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RF Explorer®

User Manual

Updated to Firmware Version 1.17

RF Explorer®

RF Explorer is an affordable Handheld Spectrum Analyzer with a growing list of features.

This little powerful unit is the tool you need

to reduce the implementation time and cost

of your next wireless project.

Updates of the RF Explorer User Manual are available online.

Please consider the environment before printing this document.

Table of Contents

Introduction

RF Explorer has been designed to be intuitive and easy to use. There is no need to read large user manuals to get advantage of its advanced functionality.

Most of the complexity inherent to full sized Spectrum Analyzers is simplified with automatic functionality resolved by the firmware. For instance, you do not need to adjust Resolution Bandwidth (RBW) everytime you select a different frequency span. Actually, you do not even need to know what RBW is. You can progress in your RF learning curve and come back to this manual and online tutorial anytime.

We welcome your feedback and look for ideas to make this manual more useful. Please contribute with ideas, suggestions, typo corrections and comments on the official discussion list

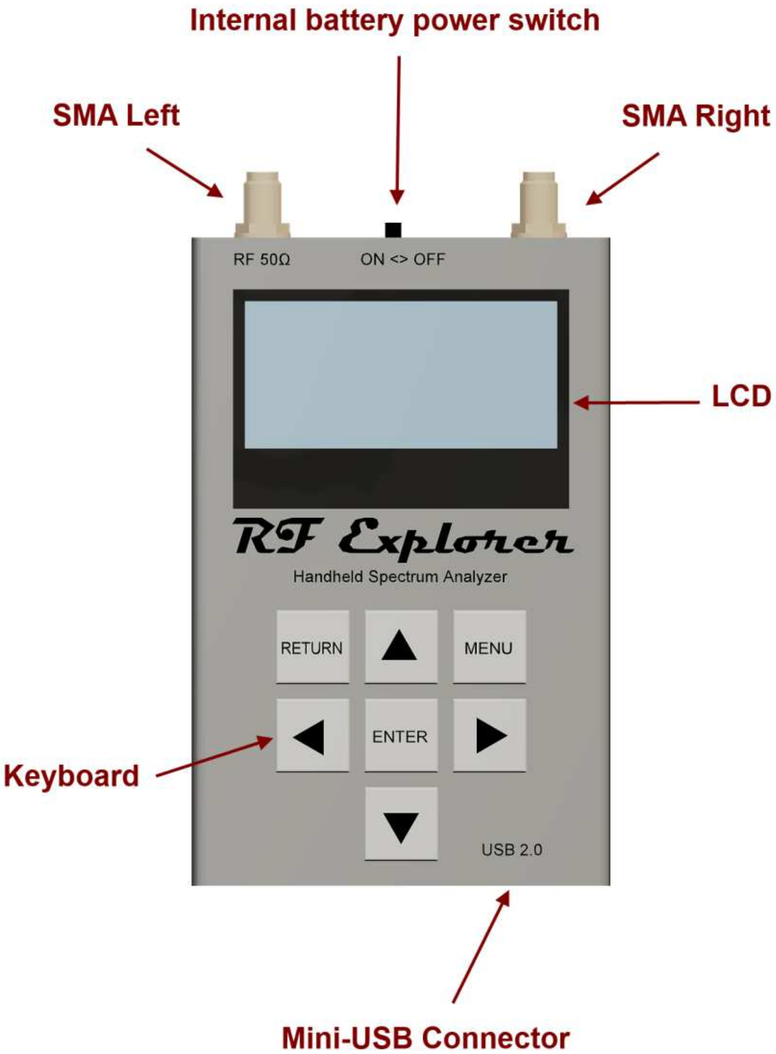
www.rf-explorer.com/forum

Description of main features

- ✓ Pocket size and light weight with solid aluminum metal case.
- ✓ The Spectrum Analyzer calculator includes Peak Max, Max Hold, Normal, Overwrite and Averaging modes.
- ✓ Lifetime free firmware upgrades available.
- ✓ Open to new features requested by user community.
- ✓ High capacity Lithium Ion battery for 16hs+ of continuous run, rechargeable by USB.
- ✓ Microsoft Windows software is free and Open Source.
- ✓ Mac OS client is free and Open Source.
- ✓ USB Communication protocol is open for custom solutions and extensions.
- ✓ Different RF Explorer models available:
  - General purpose high frequency model: 15-2700 and 4850-6100MHz
  - General purpose wideband model: 15 – 2700MHz
  - Wideband UHF - ISM models: 240 - 960MHz and 2350 - 2550MHz
  - Narrow band ISM models: 2.4GHz, 433MHz, 868MHz or 915MHz band
- ✓ Expandable: RF Explorer base model unit can be easily expanded to additional bands using the internal expansion port.
- ✓ Some models include an Integrated RF Signal Generator.
- ✓ For more details on different models and capabilities available, please check online

www.rf-explorer.com/models

Connecting RF Explorer



The unit includes 50 ohm impedance RF connector standard SMA format.

All models have a SMA left connector installed and, optionally, some models have a second SMA connector at the right position for extended range and functionality. For more details see the section Expansion Modules in page 27.

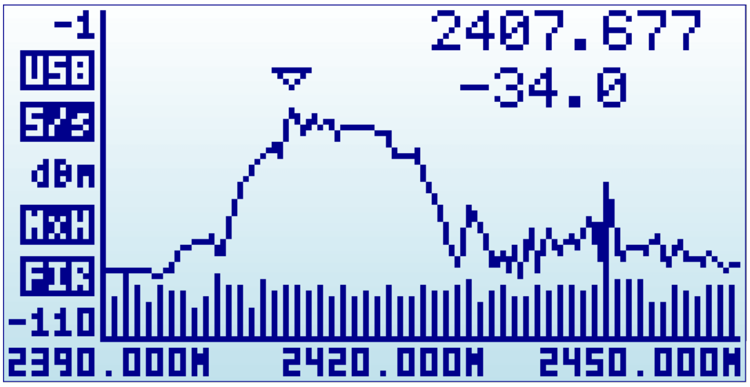
The unit will automatically start running on USB power when a compatible mini-USB cable is connected.

