ExpoM - ELF

User Manual

Version 1.6

FIELDS at work

ExpoM - ELF

User Manual

Contents

1 Description

ExpoM - ELF is a personal ELF magnetic field exposure meter for frequencies from DC up to 100kHz. Features include four selectable bands (DC – 1 kHz, DC – 10 kHz, DC – 100 kHz and higher field strengths from DC to 1 kHz), GPS based outdoor localization and Wi-Fi connectivity. The built-in Wi-Fi interface allows to stream the measurement data to an Android based device for real-time display. ExpoM - ELF is a measurement module of the ExpoM exposure measurement platform and can be extended by additional measurement devices and Smartphone Apps.

2 Case and Interfaces

2.1 Overview

The standard enclosure of ExpoM - ELF provides basic water (IP 64) and shock protection of the device. The most important elements and controls of the device are shown in Figure 1. The magnetic field sensors (1) are located at the front of the device about 15 mm underneath the arrows identifying the orientation of the three measurement axes. The Multi-color LED (2) is the main activity indicator of the device. The marker button (3) can be used to highlight specific events during a measurement.

Figure 1: ExpoM – ELF elements and controls: Magnetic field sensor orientation information (1) Multi-color LED (2), Marker button (3), Micro-USB interface (4), Charging indicator LED (5), ON/OFF switch (6)

A micro USB interface (4), a charging indicator LED (5) and the ON/OFF switch (6) are located on the lower side of the case.

Important Note: *ExpoM-ELF is delivered with a protective rubber cover on the Micro-USB receptacle. It is recommended to always put the cover on the USB interface when no cable is plugged in. This prevents unintentional electrostatic discharges (ESD) from disturbing ongoing measurements and minimizes wear and tear of the contacts.*

2.2 Multi-color LED

Status information about the operation of the device is given via the multi-color LED. The following table shows an overview about the color code and its corresponding behavior.

Situation	Multi-color LED
Device initialization (after power on)	1. Green flash immediately after switch is turned on; 2. A quick color sequence signalizes the successful initialization. After initialization, the device switches over to measurement mode.
Measurement mode	The LED lights red during each measurement. If GPS is enabled, an additional green flash signalizes a successful GPS position fix.
Active connection to PC Software	Continuous yellow light.
Auto Power down (low battery)	Series of fast red flashes, after which the device powers off.
Wi-Fi connection	Single blue flash: Wi-Fi connection established Double blue flash: Wi-Fi has been disconnected
Marker button pressed	Blue light briefly lights up
Initialization error at power on	Series of fast red flashes shortly after power-on. Device must be restarted using the ON/OFF switch.

Table 1: Color codes of the multi-color LED

3 Using ExpoM - ELF

3.1 Starting a Measurement

As soon as the device is turned on by means of the ON/OFF switch it starts to measure and log the data using the last device settings. The device can be turned on and off at any time. When ExpoM - ELF is powered on, the new measurements are appended to the existing log file preserving all previously recorded data. The data internal memory can be deleted using the ExpoM - ELF Utility on the PC (see chapter 5).

3.2 Setting a Marker

The Marker button on the top of the device can be used to flag single measurement samples. The flagged samples are highlighted by means of an ascending marker number visible in the exported data.

3.3 Personal Measurements

When using ExpoM - ELF for personal measurements the movement of the person will lead to measurement artifacts due to the magnetic sensors that are moved through the static earth magnetic fields. These artifacts can lead to a lower measurement sensitivity towards lower frequencies and have therefore to be taken into account when interpreting the measured data. This aspect is addressed in detail in our application note *"ExpoM - ELF Measurement Procedures: Tips and Recommendations"* which can be found on our homepage.

Important Notice: *A moving person carrying the device induces artifacts in the measurements. If very low field strengths are to be measured it is recommended to move the ExpoM - ELF device as little as possible during the measurements.*

4 Battery management

4.1 Charging the Battery

The USB interface is used to recharge the internal battery or power the device from an external power source. Unless fully charged, the battery is recharged as soon as the device is connected to a powered USB source (Wall adapter, PC, laptop etc.).

While ExpoM - ELF is charging the battery, the charging indicator LED near the USB connector lights solid red. At the end of the charging cycle the red indicator LED turns off.

Important Notice: *Using USB chargers that do not fulfill the USB dedicated charger port specification can lead to incomplete and slow charging process of the batteries.* ***It is strongly recommended to use an USB charger with a current rating of at least 1A (1000mA)****. More information about suitable USB charger types for ExpoM - ELF can be obtained from the distributor.*

Important Notice: *At environmental temperatures above 45°C ExpoM - ELF should not be charged. Direct exposure to sunlight during the charging process should be avoided.*

Note: *The actual charging time depends on the charger model and the type of USB cable used. Long and / or thin USB cables can significantly increase the required charging time regardless of which type of charger is used. It is recommended to use the USB cable provided with the device.*

4.2 Over-Discharge Protection (Automatic Shutdown)

To preserve its capacity over time, the internal battery must be prevented from being discharged below a critical level. ExpoM - ELF includes a battery monitoring circuit that powers the device down when a critically low battery level is detected. After such an automatic power-down it is recommended to put the ON/OFF switch in the OFF position and charge the device for at least 10 minutes before switching it on again.

5 ExpoM - ELF Utility (PC Software)

5.1 General Information

The ExpoM - ELF Utility software is required for transferring and displaying the measurement data from the ExpoM - ELF to a PC and for changing the various device settings. This software requires a 64-bit Windows operating system (tested on Windows 7, 8, and 10). A 32-bit version is available upon request.

5.2 The Main Window

Figure 2 shows the elements of the ExpoM - ELF Utility main window.

