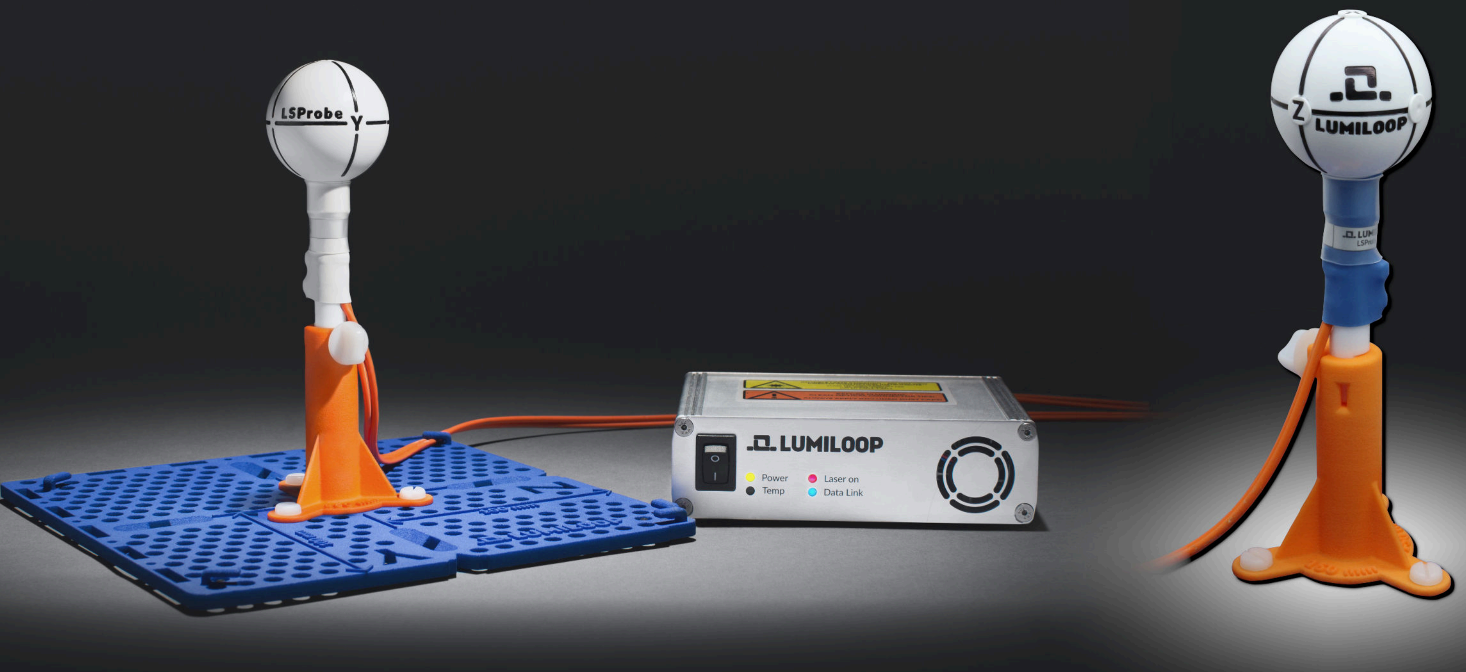
LUMILOOP

LASER-POWERED SENSOR SYSTEMS



User's Manual

LSProbe 1.2 / 1.4 / 2.0

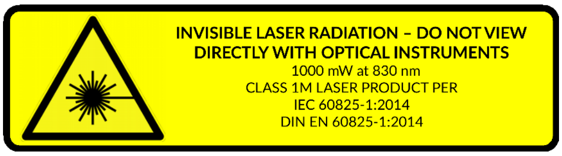
E-FIELD PROBES

Contents

1 Safety Instructions

You have purchased a high precision measurement system. Please read the LSProbe User's Manual carefully before operating the E-field probe. Please handle all parts with care, especially the fiber optics and its connectors.

- Avoid any unnecessary force that may cause the fiber to bend sharply and break.
- Cap end face when optical connectors are not plugged.
- Clean any dirt from the end face (see Section 5.1.1).
- Avoid any unnecessary stress. All components of the system are sensitive to shock and impact.
- There are no serviceable parts inside this product. Open neither the CI-250$^{(+)}$ Computer Interface nor the E-field probe. Opening can void the warranty. If there is any failure, please contact LUMILOOP GmbH.



(a) Laser Classification

(b) Cleaning Advice

Figure 1: *Safety Instructions*

Laser Safety

The LSProbe 1.2/2.0 E-field probe system is an optically closed system and is thus classified as a class 1M laser product, according to IEC 60825-1:2014 / DIN EN 60825-1:2015-07. This applies as long as the laser supply is turned on only after verifying the integrity of the fiber cable and all optical connectors, as advised in Section 5.1.

However, this classification does not mitigate the danger arising from accidental disconnection or damage of the fiber during operation. According to IEC 60825-2 / DIN EN 60825-2 ("*Safety of optical fibre communication systems*"), LSProbe 1.2/2.0 E-field probes feature Automatic Power Reduction (APR). If there is an interruption of the communication between E-field probe and computer interface, or a sudden drop of optical power, the power laser is turned off within eight milliseconds. This APR is deactivated for a maximum duration of 30 seconds during startup and measurement mode changes. Deactivation of APR is indicated by the blinking orange "Laser on" LED on the CI-250$^{(+)}$ Computer Interface (see Section 3.1.5). Interrupting optical connections during this time is dangerous!

2 System Overview

The miniaturized LSProbe 1.2/1.4/2.0 E-field probes enable unattended, continuous E-field measurements with high resolution, high speed and low noise. The galvanically insulated laser power supply of the LSProbe 1.2 and 2.0 eliminates the need for batteries. LSProbe 1.2/1.4/2.0 E-field probes are not limited to the acquisition of quasi-static fields. With their sampling rate of up to 2 MSamples/s they are also able to measure rapidly changing electric fields. The field probes' large dynamic range and fast pulse response make them applicable to entirely new use cases.

Every LSProbe 1.2/1.4/2.0 E-field probe comes with a complete set of calibration data for unparalleled linearity, temperature stability and frequency compensation. LSProbe 2.0 features additional calibration data for isotropy correction. The high-accuracy factory calibration data can be further enhanced by correction factors of accredited calibration laboratories, including LUMILOOP.

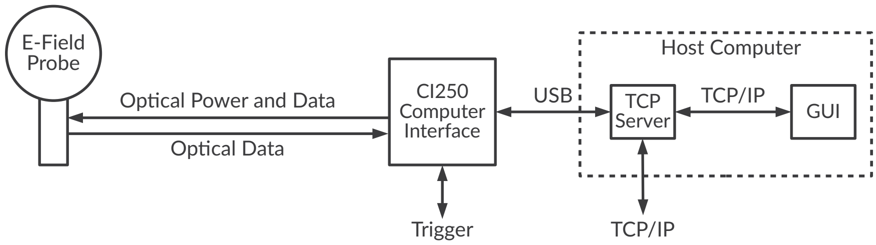


Figure 2: *LSProbe 1.2/2.0, CI250 system block diagram*

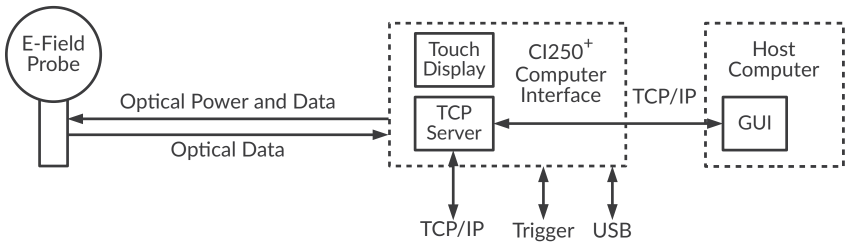


Figure 3: *LSProbe 1.2/2.0, CI250^{+} system block diagram*

As shown in Figures 2 and 3, LSProbe 1.2/2.0 systems consist of an E-field probe which records E-field values and a computer interface to process them. Digital sample values are transmitted via an optical fiber. The CI-250$^{(+)}$ Computer Interfaces also serve to supply the E-field probe optically and handle external trigger signals. As shown in Figure 4, the LSProbe 1.4 consist of a single hardware unit, which also handles external trigger signals.

CI250 and LSProbe 1.4 attach to a host computer via USB, CI250^{+} attach to a host computer using an Ethernet connection. The LUMILOOP TCP Server handles USB communication, application of calibration data, data post-processing and communication with client programs via TCP/IP SCPI commands, e.g., the LUMILOOP Graphical User Interface (GUI). For CI250 and LSProbe 1.4 the LUMILOOP TCP Server runs on the host computer, for CI250^{+} the LUMILOOP TCP Server runs directly on the CI250^{+} device and is automatically started after power-up.

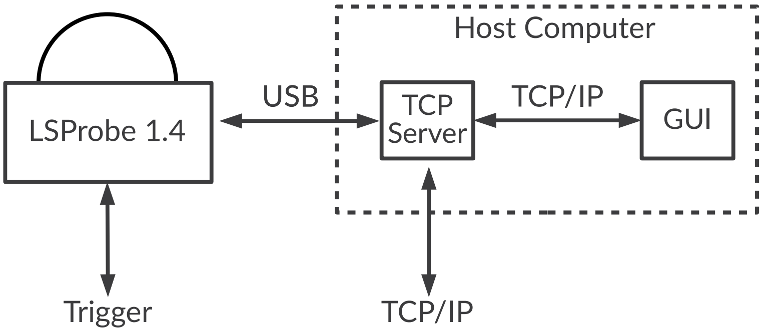


Figure 4: *LSProbe 1.4 system block diagram*

Moreover, the TCP server can receive SCPI commands via its standard input and reply via its standard output. This enables simple manual configuration and verification of the field probe's operation by typing/pasting commands into a command window.

Multiple LSProbe 1.2/1.4/2.0 E-field probes may be connected to one TCP server instance to form a Multiprobe System consisting of synchronized E-field probes which is especially suitable for field distribution analysis, statistical field analysis and reverberation chamber applications.

2.1 Data Acquisition and Processing

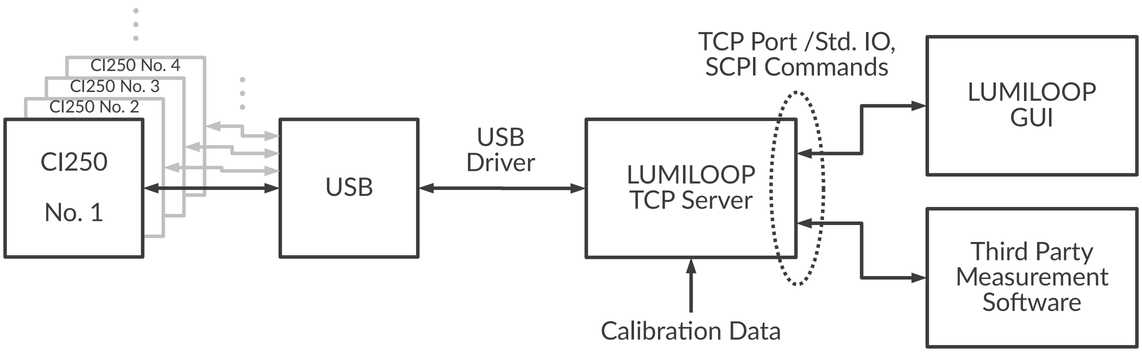


Figure 5: *LSProbe software block diagram*

The software delivered with the LUMILOOP LSProbe E-field probe system consists of:

- the USB driver,
- the LUMILOOP TCP Server,
- the LUMILOOP Graphical User Interface (GUI),
- the LUMILOOP accredited calibration data import tool (CalImport),
- the LUMILOOP laser timeout debug tool (TimeoutDialog)
- the LUMILOOP Bin2Csv command line programm for converting binary streaming data to ASCII format.

As shown in Figure 5, one instance of the LUMILOOP TCP Server communicates with all CI-250 devices which are connected to the host computer via USB 2.0. For CI-250^{+} devices the USB connection is realized within the device. Additional CI-250 devices can be connected to the "+"device via USB. The TCP server configures the device, streams all E-field strength and auxiliary data, applies calibration data to the received E-field strength values, handles trigger events and performs sensor data buffering as well as post-processing. The TCP server provides an exhaustive set of SCPI commands for simple and reliable text-based integration into test and measurement automation solutions, for details see Section 12. The TCP server supports up to 32 concurrent TCP clients.

All third party EMC software accesses the LUMILOOP TCP Server through SCPI commands, examples are given in Section 5.3.2, 5.4.2, etc. When operating multiple TCP client programs in parallel, the user is responsible for avoiding undesired interference. For example, one client must not change the measurement mode while another client relies on a different setting. Generally, concurrent access to the LUMILOOP TCP Server is discouraged except for debugging purposes.

The LUMILOOP GUI detailed in Section 5 is a graphical user interface for configuring and monitoring all device settings as well as measuring and logging data. As all clients, the LUMILOOP GUI can connect to a local or remote TCP server. For CI-250^{+} devices the "**+**" Device GUI is started automatically after system boot, communicating with the LUMILOOP TCP Server running in the background. The built-in touch display can be used to change settings manually.

2.2 E-field Value Generation

The fundamental function of the LUMILOOP TCP Server is the conversion of the sample values originating from the E-field probe to E-field values for direct readout or further processing as discussed in the following sections. Figure 6 gives an overview of the data flow within the LUMILOOP TCP Server.

The generation of E-field values applies several types of calibration data, in order to compensate for frequency response, non-linearity, temperature drift and, in case of LSProbe 2v0 devices, anisotropy. The video bandwidth of the LSProbe can be reduced by applying a software-based low-pass filter to the sample values. This filtering applies to all subsequent processing of E-field values.

2.3 Scalar E-field Values

E-field values can be read out as scalar values, i.e., individual values of the field strength of any axis or their magnitude. Optionally, a low-pass filter, which is separate from the software-based video bandwidth reduction, can be applied to the E-field values for noise reduction.

The step-wise statistics feature, described in Section 5.7 on page 78, can be used to combine a configurable number of sample values to reduce the sampling rate. Step-wise statistics generate the average, maximum and minimum E-field strength value for each interval and makes them available through a value FIFO.

2.4 E-field Waveforms

The LUMILOOP TCP Server is able to record a user-specified number of E-field values, i.e., E-field waveforms. Subsequent signal analysis, such as pulse detection, radiated power analysis, frequency/power sweep evaluation, high-resolution waveforms and statistical analysis, is based on previously recorded E-field waveforms.

E-field waveforms are stored upon receiving a trigger event. They can be queried until they are replaced by a newly recorded E-field waveform. Waveforms are recorded relative to a trigger event. Trigger events can be generated by software, by crossing a specified E-field value threshold or by externally generated trigger signals. See Section 5.4 on page 57 for further details.

Note that E-field waveforms require memory in proportion to the recorded duration of time, i.e., approximately 26/52 MB per second for LSProbe 1.2/2.0 devices. For a single E-field probe setup this limits the maximum waveform length to approximately 100/50 seconds on 32 bit systems. On 64 bit systems, the maximum waveform length is practically limited by the amount of available memory only.

