

- Correlation, sample spectrum and signal spectra standard deviation ratio columns are blank if the range or point number does not match the spectrum. The correlation column also is blank when the standard deviation of spectrum level values is half of the sample spectrum standard deviation;
- The correlation and signal spectrum standard deviation of entries characterize how well the sample spectrum matches the project sample source - how precisely such as signal may be determined. Standard deviation characterises the difference between lowest and highest level values in sample spectra - whether sample is derived from low or high level signal.

- By highlighting a sample spectrum entry it is displayed as a sample spectrum in the sample spectrum defining graph;
- The sample spectra list may be sorted by clicking the column headers.

4.4.4 Editing the sample spectra list and exchanging it with Skudra Server

Under the Sample spectra list is a group “*Edit sample spectra list*” for editing the sample spectra list and it’s exchange with Skudra Server;

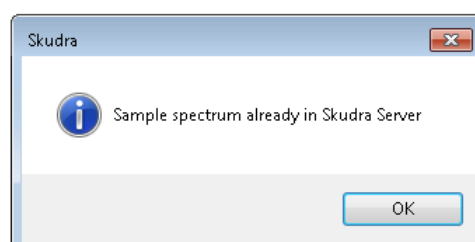
- To delete the highlighted sample spectrum from the sample spectra list the button “*delete*” (E.16) should be clicked;



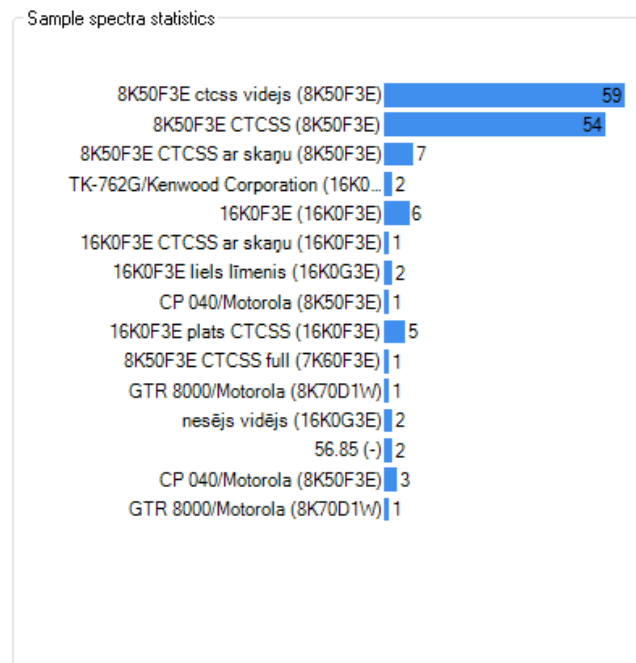
- To undo unsaved changes in the sample spectra list the button “*refresh*” (E.17) should be clicked;
- In order to save changes to the sample spectra list so that they are available also after restarting Skudra, the button “*save*” (E.20) should be clicked;
- In order to compare the sample spectra list to the saved spectra on Skudra Server, the button “*load*” (E.18) should be clicked. When loading will complete, entries both in the sample spectra list and in Skudra Server will appear in black font, in red those only in Skudra Server and blue - only locally saved spectra samples;

Sample spectra list						
Information	Use	Em. class	Step	Corr.	StDev	
Latvenergo	<input checked="" type="checkbox"/>	24K0D2D	6.25kHz/25kHz			
aCiparu	<input checked="" type="checkbox"/>	8K50F1D	6.25kHz/25kHz	1	1	
173_4	<input checked="" type="checkbox"/>		6.25kHz/25kHz	0.713	1.22	
Latvenergo	<input checked="" type="checkbox"/>	15K3F1D	6.25kHz/25kHz	0.527	0.69	
FM apraide (plats)	<input checked="" type="checkbox"/>	300K8EHF	100kHz/200kHz			
ciparu446	<input type="checkbox"/>		6.25kHz/25kHz	0.644	1.27	
16K0G2B bez 6 nesēji	<input checked="" type="checkbox"/>	16K0G2B	6.25kHz/25kHz	0.06	1.63	

- To upload highlighted sample spectrum to Skudra Server, the button “*upload*” (E.19) should be clicked. Only authorized users having acquired the authorization token from Skudra Server may update the sample spectra database. If a sample spectrum is already stored in the database, no copy will be added. A pop-up message on the upload results will appear.



- Upon clicking the button “*information*”, the distribution of sample spectrum use across different frequency channels will appear on the chart Sample spectra statistics (E.3). The distribution rows comprise all frequency channels where the highlighted sample spectrum was identified as the most alike. Each row is also marked how often the spectrum has been identified.



4.5 The functionality of the frequency assignment database

Upon clicking the button “*import licence database file*” (**Error! Reference source not found.**) , “Licence database download” or “recalculate licences” (**Error! Reference source not found.**) the table of valid licences at the monitoring site is calculated. The array of valid licences is calculated by the following algorithm:

- The theoretical transmitter field strength at the monitoring site is calculated using the Hata-Davidson radio wave propagation model (TIA TSB-88A), based on the following input data: frequency, effective radiated power of the transmitter, distance, antenna height, propagation environment at the monitoring site, the receiving antenna’s height;
- The theoretical field strength intensity is calculated for all transmitters whose licences include coordinates, effective radiated power, antenna height, class of emission;
- The user of the licence with the highest theoretical field intensity exceeding the established field intensity threshold is considered as the most probably

detectable at the monitoring site. Additionally, the numbers of all other licences over the threshold are stored for the use of Skudra Server;

- Using a geographical distance calculation method (not taking account of the Earth's curvature) from all the transmitters having coordinates in their licences, only those are selected that are not farther then the established threshold. If a valid licence was not established applying the previous clause, the user of a licence with coordinates nearest to the monitoring site within the distance threshold is considered valid;
- Additionally, the numbers of all other licences over the threshold are stored for the use of Skudra Server;
- All licences without coordinates are considered valid everywhere and are appended in parentheses to the list of valid licences at the monitoring site;
- Additionally, the numbers of all the licences without coordinates are stored for the use of Skudra Server;
- Frequencies which are not found in the Skudra Server database, but are included in the user-prepared file of specific frequencies are appended to the array of valid licences;
- Additionally, for display in the measurement section's map and manual tweaking of the licence, all licence information is stored, their theoretical field intensity at the monitoring site and their distance.

4.6 Functionality of Machine Learning

To use machine learning signal detection, corresponding function has to be enabled for particular measurement range (see 4.3). One of the parameters that is necessary to set in order to use machine learning detection is ML model. This paragraph provides instructions on how to generate ML learning model.

4.6.1 Generation of Machine Learning models

Functionality necessary to generate ML models is available in “Machine learning” panel;



Generation of ML model is divided into five steps. The first step is to select stored spectrogram data (for measurement of spectrogram see ranges and waterfall functionality).

Machine learning source data preparation

1. Selection of spectrogram data Browse files

Locating files...
 638017182871175939-0-256.zip (500 MHz - 600 MHz):
 1MHz / 25 MHz: 19200 samples
 Completed
 Total: 19200

2. Identify samples with range above (dB): 10

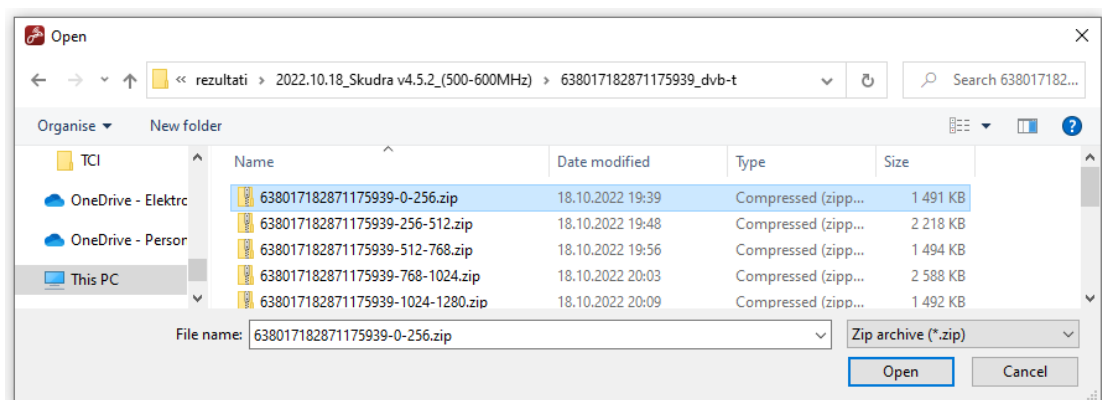
Identify 19200 samples mapped for identification
Stop Checked: 19200 , above squelch: 6860

3. Reduce amount of samples to : 5000

Load to list Save to file

5000 samples selected for Machine learning
 5000 samples processed
 populating list...completed