Important: The internal battery power switch must be in the ON position for the battery to charge when the USB cable is connected. The internal battery will not charge when the power switch is in the OFF position.

Note: There are a number of SMA adapters to easily interface RF Explorer SMA connector to any other standard RF connector format, including BNC, N, RP-SMA, etc. For more information of adapters available see section *RF Explorer accessories* in page 37.

Spectrum Analyzer mode - Main Screen

Upon start, RF Explorer goes to Spectrum Analyzer mode automatically.

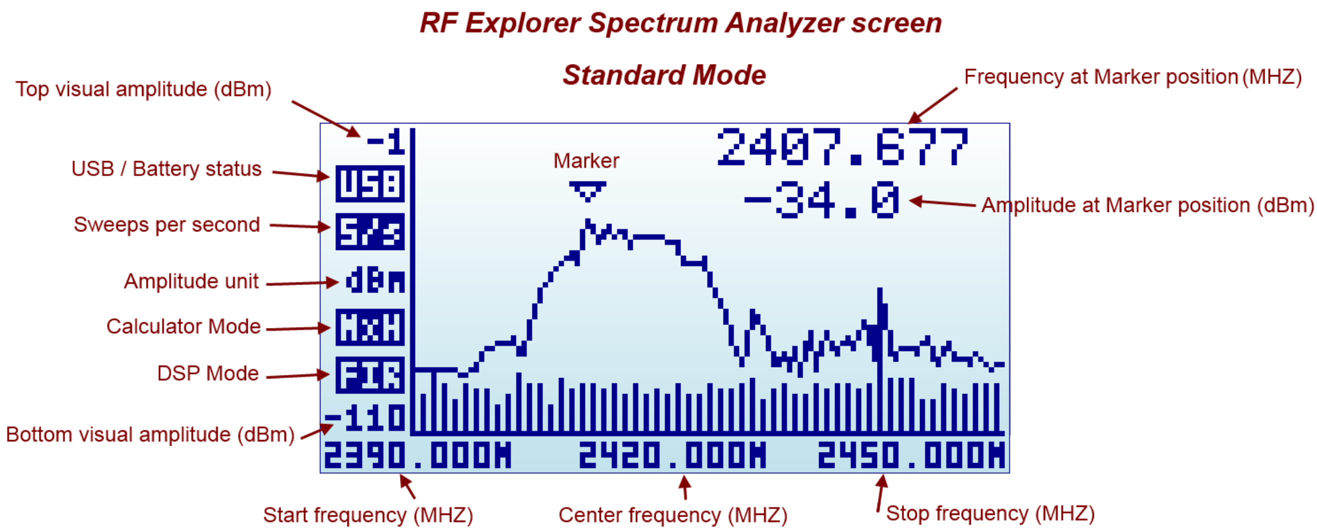


The X axis represents frequency in MHZ and Y axis display actual received power in dBm or dBuV (selectable). In this example above, the frequency span goes from 2390 MHz to 2450 MHz (that is a 60MHz range), and the visual amplitude goes from -1 dBm to -110 dBm.

Configuration settings such as amplitude reference and frequency span are preserved between sessions, stored in internal FLASH memory.

The main screen automatically displays a small marker with a triangle shape. This will indicate the peak amplitude found in the current frequency span, being the first text line the frequency in MHZ and the second line the amplitude at that particular point.

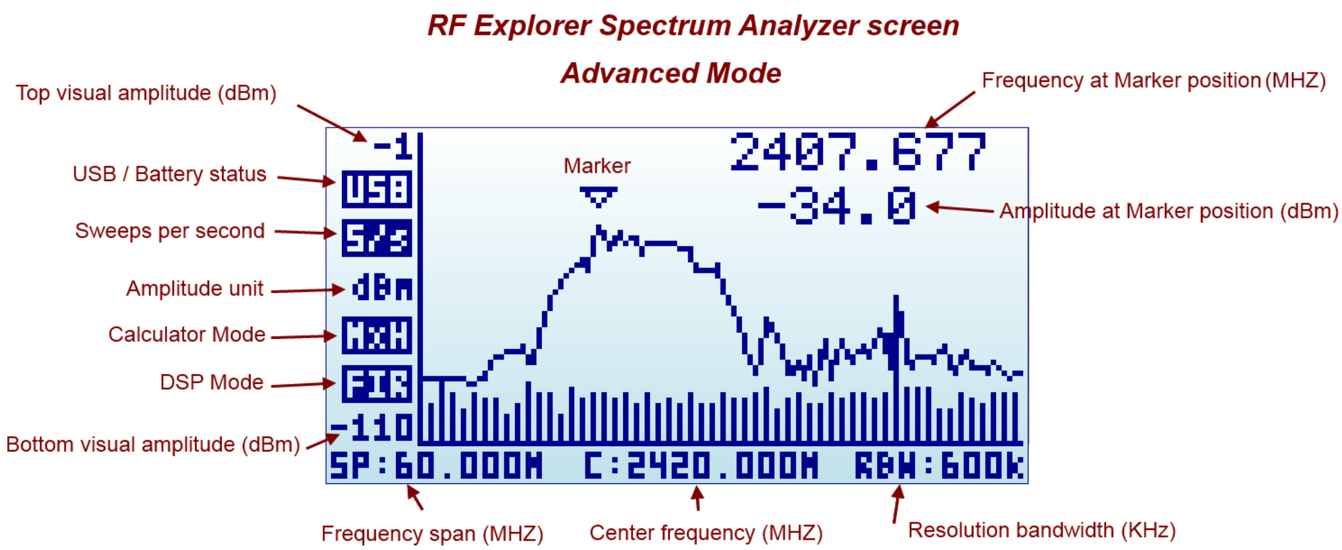
The main screen has a number of additional indicators:



The available indicators are:

- **USB / battery status**: this indicator will display USB[1] when a valid 5V USB connection is available. This will be true even if the connection is through a wall wart charger, so it does not actually means a data connection but a power bus connection. Alternatively, a battery icon with charge level indicator will display when the RF Explorer unit power switch is set to ON. If both connections are enabled, then USB and Battery will alternate and, in this case, the battery will be charging.
- **Sweeps per second**: this is an approximate value of the number of full screen sweeps happening every second. In the example above, there are 5 sweeps per second or, in equivalent terms, one sweep every 200ms.
- **Calculator mode**: this indicator may have different values as specified by the Calculator mode in the frequency menu. Please check the section Frequency Menu in page 14.
- **DSP mode**: this indicator shows the actual value being used by the Analyzer. The *DSP:Auto* is the recommended setting in the Frequency Menu (see page 14) so RF Explorer will select the best possible option as per below:
  - **FST**: Fast mode. This is the standard mode available in all models.
  - **FIR**: Filter mode. This is available in the 15-2700MHZ module only, and is the recommended one for this model.
- **Marker**: There are different operational modes for the marker, see Configuration Menu in page 20.

The analyzer screen can be turned into advanced mode using the [Return] key:

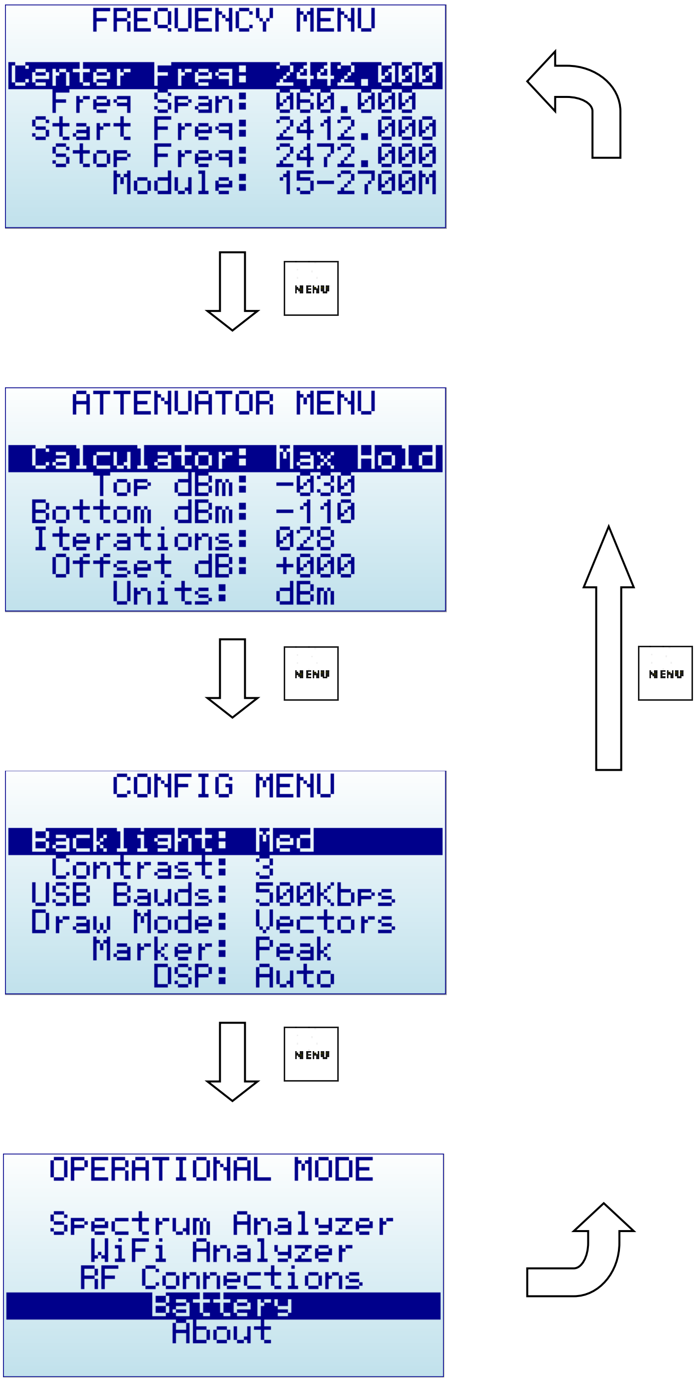


Note the frequency axis indicators changes at the bottom. More details about this screen mode in section *Analyzer screen* page 16.

[1] USB refers to Universal Serial Bus, the standard connectivity bus in all modern computers. Our fellow HAM users should not confuse this with Upper Side Band communication, even though uses the same mnemonic.

Using menus

There are several menus in RF Explorer. They are organized on different screens, which you can iterate through by using the [Menu] key. If you click [Menu] button multiple times, you will visit every one of them:



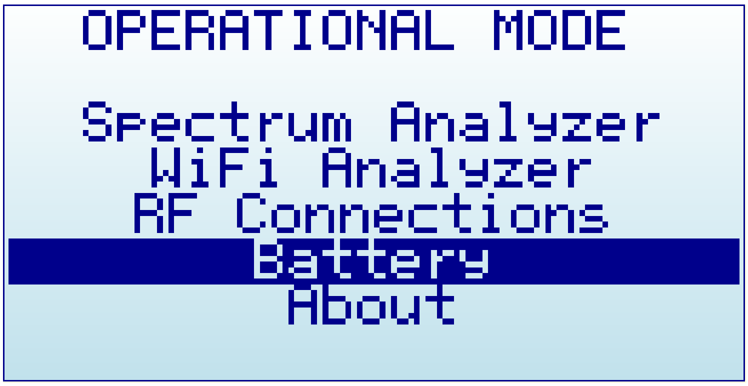
Optionally, you can use the [Left] and [Right] keys to go from one screen to another.