2.5 Sweep Analysis

The LUMILOOP TCP Server is able to analyze frequency and power sweeps recorded as E-field strength waveforms. Information about the sweep's timing and frequency steps must be provided as parameters. Each step of the sweep is evaluated individually, taking into account its length, frequency and settling times. For each part of the waveform that corresponds to a specific sweep step, the calibration data is newly computed and applied in agreement with the associated frequency for the respective sweep step. The LUMILOOP TCP Server returns the averaged E-field strength value for each step. For the precise control of timing, the signal generator generating the sweeps and E-field probe are typically synchronized using a hardware trigger line when acquiring E-field waveforms for sweep analysis. See Section 5.4.5 on page 64 for further details.

2.6 High Resolution Waveforms Using Oversampling

LSProbe 1.2/2.0 devices are able to measure the timing of acquired values relative to recorded waveforms at a much higher temporal resolution than the continuous sampling rate of the LSProbe, i.e., 2 µs. By combining multiple waveforms with each waveform's trigger timing information, the LUMILOOP TCP Server can generate high temporal resolution waveforms. The LUMILOOP TCP Server uses a histogram-based sample buffer for the compensation of trigger delay and the reduction of E-field value noise. See Section 5.5 on page 70 for further details.

2.7 Statistical Analysis

The LUMILOOP TCP Server is able to perform a statistical evaluation of E-field strength data originating from one or more E-field probes. Thus reducing programming effort, communication overhead, memory requirements and CPU load. Both scalar statistics values and histogram-like distributions are accessible through the LUMILOOP TCP Server. Statistics can be based on both continuous and triggered value acquisition as shown in Figure 6. See Section 5.6 on page 74 for more details.

2.7.1 Continuous Statistics

Continuous statistics are based on four histograms generated from all incoming E-field values. There is one histogram for x-, y-, z-axis E-field component and E-field strength magnitude. Histograms are created at a fundamental resolution of 0.005 dB. Data collection is enabled and disabled using SCPI commands or the dedicated signal lines described in Section 3.3. Continuous statistics consume a minimal amount of memory, since timing information is discarded in the process of histogram data collection. Consequently, continuous statistics can be recorded for arbitrary durations of time. Scalar statistics values and histogram-like distributions use statistics snapshots, i.e., copies of the continuously updated histogram, created at specific times. Histogram-like distributions and associated E-field values can be queried at a lower level of detail than the 0.005 dB default of the snapshot histograms. See Section 5.6.2 and 5.6.4 for details.

Snapshot creation for multiple E-field probes can be synchronized using dedicated signal lines as detailed in Section 3.3. In contrast to software-based snapshot creation, synchronized, hardware-based snapshot creation ensures that statistics of E-field probes operated in parallel will not be distorted by latency introduced by buffering, the USB hardware or the operating system's data processing.

2.7.2 Triggered Statistics

Triggered statistics create snapshot histograms from waveforms. Consequently, a set of x-, y-, z-axis and magnitude E-field waveforms must be recorded in full before statistics evaluation can take place. When compared to continuous statistics, triggered statistics have the advantage of preserving timing information in the form of the triggered waveforms. However, triggered statistics also have a number of disadvantages relative to continuous statistics:

- Triggered statistics require memory in proportion to the length of time to be evaluated and the number of E-field probes in a system, see Section 2.4 for more details.
- For the same duration of time, creating a snapshot histogram from triggered waveforms is significantly slower than a continuous statistics snapshot. This is due to the fact that triggered statistics must evaluate all samples in the recorded waveforms while continuous statistics merely require a copy of the continuously updated histogram for every snapshot.
- Triggered statistics are only available for the recorded waveforms as a whole, continuous statistics may take multiple statistics snapshots as data is being recorded.
- Triggered statistics may introduce significant delays in TCP server to client communication, especially when recording large waveforms.

It is therefore generally preferable to rely on continuous statistics when information about the waveform's shape is not essential.

2.8 Stream Recording

The LUMILOOP TCP Server is able to save a binary stream of continuously recorded x-, y- and z-axis E-field strength values directly to disk or send it to a designated TCP network port on any host reachable by the LUMILOOP TCP Server. This enables the resource-saving recording of E-field strength values for virtually unlimited durations of time. Streams can be recorded for one or multiple E-field probes. The LSProbes' trigger signals can be employed to synchronize multiple streams. In this case, one LSProbe acts as the stream master, sending one synchronization rising edge on the trigger line for every 512 µs. All other LSProbes act as stream slaves and use the master's synchronization pulses to match the sampling rate prescribed by the master. See Figures 15, 16 and 17 for the required physical connections to the BNC connector or Ext1 RJ45 socket. See Section 5.8 on page 80 for further details.

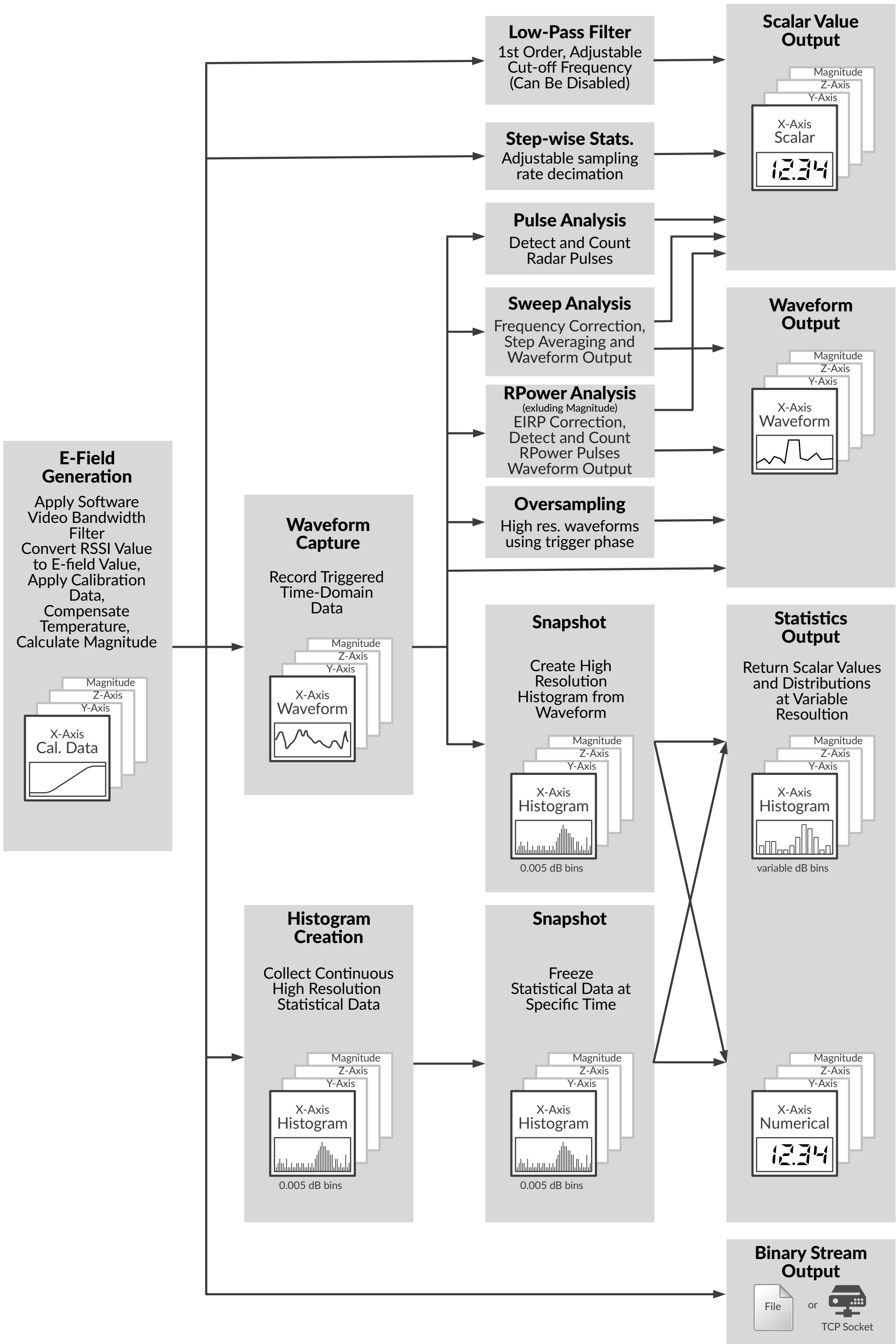


Figure 6: *Data flow diagram of E-field value processing*

3 LSProbe 1.2/1.4/2.0 Hardware

3.1 E-Field Probe Components

The hardware of the LUMILOOP LSProbe 1.2/2.0 E-field probe System consists of an LSProbe E-Field Probe, of either version 1.2 or version 2.0, with a fixed length of fiber optic cable, a CI-250(+) Computer Interface (CI) and optional accessories, such as fiber-cable extensions and probe stands for repeatable and quick measurement setup. LSProbe 1.2 covers frequencies between 9 kHz and 8.2 GHz using three monopole antennas, LSProbe 2.0 covers frequencies between 9 kHz and 18 GHz using six monopole antennas. There are three LSProbe 1.2 variants. Variant F enables measurements starting from 10 Hz, with slightly reduced sensitivity and dynamic range in the low-band mode. Variant G supports high field strength measurements up to 10 kV/m and 15 kV/m between 30 MHz and 6 GHz. Variant E is the standard variant.

The LSProbe 1.4 E-field probe is a directly USB powered measurement device, i.e. consisting of a single LSProbe unit containing a single monopole antenna. It covers frequencies between 9 kHz and 8.2 GHz. The LSProbe 1.4 is designed to survey electric fields outside of EMC chambers, e.g., on a driving vehicle, or in an industrial environment.

3.1.1 LSProbe 1.2 E-Field Probe

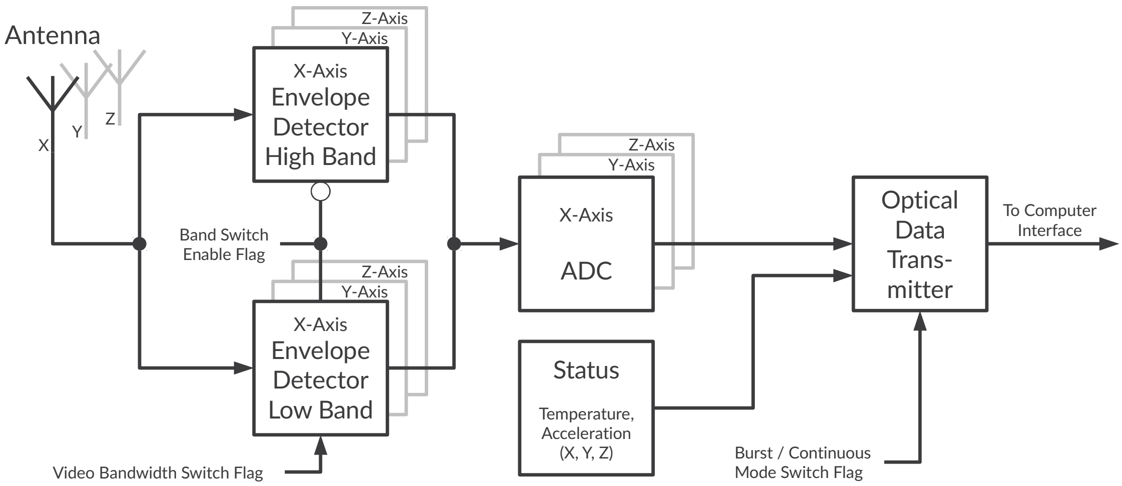


Figure 7: *LSProbe 1.2 E-Field Probe block diagram*

Figure 7 shows a simplified block diagram of the LSProbe 1.2 E-field probe. Three short monopole antennas are used to detect x-, y- and z-axis electrical fields over a wide range of frequencies and field strengths. Each axis has got one dedicated low-band and one dedicated high-band logarithmic field strength detector, of which one is selectable at a time using a mode flag (see Table 1). The low-band stretches from 10 Hz to 400 MHz, the high-band from 30 MHz to 8.2 GHz.

For each axis a 14 bit analog-to-digital converter (ADC) is used to digitize the detected signal level. A mode flag is used to select either 500 kSamples/s continuous sampling, 2 MSamples/s burst mode sampling or 2 MSamples/s y-axis continuous sampling. In burst mode each burst frame contains 597 x-, y- and z-axis field strength values, the E-field probe sends 1000 burst frames per second.

The E-field probe's optical data transmitter combines field strength values, acceleration, temperature and voltage values and additional status information to form a digital, checksum-protected optical data stream.

The 1.2 E-field probe offers up to eight[1] modes. Each mode is characterized by a specific frequency range, video bandwidth, sampling rate, sample timing and axis selection as listed in Table 1.

Table 1: *LSProbe 1.2 E-field probe measurement modes overview*

Mode	Minimum Frequency	Maximum Frequency	Video Bandwidth	Sampling Rate	Effective Sampling Rate	Sample Timing
0	30 MHz	8.2 GHz[1]	2 MHz	500 kS/s	500 kS/s	continuous
1	9 kHz[3] 30 MHz[4]	29.$\overline{9}$ MHz[4] 8.2 GHz[2]	500 Hz 2 MHz	500 kS/s	80 kS/s	continuous, interleaved
2	9 kHz[2]	400 MHz	0.5 MHz	500 kS/s	500 kS/s	continuous
3	9 kHz[2]	400 MHz	500 Hz	500 kS/s	500 kS/s	continuous
4	30 MHz	8.2 GHz[3]	2 MHz	2 MS/s	597 kS/s	burst
5	9 kHz[3] 30 MHz[4]	29.$\overline{9}$ MHz[4] 8.2 GHz[4]	500 Hz 2 MHz	2 MS/s	91 kS/s	burst, interleaved
6	9 kHz[2]	400 MHz	0.5 MHz	2 MS/s	597 kS/s	burst
7	9 kHz[2]	400 MHz	500 Hz	2 MS/s	597 kS/s	burst
8	30 MHz	8.2 GHz[5]	2 MHz	2 MS/s	2 MS/s	cont. y-axis

In modes 0, 4 and 8 only the high band detector is active. In modes 2, 3, 6 and 7 only the low band detector is active. In modes 1 and 5 the high band and low band detectors are active in an interleaved fashion. Consequently, modes 0, 2, 3, 4, 6, 7 and 8 offer the largest number of samples per second but require a mode change to cover all operating frequencies. Modes 1 and 5 span the E-field probe's entire frequency range but offer fewer samples per second.

When using SCPI commands or third party EMC software, special care must be taken to ensure an appropriate mode setting and low-pass filtering for the measurement task at hand.

[1] LSProbe 1.2 units delivered before February 2017 have six modes and do not support modes 1 and 5. LSProbe 1.2 units delivered before October 2020 do not support mode 8. Variant F does not support modes 1 and 5 because detectors are switched too quickly for the low band detector's settling time.