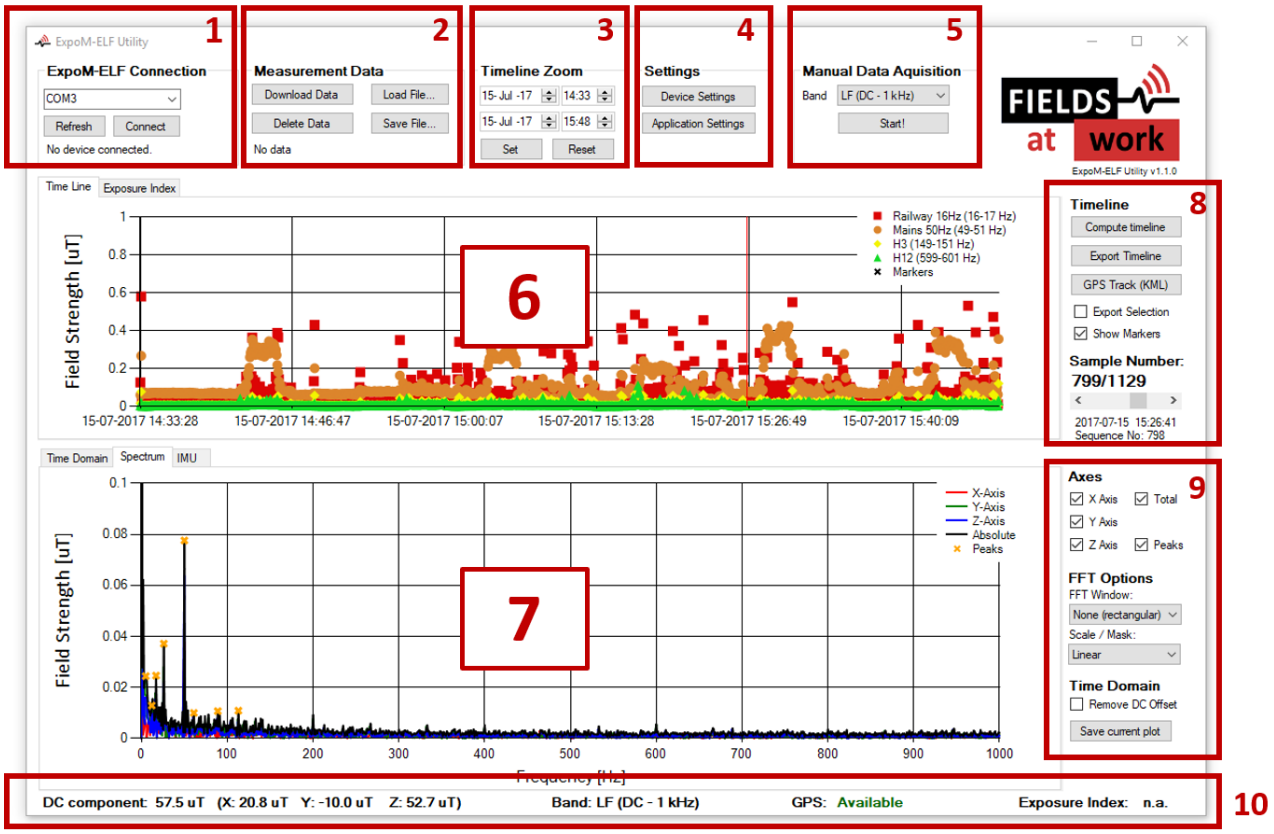

Figure 2: Main window of the ExpoM - ELF Utility

The window is organized into the following sections:

5.2.1 Device Connection (1)

Before any data can be downloaded from the device or its settings modified, a connection to the ExpoM - ELF device must be established via USB. This is done here by selecting the corresponding port and by pressing the 'Connect' button. More details about how to connect to an ExpoM - ELF device is given in section 5.3

5.2.2 Measurement Data Section (2)

This section is used to manage the measurement data. It allows to download or clear the memory content of a connected device. The currently displayed measurement can also be saved to a raw file to be loaded and viewed later without a connected device.

5.2.3 Timeline Zoom (3)

The upper and lower Date/Time pickers show the beginning and the end of the timeline, respectively. Modifying the values of these boxes will scale the horizontal axis of the timeline to fit the specified start and end date/time. The reset button restores the original view (entire measurement shown).

5.2.4 Device and Application Settings (4)

Allows to change the settings of the connected ExpoM - ELF device as well as the settings for the application (see 5.5 and 5.6, respectively).

5.2.5 Manual Data Acquisition (5)

When a device is connected to the computer, it is possible to manually trigger single measurements. The device will take a measurement in the selected band and display it in the single measurement analysis plot. Manually triggered measurements are also stored in the internal logger memory of the device.

5.2.6 Timeline & Exposure Index Plots (6)

The timeline plot shows the field strength of selected frequency components over time. A few commonly used frequencies, i.e. 16.6 Hz and 50 Hz are set by default. Additional frequencies up to can be added to the plot in the application settings (see chapter 5.5).

The timeline serves also as main navigation element. Clicking in the timeline plot selects a single measurement sample from the measurement. The spectrum and the time domain signal from this sample are automatically displayed in the single measurement analysis plots.

Note that for a frequency component to be displayed in the timeline, the corresponding measurement samples must have been recorded with a suitable ExpoM - ELF band setting. For example, it is not possible to display a 5-kHz frequency component from a sample that has been taken in the *LF (DC – 1kHz)* band.

The “Exposure Index” plot shows the computed exposure index of each measurement over time. The values are given in % relative to the regulatory mask that was selected before the last timeline update. More details about the exposure index can be found in section 5.8.

5.2.7 Single Measurement Analysis Plot: Spectrum / Time Domain / IMU (7)

This Plot allows to analyze the spectrum and the time domain signal of a single measurement sample. Switching between the two representations is done by selecting the corresponding tab. If the IMU has been activated in the device settings, the IMU tab will show the recorded gyroscope

data. The gyroscope data represents the rate of rotation of the device in degrees per second. This information can be used to estimate whether the measurement data could be affected by geomagnetic field induced movement artifacts (see also our application note No. 1, available on our homepage). Please note that IMU data is only available for measurements taken in the LF band.

5.2.8 Timeline: Navigation and Export (8)

If a measurement contains a large number of samples, it may be difficult to find a specific sample just by clicking into the timeline plot. The navigation section allows to view the samples one by one by clicking on the arrows of the horizontal scroll bar.

The timeline can be exported to an Excel or CSV file. This is done by clicking on *Export Timeline.* Please note that contents of the exported file correspond exactly to the values displayed in the timeline. If other or additional frequencies are desired, they must first be selected in the application settings. Any change in the timeline settings, including the FFT windowing option, requires the timeline to be updated (*Compute Timeline*) for the changes to be visible.

5.2.9 Single Measurement Analysis: Settings and Export (9)

These settings control the appearance of the single measurement plot.

The *Axes* settings allow to individually enable or disable the three measurement axes as well as the absolute value of the field strength, allowing to see features that may be hidden by another curve in the plot.

The settings under *FFT Options* set the appearance of the spectrum. More detailed explanations about the FFT window setting can be found in our application note *"ExpoM - ELF Measurement Procedures: Tips and Recommendations"* which can be found on our homepage. Please note that these settings are used for the calculation of the timeline. Therefore, make sure to select the desired FFT settings before updating the timeline.