Selection of spectrogram data is provided by “Browse files” button. In following open file dialog, it necessary to select single or multiple zip files that are contained in spectrogram folder. Opposed to selecting spectrograms for waterfall display, where it is necessary to select folder, for ML model generation it is necessary to select files inside spectrogram folder:



After selection of zip files and pressing “Open” button, information text box is filled with names of selected files and number of samples they contain;

Second step is to select (identify) spectrum samples to be used for generation of ML model based on difference between maximum and minimum field strength in each sample. This removes samples without change of field strength from using further steps which includes manual selection of samples that must be considered as signal. Practical value of necessary difference between maximum and minimum field strength may be considered 10 dB;

Third step is to reduce number of samples used for ML model generation, however there no practical use to limit the number below 10000. User must pay attention to set limit, because limit value is not automatically updated after identifying new

samples in second step. Reduction of data is commenced by pressing button “Load to list” or “Save to file”. By pressing “Save to file” samples will be stored in file in format, that will allow to load it to list later, including together with other files (functionality in group box management of spectrum samples). Pressing “Load to List” will load samples to list for selection of samples to be considered as signal:

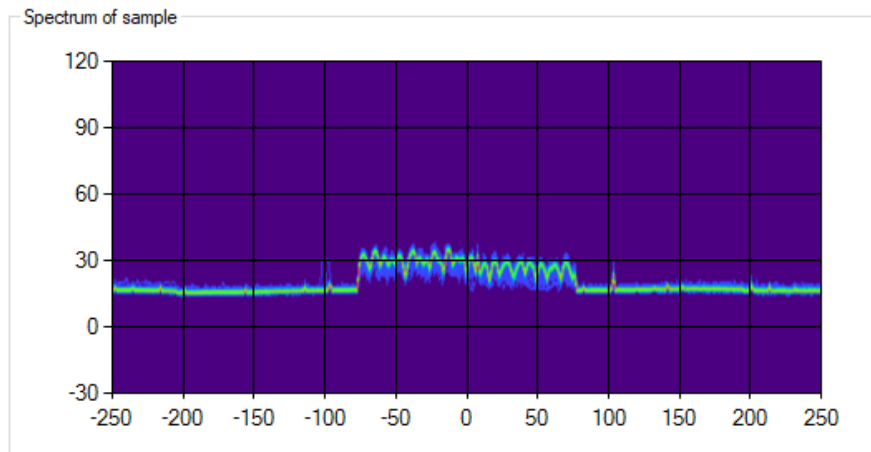
List of samples for fitting model

4. Labeling of samples

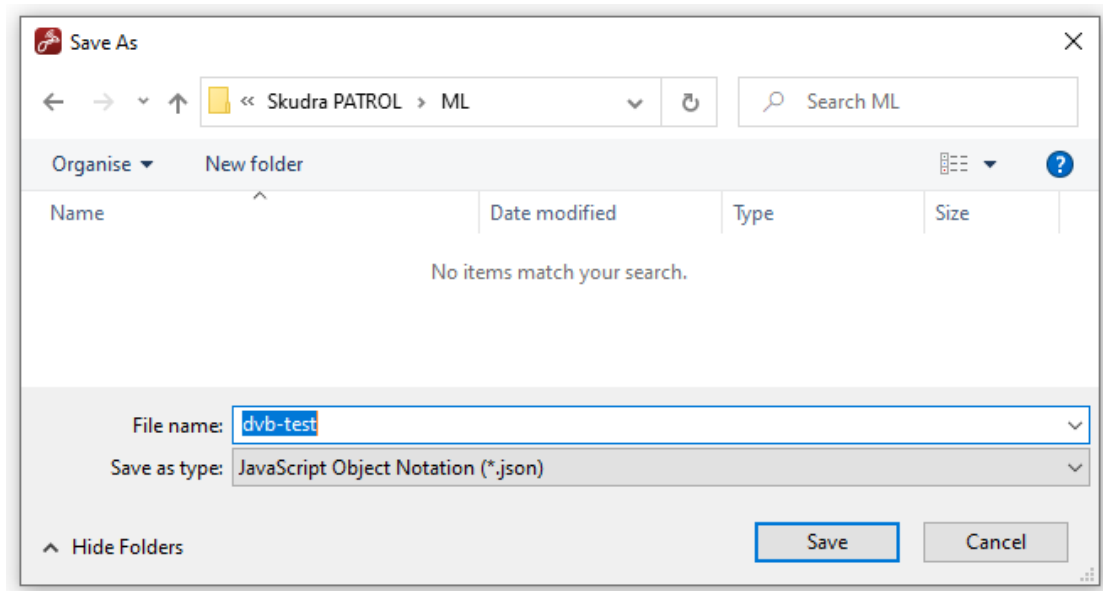
Time	Frequency	BW	offset	Label
638017182871175939	514000000	25000000	0	<input type="checkbox"/>
638017182871175939	516000000	25000000	0,0322...	<input type="checkbox"/>
638017182871175939	515000000	25000000	0	<input type="checkbox"/>
638017182871175939	526000000	25000000	0	<input type="checkbox"/>
638017182871175939	527000000	25000000	0	<input type="checkbox"/>
638017182871175939	528000000	25000000	0,0185...	<input type="checkbox"/>
638017182871175939	529000000	25000000	0	<input type="checkbox"/>
638017182871175939	530000000	25000000	0,0008...	<input checked="" type="checkbox"/>
638017182871175939	531000000	25000000	0,0083...	<input type="checkbox"/>
638017182871175939	532000000	25000000	0,0137...	<input type="checkbox"/>
638017182871175939	533000000	25000000	0	<input type="checkbox"/>
638017182871175939	534000000	25000000	0	<input type="checkbox"/>
638017182871175939	538000000	25000000	0	<input type="checkbox"/>
638017182871175939	539000000	25000000	0,1005...	<input type="checkbox"/>
638017182871175939	540000000	25000000	0,0966...	<input type="checkbox"/>
638017182871175939	541000000	25000000	0,0912...	<input type="checkbox"/>
638017182871175939	542000000	25000000	0,0243...	<input type="checkbox"/>
638017182871175939	543000000	25000000	0,0032...	<input type="checkbox"/>
638017182871175939	544000000	25000000	0,0068...	<input type="checkbox"/>
638017182871175939	545000000	25000000	0	<input type="checkbox"/>
638017182871175939	546000000	25000000	0	<input type="checkbox"/>
638017182871175939	547000000	25000000	0	<input type="checkbox"/>

Step 4 provides functionality to mark samples that must be considered as signals. Correctness of this marks has direct influence on usefulness of resulting ML model. For broad band signals, list will have several records for single signal. In such case it is important to select only the sample record that is centred on signal, otherwise broad band detection will detect signal not only on centre frequency of spectrum, but also on offset frequencies depending on how samples was marked;

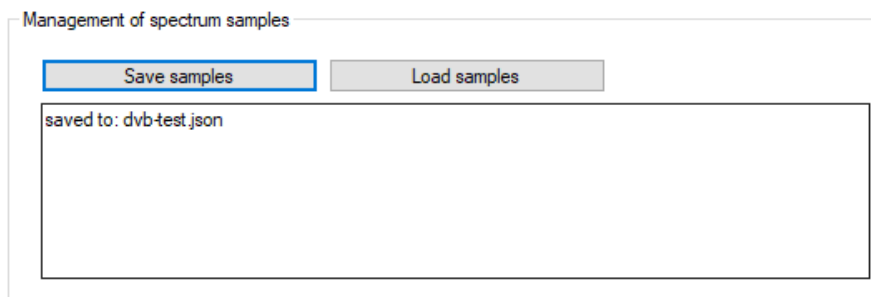
To support selecting samples to mark as signals, cumulated spectrum of sample is shown for selected record, and also value of frequency offset from record frequency (usable as additional guide to select between nearby records, when spectrum alone is not definitive) is shown in column “offset” list of samples.