You can exit from a menu anytime by using the [Return] key.

The first time you click on [Menu] button in a RF Explorer session, Frequency Menu will open. This may change as we will see later, so every time you click on [Menu] from Spectrum Analyzer main screen, you actually re-open the last menu you were working with. In this way you save time by not having to navigate through all the menus to go the same place you were before.

Operational Mode menu

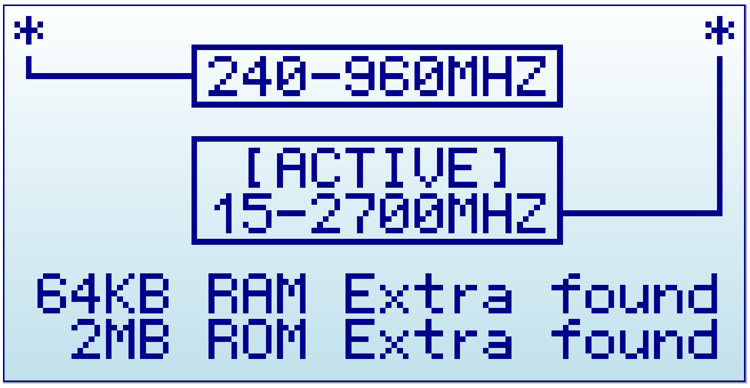
The menu display different functional modes available in your Analyzer.



Use [Up] and [Down] arrow keys to select the desired mode and click on [Enter] to activate it immediately.

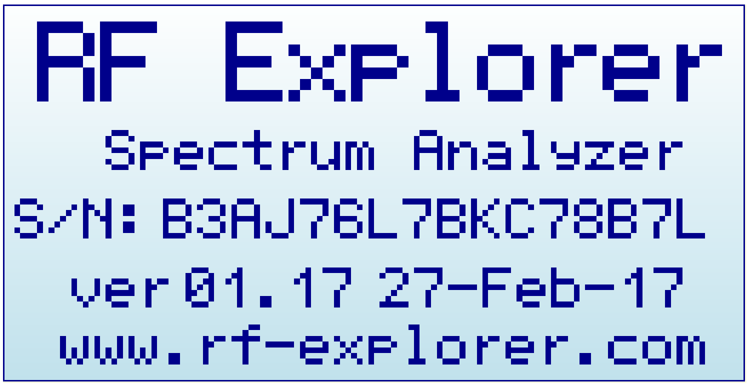
- **Spectrum Analyzer** mode is the default mode, available in all RF Explorer models
- **RF Generator** option is available in some models only. These include models ISM Combo, 2.4G, 433M, 868M and 915M, other models do not have internal RF Generator circuit. In such case, the *RF Generator* option will not display in the OPERATION MENU.

  If your analyzer includes two modules (e.g. ISM Combo) only one of the modules may include RF Generator. Please select the correct module for *RF Generator* to be available.
- **WiFi Analyzer** is available in a subset of models only, including 2.4G, WSUB3G, 3G Combo, 6G Combo and ISM Combo. In other models the *WiFi Analyzer* option will not be visible or available.
- RF Connections enumerates the installed RF modules and how each one is connected to each SMA RF port. This example below shows a standard 3G Combo with a 240-960MHz connection on the left port, and 15-2700MHz on the right port. Click on any key to get out of this screen.

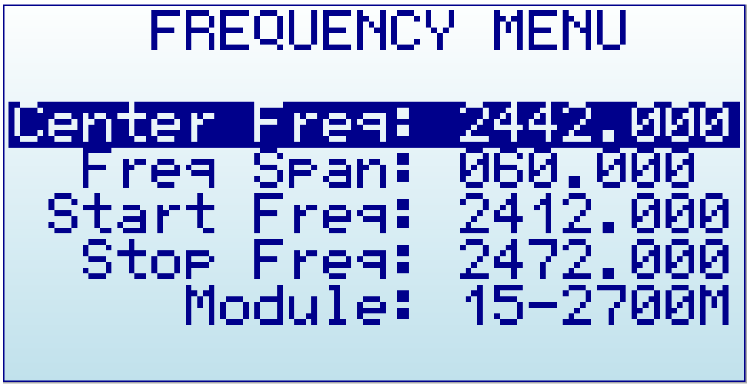


- **Battery** includes details on internal battery charge level, and assist you on charging the unit when connected to USB. For more details read section *Charging the internal battery* in page 23.

- **About** displays information about installed firmware and versioning. Use any key to get out of this screen.



Frequency Menu



- **Center Freq**: Center frequency in MHZ
- **Freq Span**: Frequency span (or range) to display on screen in MHZ
- **Start Freq**: Lower frequency range to display on screen in MHZ
- **Stop Freq**: Higher frequency range to display on screen in MHZ
- **Module**: Active selected RF module. When an expansion module is installed, click [Enter] key to enable the module you need.

The selected frequency band to display can be specified in two different but complementary ways:

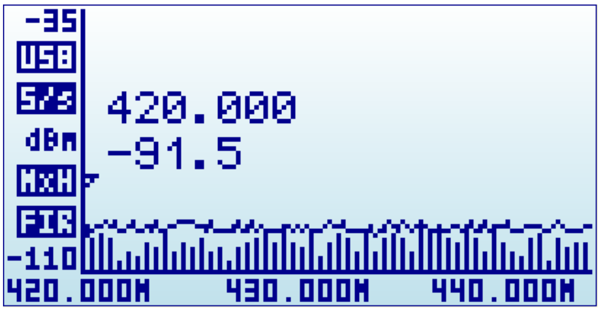
- **Center/Span**: This is the traditional Spectrum Analyzer format all engineers are used to. You basically select the Center frequency at which the band will be displayed, and then a Frequency Span.
- **Start/Stop**: This alternative mode is very useful to select frequency range between two frequencies of interest, with no need to manually calculate the Center or the Span.