The option *Remove DC offset* subtracts the DC component of the magnetic field in the active measurement, thus centering all time domain curves around the zero value. This allows to better recognize common and small signal variations across the three measurement axes. Pleas note that this change also affects the computed absolute value (i.e. the *Total* curve). From version 1.1.0 This setting affects only the visualization in the plot and has no effect on the timeline or the exported data.

Save current Plot saves a CSV file containing the spectrum data and a second file containing the time domain data. If one of the two files are not needed, the corresponding export can be disabled by unselecting the corresponding checkbox.

5.2.10 Additional Information (10)

This section displays additional information about the measurement sample that is currently displayed in the single measurement analysis plot. The information includes the static (DC) components of the measured magnetic field, the measurement band, and whether GPS location

data is available for this specific sample. Latter property determines whether the measurement is included in the GPS export (KML file) or not.

5.3 Importing Data from a Device

To import the measurement data from an ExpoM - ELF it must be connected to the computer via USB. As soon as the device is switched on, a click on the *Refresh* button in the device connection section should reveal at least one new entry in the dropdown list (Figure 3, second picture). If you have plugged in the device for the first time to your computer, it may take several minutes for Windows to search for and install the appropriate driver. The device must be switched on during this process. If the automatic driver install fails, the corresponding installer can be downloaded from our homepage and installed manually (see 0).

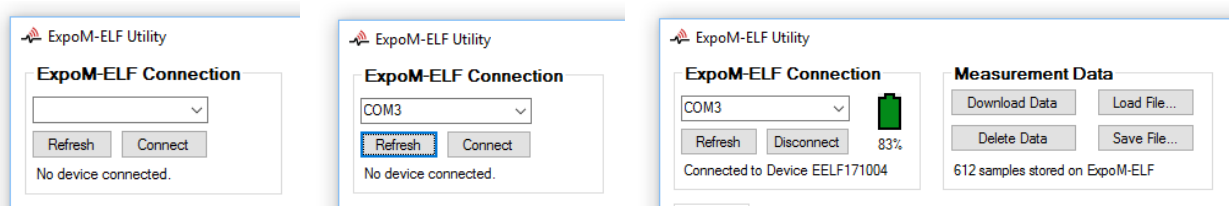

Figure 3: Connecting to ExpoM - ELF

When the correct COM port is selected, the connection to ExpoM - ELF can be established with a click on the *Connect* button. Please wait for the ExpoM - ELF device to finish the initialization process (this is signalized by a color sequence of the multi-color LED) before attempting to establish a connection.

When the connection to the device is established, the battery charge and the number of samples on the device are displayed (Figure 3, right). At this point the data can be downloaded by clicking on the corresponding button in the *Measurement Data* section.

5.4 Saving and Loading Measurement Data

Every measurement sample taken by ExpoM - ELF contains a high-resolution spectrum of the recorded magnetic field. This leads to a large amount of data that cannot be stored directly into a spreadsheet file. ExpoM - ELF Utility can save the measurements into a proprietary raw file format (.mmm) that retains all information. In addition, single measurements as well as the timeline can be exported into an Excel or CSV file.

5.4.1 Raw Measurement File (.mmm file)

When new measurement is downloaded from ExpoM - ELF we recommend to first save it into a raw measurement file (.mmm). This data format ensues that the full spectral and time domain as well as all the auxiliary information of the measurement is preserved. The raw measurement File format is proprietary and can only be opened by ExpoM - ELF Utility.

5.4.2 Export Timeline (to Excel or CSV) / GPS track (KML)

The timeline export saves all the data that is currently displayed in the timeline plot. The contents of the exported file depend therefore from the current application settings. The same applies to the GPS data export. If any parameter (FFT window, scaling etc.) was changed after downloading data from ExpoM-ELF or opening a measurement file, it is recommended to perform a timeline update (*Compute Timeline* button) before exporting the timeline.

5.4.3 Export a Single Spectrum / Time Domain Recording

The measurement sample which is currently displayed in the single measurement analysis plot can be exported to a CSV file. Please note that the spectrum is exported as displayed in the plot. The contents of the exported data will therefore vary depending on the selected FFT window and scale (logarithmic or linear) settings.

5.5 Application Settings

The application settings (Figure 4) allow to customize the list of frequencies and the corresponding colors to be displayed in the timeline. It is possible to enter arbitrary frequency ranges within the measurement range of ExpoM-ELF. The utility will then automatically determine the ExpoM-ELF band required to get the necessary measurement data (4th Column in the list). Single frequencies can be entered by setting the start and stop frequency to the same value.

The Google Earth export options allow to customize the appearance of the 3D bar graph of the exported KML files. The settings take effect immediately and will be applied to the next KML file export. The accuracy slider allows to set a filter on the quality of the GPS positioning accuracy. When this option is enabled, GPS data captured in bad reception conditions is discarded and will not be present in the KML export. **Caution:** setting the filter too strict can lead to no GPS data being exported at all. The application settings are saved locally in a file (*ELFsettings.dat*) and are automatically recalled when ExpoM - ELF Utility is started.

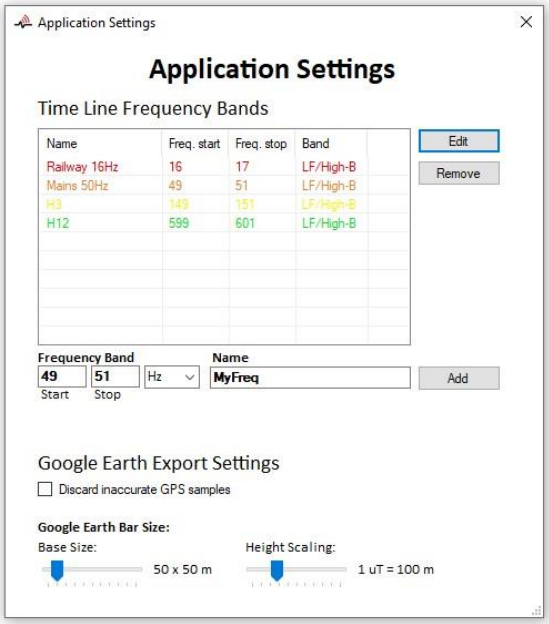

Figure 4: Application Settings window

5.6 Device Settings

The device settings dialog (Figure 5) can only be changed when a device is plugged in and successfully connected to the ExpoM - ELF Utility.