After marking samples that must be considered as signals, it is advisable to save marked samples to file for combined use, by pressing “Save samples” button:

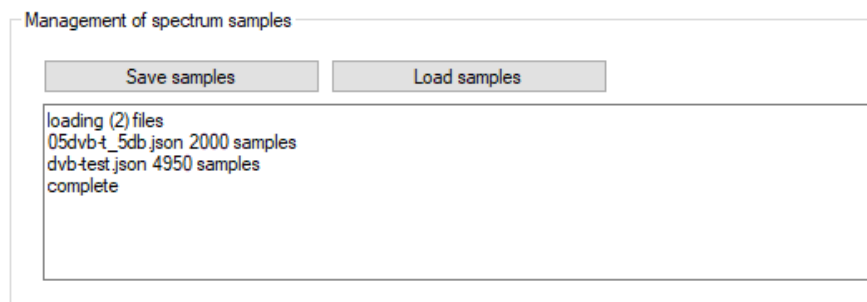


After successfully saving spectrum samples, corresponding information line is added to information text box:

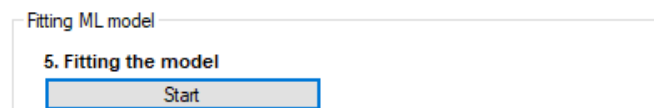


Saving spectrum samples to file provides possibility for later loading samples to be used to fit ML model from several files. Those files can be created at different channel, different antennas, different signal to noise ratios to provide most diverse spectrum samples. By pressing “Load samples” can load all files deemed necessary

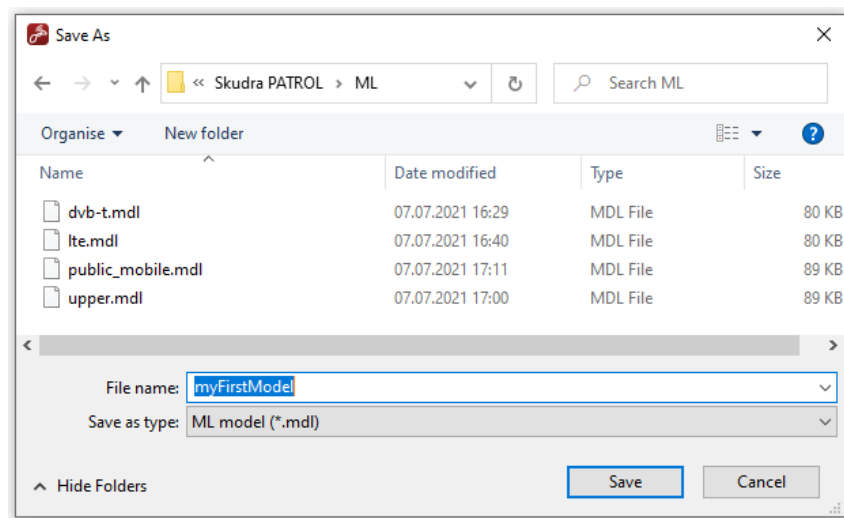
for fitting model. Samples contained in files will be added to “List of samples for fitting model”. Any samples contained in “List of samples for fitting model” before loading files will be lost:



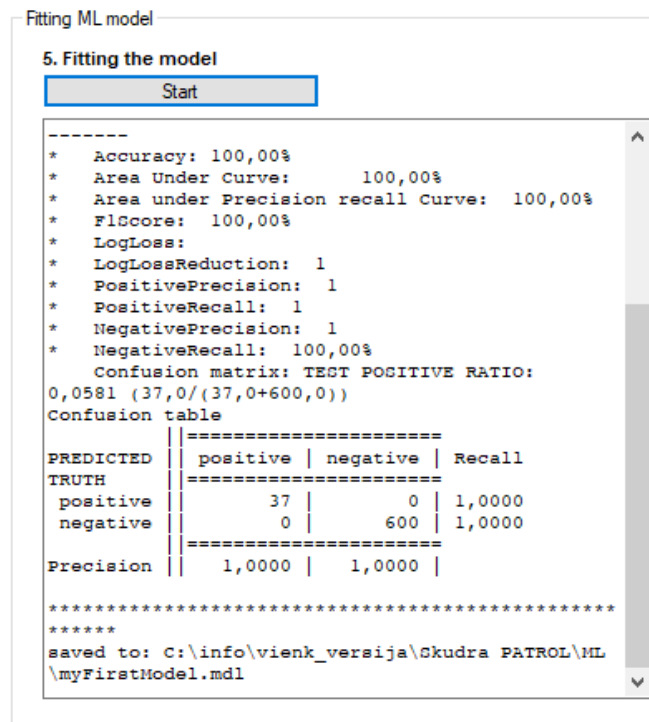
When necessary samples are loaded in list and signals are marked, Fitting of ML model can be started by Pressing “Start” in “Fitting ML model” group box:



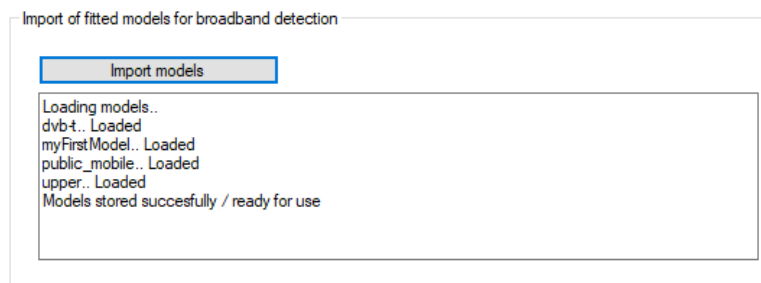
Fitting Starts with selecting file for saving ML model. Selected file name will be used to select available ML models, when defining broad band detection in Ranges panel;



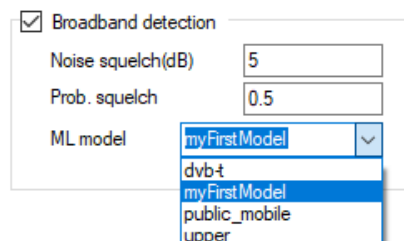
After selecting model name fitting of model is started. At the end of fitting, information on success of fitting in “Fitting ML model” group box is shown, for example: accuracy, whose low values (<90%) sometimes may be sign of incorrect marking of spectrum samples and confusion matrix, where number of cases when negative truth (no signal) is predicted as positive (signal) can be seen;



Any ML model, previously or newly created, must be imported to be available when setting measurement ranges in Ranges panel. Import of models is started by pressing “Import models” button in “Import of fitted models for broadband detection” group box.



Importing models provides possibility to select several ML models. ML models previously imported will be unloaded, and only newly selected models will be available for setting Broadband detection for measurement ranges:



4.7 Functionality of Mask Detection

Skudra Patrol provides two approaches to detection emissions above/below the set limit. First is detecting emissions above fixed squelch field strength, regardless of measurement range parameters. Second approach is to compare measured field strength to spectrum mask that is specifically designed for frequency range defined by its start frequency, stop frequency and resolution.

For mask detection with fixed squelch no mask generation is needed. Generation of specific masks for particular measurement ranges is described in section 4.7.1.

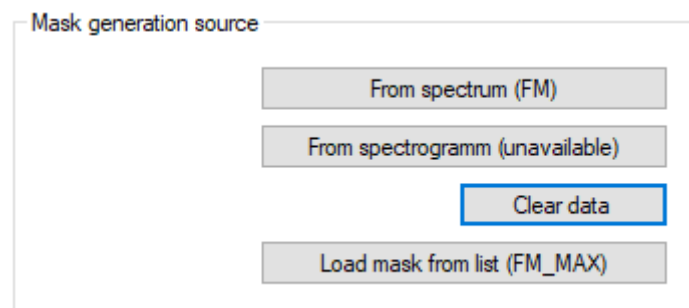
4.7.1 Mask generation

Functionality of spectrum masks' generation is available in "Masks" panel.



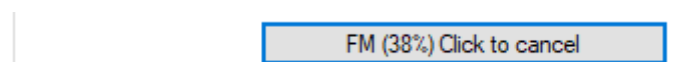
Skudra Patrol provides three data sources to generate spectrum masks:

- Maximum and minimum spectrum traces of currently displayed frequency range spectrum in "Measurements" tab,
- Currently displayed spectrogram in "Measurements" tab (which is then used to calculate maximum and minimum traces),
- Previously generated spectrum mask selected in list of masks.

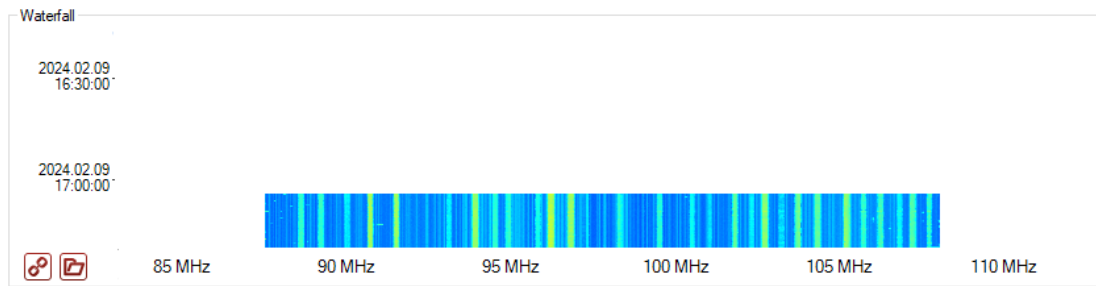


To load source for mask generation corresponding mask source button must be pressed. Availability of data source is noted in scopes on the mask data source button.