[2] Variant F 10 Hz–200 MHz

[3] Modes 1 and 5 not supported for Variant F

[4] Transition frequency from low to high band detector adjustable via SCPI command »:SYSTem:LHFrequency <Frequency>[,<MProbe>]«

3.1.2 LSProbe 1.4 E-Field Probe

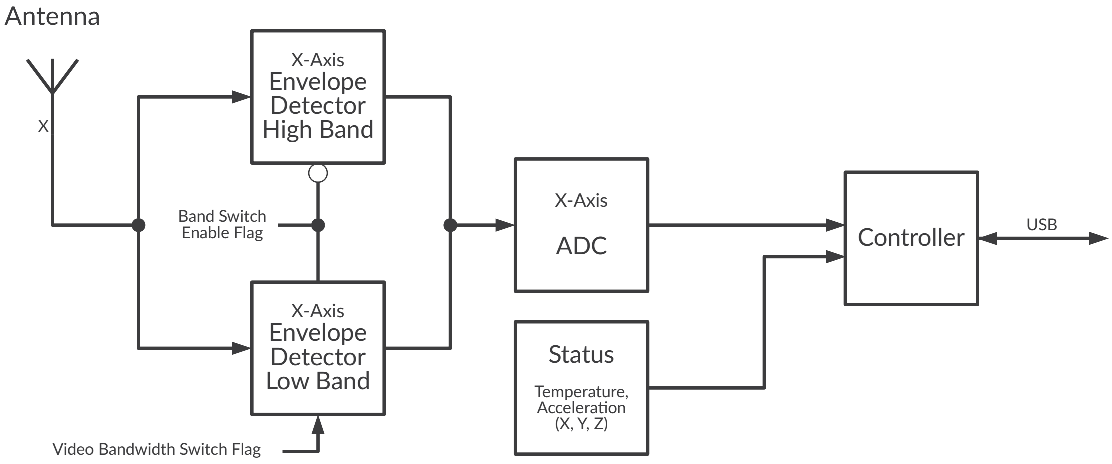


Figure 8: *LSProbe 1.4 E-Field Probe block diagram*

Figure 8 shows a simplified block diagram of the LSProbe 1.4 E-field probe. A single short monopole antenna is used to detect x-axis electrical field over a wide range of frequencies and field strengths. It has got one dedicated low-band and one dedicated high-band logarithmic field strength detector, of which one is selectable at a time using a mode flag (see Table 2). The low-band stretches from 9 kHz to 400 MHz, the high-band from 30 MHz to 8.2 GHz.

For the x-axis a 14 bit analog-to-digital converter (ADC) is used to digitize the detected signal level. The E-field probe's data transmitter combines field strength values, acceleration, temperature and voltage values and additional status information to form a digital, checksum-protected data stream.

The 1.4 E-field probe offers up to four modes. Each mode is characterized by a specific frequency range and video bandwidth, with a continuous sampling rate of 2 MSamples/s as listed in Table 2. In mode 0 only the high band detector is active. In modes 2 and 3 only the low band detector is active. In mode 1 the appropriate detector is chosen by the software according to the set frequency. Mode 1 spans the field probe's entire frequency range. The crossover frequency between the two detectors can be changed via the SCPI command »:SYSTem:LHFrequency <Frequency>[,<MProbe>]«.

When using SCPI commands or third party EMC software, special care must be taken to ensure an appropriate mode setting and low-pass filtering for the measurement task at hand.

3.1.3 LSProbe 2.0 E-Field Probe

Figure 9 shows a simplified block diagram of the LSProbe 2.0 E-field probe. Six short monopole antennas are used to detect electrical fields using the x_a, y_a, z_a, x_b, y_b and z_b antennas over a wide range of frequencies and field strengths.

Each a–axis has got one dedicated low-band and one dedicated high-band logarithmic field strength detector, of which one is selectable at a time using a mode flag (see Table 3). For the b–axes, only a

Table 2: *LSProbe 1.4 E-field probe measurement modes overview*

Mode	Minimum Frequency	Maximum Frequency	Video Bandwidth	Sampling Rate	Effective Sampling Rate	Sample Timing
0	30 MHz	8.2 GHz	2 MHz	2 MS/s	2 MS/s	continuous
1	9 kHz 30 MHz	$29.\overline{9}$ MHz[4] 8.2 GHz	500 Hz 2 MHz	2 MS/s	2 MS/s	continuous
2	9 kHz	400 MHz	0.5 MHz	2 MS/s	2 MS/s	continuous
3	9 kHz	400 MHz	500 Hz	2 MS/s	2 MS/s	continuous

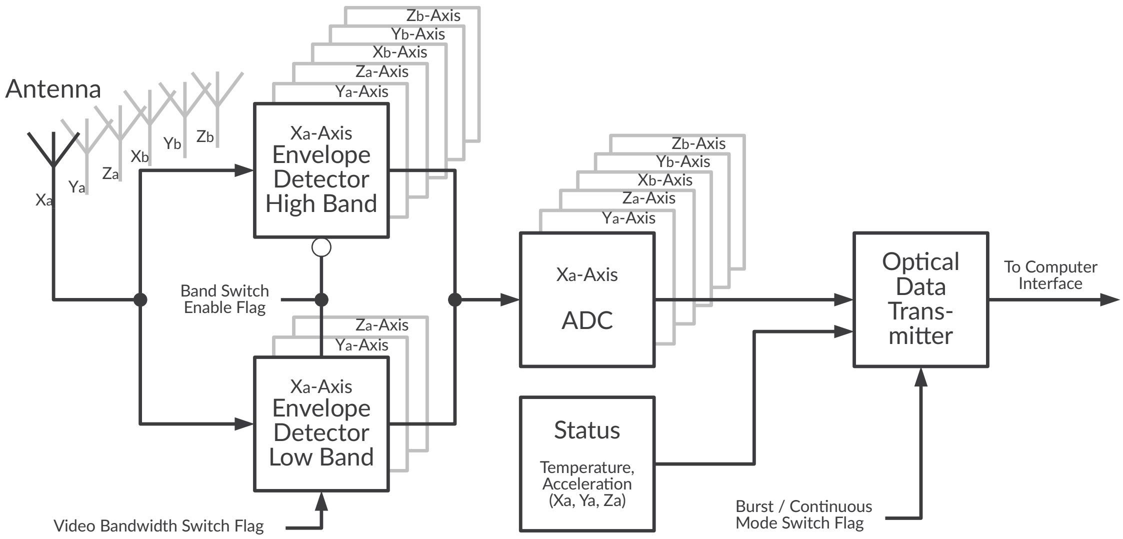


Figure 9: *LSProbe 2.0 E-Field Probe block diagram*

high -band detector is used for improved isotropy at high frequencies. The low-band stretches from 9 kHz to 1 GHz, the high-band from 700 MHz to 18 GHz.

For each axis a 14 bit analog-to-digital converter (ADC) is used to digitize the detected signal level. A mode flag is used to select either 500 kSamples/s continuous sampling, 2 MSamples/s burst mode sampling or 1 MSamples/s y-axis continuous sampling. In burst mode each burst frame contains 298 x-, y- and z-axis field strength values, the E-field probe sends 1000 burst frames per second.

The E-field probe's optical data transmitter combines field strength values, acceleration, temperature and voltage values and additional status information to form a digital, checksum-protected optical data stream.

The LSProbe 2.0 E-field probe offers up to seven[7] modes. Each mode is characterized by a specific frequency range, video bandwidth, sampling rate, sample timing and axis selection as listed in Table 3.

Table 3: *LSProbe 2.0 E-field probe measurement modes overview*

Mode	Minimum Frequency	Maximum Frequency	Video Bandwidth	Sampling Rate	Effective Sampling Rate	Sample Timing
0	700 MHz	26.5 GHz[8,9]	50 MHz	500 kS/s	500 kS/s	continuous
1	9 kHz 700 MHz[6]	$699.\overline{9}$ MHz[6] 26.5 GHz[8,9]	175 Hz 50 MHz	500 kS/s	44 kS/s	continuous, interleaved
2	9 kHz	1 GHz	230 kHz	500 kS/s	500 kS/s	continuous
3	9 kHz	1 GHz	175 Hz	500 kS/s	500 kS/s	continuous
4	700 MHz	26.5 GHz[8,9]	50 MHz	2 MS/s	298 kS/s	burst
8	700 MHz	26.5 GHz[8,9]	50 MHz	1 MS/s	1 MS/s	cont. y-axis
9[7]	700 MHz	26.5 GHz[8,9]	50 MHz	2 MS/s	2 MS/s	cont. ya-axis

In modes 0, 4, 8 and 9 only the high band detector is active. In modes 2 and 3 only the low band detector is active. In mode 1 the high band and low band detectors are active in an interleaved fashion. Consequently, modes 0, 2, 3, 4, 8 and 9 offer the largest number of samples per second but require a mode change to cover all operating frequencies. Mode 1 spans the E-field probe's entire frequency range but offers fewer samples per second.

When using SCPI commands or third party EMC software, special care must be taken to ensure an appropriate mode setting and low-pass filtering for the measurement task at hand.

3.1.4 Video Bandwidth Considerations

E-field probe video bandwidth is defined as the -3 dB cut-off frequency of the first order low pass filter operating on the envelope of each logarithmic field strength detector. For accurate operation the detected frequency should be at least ten times larger than the video bandwidth. The LSProbe 1.2/2.0 low-band detector offers a choice between low and high video bandwidth. I.e., approximately 500 Hz/500 kHz for LSProbe 1.2 and 175 Hz/230 kHz for LSProbe 2.0 E-field probes. The low-band detector video bandwidth is selectable using a mode flag (see Table 1/3). The LSProbe 1.2/2.0 high-band detectors have a fixed video bandwidth of approximately 2 MHz/50 MHz.

As highlighted in Figure 10/11, most applications are covered by modes 0, 1, 3, 4 and 8. Combinations of other field probe modes and frequencies require software-based low-pass filtering of RSSI values in order to guarantee aliasing-free measurement values. E.g., mode 2 of LSProbe 1.2 has a

[6] Transition frequency from low to high band detector adjustable via SCPI command »:SYSTem:LHFrequency <Frequency>[,<MProbe>]«

[7] LSProbe 2.0 units delivered before April 2024 do not support mode 9.

[8] LSProbe 2.0 Variant A with reduced dynamic range above 18 GHz.

[9] LSProbe 2.0 units delivered before August 2025 up to 18 GHz.

video bandwidth of 0.5 MHz and will only yield sufficiently ripple-free results for frequencies larger than 10 MHz. In this case lower frequencies cannot be measured reliably without further measures.

For this reason, the LUMILOOP TCP Server supports software-based video bandwidth reduction, which will be applied automatically when needed. Figure 10 summarizes the supported operating modes, frequencies, sampling rates and variants for LSProbe 1.2, Figure 11 does the same for LSProbe 2.0. For LSProbe 1.2 Variant F, software-based video bandwidth reduction is always applied below 9 kHz. Bandwidth reduction is also required in mode 2 when operating below the excluded frequency range. The excluded frequency range for the LSProbe 1.2 is 200 kHz to 10 MHz for mode 2 and 800 kHz to 10 MHz for mode 6. For the LSProbe 2.0 excluded frequency range is 200 kHz to 3 MHz for mode 2 and 800 kHz to 3 MHz for mode 6.

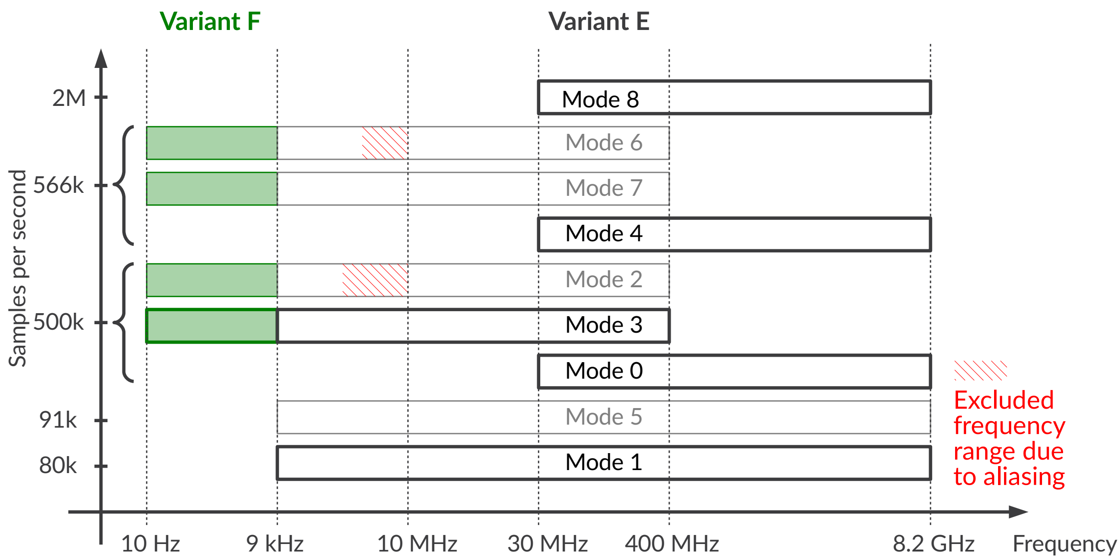


Figure 10: *Operating modes versus frequency and sampling rate for different LSProbe 1.2 variants*

3.1.5 CI-250$^{(+)}$ Computer Interface

The CI-250$^{(+)}$ Computer Interface connects the E-field probe to a host computer. It contains:

- a supply laser powering and transmitting data to the E-field probe,
- a thermoelectric temperature controller for cooling or heating the supply laser,
- an optical receiver for E-field probe data,
- a BNC trigger input/output connector for synchronization,
- an RJ45 trigger input/output connector for synchronization and
- a USB 2.0 interface connecting to the host computer.

As shown in Figure 12 the main switch is located on the left side of the front panel. In "0" position, it disconnects the computer interface's external 5 V supply. The right side of the front panel is occupied

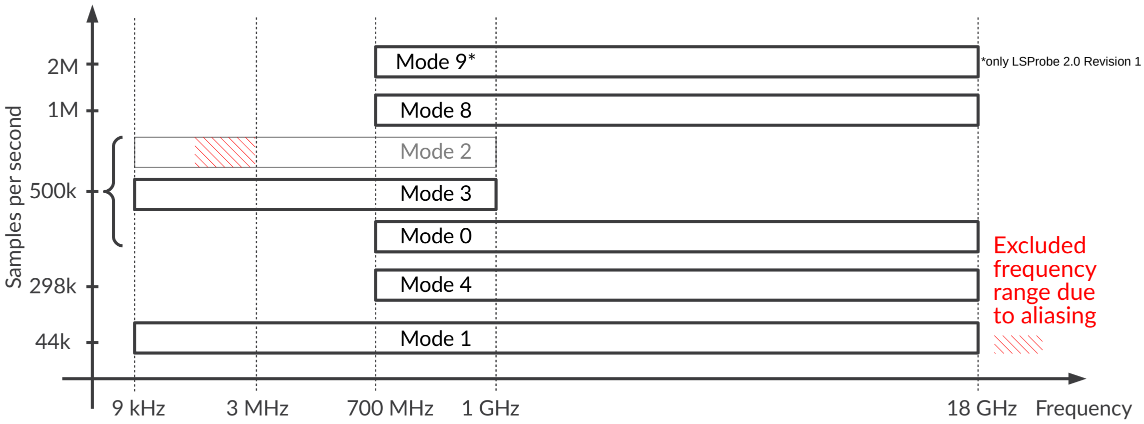


Figure 11: *Operating modes versus frequency and sampling rate for LSProbe 2.0*

by the air outlet of the laser temperature controller and must not be obstructed. Four labeled LED indicators display the CI-250(+) Computer Interface's operating state as follows:

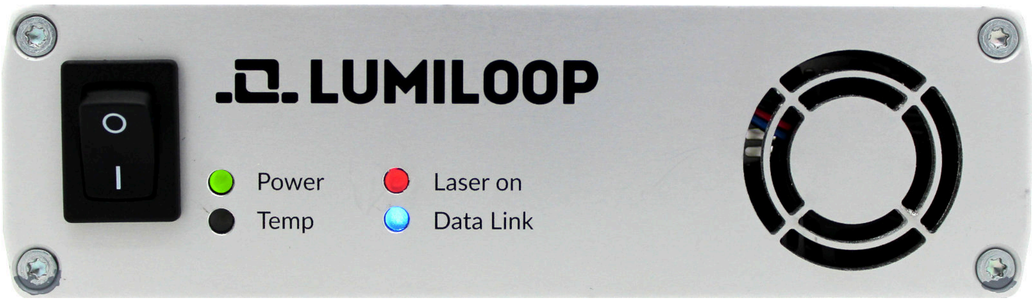


Figure 12: *CI-250 front panel*

Power (green)

Flashing
Main switch is on, computer interface is inactive.