The *Date and Time* section is dedicated to the internal clock of the ExpoM - ELF device. Although ExpoM - ELF uses a high precision real-time clock, it may be necessary to adjust it from time to time (i.e. to precisely synchronize multiple ExpoM - ELF devices with each other). This can be achieved with the option *Sync with PC*. This synchronizes the clock of the connected ExpoM - ELF with the clock of the computer. The date / time synchronization is applied to the device immediately (no device restart is necessary).

The *Data Logger* options allow to choose which of the bands shall be measured during automatic data logging. The selected bands are all measured one after another within the selected measurement interval. Please note that the minimum recommended measurement interval is higher when more than one band is selected (see 7.6).

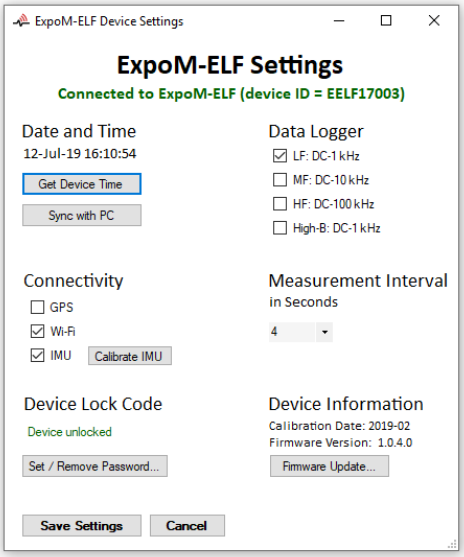

Figure 5: Device settings window

In the *Connectivity* options, the optional hardware modules of ExpoM-ELF can be switched on or off if they are not used to increase battery lifetime. This setting also allows to calibrate the gyroscope offset of the built-in IMU ("calibrate IMU"). This procedure lasts less than one second but requires the device to be placed on a perfectly steady and vibration free support for best results.

When new measurement settings are saved to the device, the connected ExpoM - ELF device must be switched off and on again for all changes to take effect.

Important Notice: *The accuracy and reliability of the GPS localization depends on the environmental conditions. Inside buildings and homes GPS localization may not be possible. After switching on the device, the GPS receiver may take several minutes to search for satellites. No position data will be logged during this time. The first few GPS measurements can have reduced position accuracy.*

5.6.1 Device Lock Code

The ExpoM-EF Utility software is freely available and can be downloaded by anyone. To prevent any access to the device settings and the measurement data by unauthorized persons (e.g. participants in epidemiological studies), the device can by locked with a six-digit access code. When a device is locked, no connection can be established to ExpoM-ELF Utility unless the correct unlock code is entered (Figure 6).

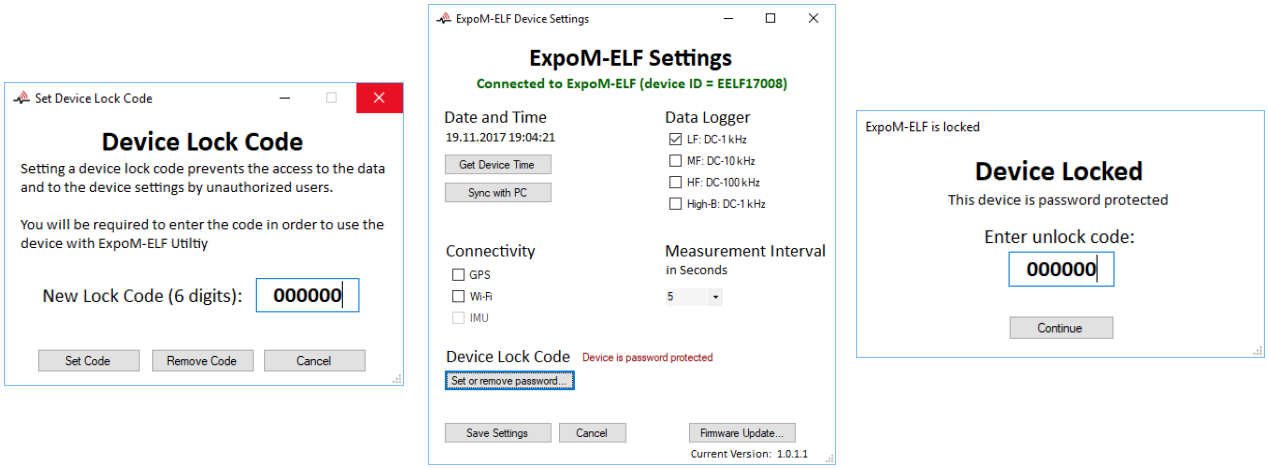

Figure 6: Setting and removing a device lock code (left); Settings window with a password protected device (middle); Unlock dialog when attempting to connect to a locked device (right).

5.6.2 Firmware Update

The firmware of ExpoM - ELF can be updated to improve its functionality and features. Firmware updates are published on our homepage and can be loaded to the device by the user.

When a device is connected to the PC, the firmware updater can be started by clicking on the corresponding button on the bottom right of the device settings window. The update dialog will appear (Figure 7).

Before applying the update, the connected ExpoM - ELF device must be put into update mode. This is achieved with following steps: Switch off the ExpoM - ELF device and switch it on again while pressing the marker button. The multi-color LED will flash slowly with a bright color. The firmware update process consists of two steps. First, a valid update file must be selected. After that, the file can be transferred to the device. This step takes a few seconds to complete. When the update is successfully terminated, the ExpoM - ELF device must be restarted using the ON/OFF switch. The updated firmware is now active.

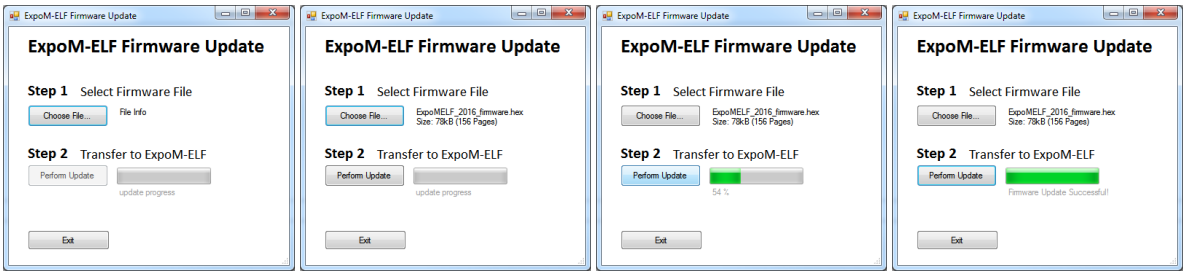

Figure 7: Firmware update procedure

5.7 Data Format (Timeline Export)

The software allows to save the measurement data as Excel (.xlsx) and CSV. The organization and information content of the two files is the same for both file formats.