The valid values for Frequency and Span are defined based on RF Explorer model and operational mode.

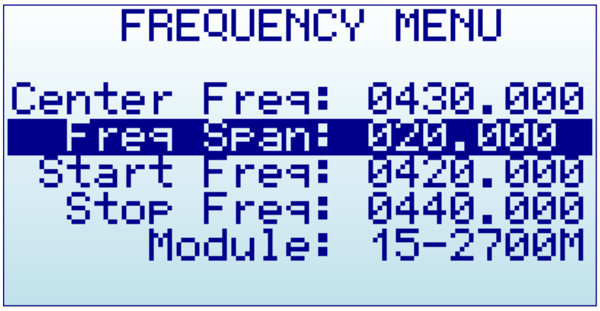
As you edit Center/Span or Start/Stop, the other values are updated accordingly, so feel free to use the method you prefer. In general, you will use Center/Span more frequently when you know the frequency you want to look at, and probably Start/Stop when you just want to look at a larger span to see what is happening in a specific range.

To navigate through the menu, just use [Up] and [Down] keys to go to the option you want, then click on [Enter] to edit that option, [Left] or [Right] to go to the digit you want to change, and [Enter] to confirm or [Return] to cancel.

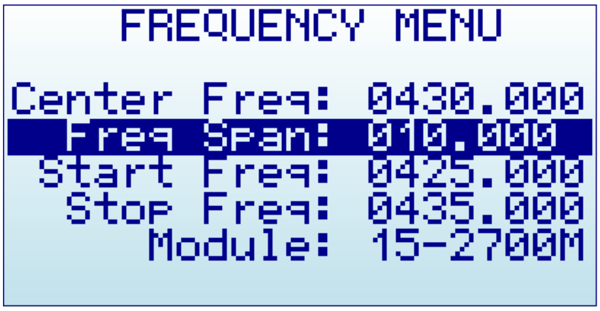
As an example, a center frequency of 430MHz with a 20MHz span:



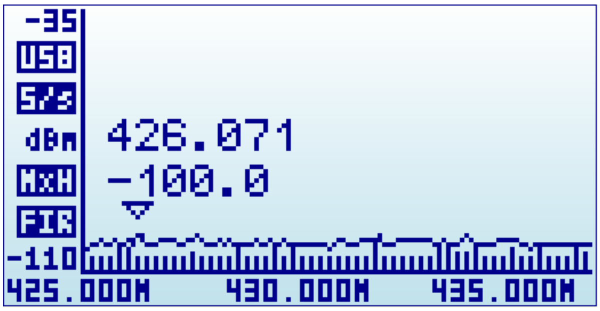
A click on [Menu] button will open the Frequency Menu:



Selecting a span of 10MHz, the Start/Stop frequency changes accordingly:



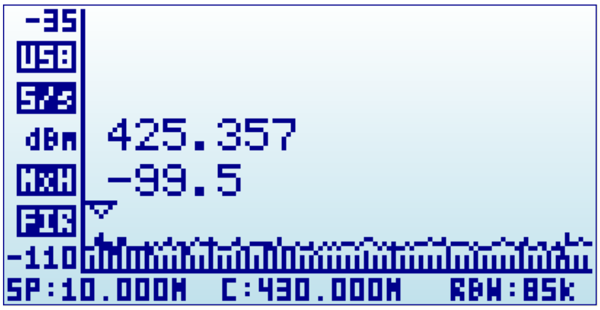
A click on [Return] button will close the menu and go back to Spectrum Analyzer main screen.



***Note**: While RF Explorer Spectrum Analyzer screen is enabled, the [Left] and [Right] buttons can be used to increase or decrease the Start/Stop frequency, virtually moving the visible spectrum to the left or the right 25% on every key press. This is helpful in order to offset the visual range without need to specify a new numeric range.*

Analyzer screen in Advanced Mode

Alternatively, there is a simpler way to increase and decrease frequency span while keeping the center frequency. As this is a usual workflow, the RF Explorer Spectrum Analyzer screen enables the [Return] key to switch between standard visualization mode and advanced mode.



In this screen above, the frequency reading at the bottom changed from Start/Center/Stop frequency to Span/Center/RBW. When this mode is enabled, a key press on [Left] or [Right] button will increase or decrease to double and half frequency span respectively.

As an example, to increase the span from 10MHz to 20MHz, a single click to the [Left] button is enough, no need to go back to the Frequency Menu.

Advanced: Understanding RBW

The advanced mode displays the currently selected RBW (Resolution Band Width). This is an important concept for advanced users.

The RBW references the internal filter used to discriminate the bandwidth of each sweep step. In RF Explorer, each measurement dot represents a range of frequencies, and there are exactly 112 steps on each sweep. As an example, in a 10MHz span, each of the 112 measurement steps represents 10MHz/112=0.089MHz or, in other words, 89KHz.

The range of frequencies represented on each sweep step is a level of uncertainty; screen resolution is limited to that RBW. With a resolution of 89KHz on screen (for a 10MHz span), the best accuracy expected is exactly that value. In other words, a frequency reading of 430.100MHz on screen may mean a range of +-44.5KHz each side, as the filter will not discriminate further than that for a 10MHz span.