Continuously on
USB connection to LUMILOOP TCP Server has been established.

Continuously off
Main switch is off, power supply is disconnected or computer interface firmware is missing or compromised, see Section 5.2.1 for details.

Temp (red)

Continuously off
Temperature of the supply laser is being controlled within the laser's safe operating range.

Continuously on
Temperature of the laser is above its safe operating range, laser is being cooled.

Flashing
Temperature of the laser is below its safe operating range, laser is being heated.

Laser on (orange)

Continuously off
The supply laser is off.

Flashing
The supply laser is on, the E-field probe is in start-up or mode change operation. The rapid laser shutdown safety function has been deactivated temporarily. **The optical cables must not be disconnected in this state.**

Continuously on
The supply laser is on, the E-field probe is operating in the requested mode. The rapid laser shutdown safety function is operational.

Data Link (blue)

Continuously off
No data is being received from the E-field probe.

Flashing
The optical data and power link has failed and the supply laser has been turned off.

Continuously on
Data is being received from the E-field probe.

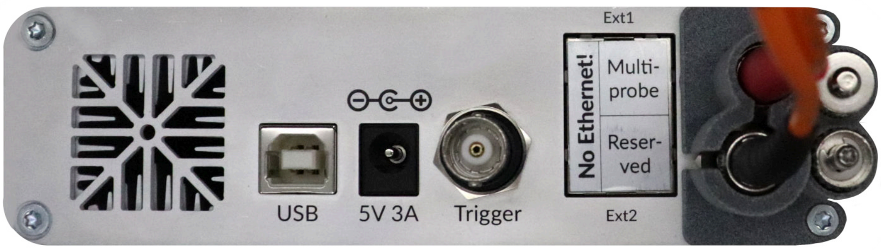


Figure 13: *CI-250 back panel*

The CI-250$^{(+)}$ Computer Interface's back panel shown in Figure 13 contains the air inlet of the laser temperature controller and must not be obstructed.

Optical connectors are located on the right side of the back panel. ***When the optical fibers are disconnected, connectors must be covered with the supplied dust caps as shown in Figure 13.*** The upper FC connector is the supply laser output. The lower ST connector is the optical data input.

The following electrical connectors are located at the bottom edge of the back panel, left to right:

USB
USB B connector attaching the computer interface to the host computer.

5 V 3 A
: External DC power supply, barrel jack 2.1/5.5 mm.

Trigger
: Trigger input/output BNC connector using 5 V CMOS logic levels.

Ext 1
: RJ45 extension connector for Multiprobe Systems. ***No Ethernet interface!***

Ext 2
: RJ45 connector for LSPM x.1 ID. ***No Ethernet interface, do not connect!***

The CI-250$^{(+)}$ Computer Interface can be used to connect an LSProbe 1.2/2.0 E-field probe or an LSPM 1.1/2.1 power measurement head to the host computer. In order to distinguish between the two, an LSPM x.1 ID as depicted in Figure 14 is used. The LUMILOOP TCP Server will enumerate the connected CI-250 device as an optically supplied power meter system, if an LSPM x.1 ID is connected to the EXT2 jack of a CI-250$^{(+)}$ Computer Interface. Otherwise, the TCP-Server will treat the connected system as a field probe system.

Figure 14: *LSPM x.1 Identifier (ID).*

3.2 Trigger Inputs and Outputs

The CI-250$^{(+)}$ device features two independent trigger inputs and outputs. The BNC connector on the back of the CI-250$^{(+)}$ device uses a single-ended 5 V CMOS logic trigger signal. Figures 15 and 16 show the basic point-to-point setup for using an external device as either trigger target or trigger source. The external device can be another CI-250$^{(+)}$ device or an electrically compatible third-party device.

The Ext1 RJ45 socket on the back of the CI-250$^{(+)}$ device uses a differential 3.3 V CMOS logic trigger signal. This signal can be used to exchange trigger signals in a Multidevice setup containing two or more CI-250$^{(+)}$ devices as shown in Figure 17. When an LSFrame 1.0 Product Integration Frame - Basic is used, all CI-250$^{(+)}$ devices can plug into the former dedicated differential logic lines. The Ext1 RJ45 sockets are not recommended for use with third-party devices.

Figure 15: *External trigger output using BNC connector*

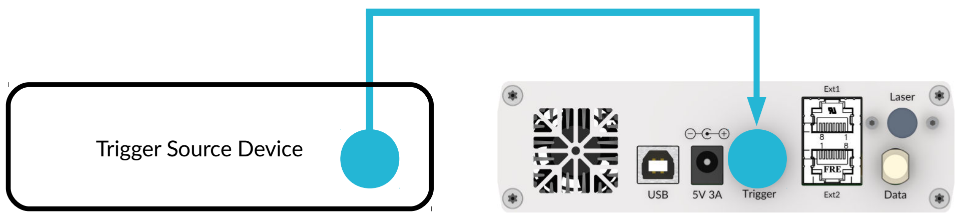


Figure 16: *External trigger input using BNC connector*

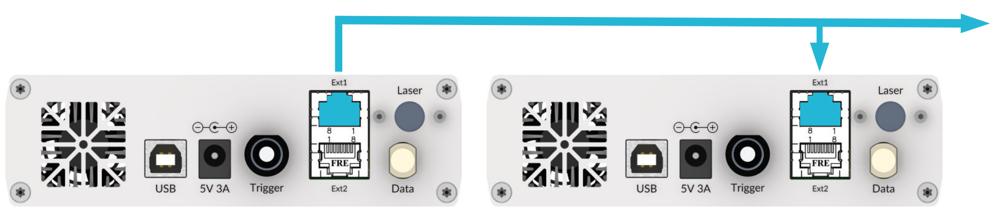


Figure 17: *External trigger input and output using Ext1 RJ45 sockets*

3.3 Multi Device Systems - Systems with multiple LSProbe and/or LSPM devices

Synchronized continuous statistics for Multi Device Systems containing one or multiple LSProbe 1.2/2.0 and/or LSPM 1.0/2.0/1.1/2.1 devices require a hardware link via the "Ext 1" extension connector of every computer interface and power meter. If a systems with two devices is to be used, a straight shielded RJ45 (EIA/TIA 568) patch cable is sufficient, see Figure 18.

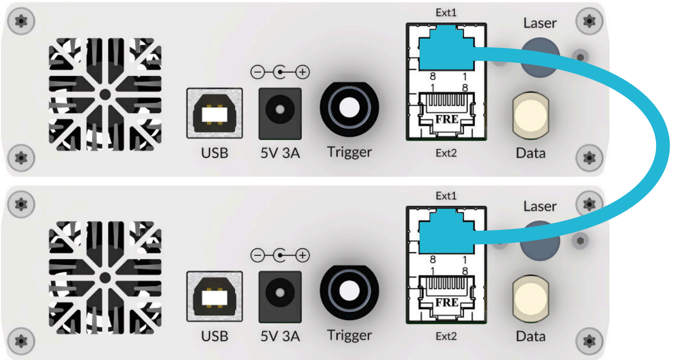


Figure 18: *Multiprobe connection for two CI-250 devices, two LSPM 1.0/2.0 devices, one LSPM 1.0/2.0 and CI-250 device.*

For larger Multi Device Systems, an LSFrame 1.0 Product Integration Frame - Basic as shown in Figure 20, connects to each CI-250$^{(+)}$ Computer Interface and LSPM 1.0/2.0. Note that the barrel plug patch cables used for supplying the devices via the LSFrame 1.0 Product Integration Frame - Basic are not shown.

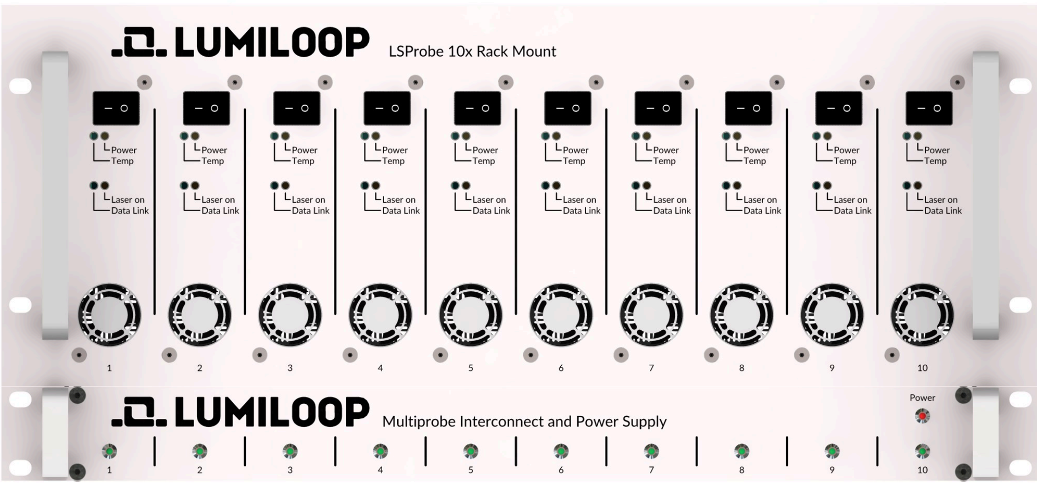


Figure 19: *LSFrame 1.0 Product Integration Frame - Basic with ten CI-250 Computer Interfaces*

In a Multi Device System continuous statistic can be realised in a synchonized or not synchronized fashion. For unsynchronized operation the **statistics sync** state of each device device has to be set to software using the SCPI command »:STATistics:MAster <State>[,<MProbe>]«. For synchronized

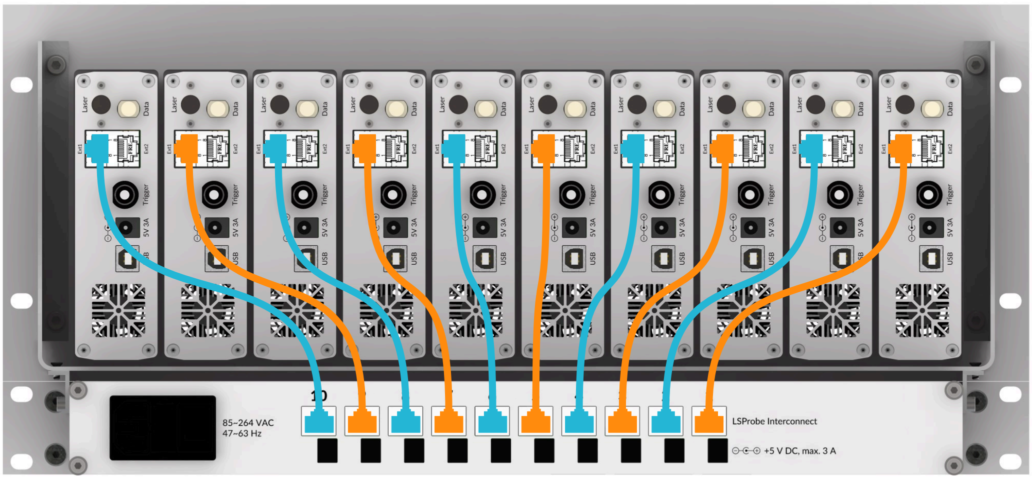


Figure 20: *Multi Device connections for nine CI-250$^{(+)}$ Computer Interfaces and one LSPM 1.0/2.0*

operation one CI-250$^{(+)}$ Computer Interface or LSPM 1.0/2.0 is configured as the statistics master, all other devices have to be configured as slaves. In this case the Multi Device master controls continuous statistics collection via dedicated enable and snapshot lines. The hardware link also carries lines indicating the master/slave status of each computer interface or LSPM 1.0/2.0 in a Multi Device System. As shown in Figure 19 there are dedicated indicator LEDs on the LSFrame 1.0 Product Integration Frame - Basic. The master is indicated by a flashing LED. Multi Device slaves' LEDs are on continuously if the statistics collection is turned on. Continuously off LEDs indicate that statistics collection is off. In case of unsynchronzied continuous statistic, all LEDs are permanentely off.

Please note that special care must be taken if multiple LSPM and LSProbe devices are connected to a host computer. The USB data rate for each of the respective devices is as follows:

- LSProbe 1.2: 3.5 MByte/s
- LSProbe 2.0: 6.5 MByte/s
- LSPM 1.0/2.0: 13 MByte/s
- LSPM 1.1/2.1: 6.5 MByte/s

As the practical maximum data transfer rate for each USB 2.0 root hub is 30 to 40 MB/s, only 3 LSPM devices, 8 LSProbe 1.2 devices or 6 LSProbe 2.0 devices should be connected to the same root hub.

4 LUMILOOP Software

4.1 LUMILOOP TCP Server and GUI Installation

The LUMILOOP software fully supports Windows 7 and later versions. On Windows XP and Windows 2000 systems only the LUMILOOP TCP Server can be used together with third party software. Stand alone devices CI-250^{+} and LSPM 1.0^{+}/2.0^{+} are delivered with the LUMILOOP TCP Server and LUMILOOP GUI already installed. Please refer to Section 6 for instructions on using and updating the Software.

The LUMILOOP installer handles the installation of the software for all LSProbe and LSPM devices. Software installation consists of the following steps:

1. Run the LUMILOOP installer. Follow the displayed installation instructions carefully. When asked for permissions for driver installation grant the permissions, this is required for serial protocol emulation as described in Section 8 on page 132.
2. Copy the supplied calibration data into the `lsprobe` subdirectory of the calibration directory selected during LUMILOOP TCP server and GUI installation, e.g., if the calibration data directory is `C:\Program Files (x86)\LUMILOOP\cal` and the serial number of the LSProbe 2.0 is `42`, please copy the whole directory named `2v0sn42` from the installation medium into the `cal\lsprobe` directory. Repeat the procedure for all LSProbe 1.2/2.0 connected to the host computer. For convenience, in case of updating an existing LSProbe and/or LSPM software installation, the installer will ask for permission to copy existing calibration data to the new installation directory.

The installation path of the LUMILOOP software is stored in a system-wide environment variable named `LUMILOOP_PATH` which is set during software installation. The installation path contains subdirectories named `bin`, `cal`, `doc` and `lib`. All executable files are stored in the `bin` sub-directory.

The `bin` sub-directory also contains the default LUMILOOP TCP Server and GUI configuration file named `LUMILOOP.ini`. Upon first-time start of either LUMILOOP TCP Server or LUMILOOP GUI the default `LUMILOOP.ini` will be copied to the user's `LOCALAPPDATA` path, i.e., each user using the LUMILOOP software gets their own `LUMILOOP.ini` file. All changes in the LUMILOOP TCP Server or LUMILOOP GUI setup will be saved only to the respective user's ini-file.

`LUMILOOP.ini` contains the following sections:

`MAIN`

`CAL_PATH`
: Defines the directory containing the calibration data subdirectories `\lsprobe` and `\lspm` for all installed devices, set during installation. This setting is only used during (re-) installation.