5.7.1 Date and Time

Contains the date and time at which the corresponding sample was taken.

5.7.2 Sequence Number

Each measurement is labeled with a sequence number. Every time ExpoM - ELF is switched on the sequence number starts at 1. If not interrupted by a power cycle, the sequence number counts up to 65535 after which it restarts at 1.

5.7.3 Field Strength

The measured field strength of the frequency bands selected in the timeline. All field values are expressed in Microtesla (µT).

5.7.4 DC Components

Mean value of the recorded field strength subdivided into its X, Y, and Z components. If no DC source (permanent magnet) is present, this value represents the strength of the geomagnetic field.

5.7.5 Exposure Index

Exposure index in % according to the corresponding spectral mask selection in ExpoM-ELF Utility (see 5.2.65.8 for details).

5.7.6 GPS Data

The recorded GPS data consists of the following 7 parameters:

GPS Fix	*invalid*: no valid GPS data available *2D*: 2D only (no accurate altitude information) *3D*: full GPS localization
Latitude	NMEA format: DEGREE MINUTES (decimal representation)
Longitude	NMEA format: DEGREE MINUTES (decimal representation)
Altitude	Meters above mean sea level. Caution: GPS altitude accuracy is usually lower than horizontal position accuracy
HDOP	GPS fix uncertainty (low value = better). < 2: very good; 2-5: OK; >5: limited accuracy
#Satellites	Number of satellites in view; higher numbers mean more robust GPS reception
Speed	Speed in km/h determined by GPS. In bad reception conditions, speeds up to several km/h are sometimes measured even in stationary conditions.

5.7.7 Marker

Tracks the number of marker button activations. The measurement that was active at the time the marker button was pressed contains the corresponding marker number. Otherwise this entry is empty.

5.7.8 Battery charge

State of charge of the internal battery at the time of the measurement

5.7.9 Measurement mode

This column logs the circumstance that triggered the measurement, e.g. whether it was taken during autonomous logger operation (“Logger”), while controlled by the smartphone app (“App”), or manually triggered from ExpoM-ELF Utility (“PC Utility”). The availability of this information depends on the firmware version installed on the device when the measurement was taken.

5.8 Regulatory Masks and Exposure Index

Starting from version 1.1.0 and newer, ExpoM-ELF Utility offers the possibility to evaluate the measurements relative to various regulatory mask. The evaluation is performed in the frequency domain. An example is shown in the following picture (Figure 8):

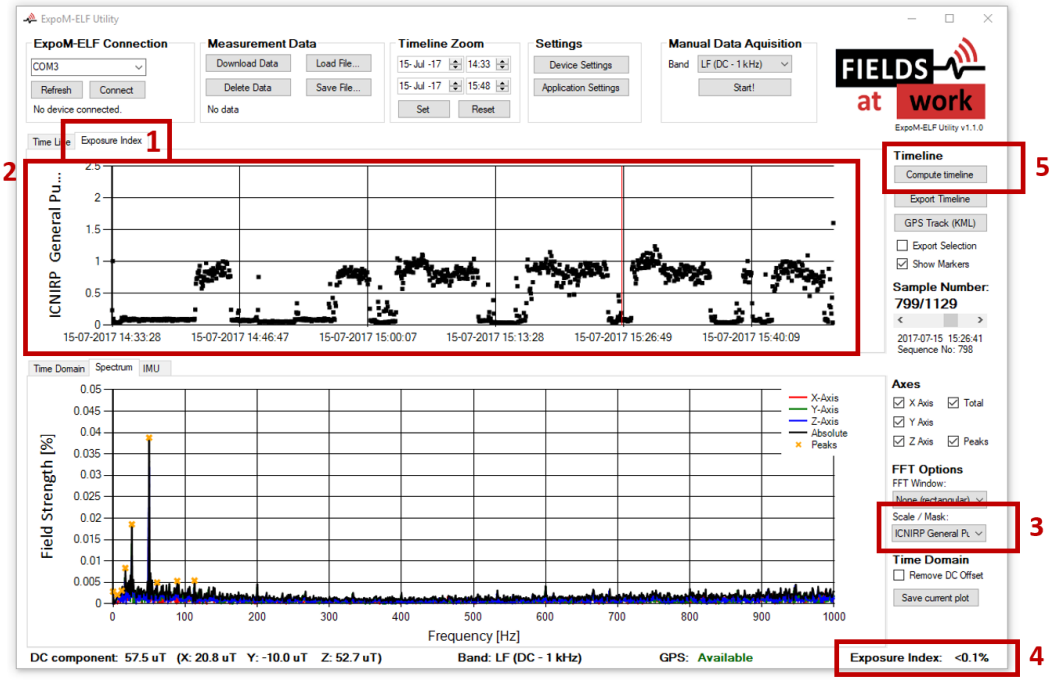

Figure 8: Example evaluation of a measurement according to ICNIRP General Public mask

The first step consists in selecting the desired regulatory mask in the “FFT options” section (3). This will change the current spectrum representation from absolute values in Microtesla to relative intensity in percent of the limiting values defined by the selected reference level mask. Based on these values the exposure index is also computed and displayed in the lower right corner of the main window (4). By selecting the exposure index tab (1) of the timeline, the exposure index over time can be displayed (2). Please note that a manual update of the timeline is required (5) to update the entire exposure index timeline (1) when a different mask has been selected (3). Additional information about the implemented regulatory masks and the computation of the exposure index can be found in our ExpoM-ELF application note no. 2 (available in the download section of our homepage).

5.9 Installing the USB Driver

The USB driver required for ExpoM ELF is included with most Windows versions and is automatically installed the first time ExpoM - ELF is connected to the PC. This driver installation process might take up to 5 minutes depending on the PC configuration. During this time, the device must be switched on and remain plugged to the USB port of the PC. When the device is installed successfully, the device is immediately found on the same COM port when it is reconnected to the PC.

If the automatic driver installation fails, however, it is necessary to first install the driver manually and repeat the process. The driver can be downloaded from our homepage.

6 ExpoM-ELF Smartphone App

The ExpoM - ELF app allows to trigger and display measurements from one or more ExpoM-ELF devices from a smartphone. The app requires an Android compatible device (Android Version 4.1 or newer).

6.1 Connecting to an ExpoM-ELF device

To connect the app with an ExpoM-ELF device, following two requirements must be fulfilled:

1) WiFi must be enabled on the corresponding ExpoM-ELF device using the PC utility (Figure 5).