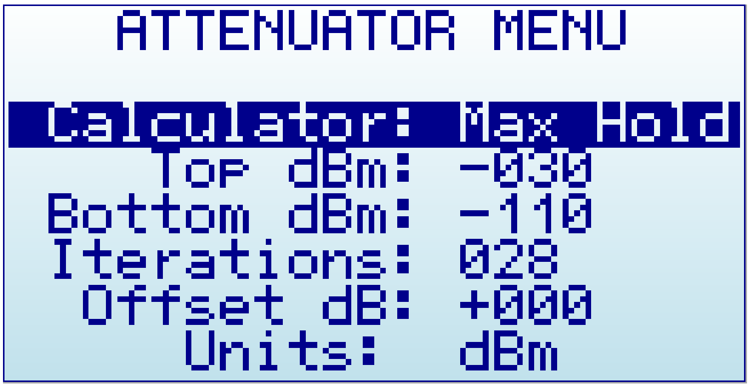
In addition to that, RBW has an important impact on the sensitivity of the Spectrum Analyzer. The wider the filter bandwidth, the higher the spectral noise and therefore the lower the sensitivity. This is visible by an increasing noise floor as the RBW is larger, and lower noise floor as the RBW is narrower. Based on this, the narrowest RBW would look like the better choice for all measurements but as you get a narrower RBW you also decrease the scan speed notably, due to the slower nature of narrow filter as well as the need to measure more sweep points to cover the full span.

To put it simple: Selecting the best combination of RBW, scan speed and sensitivity requires significant experience. In most Spectrum Analyzers, operator needs to fully understand and select RBW for each measurement, being this one of the most challenging aspects of proper Spectrum Analyzer usage.

Fortunately, this is not the case with RF Explorer: The design of the internal DSP includes sophisticated internal tables and algorithms to make the best possible choice at all times automatically. No user intervention is required to get the best compromise between scan speed, noise floor and sensitivity every time.

In all cases, the internal RBW can be checked anytime on the advanced screen mode.

Attenuator Menu



- **Calculator**: internal DSP calculator mode.
- **Top dBm**: Visual max amplitude on screen.
- **Bottom dBm**: Visual min amplitude on screen.
- **Iterations**: Internal DSP calculator iterations.
- **Offset dB**: external dB attenuation or gain value to compensate for external devices, such as attenuators or amplifiers.
- **Units**: dBm or dBuV.

RF Explorer automatically handles internal pre-amplifier and attenuator in order to provide the best possible dynamic range with no need of manual selection. The selected Top and Bottom dBm are visual limits, not real internal limits.

The internal DSP optionally performs advanced calculations in order to configure the analyzer for the required measurement:

- **Calculator** offers multiple modes to display data, to change mode click on [Enter] key:
  - **Max**: Peak values are used from the last sweep Iterations (see menu option at the bottom). This is the standard mode you will want to use to detect rapidly changing DSS signals or find for worst case channel occupancy.
  - **Max Hold**: Capture all activity in the band including the Max signal envelope mode with vector graphics and real-time activity with vertical bars. Use this mode anytime you want to detect activity for a long period of time. It is a very powerful mode to detect activity in busy bands such as 2.4 GHz. As this is a cumulative mode, while on Spectrum Analyzer screen you can clear the spectrum anytime with the RETURN button.
  - **Average**: Arithmetic media average is calculated over the last sweep Iterations. This is the best possible choice to remove unwanted white noise from screen, particularly useful in constant wave (CW) and channel signals display.
  - **Normal**: No calculation is done, just raw data as result of the realtime sweep.
  - **Overwrite**: Useful to track unlimited activity in the band. Darker areas will point to high activity signal. You can clear the spectrum anytime with the RETURN button.
- **Iterations**: The number of sweep data iterations to perform calculations on. It goes from 1 to 16. As an example, a value of 5 with Calculator: Average means the DSP will use 5 complete accumulated sweeps to average data.

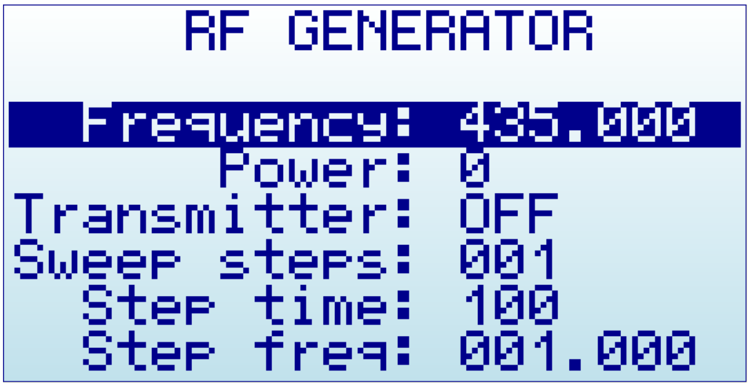
***Note**: Selecting a higher or lower Top dBm value is a very frequent workflow, as you typically want to zoom in or out based on signal power being measured. RF Explorer Spectrum Analyzer main screen offers two keyboard shortcuts: [Up] and [Down] arrow keys can be used to increase or decrease Top dBm respectively* *by 5dBm each time. This shortcut, together with [Left] and [Right] for moving Center Frequency or Span as described before, are very convenient to make configuration changes real-time with no need to visit the Menu.*