`SAVE_PATH`
: Defines the directory that saved files will be stored in. This setting is used by the LUMILOOP TCP Server and the LUMILOOP GUI, the default value is the path of the LUMILOOP TCP Server and LUMILOOP GUI.

`UPDATE_CHECK`
: Enable or disable checking for software updates on the LUMILOOP homepage when the LUMILOOP GUI is run. This setting is used by the LUMILOOP GUI only. If set to "1" update checking is enabled, if the variable is set to "0" update checking is disabled, the latter is the default.

`TIMEOUT_DIALOG`
: Enable or Disable the Laser Timeout Dialog. This setting is used by the LUMILOOP TCP Server and the Laser Timeout Dialog. If set to "1" the TimeoutDialog GUI will be started when a timeout error occurs, this is the default state. If the variable is set to "0", the Laser Timeout Dialog will not be started automatically.

`REGISTER_DIALOG`
: Enable or Disable the product registration dialog. This setting is used by the LUMILOOP TCP Server. If set to "1" the dialog will be opened after the start of the TCP Server. If the variable is set to "0", the dialog will not be started.

`LSProbe TCP Server`
: This section is used by the LUMILOOP TCP Server only.

`PORT`
: Defines the TCP port number of the LUMILOOP TCP Server for all LSProbe devices. This value is set during installation. The default value is 10,000.

`COM_PORT`
: Defines the minimum COM port number for Serial Port Protocol Emulation. The value is set during installation. This setting is used by the LUMILOOP TCP Server during operation of a field probe in mode 1, the default value is COM10. A value of "0" disables the Serial Port Protocol Emulation in mode 1.

`CAL_PATH`
: Defines the directory containing the calibration data sub-directories for all E-field probes. The default value is the `cal/lsprobe` directory of the LUMILOOP TCP Server.

`SAVE_PATH`
: Defines the directory that saved files of the LUMILOOP TCP Server for LSProbe devices will be stored in. This setting is optional. The default value is the path set in the `MAIN` section of the `INI` file.

`LEGACY_IDN`
: Disable or enable the old LSProbe 1.2 TCP Server identification string. This setting is intended for third party software depending on the return string of the »*IDN?« SCPI-command. If set to "0" the new identification syntax "Lumiloop,LSProbe,1.x/2.x,..." is returned. If the variable is set to "1", the old identification string "Lumiloop,LSProbe,1.2,..." will be returned, the former is the default.

`LSPM TCP Server`
: This section is used by the LUMILOOP TCP Server only.

`PORT`

Defines the TCP port number of the LUMILOOP TCP Server for all LSPM devices. The default value is 10,001.

`CAL_PATH`

Defines the directory containing the calibration data sub-directories for all power meters. The default value is the `cal/lspm` directory of the LUMILOOP TCP Server.

`SAVE_PATH`

Defines the directory that saved files of the LUMILOOP TCP Server for LSPM devices will be stored in. This setting is optional. The default value is the path set in the `MAIN` section of the `INI` file.

`LEGACY_IDN`

Disable or enable the old LSPM 1.0 TCP Server identification string. This setting is intended for third party software depending on the return string of the »*IDN?« SCPI-command. If set to "0", the new identification syntax "LUMILOOP,LSPM,1.x/2.x,..." is returned. If the variable is set to "1", the old identification string syntax "Lumiloop,LSPM,1.0,..." will be returned, the former is the default.

`GUIConnectionX`

One or more `GUIConnection` sections are used by the LUMILOOP GUI to store connections settings to different LUMILOOP TCP Server. `X` is an integer number

`ENABLE`

Enable or disable the LUMILOOP TCP Server connection. If set to "1" the LUMILOOP GUI will try to (re-) establish a connection to the TCP Server given by the `HOST` and `PORT` settings below. If set to "0" the section is ignored.

`HOST`

Defines the host name or IP address of the computer running the TCP Server. The default value for the first and second connection is localhost.

`PORT`

Defines the TCP port number of the LUMILOOP TCP Server on the computer running the TCP Server. The default value for the first connection is the `PORT` setting in the `LSProbe TCP Server` section of the `INI` file. The default value for the second connection is the `PORT` setting in the `LSPM TCP Server` section of the `INI` file.

`GUI MProbe Configurations-NAME`

Configure Probe setups for different ISO-standards associated with the name NAME

`ISO_11451-2`

Comma separated list of LSProbe 1.2/1.4/2.0 serial number and version separated by a ":" defined for this name and ISO setup

`ISO_11452-11_/_IEC_61000-4-21`

Comma separated list of LSProbe 1.2/1.4/2.0 serial number and version separated by a ":" defined for this name and ISO setup

`ISO_11451-5`
Comma separated list of LSProbe 1.2/1.4/2.0 serial number and version separated by a ":"defined for this name and ISO setup

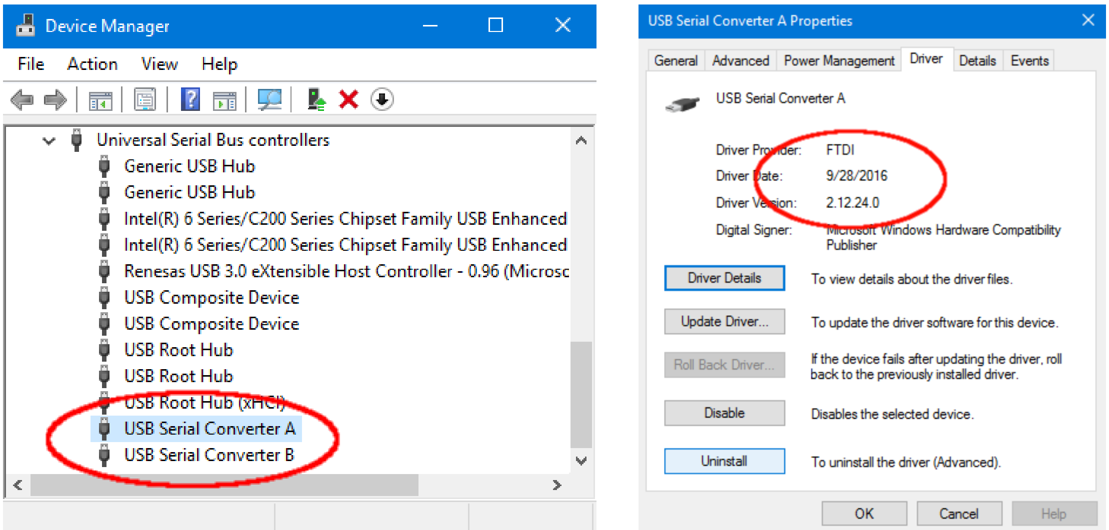
`GUI Plot Configurations`
Define plot configurations, for example background, foreground and plot colors, and line width. This section is used by the LUMILOOP GUI only for saving of specific plot configurations.

If the LUMILOOP TCP Server and LUMILOOP GUI are supposed to run on different host computers, the installer must be run on both systems.

4.2 USB Driver Installation

If the host computer has access to the online Microsoft Windows Update, the drivers should be installed automatically when a CI-250 device is connected and powered-up for the first time. Note that for normal operation no internet access is required.

After successful driver installation the Device Manager will list the CI-250 device as "USB Serial Converter A" and "USB Serial Converter B" as shown in Figure 21(a) and (b). Note that the device naming is generic and references neither LUMILOOP nor LSProbe. However, this does not affect the proper operation of the E-field probe.



(a) Device Manager USB device (b) Current FTDI USB driver version

Figure 21: *Correctly installed FTDI USB driver*

If the automated install fails, or if the host computer has no Internet connection, execute the FTDI USB driver installer `CDM v2.12.28 WHQL Certified.exe` contained in the LUMILOOP software installation path's `lib` directory as shown in Figure 22.

It is strongly advised to observe the following recommendations:

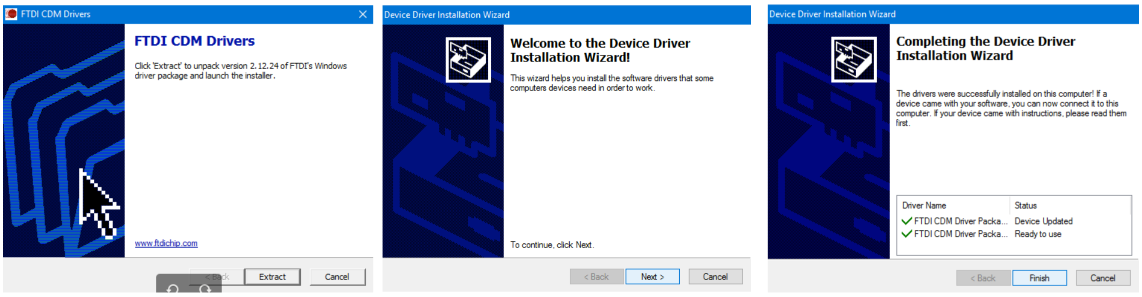
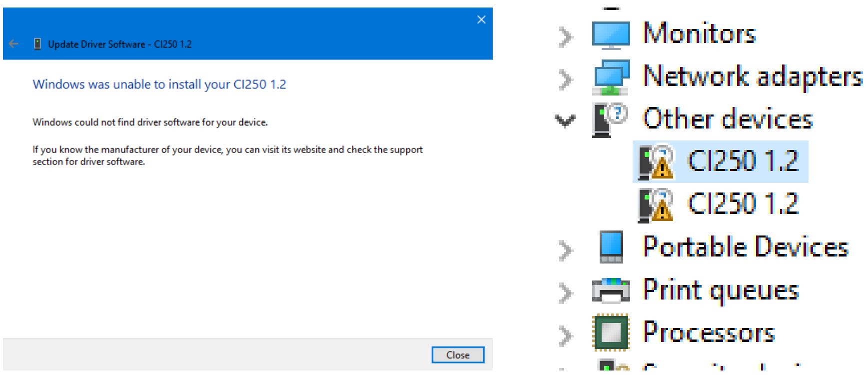


Figure 22: *Manual FTDI USB device driver installation*

- Plug the CI-250 device directly into the computer. Do not use a USB hub or docking station.
- Do not connect other high bandwidth USB devices to the same USB root hub. In rare cases this may reduce read performance significantly, resulting in unreliable operation and eventual loss of measurement data.
- Especially, do not operate the computer interface on a USB port where a USB graphics adapter is installed or was previously installed. The USB graphics driver may disturb communications even if the hardware is no longer attached.

4.2.1 Troubleshooting USB Driver Installation

If no CI-250 device and no other FTDI hardware have previously been connected to the computer and automatic Windows driver installation is deactivated or no Internet connection is available the error message shown in Figure 23(a) will be displayed. In this case the Device Manager's "Other devices" section will give an output similar to Figure 23(b), listing the CI-250 device's USB end points as unknown devices.



(a) Installation failure message (b) Device Manager output

Figure 23: *USB device driver failure messages*

Make sure that you are using the most recent FTDI USB driver. The driver version at the time of writing is 2.12.28. Using out-of-date USB drivers may result in improper operation.

Check the driver version by opening the Device Manager and extending the "USB-Controller" category. Right-click "USB Serial Converter A" and select "Properties". Open the "Driver" tab to view the FTDI USB driver version as shown in Figure 21(b). If an older version of the FTDI driver has been installed click on "Uninstall". In the following dialog, make sure to check "Uninstall the driver software for this device" as shown in Figure 24, failing to do so will prevent driver updates.

Make sure to repeat the uninstall process for all CI-250 devices using old FTDI USB driver versions. Note that the process must be executed for both "USB Serial Converter A" and "USB Serial Converter B" of every CI-250 device. Power-cycle each CI-250 device and repeat the installation procedure as described above in Section 4.2.

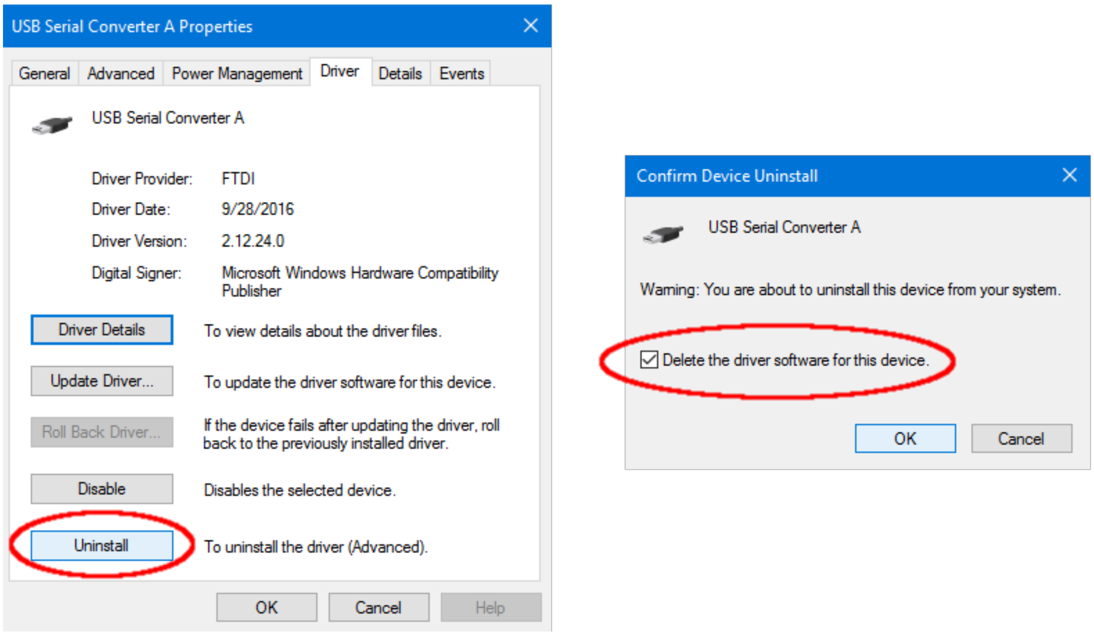


Figure 24: *Uninstalling the FTDI USB driver*

4.3 Silent Installation and Deinstallation

The LUMILOOP software is also capable of silent installation. Open a Windows Command Prompt window and pass the "/S" command to the LUMILOOP installer in the command line, as depicted in Figure 25. The installer will not display any dialogs or ask for user input. A custom ini-file with values deviating from the default settings can be passed to the installer by using the "/INI=" command followed by the complete path to the ini-file. Sections "[MAIN]", "[LSProbe TCP Server]" and "[LSPM TCP Server]" will be used to overwrite the default settings. The ini-file must be in the same format as the `LUMILOOP.ini`, detailed in Section 6.6. To change the default installation path, the "/D=" command followed by the desired path without quotes can be used. Alternatively, add an"INSTALL_DIR" key-value pair with the desired path to the "[MAIN]" section of the ini-file and use the afore mentioned "/INI" command.

The following optional command line parameters can be used for silent installation, to change the

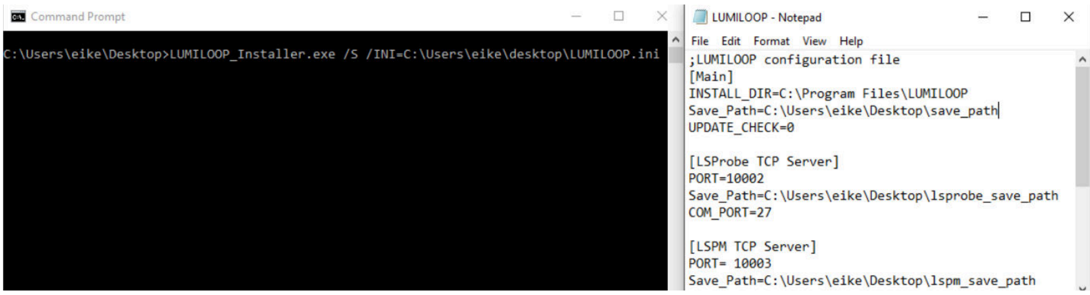


Figure 25: *Silent installation of the LUMILOOP software*

default settings. Configure the desired setting using the designated flag followed by a "=" and the setting without quotes, e.g. "/PORT_LSPROBE=10003" to change the port of the LSProbe TCP Server to "10,003".