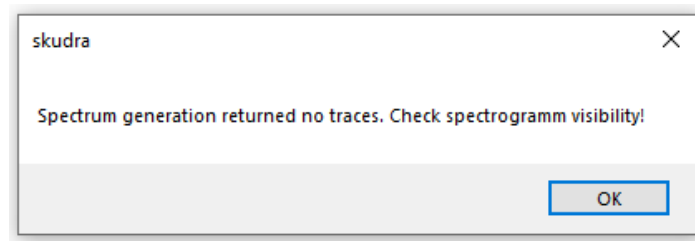
If loading data from spectrogram, depending on size of spectrogram, maximum and minimum trace calculation may take considerable time. Therefore, progress percentage is shown load button as well as option to cancel calculation:



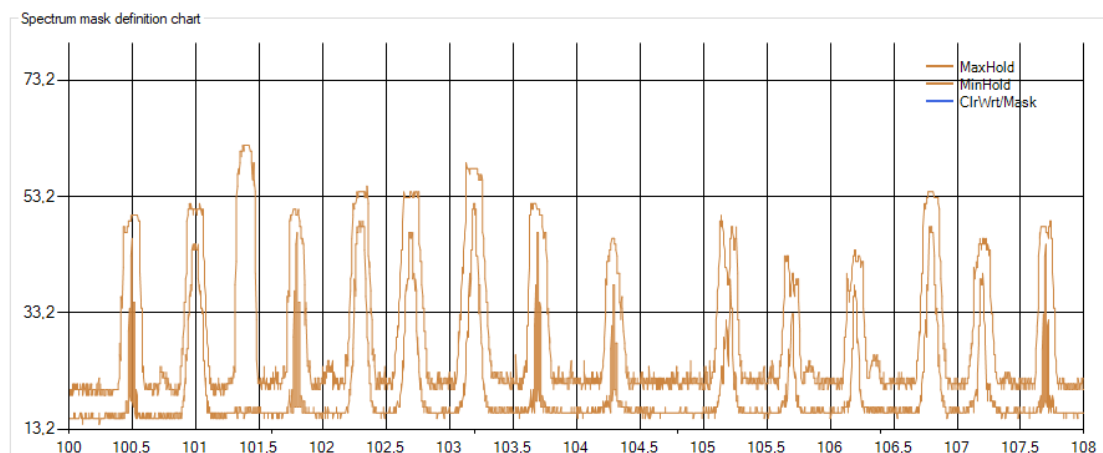
Also spectrogram data used for calculating maximum and minimum traces is limited by time range displayed in spectrogram panel in "Measurements" tab.



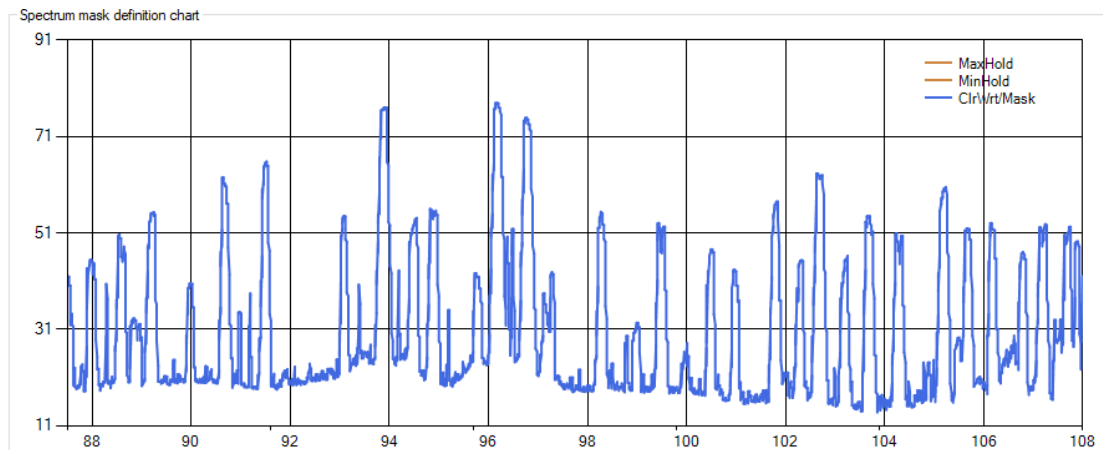
Time limits can be used to exclude unwanted parts of spectrogram or to shorten calculation time. However, user must also ensure that spectrogram is displayed at all, otherwise no traces will be calculated:



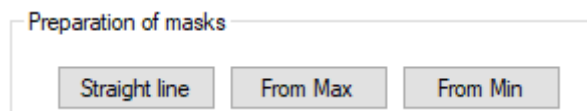
After successfully loading maximum and minimum traces from frequency range spectrum or spectrogram, corresponding ranges will be loaded in spectrum mask definition chart:



If loading mask from list, selected mask will be loaded in spectrum mask definition chart as ClrWrt/Mask trace:



In general, after loading source data, new mask template can be generated from maximum or minimum traces, or set as straight line by pressing corresponding buttons:

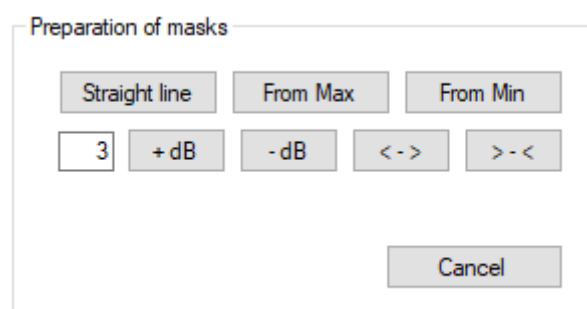


However, this functionality can be limited by markers, as further described in (4.7.2)

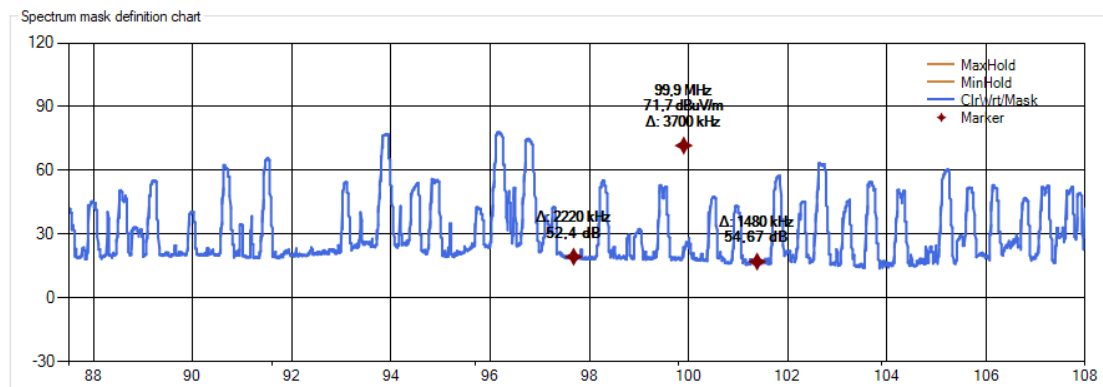
4.7.2 Mask manipulation

Mask manipulations are available as soon as ClrWrt/Mask trace is available in spectrum mask definition chart. ClrWrt/Mask trace can be added in following ways:

- By selection in list of masks. This function is available only if there are no mask manipulation in progress and selected mask is compatible with maximum and minimum traces loaded in mask definition chart,
- By loading selected mask from list (specifically pressing “Load from list” button),
- From maximum trace (if loaded) by pressing “From Max”,
- From Minimum trace (if loaded) by pressing “From Min”.



Once ClrWrt/Mask trace is available, markers can be added to limit “Preparation of masks” functionality in frequency domain. Markers can be added by mouse left-click while holding “Ctrl” key. Other marker functions are the same as those of frequency range spectrum (4.1.14), with exception that in Spectrum mask definition chart markers can be added to ClrWrt/Mask trace only and middle marker is not set to trace, and it is freely adjustable.