Configuration Menu

- **Backlight**: Several levels of display backlight. RF Explorer has good visibility indoor and outdoor, including direct sunlight. The level of backlight should be the appropriate for each condition, and you may want to limit backlight brightness to preserve battery capacity.
- **Contrast**: There are 10 different display contrast levels to choose from.
- **USB Bauds**: Default is 500Kbps, which is also the recommended setting. In the rare case you experience a problem when connecting with the PC, you may want to change this to 2400bps slower speed. However, this is not recommended as the connection will go really slow, so do this only if there is a good reason to. The port speed in the RF Explorer and PC Client settings must match to properly establish a connection.
- **Draw mode**: Vectors is the standard mode, and Fill can be specified if additional contrast is required by filling the area behind the signal.
- **Marker**: There are three different modes available for the Marker on the Spectrum Analyzer screen:
  - **Peak**: The marker will automatically detect the peak value on screen.
  - **Manual**: The marker can be manually moved anywhere on screen by using [Left] and [Right] buttons. When this mode is selected, the standard functions to move Center Frequency or Span are disabled.
  - **None**: The marker is not displayed.
- **DSP**: The DSP (Digital Signal Processor) can be configured in different ways in order to select the best possible choice of noise reduction, image rejection and scan speed.
  - **Auto**: This is the recommended option for all users. When Auto mode is enabled, the internal configuration tables will select the best possible algorithm. The Spectrum Analyzer screen will display a FIR (Filter) or FST (Fast) mode to indicate the actual DSP mode being used.
  - **Filter**: This mode is currently functional in the 15-2700MHz module only, but other modules may implement it in the future. When Filter mode is enabled, the DSP will scan the spectrum several times in order to reject unwanted spurs and image frequency out of the screen. As result of that, the scan speed is slower than compared with Fast mode.
  - **Fast**: This mode is recommended for advanced users only. When it is selected on the 15-2700MHz module, the DSP will not process spurs and therefore unwanted signals may display on screen.

RF Generator mode

Some RF Explorer models can generate a CW RF tone or a configurable sweep for testing RF receivers and simulating interference very easily.



- **Frequency**: Transmit frequency in MHZ in single tone mode, or start frequency in MHZ in sweep mode.
- **Power**: Transmit power in dBm, increasingly changed by 3dB steps each time [Enter] key is pressed. Accuracy is typically +-3dB and can be significantly influenced by the matching load. Pure 50 ohm loads will give better results than loads with some high VSWR values due to impedance unmatched, for instance an antenna not tuned for the transmit frequency.
- **Transmitter**: Switch to ON to start transmitter, to OFF will stop the transmitter. It is important to switch the transmitter to ON only when a load is connected.
- **Sweep steps**:
  - When defined to 1, the RF Generator will work in ***single tone mode***. In this mode it will permanently transmit a CW on the frequency specified.
  - When defined to any value from 2 to 255, the RF Generator will work in ***sweep mode***. In this mode it will transmit a tone starting on the frequency specified, and then will hop to a frequency value that is *Step freq* MHZ higher, lasting *Step time* milliseconds, till it reach the number of steps. After the last programmed frequency is transmitted it will go back to the first frequency, repeating the cycle till the transmitter is set to OFF by the user.
- **Step time**: Defines the milliseconds to transmit each tone before the next hop. Valid range is 5-255ms. Used in sweep mode only.
- **Step freq**: Defines the incremental frequency of each hop in the sweep. Valid ranges goes from 0.010 to 2.55 MHz. Used in sweep mode only.

To return to Spectrum Analyzer from RF Generator, use [Menu] button and select Spectrum Analyzer in the OPERATIONAL MENU.

IMPORTANT

You must have connected a 50 ohm antenna or RF load before you switch your transmitter ON.

If you switch the transmitter ON without a proper antenna, you may damage the RF module of your RF Explorer, as the power amplifier will not have a load to feed. Think of the equivalent to an audio amplifier running at full power with no speakers connected: you are likely damaging the power transistors.

You can use any kind of RF 50 ohm load, including a dummy load, a coaxial with a 50 ohm termination, etc. If you use a load different than 50 ohm, the reflected wave may also damage the power amplifier.

Except you need full power for a range test, we suggest always use the lowest power level to minimize battery consumption and EMI radiation. Note local regulations must be observed, so double check you are not radiating a tone with power or frequency that may interfere with other equipment.

The RF Generator is limited to the same frequency band than the Spectrum Analyzer; therefore you can transmit any frequency of choice in the specific band of your model. In some cases, the sweep steps or the sweep frequency will be limited to a lower value than you may expect: this is because the combination of start frequency, step and number of steps must fit into the available range in all cases.

RF Explorer internal battery

The internal battery is a high capacity Lithium-ion polymer 1000mAh. This is the same battery technology used in cell phones and modern laptops and tablet computers.

The power switch is a *true hard switch* connecting the battery in ON position, fully isolating the battery in the OFF position. As the battery is fully disconnected in the OFF position, you can keep your RF Explorer stored for months and the battery will keep the charge intact, as opposed to cell phones or laptops which typically implement a *soft switch* which slowly discharge the battery by drawing a microamperes continuously from it. This doesn't happen in your RF Explorer.

We designed RF Explorer power circuitry in a way you can always have your RF Explorer ready to use!

Note there is actually a self-discharge effect in the battery but it is so negligible that you can store your device for a year or more and a battery will not be depleted.

IMPORTANT

Never charge your device unattended or in any place where there is a risk of fire.

Never store RF Explorer in a place where temperature may go beyond 50ºC (122F). A car can heat up incredibly quickly in the *sun*, especially in the summer, and damage or reduce the lifetime of your battery if stored in such an environment.

If you manipulate RF Explorer to assemble an Expansion Module, always proceed very carefully with the Lithium Ion battery and make sure it is not punctured, damaged or inflated in any way. A healthy battery is a flat rectangle with no signs of any deformation. If you have any doubt, please take a picture of your unit and send it to us for further help.

If your battery doesn't seem to hold a charge or work properly, or if the unit gets hot when charging, switch the power button OFF immediately and review and/or replace your battery.

Never use RF Explorer with a damaged battery or with a Lithium Ion battery different than the one officially supplied by technical service, which includes a protection circuit for safety. Contact QC@SeeedStudio.com if you have any question on any matter related with your battery or if you need a replacement.