`/D=<installation-path>`
: Set the installation path of the LUMILOOP software to `<installation-path>`. The default path is `C:\Program Files (x86)\LUMILOOP`.

`/INI=<installation-configuration-file-path>`
: Use the file pointed to by `<installation-configuration-file-path>` for user defined configurations during installation. The ini-file must be in the same format as the `LUMILOOP.ini` file, detailed in Section 6.6.

`/PORT_LSPROBE=<port>`
: Set the TCP port number of the LUMILOOP TCP Server for all LSProbe devices to `<port>`. The default value is 10,000.

`/PORT_LSPM=<port>`
: Set the TCP port number of the LUMILOOP TCP Server for all LSPM devices to `<port>`. The default value is 10,001.

`/CAL_PATH=<calibration-data-path>`
: Set the directory containing the calibration data subdirectories to `<calibration-data-path>`. Subdirectories `\lsprobe` and `\lspm` for the different device types will be automatically created.

`/SAVE_PATH=<save-path>`
: Set the directory that saved files will be stored in to `<save-path>`.

`/SAVE_PATH_LSPROBE=<save-path>`
: Set the directory that saved files of the LUMILOOP TCP Server for LSProbe devices will be stored in to `<save-path>`.

`/SAVE_PATH_LSPM=<save-path>`
: Set the directory that saved files of the LUMILOOP TCP Server for LSPM devices will be stored in to `<save-path>`.

`/UPDATE_CHECK=<0/1>`
: Enable or disable checking for software updates on the LUMILOOP homepage when the LUMILOOP GUI is run.

`/TIMEOUT_DIALOG=<0/1>`
: Enable or Disable the Laser Timeout Dialog.

`/REGISTER_DIALOG=<0/1>`
: Enable or Disable the product registration dialog.

If no parameters or ini-file is stated, the default settings will be used as stated in Section 6.6.

To uninstall the LUMILOOP software silently, the "/S" command must be passed to the uninstaller in the command line. The "uninstaller.exe" file is located in the `bin` sub-directory of the LUMILOOP installation path.

5 Measuring E-field

5.1 Getting Ready to Measure

5.1.1 Making Optical Connections

If the optical fibers have already been installed make sure that there is no apparent damage to the fibers and that there are no sharp bends or pinches. **Warning: Never switch the CI-250$^{(+)}$ Computer Interface on with no E-field probe being connected to it!**

Figure 26: *E2000 coupler of sacrificial optical cable assembly*

Sacrificial optical cables are supplied with each LSProbe 1.2/2.0 . Always use the E2000 connectors shown in Figure 68 for breaking and making the optical connection. The E2000 connectors of the sacrificial cable assembly include automatic shutters preventing contamination and resulting optical fiber burn-in. Nevertheless, all optical connectors must be kept in a perfectly clean condition at all times.

The principle of the sacrificial cable assembly is explained in Figure 27. In case of a fiber connector burn-in only **a pair** of sacrificial cables need to be replaced, allowing for rapid and cost-effective fault recovery without requiring external service.

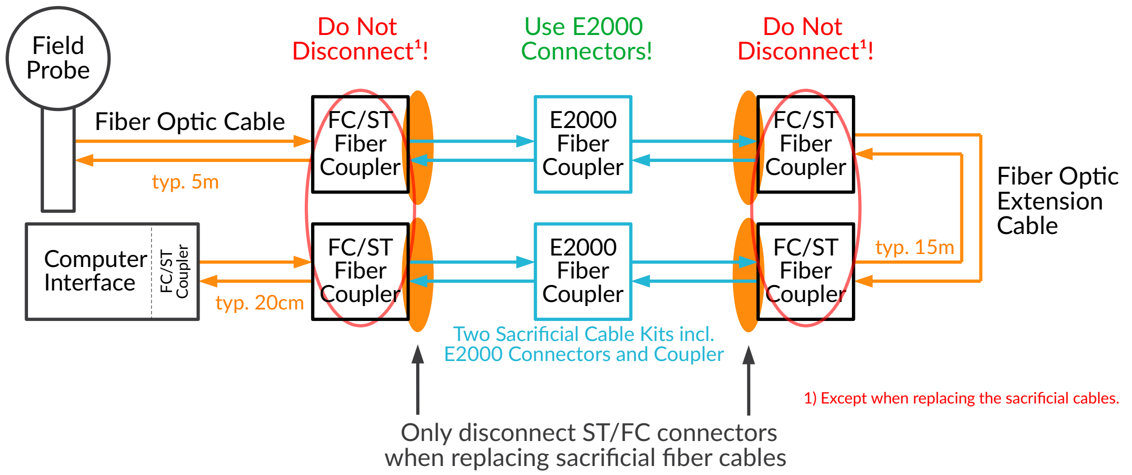


Figure 27: *Principle of sacrificial optical cable assembly*

For optical fiber installation using the ST/FC connectors, e.g., when replacing a pair of sacrificial cables, carefully follow the steps below for one optical fiber at a time, starting with the ST Data connector (black bend protection):

1. Remove the dust caps.
2. Check the ceramic ferrules, i.e., the white ceramic cylinder at the front of the fiber connector, for apparent damage.
3. Always clean the fiber connectors before plugging! This is essential for preventing dust-induced fiber burn-in. Use a lint-free tissue, moistened with isopropyl alcohol (IPA) or a fiber optic connector cleaner, and gently wipe the front surface of the ceramic ferrules.
4. Plug in the ST Data connector (black bend protection) and lock the bayonet nut connector.
5. Plug in the FC laser supply connector (red bend protection) and tighten its nut. Make sure that the connectors key slides into the corresponding notch, Figure 70 for the correct alignment.

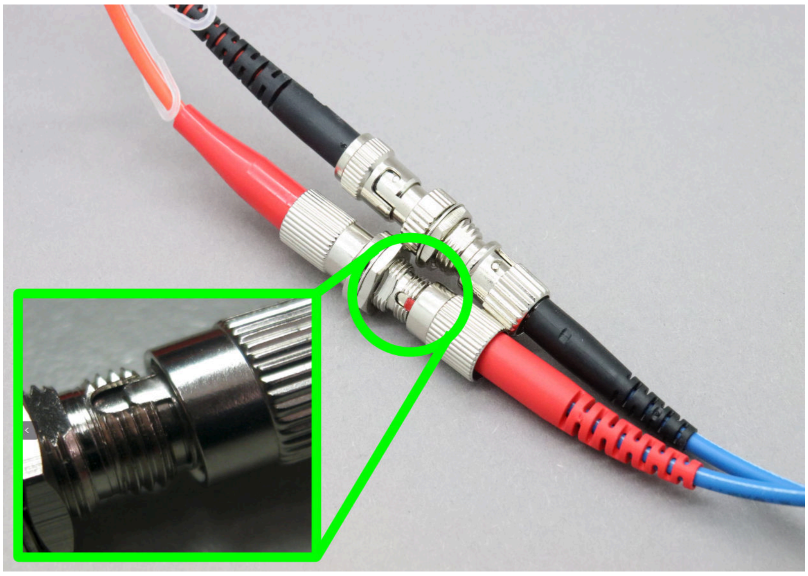


Figure 28: *FC fiber connector alignment*

When unplugging fiber optics, **always** place the supplied dust caps **immediately** on both the fiber cable connectors and the optical ports of the CI-250$^{(+)}$ Computer Interface. Purchasing a fiber optics cleaning kit is strongly recommended.

5.1.2 Making Electrical Connections

When installing the LUMILOOP LSProbe system for the first time make the following electrical connections:

1. Connect the supplied mains adapter.
2. Connect the CI-250 device to the host computer using the supplied USB cable.
3. Optionally connect the CI-250 device to any trigger sources or sinks via the BNC trigger connector.

Switch on the CI-250 device setting the front panel switch to “1” and observe the green power LED starting to flash.

5.2 E-Field Probe Start-Up and Mode Selection

5.2.1 Starting the LUMILOOP TCP Server

Carefully follow all instructions in the previous sections. Start the LUMILOOP TCP Server and ensure correct operation by verifying that the green power LED is constantly on and the LUMILOOP TCP Server has enumerated all connected CI-250 Computer Interfaces, listing their serial numbers similar to Figure 29. The LUMILOOP TCP Server will open inside a terminal window displaying status information, debugging output and error messages.

Upon start-up, the LUMILOOP TCP Server will display the set environment variable `LUMILOOP_PATH` pointing to the installation path, a tabular summary of the settings read from the configuration file concerning the LUMILOOP TCP Server and a tabular summary of all available LSProbe and LSPM calibration data.

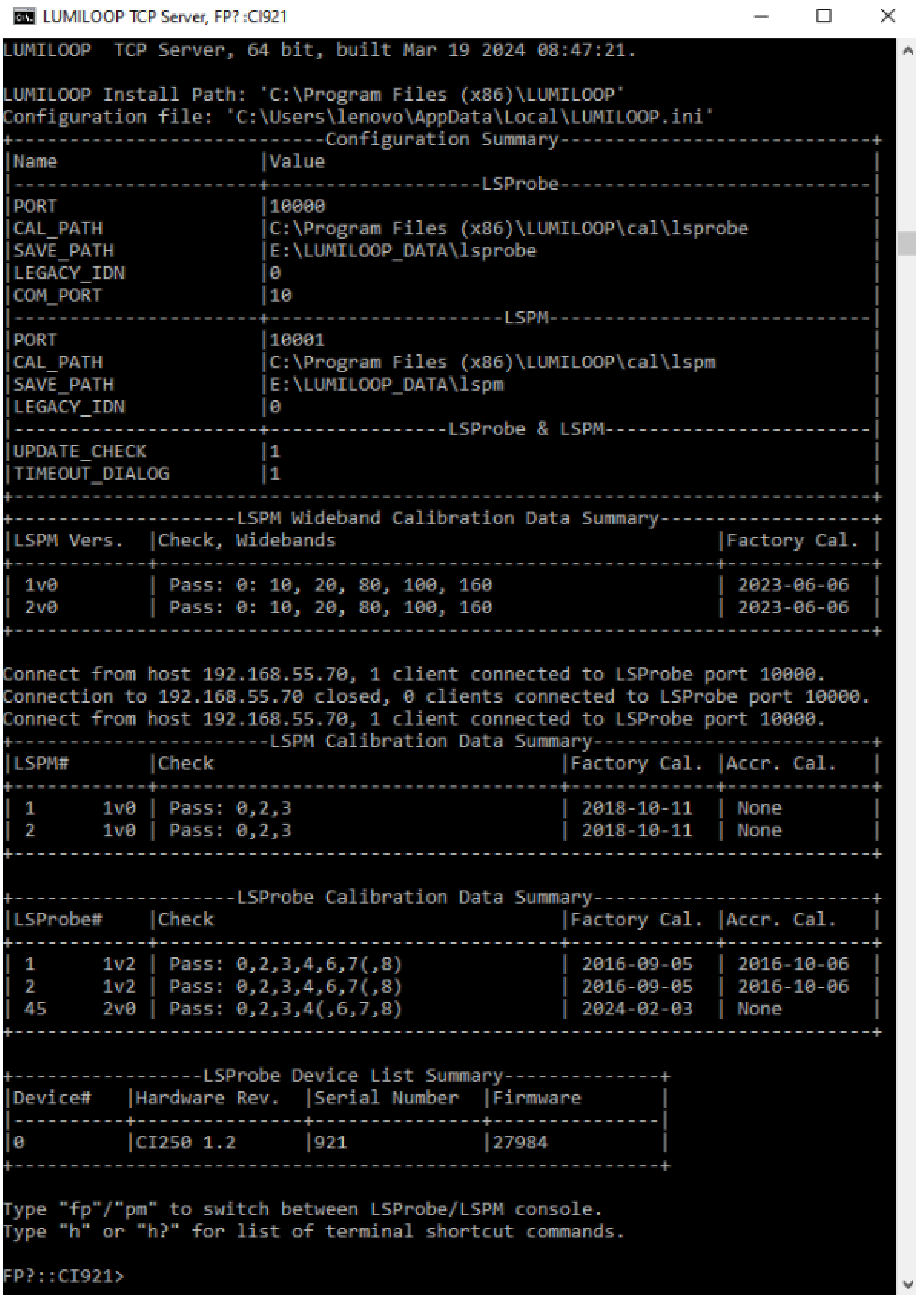
During device enumeration, the firmware of each CI-250$^{(+)}$ Computer Interface is loaded onto each device. The LUMILOOP TCP Server executable incorporates the current firmware image required for proper operation. After device enumeration the LUMILOOP TCP Server will list all detected CI-250 Computer Interfaces with their respective serial numbers and firmware revision numbers in the “LSProbe Device List Summary” table. If devices are added to or removed from the host computer after starting the LUMILOOP TCP Server, the server will detect these events, update the respective device's firmware and display an updated summary table. Re-enumeration may also be forced by sending an »*RST« SCPI command.

Since the LUMILOOP TCP Server needs to open a TCP port, the system's firewall may ask for permission for network access. Access must be granted to operate the LUMILOOP TCP Server (see Figure 30).

The LUMILOOP TCP Server is able to handle all connected LSProbe as well as LSPM devices. For backward compatibility and convenience of use, the LSProbe Field Probes and LSPM Power Meters are handled separately. Standard ports for accessing the LSProbe Field Probes is port 10000 and port 10001 for the LSPM Power Meters respectively. To modify the standart ports, please refer to Section 6.6.