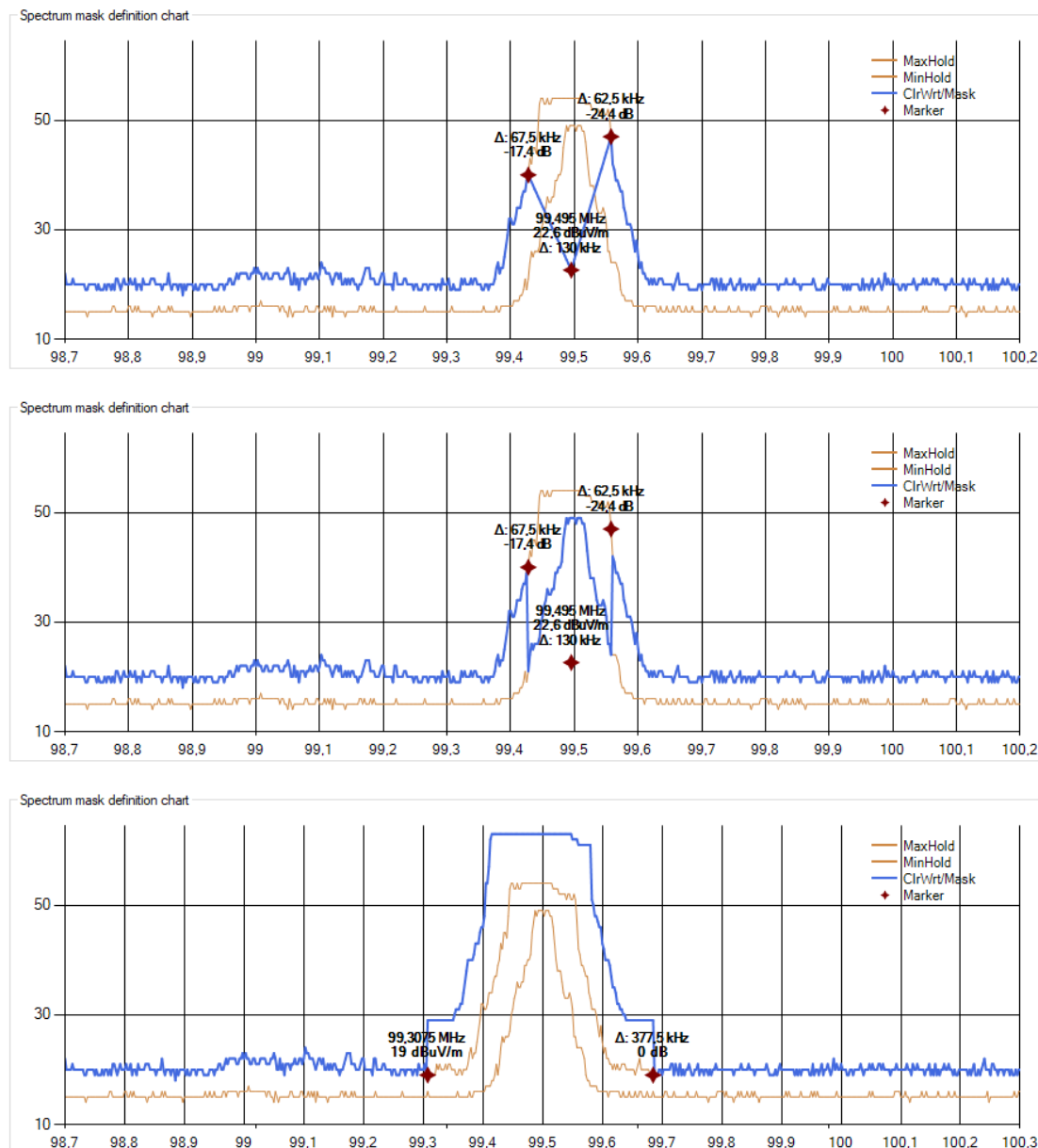
Further spectrum mask in frequency range between outer markers can be altered as follows:

- Markers can be connected with straight line by pressing “Straight line” button,
- Spectrum mask can be updated with values from maximum trace by pressing “From Max” button,
- Spectrum mask can be updated with values from minimum trace by pressing “From Min” button,
- Mask trace points can be increased by value (dB) set in textbox in the left by pressings “+dB” button,
- Mask trace points can be decreased by value (dB) set in textbox in the left by pressings “-dB” button,
- Mask trace can be broadened (each point is given value maximum value of itself and two closest neighbours) by pressing “<->” button,
- Mask trace can be narrowed (each point is given value minimum value of itself and two closest neighbours) by pressing “>-<” button.

If no markers are set, functions described above are deployed for whole frequency range of mask.

Maximum and minimum values of spectrum mask is 120 dBuV/m and -30 dBuV/m, respectively. Therefore, to shape spectrum mask’s base as straight line it is possible to decrease values below -30 dBuV/m, where values will clipped, and then increase values again.

Examples of mask manipulation:



4.7.3 Mask administration

Following mask administration options are available:

- Add generated (manipulated) mask to list. Mask name is proposed the same frequency range name or spectrum mask name from which new mask have been created. If mask with same name already exists “(1,2,3...)” is added to the name,
- Overwrite mask selected in list with newly created,
- Delete selected mask from list,

Mask list administration

Add to list

Overwrite

Delete

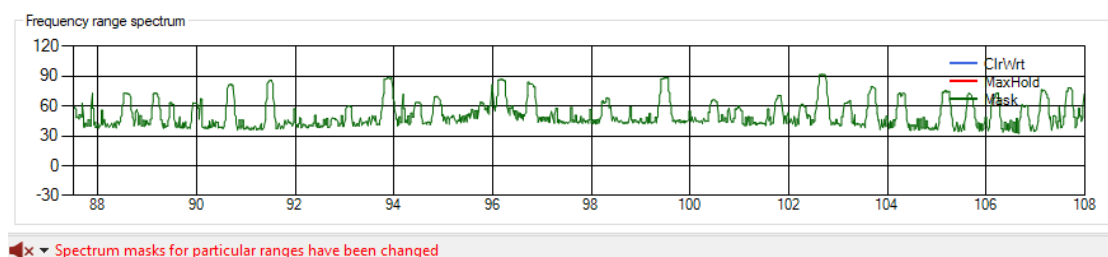
- It is possible to name of selected mask in list, by directly editing the name on the list.

List of masks

Name	F1(MHz)	F2(MHz)	Res.(Hz)	Used
FM	87,5	108	2500	<input type="checkbox"/>
FM(1)	87,5	108	2500	<input checked="" type="checkbox"/>

- For mask to be used in remotely controled measurements by Skudra Server, it has to be set as “Used” by clicking checkbox in list of masks. Only one mask with distinct Start frequency (F1), Stop frequency (F2) and Resolution (Res.) combination can be set as used.

If mask manipulations render changes in spectrum masks for measurement ranges set in Ranges panel, warning text “Spectrum masks for particular ranges have been changed” is displayed on statusbar.



Mask names compatible to measurement range (with corresponding Start frequency, Stop frequency and Resolution combination) is displayed and selectable in Mask detection’s Max. mask/Min. mask dropdowns in Ranges panel:

☒ Mask detection

Max. mask

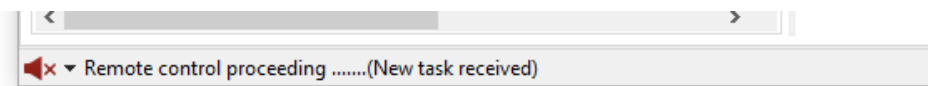
Min. mask

Step(kHz):
 /
BW:

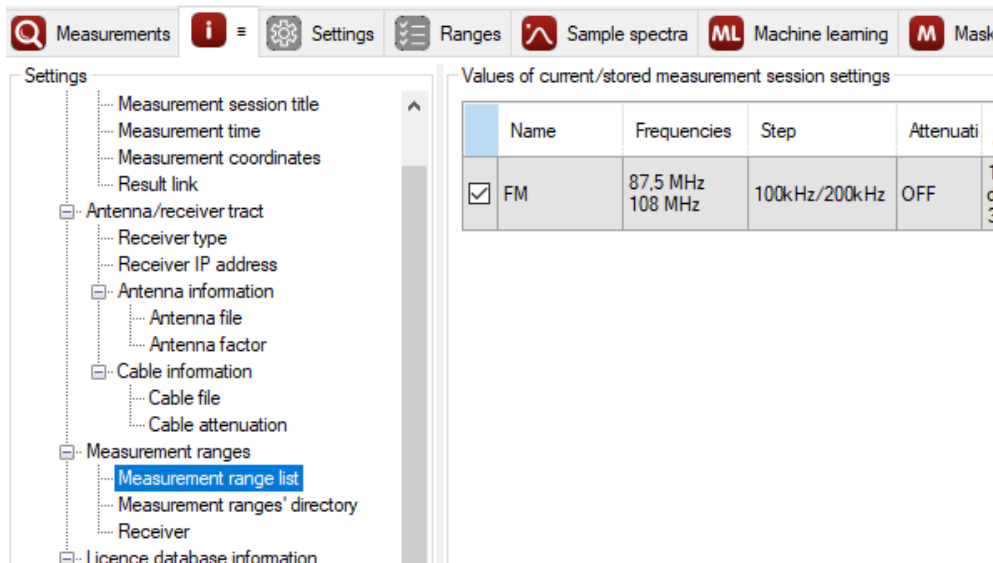
4.8 Functionality of Remote Control

If set to remote control (4.1.1) operation, Skudra Patrol signal Skudra server for acceptance of remote tasks and performs measurement according to received tasks.

- To set Skudra Patrol to remote mode, it is necessary to that user is authorised (4.2.7);
- By toggling “Remote” button to enabled, remote operation is started in following order:
 - Skudra Patrol registers on Skudra Server as available for remote control. Information registered contains computer host name and IP address, location (N/E), receiver model and serial number;
 - Additionally spectrum masks and machine learning models available at local Skudra Patrol is registered on Skudra Server;
 - Skudra patrol requests measurement ranges set for particular receiver/ computer at Skudra Server;
 - If there are no set measurement ranges at Skudra Server, Skudra Patrol idles until measurement ranges is added or remote mode disabled;
- Measurement ranges set at Skudra Server are time limited (they have defined start and stop times). If start time is set to be in future, Skudra Patrol start measurement at set time (provided that remote mode still active) and stop at stop time;
- If measurement ranges are edited or added at Skudra Server, Skudra Patrol immediately receives notification and if necessary, updates measurement ranges. If changes set at Skudra Server impact remote measurements currently performed, measurement is stopped and results are saved and if necessary new measurement is started;
- Informative message is displayed at status bar’s left side, informing that remote control is active (“Remote control proceeding...”) and that “New task received”, if Skudra Server has notified of changes in scheduled measurements;



- Options available in measurement ranges (4.3), start and stop times, and option to upload measurement’s results to Skudra Server is available at Skudra Server;



- Information on currently remotely measured ranges and other settings is available in “Stored measurement settings” panel(3.2).