Charging the internal battery

To charge the internal battery, plug it in to a powered USB port or USB wall-wart charger via the USB mini socket. For the internal charger to access the battery, you must set the power switch to ON position, otherwise the device will be running from USB but will not use or charge the internal battery.

RF Explorer may draw up to 500mA according to USB standard, and may take up to 3hs max to charge a fully discharged battery in normal conditions. We recommend the first time to be charged for up to 8hs.

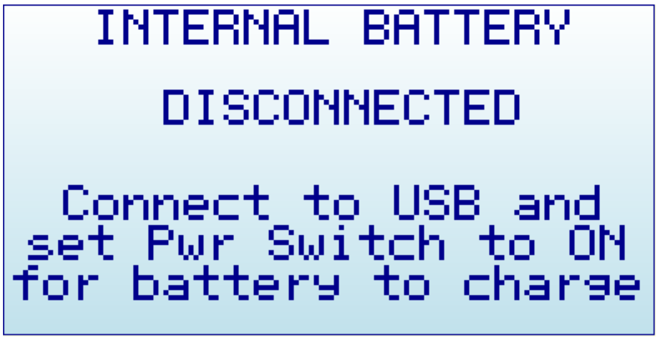
It is ok having the battery connected forever to the USB port, the internal charger will stop and start the charge when needed.

If your USB port is unpowered it may not be capable of delivering more than 100mA; the battery may not be charged at all. If you have no other option available than a 100mA USB port, set the LCD backlight to OFF in the OPTIONS MENU and keep charging for as long as needed (it may take up to 24hs in these conditions so you should use a powered USB port whenever possible).

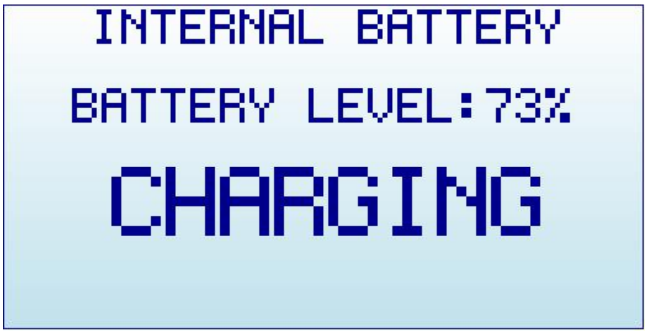
Using the Battery dedicated screen

In latest firmware versions, you can use the specific Battery menu option for better battery charge control. Note: As long as the USB is connected and the power switch is in the ON position, the battery will charge. However, you can get additional information when using the Battery specific menu.

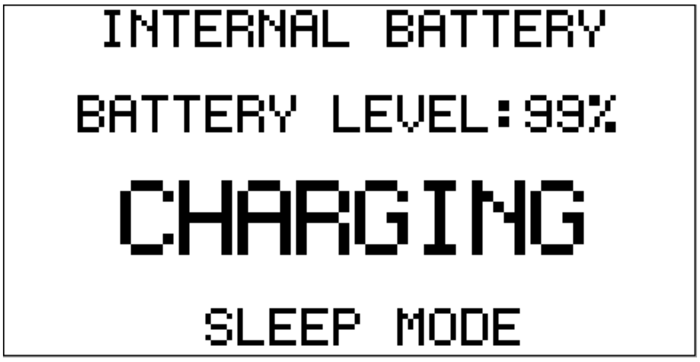
Inside this INTERNAL BATTERY charger screen, it is easier to realize if the battery is being charged. In this case below, it clearly indicates the power switch is not in the ON position and, therefore, battery is not being charged.



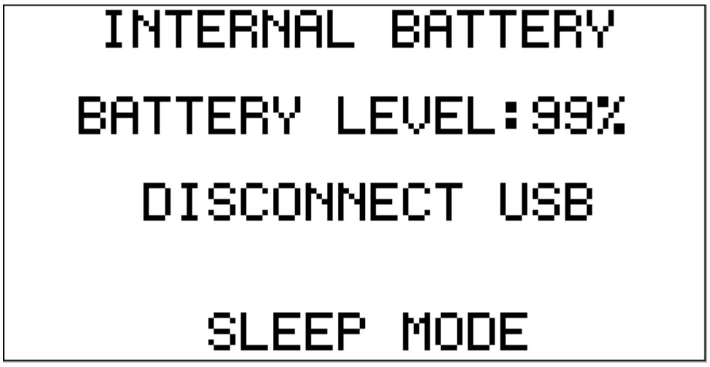
As soon as the power switch is set to the correct position, the screen will display correct charging status.



At this point you can close this screen pressing ENTER or RETURN. If you keep it active for more than 15 seconds, it automatically sets the device in SLEEP MODE - all internal circuits and LCD backlight go off, except for charging and minimal CPU monitoring - This is the recommended procedure to charge the device overnight. Note: for the sake of clarity, below black/white screen images are depicted when LCD backlight is OFF.



In this mode you can stop charging whenever the device reaches 99% or 100%, which may take up to 2 or 3 hours under normal condition and depending on initial battery charge level. When the charging algorithm detects the battery fully charged and a minimum of 2hs connected, it will suggest disconnecting the USB cable.



Calibrating the battery capacity

The INTERNAL BATTERY screen, at this point, can re-calibrate the available battery power level. This is a useful feature to adjust what reference voltage the internal charger considers 100% capacity. This reference is subject to change over time as the internal battery reduces total capacity over many charge cycles. As a reference, 500 charge cycles will typically reduce the total battery capacity about 30% - in order for this new capacity to be consistent with the battery icon on screen, you can easily recalibrate after the charge process completed.

In the previous example screen, if the battery charge remains at 99% (or any other level) after the internal charger timer completes 3hs charge process, it will keep asking to DISCONNECT USB.

By doing so, the firmware adjust for a few seconds the new charge level and save in internal ROM for future use.