2) The *mobile hotspot* functionality must be activated on the smartphone (Figure 9, first image). This option is typically found in the system settings in the category *mobile hotspot and tethering*. The exact location and naming may vary depending on the model and brand of your smartphone. The mobile hotspot must be activated with following settings:

Network Name: **expom-wifi**
Password: **expom-elf**

These settings will allow the ExpoM-ELF device to recognize the hotspot. This procedure is also explained in the in-app setup guide (Figure 9, second image).

At this point you can switch on your ExpoM-ELF device. If the hotspot is active and correctly set up, the ExpoM-ELF device will automatically connect to your smartphone and will be visible in the device selection menu on top of the main screen of the app (Figure 9, third image). You can then select the desired device from the menu. After that, everything is set up to use all features of the app (Figure 9, last image).

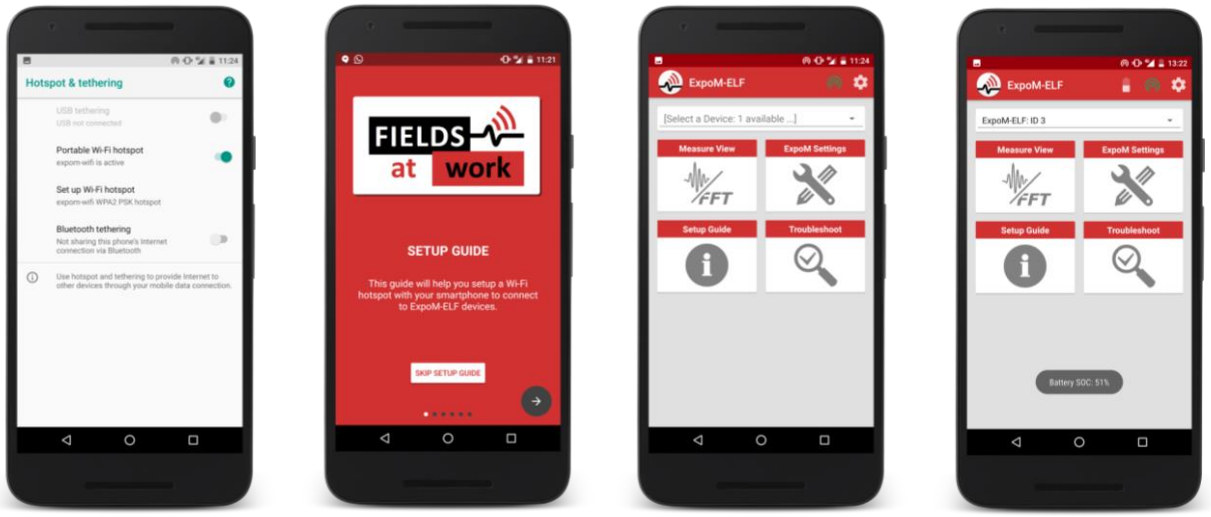

Figure 9: Connecting an ExpoM-ELF device with the App: Set up the mobile hotspot (1); Start the app (2) and switch on ExpoM-ELF device(s). All devices within reach (WiFi must be enabled) will be listed in the list on the top of the app (3); Select the ID of the desired ExpoM-ELF in the main menu (4).

6.2 App Functions

All functions of the app are accessible from the main menu (Figure 9, right).

6.2.1 Measurement view

The green arrow on the bottom left of the measurement view (Figure 10) triggers a measurement on the connected ExpoM-ELF device. A measurement is taken in the selected frequency band and the data is immediately transmitted and plotted in the app. The slider on the top right (*Time/FFT*) allows to switch between the time and frequency domain representation of the measurement. Holding down the sample button toggles the auto refresh mode. In this mode, a measurement is taken automatically at regular time intervals.

Figure 10: Measurment view: Spectrum and time domain representation

The settings icon on the right of the *Time/FFT* slider opens the plot settings (Figure 11). This view allows to change the measurement band for the measurement view as well as the interval of the auto refresh mode.

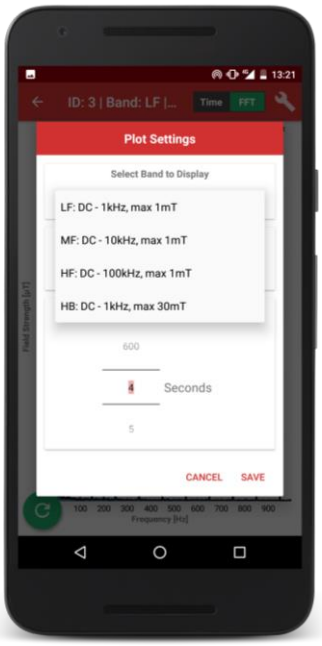

Figure 11: Measurement view: Plot settings

6.2.2 Device settings

The device settings view (Figure 12, left) allows to modify the most important measurement settings of the device when it is operated in logger mode. It provides the same functionality as the device settings dialog of the PC utility (Figure 5) but with a reduced number of options. The option *Sync Date and Time on Device* synchronizes the internal clock of the ExpoM-ELF device with the smartphone clock. On the bottom of this view, the current state of charge (SOC) of the device's battery is shown.

6.2.3 App Settings and Information

The app settings view (Figure 12, right) allows to disable the automatic display of the setup guide when the app is started. In addition, it contains all relevant information about the installed app revision.

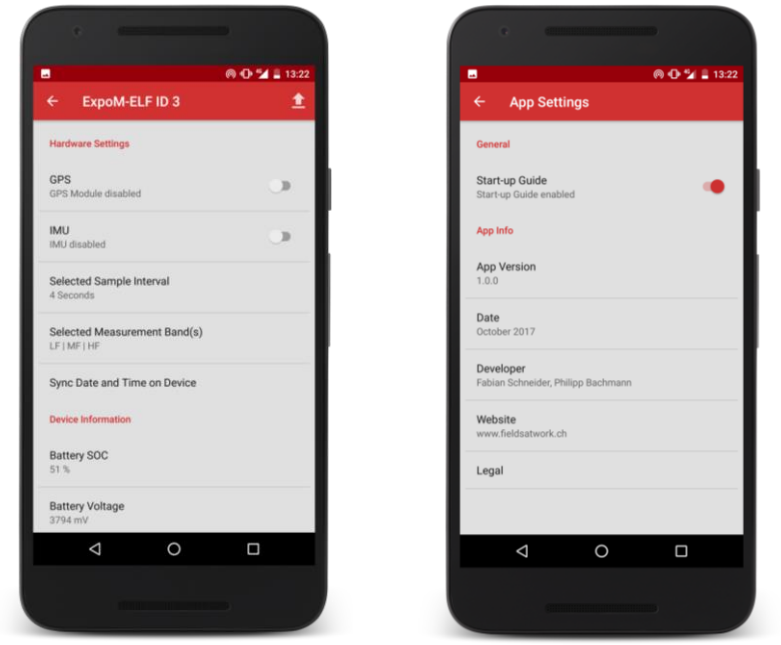

Figure 12: Device settings (left) and app settings / information dialog (right)

6.2.4 Setup Guide and Troubleshoot Utility

The setup guide that is shown by default on startup can be started at any time from the main view. If you are not able to establish a connection to your ExpoM-ELF device, the troubleshoot utility can assist you to find the solution by checking whether all required steps have been setup correctly.