5 Software operating principles

5.1 Measurement of range spectra

- Measurements are done in the chosen bands with start and end frequencies set in the settings, with a defined signal attenuation and channel step. Other spectrum scanning parameters are specific to signal determination and no editing is foreseen. The bands selected cannot be changed during scanning;
- Scanning of the bands is cyclic - after scanning the last range scanning is continued in the first range;
- Signal detection is done parallel to spectrum scanning, thus in real life the scanning speed and repetition rate is determined by the performance of the receiver.

5.2 Signal detection

Manipulation of the signal detection process during measurement is not foreseen - the process depends on settings applied before the measurement (functionality of settings and ranges).

5.2.1 Narrow band detection

- The receiver is controlled according to the chosen measurement bands. Arrays of spectra blocks in the receiver’s FFT range are acquired;
- The noise level of each frequency block is determined by a practically acquired algorithm;

- In cases when the emission levels in the frequency channels exceed the noise level set to be the detecting threshold (squellch setting functionality), signal search continues in the particular channel;
- In cases when the central frequency of an emission determined by a practically acquired algorithm corresponds to the frequency channel under investigation, the emission's spectrum is compared to the sample spectra. If not, the comparison will be done in the next channel or any other channel where the signal central frequency will be located
- Comparison of spectra is done by Pearson's correlation function. If the correlation result's determination coefficient exceeds the set value (setting functionality), a signal (transmitter operation) is detected on the frequency;
- If frequency channels overlap (in case of 12,5 kHz and 31,25 kHz channels), the channel with the highest correlation is considered to be detected.

5.2.2 Broadband detection

The sample spectra functionality is best suited for detection of signals whose spectral shape is defined mostly by signal itself. That is not the case for broadband signals, where received spectrum shape is influenced by multipath fading. To cover detection of broadband signals Skudra Patrol employs machine learning algorithms.

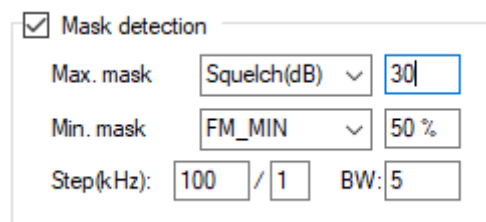
- It is important to note that machine learning approach is highly dependant on diversity of spectrum samples. For example, if model is fitted for dvb-t signal, it won't detect LTE signal. Further, if model is fitted for single dvb-t signal, model's applicability will be reduced, when there are two signals side by side. The same is true for high power signals versus signals close to noise floor or inside interfering signals. To accommodate various reception scenarios, best way is to fit ML models using data obtained from drive test (provides different signal to noise ratios and interference scenarios) and data from different regions where different channel configurations exist;
- Output of ML model is 1 if emission classifies as signal, 0 - as not signal, values between 1 and 0 denotes probability of emission being signal. If value of probability reaches set probability squellch (see Prob. Squellch 4.3), emission is considered as signal.
- Compared to correlation techniques used in narrow band detection, where correlation values have continuous distribution, probability values tend to have values closer to 1 or 0. Therefore limiting probability values has less influence on detection of compared to narrow band's correlation squellch, and generally to change behaviour broadband model refitting is necessary;
- Before ML model is applied, value close to interdecile range of emission's spectrum in 25 MHz band, is compared to noise squellch (see Noise squellch(dB) 4.3). Detection of signal is continued with ML model only if noise squellch value is reached. It is recommended to set noise squellch value close to that

used when fitting ML model (4.6.1), otherwise ML model would be used on data it was not fitted for, which may yield unexpected results.

5.2.3 Mask detection

In general functionality of Skudra Patrol is aimed towards detection of actual operation of transmitter at particular frequency. However, there are cases when any emission or elevated noise outside above specified limits must be identified. Typical use cases would be detection of out of band emissions from FM broadcasting stations or detection of emissions in public mobile guard bands.

To meet these requirements Skudra Patrol provides functionality of Mask detection.



- Mask detection provides two detection directions - above mask (Mask. mask) and below mask (Min. mask), which can be used separately or both together and together with other detection types (for example, narrow band detection).
- Mask detection is configurable to use fixed squelch with value in dBuV/m set to the right of mask dropdown.
- Mask detection is configurable to use user defined spectrum mask. In this case percentage of mask signal is overshooting or undershooting to be considered as detection must be set. 0 % - any point spectrum above (or below) mask will trigger detection, 100% - all points of signal spectrum have to above (or below) mask to trigger detection.
- Mask detection bandwidth (BW) is set to compare signal against mask only in set bandwidth in the center of channel. For example, it can be used to compare mask to signal only at stable part of signal (carrier frequency).
- Practically spectrum in mask detection bandwidth contains more than single spectrum point. It may be relevant (for example spectrum changes due to modulation) whether mask is overshoot by all spectrum points (100%) or just single point (0%). Overshoot/undershoot percentage can be set in text box to the left of mask type dropdown, if user defined mask is selected;
- Channel step for mask detection is set independently from measurement range's channel step. This allows to use any channel step. Further channel's step divisor is introduced, to use channel steps that are not integer values, for example $25\text{kHz}/3 = 8,333\text{ kHz}$;
- Width of spectrum channel is defined by measurement range's channel's step second value (e.g. 25 MHz for "1MHz/25MHz" channel step), unlike

narrowband and broadband detection, width of spectrum has no influence on mask detection channelling; Spectrum corresponding to width of channel will be used to establishment of signal parameters (5.6);

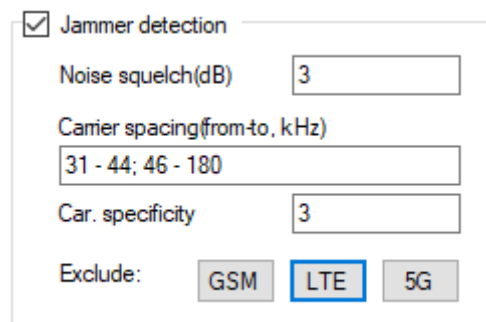
- Detections related to maximum mask overshooting or minimum mask undershooting are recorded in list of detection results with emission class “mask+” and “mask-” respectively.

Mask detection is dependent on EM conditions at particular site, therefore specific procedure for transfer of masks from one measurement site to another is not foreseen.

5.2.4 Jammer detection

Skudra Patrol provides specific detection of signals generated by public mobile and GNSS jammers. Usually, jammer signal is constructed by mesh of carriers. In order detect jammer signal repetitiveness of jamming carriers is measured.

- Repetitiveness of jammer’s carriers is expressed as Carrier specificity for required carrier spacing ranges. For example, if emission contains carriers separated from each other (carrier spacing) by 100 kHz and power contained in those carriers is by certain amount higher than typical value of other spacing components, then emission will be detected as jammer. However, jammer detection process includes several mathematical conversions, in a way that dB relation between noise and carriers level is lost. Therefore, Carrier specificity value is expressed as comparative measure from 0 up to 5 (usually) with practical jammer detection squelch level of 1 to 2;



☒ Jammer detection

Noise squelch(dB)

Carrier spacing(from-to, kHz)

Car. specificity

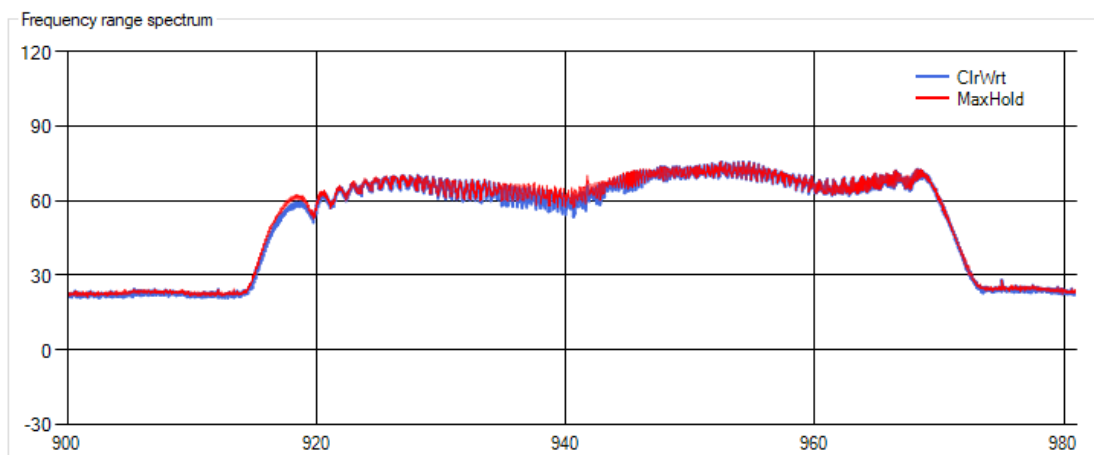
Exclude:

- Jammers for public mobile networks and GNSS usually have carrier separated by 60 to 160 kHz, yet jammers designed for 433 MHz band can have carrier spacing in range 1 to 5 kHz. To provide jammer detection for diverse types of jammers, jammer detection is available for all channel steps, providing options for jammers with finer or broader carrier spacing.
- In practice spectrum resolution (channel step) limits Carrier spacing ranges usable for reliable jammer detection:
 - 6.25kHz/25kHz (also IQ) limits to 1-10 kHz

- 10MHz/100MHz limits to 2-50 kHz
- 100kHz/200kHz limits to 10-200 kHz
- 1MHz/25MHz limits to 20 - 500 kHz

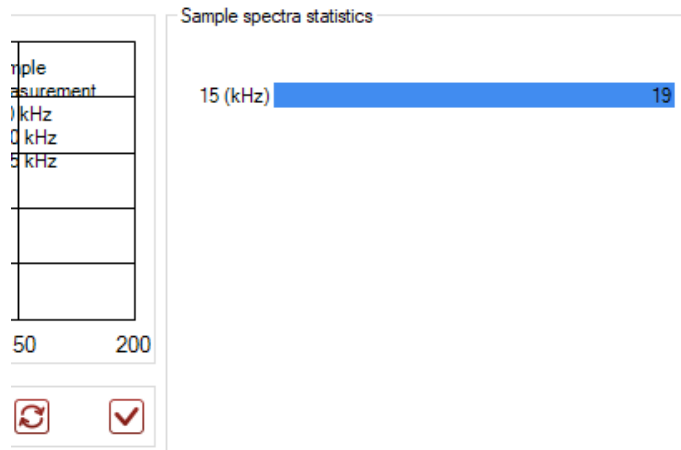
Those limits are approximate and twice broader limits may be usable;

- As jammer detection is available for every channel step, selecting appropriate channel step increases scanning speed. For example, most public mobile jammers can be detected with 2,5 kHz resolution provided by 100kHz/200kHz channel step;
- Many wanted signals contains repetitive carriers. For example, LTE signal has traces of repetitive carriers with spacing of 45 kHz. To exclude such carriers from calculation carrier spacing ranges must be set (example: 31-44;46-180). To aid exclusion, it is possible to add predefined carrier spacing exclusions for GSM, LTE, 5G by pressing respective buttons;
- Noise squelch determines necessary interdecile range of emission's spectrum in 0.5 MHz, 2 MHz, 10 MHz or 20 MHz bands (respectively for 6.25kHz/25kHz, 10MHz/100MHz, 100kHz/200kHz and 1MHz/25MHz channel steps), to proceed to jammer detection;
- Rarely local emissions, for example, from power adapters, may have repetitive carriers. Their influence can be limited by setting noise squelch. However unnecessary setting high noise squelch values may limit potential of jammer detection, because even emissions with low signal to noise ratio (lower than carrier specificity) can have high carrier specificity. Caution setting high noise squelch is particularly important, because usually jammer's signal power density is low and most detection will happen close to noise level;



- Guidance what repetitive carrier spacing frequency to exclude from by spacing ranges, can be obtained by selecting false jammer detection record in signal detection result list (4.1.8) and in sample spectra section (3.5) clicking "download" button (E.12, otherwise used to obtain new sample spectra). After that breakdown of carrier spacing with highest specificity is

displayed in “Sample spectra statistics” group. Carrier spacings displayed may be excluded by spacing ranges to mitigate false jammer detections.



- Usually jammers cover broad frequency ranges, sometimes in excess of 100 MHz. Therefore, depending on bandwidth of jammer, signal will be stored in 100 MHz, 250 MHz or 500MHz span, resolution will be reduced to 400 kHz, 1 MHz or 2 MHz respectively. However, if waterfall spectrogram storage is enabled, spectrum in full resolution will be available through waterfall spectrogram.

5.3 Direction finding

Skudra Patrol provides functionality to trigger direction finding (DF) on detected signals. Ranges tab provides DF triggering (4.3.9) configuration for each measurement range. Direction finding results for each frequency channel are displayed on map (4.1.17) and stored in measurement results file.

Intended objectives of DF triggering is to provide quality directions to the source of detected signal, to reasonably share DF time between continuous and infrequent signals, and to reserve DF time for most important detections. Objectives are realised through following functions:

- Direction finding is triggered by signal detection event. Considering that direction finding is more time-consuming operation than spectrum scanning in most cases queue of direction finding requests is created. Each DF request has distinct frequency and measurement range combination.
- Direction finding request queue is prioritised by more seldom requests, so that infrequent signals and continuous signals have equal chance of being DF-ied. Even more priority is given to seldom requests if request queue is more than 10 frequencies long. Priority is further increased after queue has reached length of 20, 30, 100 frequencies.

☒ Triggered DF
 Dwell time(s) Quality(%)
 Trigger conditions (Field str., count, freq.)
 >dBuVm x
 DF list(MHz):

☐ Report DF to Skudra Server

- Receiver's DF measurement time (averaging time) always is set 100 ms. If triggered DF dwell time is set to 0 seconds, direction received from DF equipment is returned as result of request. If dwell time is set longer than 0 seconds, most probable value of direction results received from DF equipment during dwell time is returned. When calculating most probable direction, it is taken into consideration that signals during the dwell time may be received from several sources.
- DF results with quality lower than set limit in text box "Quality(%)" are not taken into account, when calculation most probable direction during dwell time. If no result from DF equipment above quality squelch is received, DF request is returned as unsuccessful e.g. no direction is stored.
- Trigger field strength condition determines that DF request is made only for signals above set field strength threshold. This condition is usable to ensure that DF request are made only for signals with field strength sufficient for direction finding, or to limit direction to signals of highest field strength;
- Count of signals trigger condition limits the number times signal has to be detected for DF request to be made. Functionality can be used to exclude from direction finding signals with low probability of repeating.
- Frequency trigger condition can be configured whether all signals ("Any" satisfying other conditions are DF-ied, or only those without licence assignments, or only those with channel frequencies listed in text box "DF list (MHz)".

5.3.1 Direction finder settings changed by Skudra PATROL

To ensure reliable direction finding some of the direction finders RF settings are changed upon first or each DF request:

- DF bandwidth is automatically switched between 7.5 kHz (9 kHz for SignalShark), 15 kHz, 120 kHz, 240 kHz (150 kHz for PR200 and EM200) and 2,4 MHz (2 MHz for PR200 and EM200) depending on bandwidth of detected signal. However, setting these values requires to set DF selection and DF

span. To merit faster DF, bandwidth is set indirectly through DF step (if possible).

- DF measurement mode is set to Normal (regulated by DF squelch).
- Spectrum measurement time is set to “Auto”;
- Settings like DF squelch threshold, antenna polarisation or amplification, direction finders attenuation, DF antenna RF-input are changed according to values set to DF equipment settings (4.3.10) for each range or as manually overridden by user (see. 5.3.2)
- For some settings “-” value is available, which means that value already set in direction finder by other means (e.g. GUI) will be used. However, **when using same equipment for direction finding and scanning, settings relevant also to direction finding may be set during scanning by receiver settings (4.3.1) and vice versa.**

It is important to note that in versions below 4.5.8 Skudra PATROL sent “reset” command to direction finder that resulted in default location (“Munich”) and magnetic declination corresponding to that location. Starting version 4.5.9 reset command is not sent.

5.3.2 Direction finding override

Direction finding override functionality is available, if any active (set as used) measurement range has DF triggering enabled (4.3.9).

- DF override - direction finding on manually selected frequencies is started by user clicking “START DF...” and stopped by clicking “STOP DF...”.
- During DF override direction finding is done on frequencies, corresponding to records that has been selected in signal detection list on the moment of user clicking “START DF...”.
- For DF override automatically created direction finding queue is replaced with user created. Still, as scans progress, new frequencies are added to automatically created DF queue, which will be used as DF override is stopped by user.

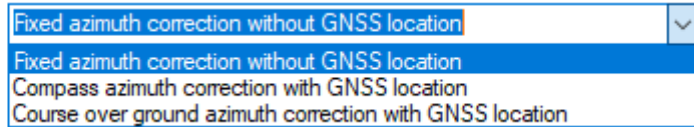
Information on how to use direction finding override is available in section 4.1.18.

5.3.3 Dynamic bearing and location correction by Compass and GNSS

Skudra PATROL provides functionality to use compass correction for bearing results and GNSS coordinates for location. Both corrected bearing and GNSS location is used when DF results are reported to Skudra Server (5.4), however location is discarded for results saved locally in Skudra PATROL.