5.2.2 Interacting with the LUMILOOP TCP Server

The LUMILOOP TCP Server can be used to execute SCPI commands interactively. As shown in Figure 29, it will display a command prompt indicating the serial numbers of the computer interface and E-field probe which SCPI commands are exchanged with. The prompt will change when a different computer interface is selected or when an LSProbe 1.2/2.0 E-field probe becomes operational. The same information can also be found in the title bar of the TCP Server terminal window.



```
LUMILOOP TCP Server, FP? :CI921
LUMILOOP  TCP Server, 64 bit, built Mar 19 2024 08:47:21.

LUMILOOP Install Path: 'C:\Program Files (x86)\LUMILOOP'
Configuration file: 'C:\Users\lenovo\AppData\Local\LUMILOOP.ini'
+---------------------------Configuration Summary----------------------------+
|Name                   |Value                                                |
|-----------------------+-----------------LSProbe----------------------------|
|PORT                   |10000                                                |
|CAL_PATH               |C:\Program Files (x86)\LUMILOOP\cal\lsprobe         |
|SAVE_PATH              |E:\LUMILOOP_DATA\lsprobe                             |
|LEGACY_IDN             |0                                                    |
|COM_PORT               |10                                                   |
|-----------------------+-------------------LSPM-----------------------------|
|PORT                   |10001                                                |
|CAL_PATH               |C:\Program Files (x86)\LUMILOOP\cal\lspm             |
|SAVE_PATH              |E:\LUMILOOP_DATA\lspm                                |
|LEGACY_IDN             |0                                                    |
|-----------------------+---------------LSProbe & LSPM-----------------------|
|UPDATE_CHECK           |1                                                    |
|TIMEOUT_DIALOG         |1                                                    |
+----------------------------------------------------------------------------+
+-------------------LSPM Wideband Calibration Data Summary-------------------+
|LSPM Vers.   |Check, Widebands                                 |Factory Cal. |
+-------------+-------------------------------------------------+------------+
| 1v0         | Pass: 0: 10, 20, 80, 100, 160                   | 2023-06-06  |
| 2v0         | Pass: 0: 10, 20, 80, 100, 160                   | 2023-06-06  |
+----------------------------------------------------------------------------+

Connect from host 192.168.55.70, 1 client connected to LSProbe port 10000.
Connection to 192.168.55.70 closed, 0 clients connected to LSProbe port 10000.
Connect from host 192.168.55.70, 1 client connected to LSProbe port 10000.
+----------------------LSPM Calibration Data Summary-------------------------+
|LSPM#        |Check                         |Factory Cal.  |Accr. Cal.      |
+-------------+------------------------------+--------------+----------------+
| 1      1v0  | Pass: 0,2,3                  | 2018-10-11   | None           |
| 2      1v0  | Pass: 0,2,3                  | 2018-10-11   | None           |
+----------------------------------------------------------------------------+

+-------------------LSProbe Calibration Data Summary-------------------------+
|LSProbe#     |Check                         |Factory Cal.  |Accr. Cal.      |
+-------------+------------------------------+--------------+----------------+
| 1      1v2  | Pass: 0,2,3,4,6,7(,8)        | 2016-09-05   | 2016-10-06     |
| 2      1v2  | Pass: 0,2,3,4,6,7(,8)        | 2016-09-05   | 2016-10-06     |
| 45     2v0  | Pass: 0,2,3,4(,6,7,8)        | 2024-02-03   | None           |
+----------------------------------------------------------------------------+

+----------------LSProbe Device List Summary--------------+
|Device#    |Hardware Rev.  |Serial Number  |Firmware      |
|-----------+---------------+---------------+--------------|
|0          |CI250 1.2      |921            |27984         |
+----------------------------------------------------------+

Type "fp"/"pm" to switch between LSProbe/LSPM console.
Type "h" or "h?" for list of terminal shortcut commands.

FP?::CI921>
```

Figure 29: *LUMILOOP TCP Server terminal window*

At any given time the console can communicate either with field probes or with power meters. The mode of communication is indicated by the prefix of the console's prompt. The "FP" prefix indicates that the console is in the field probe communication mode. The "PM" prefix indicates that the console is in the power meter communication mode. In order to switch from field probe mode to power meter mode and vice versa, one should use the "pm" and "fp" commands respectively.

If multiple power meters, or E-field probes are connected, select the active device with the SCPI com-

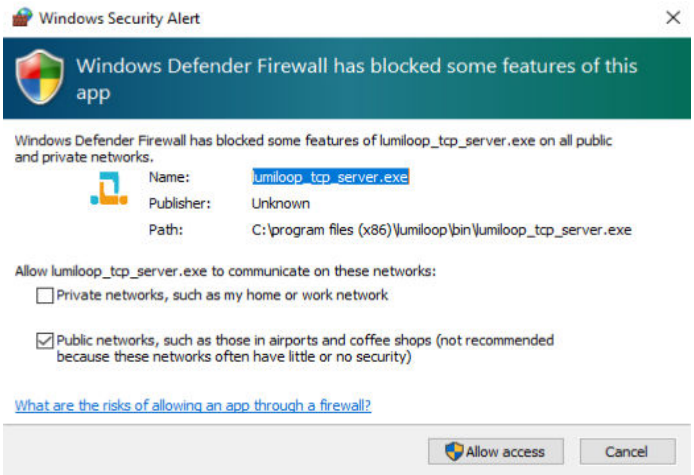


Figure 30: *Microsoft Windows Firewall requesting TCP port access permissions*

mand »:SYSTem:CISerial <Value>« for the LSProbe or LSPM 1.1/2.1 or »:SYSTem:SERial <Value>« for the LSProbe 1.4 or LSPM 1.0/2.0. The command prompts prefix will change when a different device is selected. If a Computer Interface with a field probe (without an LSPM x.1 ID) is connected to the computer running the LUMILOOP TCP Server, after start the prompt will be in field probe mode. Otherwise, the prompt will be in power meter mode.

Convenient short-cut commands such as »on« and »off« for enabling and disabling the laser supply of laser powered devices are available. Entering »h« will display a list of available shortcut commands. All shortcut commands, with the exception of the loop command, are executed for all enumerated devices.

The prompt features a basic command history that can be accessed, using the up and down cursor keys. The command history also includes SCPI commands issued in previous TCP Server sessions.

The command prompt can also be used for repeated execution of any SCPI command or shortcut command, e.g., polling queries. This can be achieved by entering »l«, i.e., lower case L, followed by an optional number of milliseconds, a space and a command. If the polling interval is omitted, a default value of 500 ms will be used. For example, the simple looped shortcut command »l e« can be used to query the field strength of all axes and the field strength magnitude every 500 ms of all enumerated devices. The x-axis field strength can be polled every 100 ms by entering »l100 :meas:x?«. Note that shortcut commands, polling and command history are not supported for TCP client connections.

5.2.3 General Notes on the LUMILOOP GUI

The LUMILOOP GUI has three modes of operation: Basic Mode, Table Mode and Expert Mode. It will always start in Basic Mode as shown in Figure 33. Table Mode as shown in Figure 34 can be set using the "Table GUI" button in the bar at the bottom of the Basic GUI or using the keyboard shortcut Ctrl+A. Expert Mode as shown in Figure 41 can be set using the "Expert GUI" button in the bar at the bottom of the Basic GUI or using the keyboard shortcut Ctrl+E. To switch back to Basic GUI Mode press Ctrl+E again or go to the “View” menu of the Expert GUI and select “Basic GUI Mode”.

The LUMILOOP GUI is intended as an easy to use demonstration software for all LSProbe capabilities. The LUMILOOP GUI is designed in such a way that it will not issue any configuration commands to the LUMILOOP TCP Servers unless the user changes a setting using one of the controls. This feature allows for running the LUMILOOP GUI in parallel with any third-party EMC software and observing all E-field probe settings and measurement results, which is especially useful during third party EMC software integration and function testing.

(a) Match

(b) Mismatch

Figure 31: *Frequency and Mode control for matching (a) and mismatching (b) TCP server and GUI settings*

When there is a mismatch between a setting of the LUMILOOP TCP Server and the expected setting of the GUI, the text of the control element will turn red. A black font color indicates that the GUI's settings are in sync with the TCP server. Figure 31 shows the behavior of the GUI for matching and mismatching frequency and mode settings.

The LUMILOOP GUI is able to communicate with multiple LSProbe and LSPM devices and multiple LUMILOOP TCP Server at the same time. For backward compatibility and convenience of use, the LUMILOOP TCP Server handles LSProbe Field Probes and LSPM power meter separately. Standard ports for accessing the LSProbe Field Probes is port 10000 and port 10001 for the LSPM Power Meters respectively. The default first two connections of the LUMILOOP GUI are set to the local LUMILOOP TCP Server on the same PC using the LSProbe port and LSPM port set during installation. To enable, disable, delete or add another connection, the “TCP Server Connections” dialog, as show in Figure 32, is used. It is opened via the “Connections” button on the left side of the bar at the bottom of the LUMILOOP GUI in Basic Mode, or in Expert GUI Mode via the “TCP Server Connections” item in the “Settings” menu. If a connection is enabled, the LUMILOOP GUI tries to connect to the respective LUMILOOP TCP Server until a connection can be established or the connection is disabled. If the LUMILOOP GUI tries to connect to a TCP Server which is too old, e.g. versions before November 2023, the LUMILOOP GUI will throw an error and automatically disable the connection. It is recommended to disable all connections that are currently not in use.

Upon startup the LUMILOOP GUI will attempt to automatically open all configured connections set in the `LUMILOOP.ini` file. Figure 33 shows the GUI upon start-up. For all connected devices of all client connections a separate frame is displayed. The Devices are sorted primary by type, secondary by version and tertiary by serial number in ascending order. If present, the first devices listed are the LSProbe 1.4 devices, followed by all CI-250 with E-field probes connected, followed by conventional LSPM 1.0 power meters, LSPM 2.0 power meters and CI-250 devices with laser powered power meters at the end.

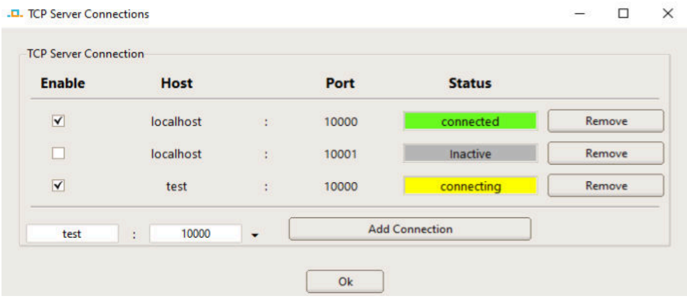


Figure 32: *Dialog for managing TCP Server Connections of the LUMILOOP GUI*

Each frame will display device version and serial number and in case of optical linked LSProbe and power meter devices the CI-250[(+)] Computer Interface number. The "LSProbe 1.2/2.0 CI# | FP#" field will display "?" instead of the E-field probe's serial number if the E-field probe connected to the computer interface is turned off. Additionally, the set operating mode, set frequency, set low-pass filter, the temperature of the LSProbe and, in case of laser powered systems, the laser status are displayed. If no devices have been enumerated the LUMILOOP GUI window will display the status information of all its configured TCP Servers client connections.

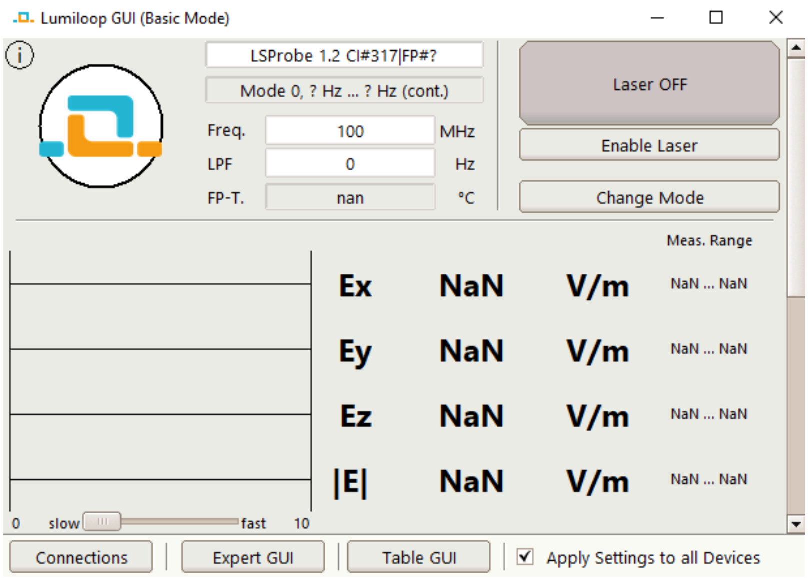


Figure 33: *LUMILOOP GUI upon startup in Basic Mode*

The initial size of the LUMILOOP GUI in Basic Mode will show only a single device frame. If more than one device is available, a vertical scrollbar will appear on the right side. The Basic GUI window can be resized to show more than one device frame at the same time. With the user resizing the GUI, all available frames are automatically arranged in the available space in a horizontal or vertical fashion. The overall window size is always reduced so that a minimum of free space is visible, as shown in Figure 35.

In LUMILOOP GUI Expert Mode, only a single device will be displayed at the same time. To change

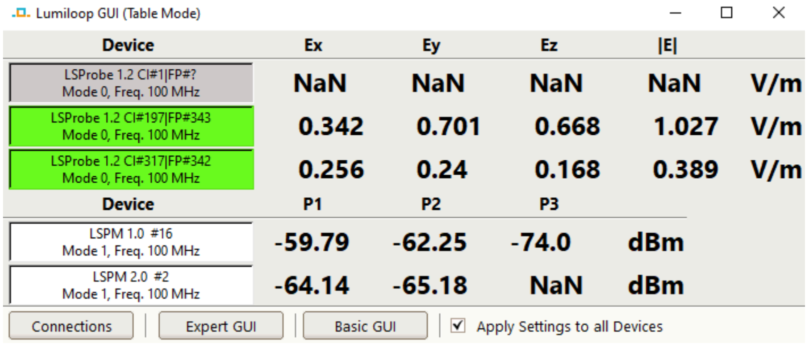


Figure 34: *LUMILOOP GUI in Table Mode*

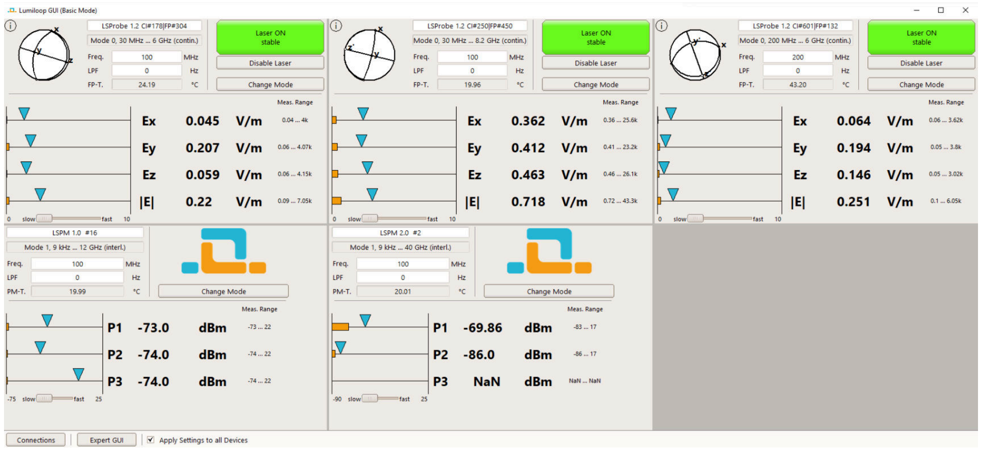


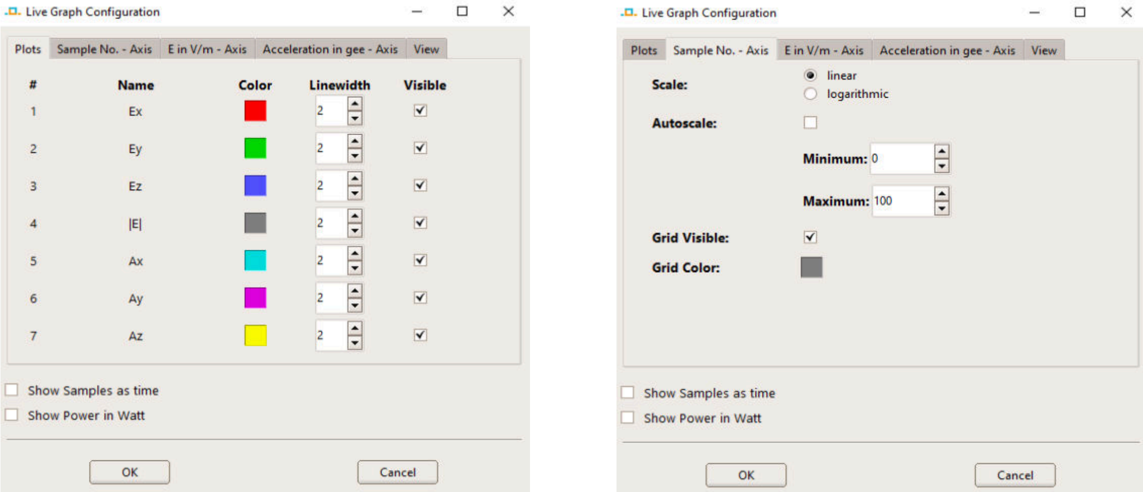
Figure 35: *LUMILOOP GUI in Basic Mode resized to fit all connected device frames*

the active device, left click within the white "Device" indicator field in the "Settings" toolbar. A drop down list will appear, listing all available connected devices as depicted in Figure 33. Alternatively the arrow left and right buttons to its left side can be used to walk through all all connected devices.