7 Technical Specifications

7.1 Frequency Bands and Measurement Range

Detection method	Time-domain sampling (4096 samples) with digital processing and filtering
Sensors	Tree axis TMR sensor; Hall sensors
Measurement interval	User-selectable; from 4 seconds to 6000 seconds in steps of 0.25 second

7.2 Bandwidth and Resolution

The measurement range of the device is subdivided into four bands: Three high sensitivity ranges with variable frequency resolution cover the frequency range from DC to 1 kHz, 10 kHz, and 100 kHz, respectively. An additional high field strength mode allows measurement up to 30 mT (RMS) from DC to 1 kHz.

Band Name	Bandwidth	Resolution Bandwidth	Maximum Field Strength
LF (high resolution)	DC – 1 kHz	1 Hz	1000 µT RMS (±1500 µT peak)
MF	DC – 10 kHz	10 Hz	1000 µT RMS (±1500 µT peak)
HF (high bandwidth)	DC – 100 kHz	100 Hz	1000 µT RMS (±1500 µT peak)
High-B	DC – 1 kHz	1 Hz	30 mT RMS (±45 mT peak)

7.3 Sensitivity

Band	Frequency Range	Spectral Noise Density
LF, MF, HF Band	16 Hz - 150 Hz	< 5 nT /$\sqrt{\text{Hz}}$ (see noise floor spectra below)
LF, MF, HF Band	150 Hz – 100 kHz	< 2 nT /$\sqrt{\text{Hz}}$ (see noise floor spectra below)
High-B Band	DC – 1 kHz	< 0.2 µT/$\sqrt{\text{Hz}}$ (see noise floor spectra below)

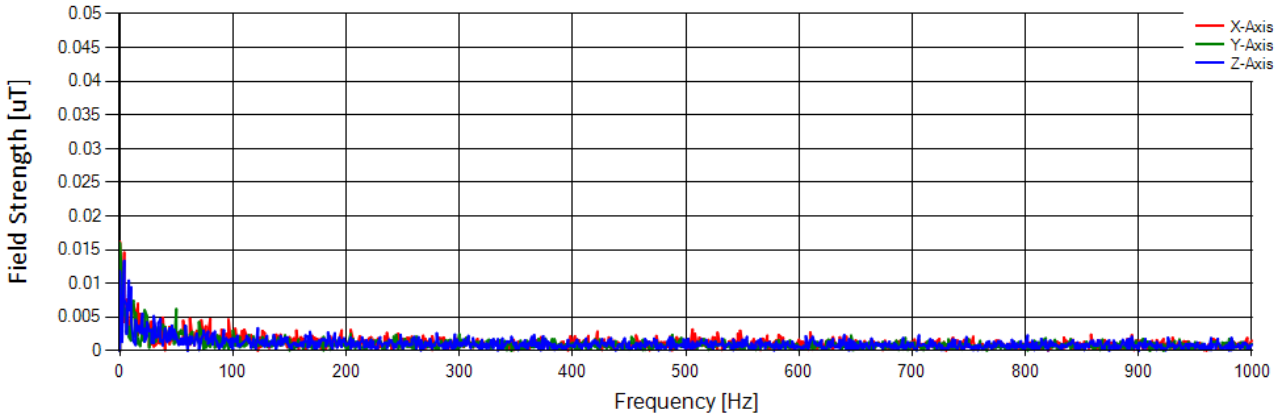

Figure 13: Typical noise floor: LF band (DC – 1 kHz)

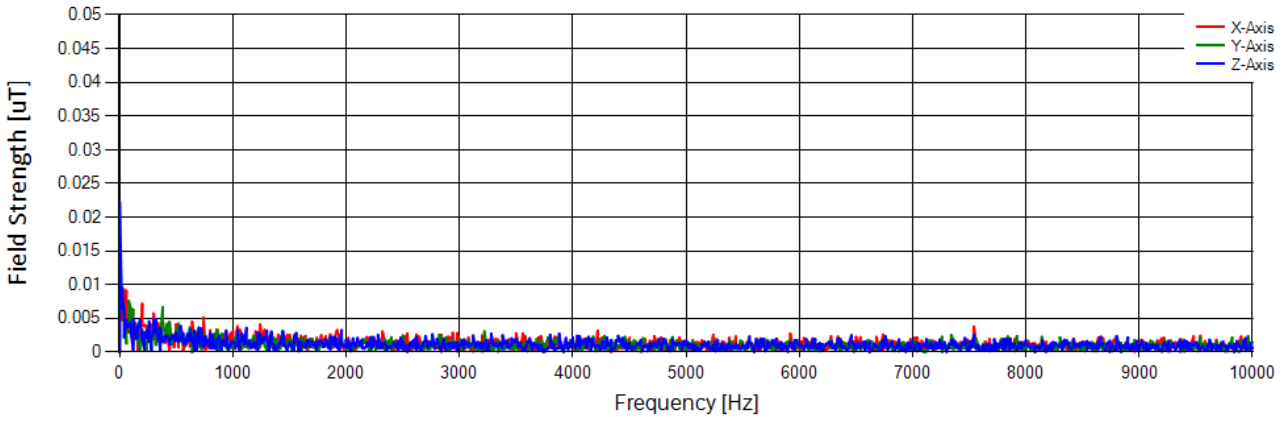

Figure 14: Typical noise floor: MF band (DC – 10 kHz)