Bearing and location correction can be enabled by selecting “Compass azimuth correction with GNSS location” or “Course over ground azimuth correction with GNSS location” in Azimuth and location dropdown (4.2.2)

Azimuth and location:

A screenshot of a software interface showing a dropdown menu. The label 'Azimuth and location:' is to the left of the dropdown. The dropdown is currently open, showing four options: 'Fixed azimuth correction without GNSS location' (highlighted in blue), 'Fixed azimuth correction without GNSS location' (in white), 'Compass azimuth correction with GNSS location' (in white), and 'Course over ground azimuth correction with GNSS location' (in white).

Fixed azimuth correction without GNSS location
Fixed azimuth correction without GNSS location
Compass azimuth correction with GNSS location
Course over ground azimuth correction with GNSS location

However, enabling bearing and location correction, has effect only if physical GNSS source is available. Further exact compass and GNSS source will be chosen after first direction requested through triggered DF (4.3.9) by following scheme:

1. If physical GNSS source is not available, then
 - 1.1. Skudra PATROL is running with dynamic bearing and location correction disabled;
 - 1.2. Skudra PATROL has set direction finder's bearing correction by compass to disabled (fixed North offset in use) and GNSS source to manual;
2. If physical GNSS source is available, then
 - 2.1. First choice location source is DF antenna built-in GNSS source;
 - 2.2. Second choice location source is GNSS source connected (or built-in) to direction finder;
 - 2.3. If to use compass azimuth correction is selected:
 - 2.3.1. First choice compass is DF antenna built-in compass;
 - 2.3.2. Second choice compass is compass connected to direction finder;
 - 2.3.3. If no compass is available Skudra PATROL sets direction finder's bearing correction by compass to disabled (fixed North offset in use) and GNSS source to manual;
 - 2.4. If to use course over ground azimuth correction is selected:
 - 2.4.1. First choice is "Course over ground" derived from DF antenna's built GNSS source;
 - 2.4.2. Second choice compass is "Course over ground" derived from GNSS source connected (or built-in) to direction finder;
 - 2.5. Software azimuth correction is never used.

Selections made here are stored in direction finder, and may influence results of other software used after Skudra PATROL.

5.4 Direction finding: Report DF results to Skudra Server

If accordingly configured (4.3.9) Skudra Patrol reports direction finding results realtime to Skudra Server. For further storage, realtime display and triangulation. Following data is sent to Skudra server:

- Frequency channel;
- Most probable direction to signal source, obtained according to 5.3;
- Timestamp of DF;
- All DF results, obtained during the dwell time period;

- Coordinates of direction finder during the dwell time if compass functionality in settings panel (4.2.2) is enabled. Otherwise coordinates set in settings panel (4.2.5) are sent;
- If direction finding is unsuccessful, field strength of signal associated with the coordinates is still sent to Skudra Server.

5.5 The storage of signals detected

All detected signals are aggregated by frequency channel to minimise storage space and processing power, as well as efficient access to monitoring results.

- All signals found in any single frequency channel are stored in one array (cumulated spectrum) creating a matrix, the elements of the matrix showing how often the index value (frequency and level) is detected;
- Every time when, monitoring a frequency channel, a signal is detected, it's level is stored. Information on the number of scans when no signal was detected is also stored;
- The average correlation value of all signal detection events in a channel is stored;
- Each scan's start time is stored. This value corresponds to signal detection time and is referenced to each detection event
- The sample spectra use statistics are stored - how often each sample spectrum was detected as most appropriate;
- Distribution of triggered DF results (if available) is stored.

5.6 The establishment of signal parameters

A single value for each parameter is obtained for each frequency channel.

- The field strength is calculated as the maximum electromagnetic field strength dB μ V/m, exceeded in 2 % of signal detection cases. The intensity is calculated adding to the signal level the earlier set antenna factor (**Error! Reference source not found.**) and cable attenuation (**Error! Reference source not found.**);
- The field strength for each signal detection case is calculated as the spectrum maximum value in the signal bandwidth (the FFT resolution for 100 kHz channel step FFT is 2,5 kHz, for 6,25 kHz step - 125Hz, *Blackman* windowing);
- Bandwidth - The detected signal maximum bandwidth exceeded in 5 % cases of signal detection at a signal to noise ratio at least 30 dB. If the signal to noise ratio never has exceeded 30 dB, the presented bandwidth is calculated as the maximum unique bandwidth level pairs exceeded in 5 % of detected signals;

- The signal bandwidth in each detection event is determined by the 1% B (99% power in bandwidth) method if signal to noise ratio at least 30 dB, and by the mid-level between the maximum level and noise level if the signal to noise ratio is less than 30 dB;
- The signal activity percentage is calculated as a percentage of signals detected over the total number of scans.

6 File formats

6.1.1 The file format of the antenna factor and cable attenuation

- The antenna factor and cable attenuation is delivered to the software by an UTF-8 text file (*.txt). Each row of the file comprises pairs of frequencies in MHz and attenuation coefficient in dB separated by the tabulation symbol (TAB). The decimal sign is point (.).
- The antenna factor and cable attenuation should be delivered with a positive sign enabling the calculation of the resulting field intensity by summing up the received signal level, the antenna factor and the cable attenuation.

6.1.2 The file format of the licence database

- The antenna factor and cable attenuation is delivered to the software by an UTF-8 text file (*.txt).
- Each file row comprises 20 tabulation symbol separated (TAB) values:
 1. Reserved for future use
 2. Frequency (MHz)
 3. User
 4. Reserved for future use
 5. Reserved for future use
 6. Comment
 7. Effective radiated power (dBd)
 8. Reserved for future use
 9. Reserved for future use
 10. Antena height over ground (m)
 11. Class of emission
 12. Reserved for future use
 13. licence identifier
 14. Reserved for future use
 15. Decimal coordinate (E)
 16. Decimal coordinate (N)
 17. Reserved for future use
 18. Reserved for future use
 19. Reserved for future use

20. Reserved for future use

- All values are given in single quotes as '*value*'. The decimal sign is point (.).

6.1.3 The format of the specific frequency file

- The specific frequencies are delivered to the software by an UTF-8 text file (*.txt). Each file line contains a frequency in Hz, the frequency user and class of emission separated by the tabulation symbol (TAB).
- The frequency may only be a positive integer. The class of emission is not mandatory.

6.1.4 The file of radiofrequency applications

- The radiofrequency application information is delivered by a “xlsx” format file, that should be downloaded from the web-site <https://efis.cept.org/>, choosing necessary country in the tab “*Application*” and then pressing search.

The screenshot shows the EFIS web interface with the 'Application' tab selected. The interface includes the following elements:

- Navigation Bar:** Home, Freq. bands, Allocation, Application (selected), Documents, Interfaces, Right Of Use, Information.
- Frequency Range:** Input fields for 'from' and 'to' with a unit dropdown set to 'MHz'.
- Application:** Three dropdown menus for '<all application terms>', '<all level 2 application terms>', and '<all level 3 application terms>'. A checkbox for 'Search only in the selected level' is present.
- Search Options:** Radio buttons for 'Hierarchical' (selected), 'Alphabetical', and 'Abbreviations'.
- Frequency Tables:** A dropdown menu labeled 'Select one or more' is open, showing a list of countries: Germany, Greece, Hungary, Iceland, Ireland, Italy, Kosovo*, Latvia (highlighted), Liechtenstein, and Lithuania.
- Search Button:** A button labeled 'Search' at the bottom.

- After that by click “Export search results to XLSX (country as columns)” EFIS application file supported by Skudra Patrol is downloaded;

Search results

Showing result of search for results in range 0 Hz - 1000 GHz from tables: 'Latvia;' in total 1170 results

Export search results to XLSX

Export search results to XLSX (country as columns)

- The radiofrequency application information is delivered by a “csv” format file, that should be downloaded from the web-site <https://efis.cept.org/>, choosing necessary country in the tab “*Application*”;
- Length of each application record contained in radiofrequency application information file is not limited, however, for efficiency reasons, Skudra PATROL/SERVER limits its length to about 2000 symbols.

6.1.5 CSV file of radiofrequency applications

Skudra Patrol also supports previous EFIS “csv” format for applications file. This coma separated values file must be composed in following manner:

```
"Lower Frequency";"Upper Frequency";"Latvia"
"14 kHz";"19.95 kHz";"Inductive applications / Defence systems"
"19.95 kHz";"20.05 kHz";"Standard frequency and time signal"
"20.05 kHz";"70 kHz";"Inductive applications / Defence systems"
"70 kHz";"72 kHz";"Inductive applications"
"72 kHz";"84 kHz";"Inductive applications / Defence systems"
"84 kHz";"86 kHz";"Defence systems / Inductive applications"
"86 kHz";"90 kHz";"Inductive applications / Defence systems"
```

- For each frequency application there are 3 values: “Lower frequency”, “Upper frequency” and “Application”;
- Each value is inside double quotes, and is separated by semicolon;
- Each application is separated by “new line” symbol;
- Decimal separator for frequencies is point “.”;
- Frequencies can be of Hz, kHz, MHz or GHz units.