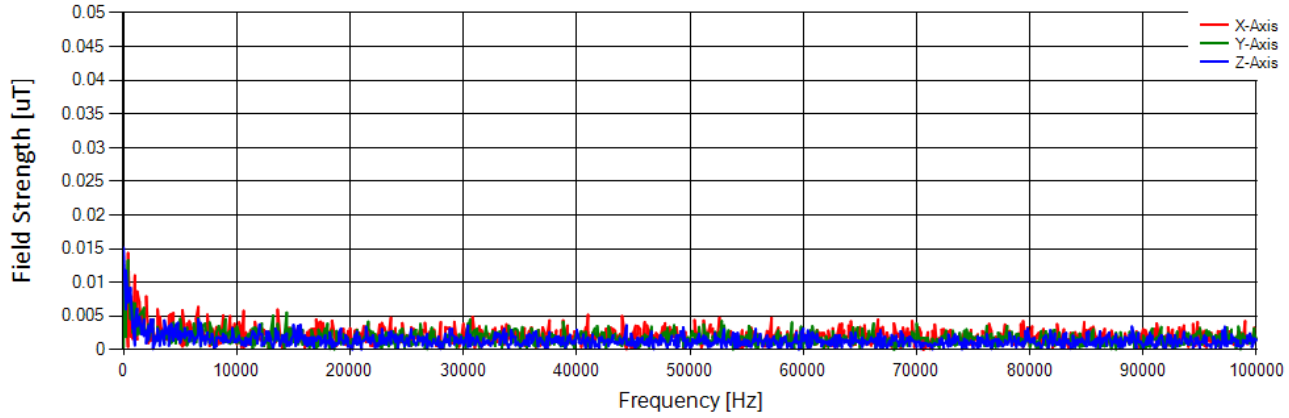

Figure 15: Typical noise floor: HF band (DC – 100 kHz)

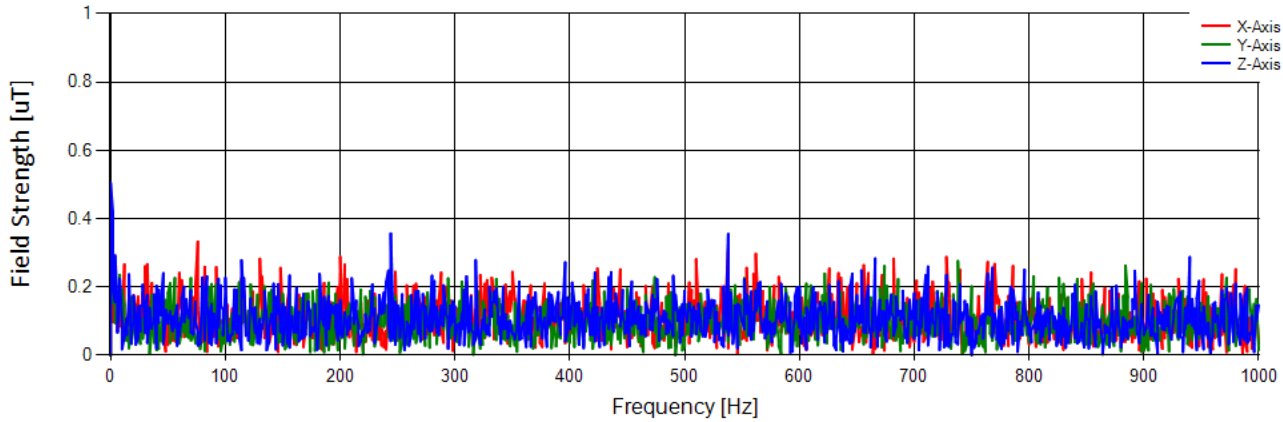

Figure 16: Typical noise floor: High-B band (DC – 1 kHz)

7.4 Accuracy and Drift

Band	Basic Accuracy 25°C ±10°C	Typical DC Offset 25°C ±10°C	Temperature Drift 0°C to +50°C	Axis Crosstalk
LF	± 3%	± 5 µT	Sensitivity: 0.1% / °C DC Offset: <0.8 µT / °C	< 30 dB
MF	± 3%	± 5 µT		< 25 dB
HF	± 3%	± 5 µT		< 10 dB
High-B	± 3%	± 0.05 mT	Sensitivity: 0.05% / °C Offset: <2.5 µT / °C	< 25 dB

7.5 Linearity

DC linearity: less than 1% max. absolute relative deviation within the specified measurement range

Total Harmonic Distortion:

Total Harmonic Distortion	Band	Test Condition
< -45 dB	LF Band	100 µT RMS; Sinusoidal field at f = 100 Hz
< -45 dB	MF Band	100 µT RMS; Sinusoidal field at f = 1 kHz
< -45 dB	HF Band	100 µT RMS; Sinusoidal field at f = 10 kHz
< -45 dB	High-B Band	1 mT RMS; Sinusoidal field at f = 100 Hz

7.6 Automatic Data Logging

All measurements performed with the device are automatically stored to the internal memory. The device can be configured to take a measurement on one or multiple bands (see 7.2) within one measurement interval. If multiple bands are selected it may be necessary to increase the measurement interval. The recommended minimum measurement interval settings are given in the following table (Table 2).

Measurement Settings	GPS ON	GPS OFF
One band	4 seconds	4 seconds
Two bands	5 seconds	4 seconds
Three bands	6 seconds	5 seconds
All bands (LF + MF + HF + High-B)	7 seconds	6 seconds

Table 2: Recommended minimum measurement interval

Selecting a measurement interval shorter than the recommended value may lead to individual samples being taken at irregular (i.e. longer than expected) time intervals.

7.7 Connectivity and Data Management

Time	Integrated precision (± 2 ppm) real time clock
Connectivity	USB interface (Micro-USB), Wi-Fi (802.11b/g/n), GPS/GLONASS receiver
Marker	Built-in marker button to highlight specific events or trigger measurements
Storage	Internal data logger memory for >250'000 measurements

7.8 Battery Management

Battery	Built-in rechargeable Li-ion battery
Typical operating time	> 24h (10 sec measurement interval, GPS disabled)
Charging	Micro-USB interface USB compliant chargers are supported (≥ 1.5A recommended) A full charge takes about 2 h.

7.9 PC software (ExpoM-ELF Utility)

Processor	Dual core processor recommended
Operating Systems	64-bit Windows 7, 8, 10; (32-bit software version available upon request)
Memory	4 GB RAM minimum. 8-16 GB recommended for large measurement files
License	No license required; free download at www.fieldsatwork.ch/downloads
Compatibility	ExpoM-ELF Utility release 1.0.9 and newer require firmware version 1.0.2 or newer to be installed on the ExpoM-ELF device for correct operation.

7.10 Other

Size	16 cm x 8 cm x 3.5 cm (L x W x H)
Weight	300 g
Operating Conditions	Temperature: -5°C to +50°C Rel. humidity: 0% to 90% (non-condensing)