In LUMILOOP GUI Expert Mode, all subsystems as well as a graphic display of the measurement values is provided. To switch between different subsystems, either use the buttons in the "View" toolbar beneath the menu, or select the desired subsystem via the respective entry in the "View" menu.

The graph and plots in Expert GUI Mode can be configured through a dialog window as shown in Figure 36. It can be opened via the gear button on the right top corner of each plot or via the "Graph" menu item "Configure Graph". Pressing "Cancel" will discard all changes, using "OK" to exit the graph configuration dialog will adopt the changed settings. Background and foreground settings for the complete plot can be adjusted in the "View" tab. Certain settings, such as plot line color and plot line width are automatically saved to the LUMILOOP.ini file and get reset upon next start of the LUMILOOP-GUI.

Adjusting the x- and y-axis can be done by changing the desired setting in their respective tab in the "Configure Graph" dialog. To manually zoom in to a specific region, press the left mouse in the graph window and drag until the desired size is reached and the region of interest is framed. To go back to the full range either press Ctrl+F or use the "Graph" menu item "Reset Zoom".



(a) Plot configuration (b) x-axis configuration

Figure 36: *Graph configuration dialog for (a) all depicted plots (b) X-axis of the graph*

In Expert Mode, additional windows can be opened using the key shortcut Ctrl+N or the "View" menu entry "Open new Expert Window". To differentiate between the primary and any secondary windows, the window title of all additionally opened expert windows is extended to include the appendix "secondary window".

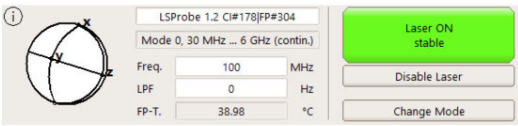
5.2.4 Enabling the Supply Laser Using the GUI

Figure 37: *LUMILOOP GUI laser indicator when off, during start-up, in safe operation and upon encountering a time-out error*

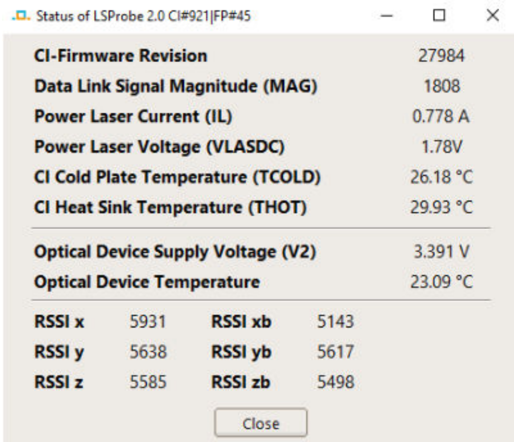
Clicking the "Enable Laser" button will activate the supply laser and set the E-field probe to the desired mode of operation. The orange "Laser on" indicator LED at the front of the Computer Interface will show the activity of the supply laser. **Warning: When the orange LED is flashing, Automatic Power Reduction (APR) is disabled. Interrupting optical connections is dangerous!** The GUI's "Laser Status" indicator will turn yellow and display "Laser Startup - Eye Safe OFF" to warn the user of this fact (see Figure 37).

As soon as both the orange "Laser on" indicator and the blue "Data Link" indicator are continuously on Automatic Power Reduction is active and the laser connection is eye-safe. If any of the optical fibers gets interrupted, the supply laser will be switched off within one millisecond and the GUI will present the red indicator shown in Figure 37.

Clicking on the information icon in the top left corner next to the E-field probe pictogram will open a subwindow as shown in Figure 77, imparting information for observing the laser link status of the respective device, e.g. magnitudes of the optical receiver's signal strength, the laser supply current and voltage, as well as the Computer Interface's temperature. Additionally, the uncalibrated 14 bit ADC measurement values, i.e. RSSI values, for each axis are displayed.



(a) Laser link status icon



(b) Laser link status window

Figure 38: *LUMILOOP GUI laser link status icon & window*

5.2.5 Mode Selection Using the GUI

For accurate E-field strength measurements the field'sfrequency must be specified using the "Freq." input field. Values are entered in hertz, SI unit prefixes may be used, e.g., "1.8G" for 1.8 GHz. The decimal separator is "." (decimal point). Frequency values outside a mode's supported frequency range will result in undefined E-field values, i.e."NAN". When changing the operating mode and the set frequency is not contained in the new operating mode's frequency range, the frequency is adapted to the nearest valid value, e.g. the minimum or maximum frequency of the new mode.

To reduce noise of the measured E-field values, a software-based low-pass filter can be set via the "LPF" field. A value of "0" disables low-pass filtering, while a non-zero value sets the -3 dB cut-off frequency for the low-pass filter used for E-field values. Below the low-pass filter field, the temperature of the E-field probe is shown.

By clicking on the "Change Mode" button in the Basic GUI or on the button depicting a gear next to the "Mode" indicator field in the Expert GUI, the "Operating Mode configuration" dialog as shown in Figure 39 is opened. The subdialog depicts assorted information regarding the available modes, i.a. supported modes of the respective device, its calibrated frequency ranges, video bandwidths, sampling rates and the type of the detector used for each mode. For the interleaved modes 1 and 5 (mode 5 only present at LSProbe 1.2/2.0)the switching point can be changed within the overlapping frequency range, using the lower field in the "Minimum Frequency" column of the respective mode, see Figure 39. If the field probe is off or the calibration data does not exists, "?" will be displayed in fields dependent on the the respective calibration data and device version of the LSProbe. If the laser is enabled, frequency range and supported modes are shown as permitted by the LSProbe revision, mode and calibration data. If a mode is not supported by an LSProbe device, its button is disabled. The depicted values are a device-specific version of the data shown in Table 1 to Table 3 on page 24 to page 27.

Mode	Minimum Frequency	Maximum Frequency	Video Bandwidth	Sampling Rate	Effective Sampling Rate	Detector	Sample Timing
0	30 MHz	6 GHz	2 MHz	500 kS/s	500 kS/s	high band	continuous
1	10 kHz 30 MHz	29.9 MHz 6 GHz	500 Hz 2 MHz	500 kS/s	80 kS/s	low band high band	continuous, interleaved
2	10 MHz	400 MHz	0.5 MHz	500 kS/s	500 kS/s	low band	continuous
3	10 kHz	400 MHz	500 Hz	500 kS/s	500 kS/s	low band	continuous
4	30 MHz	6 GHz	2 MHz	2 MS/s	566 kS/s	high band	burst
5	10 kHz 30 MHz	29.9 MHz 6 GHz	500 Hz 2 MHz	2 MS/s	91 kS/s	low band high band	burst, interleaved
6	10 MHz	400 MHz	0.5 MHz	2 MS/s	566 kS/s	low band	burst
7	10 kHz	400 MHz	500 Hz	2 MS/s	566 kS/s	low band	burst
8	30 MHz	6 GHz	2 MHz	2 MS/s	2 MS/s	high band	cont. y-axis
9	30 MHz	6 GHz	2 MHz	2 MS/s	2 MS/s	high band	cont. ya-axis

Figure 39: *LUMILOOP GUI Operating Mode configuration dialog*

5.2.6 Enabling the Supply Laser and Mode Selection Using SCPI Commands

After establishing the TCP/IP connection, the SCPI commands »:SYSTem:CISerial? [<MProbe>]« and »:SYSTem:CISerial <Value>« can be used to query all enumerated CI-250 Computer Interfaces and set the serial number of the computer interface to be accessed. If only a single computer interface is attached to the host computer, it will be selected automatically and its serial number can be queried using »:SYSTem:CISerial? [<MProbe>]«. »:SYSTem:CISerial? [<MProbe>]« and »:MEASure[:FProbe]:SERialnumber? [<MProbe>]« can be used with the MProbe parameter set to zero to list all enumerated CI-250 Computer Interfaces and their corresponding connected field probe numbers.

The desired operating mode of the selected E-field probe is set using »:SYSTem:MODe <Mode>[,<MProbe>]«. Refer to Table 1 to Table 3 on page 24 to page 27 for a list of valid modes. Set the operating frequency in hertz using »:SYSTem:FREQuency <Frequency>[,<MProbe>]«. If the mode is changed and the last frequency is outside of this mode's supported frequency range, the operating frequency will be diverted to the nearest supported frequency. In all other instances, where the operating frequency is set outside the calibrated frequency range, SCPI queries returning an E-field value will return "NAN". »:SYSTem:FREQuency? [<MProbe>]« can be used to verify the frequency setting.

»:SYSTem:LASer:ENable <Value>[,<MProbe>]« is used to enable the supply laser. During start-up the commands »:MEASure[:FProbe]:MODe? [<MProbe>]« and »:SYSTem:LASer:TOut? [<MProbe>]« are used to poll the optical link status until either the requested mode has been set successfully or a time-out condition and thus a faulty optical link has been detected. The E-field probe may take several tens of seconds to successfully set a mode. »:SYSTem:MODe <Mode>[,<MProbe>]« may be issued at any time to request a mode change in which case the described polling procedure needs to be repeated. **Warning: As long as the requested mode has not been established and the orange LED is flashing, Automatic Power Reduction (APR) is disabled. Interrupting optical connections is dangerous!**

5.3 Continuous E-field Measurements

While the LSProbe is capable of exceptionally high speed measurements it is also able to perform high precision measurements of quasi-static electric fields. For continuous E-field measurements the TCP server receives all E-field strength values, applies calibration data and performs low-pass filtering if configured accordingly. X-, y- and z-axis acceleration data is recorded and optionally low-pass filtered as well. The acceleration values give an indication which axis is pointing up. When an antenna is pointing directly up, a value of one g, i.e., 9.81 m/s^2, is returned for the corresponding axis' acceleration, minus one g will be returned when the antenna is pointing directly down. During laser enabled state, the current orientation of the LSProbe is depicted in the LUMILOOP GUI in Basic Mode on the left upper side.

5.3.1 Continuous Measurements Using the GUI

As depicted in Figure 40, the LUMILOOP GUI in Basic Mode displays the measured E-field values for x-, y- and z-axis E-field component and E-field magnitude values in the lower part of the frame. On the left half of the lower frame, a graphical representation of the measured E-field values is given via a bargraph. The orange bargraph represents the instantaneous E-field values, while the blue triangle is a peak marker with decay function. The fall time of the peak marker can be adjusted with the slider below the bargraph. On the right side of the lower frame, a numerical representation of the instantaneous E-field strength value is given, as well as the current measuring range of the device.

In the Expert Mode LUMILOOP GUI, continuous measurements are depicted in the "Live" tab as shown in Figure 41. E-field and acceleration data is displayed both numerically and graphically. Values are polled perpetually with an update rate in the order of 25 samples per second. The actual polling frequency depends on the speed of the host computer and the speed of the network connection, in case of remote operation. The calibrated range of E-field strength values for the current operating mode, frequency and E-field probe temperature is displayed textually below the x-, y-, z- and magnitude value of the electric field strength. It can be hidden via "Show Calrange data" item in the "Graph" menu. In addition, statistical data like the minimum, maximum and average value for each graph can be displayed via 'Show Statistic data" item in the "Graph" menu.

To configure the number of samples shown open the "Live Graph Configuration" dialog through the gear button on the right top corner of the plot and select the "Sample No. - Axis" or "Time in Seconds - Axis" tab if the samples are shown as time. "Maximum" determines the maximum number of samples displayed in the plot at the bottom of the window. It will show at most this many most

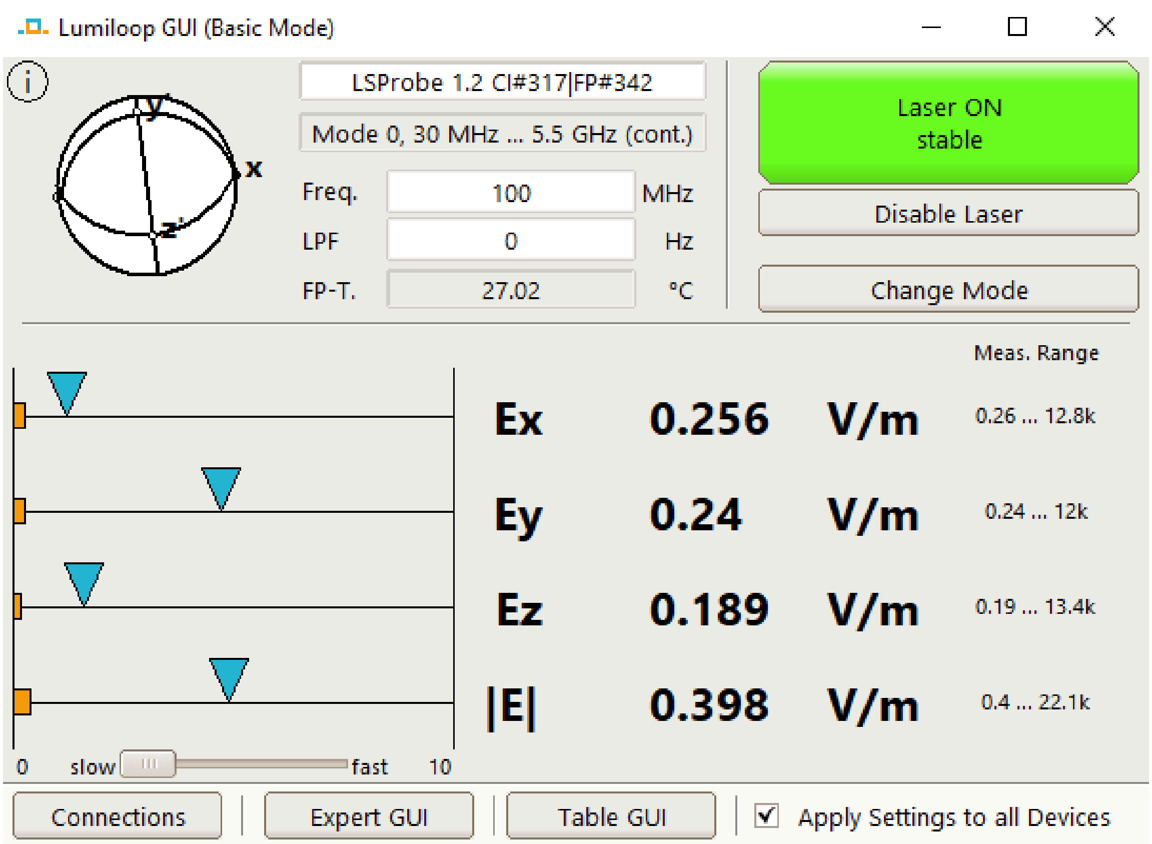


Figure 40: *LUMILOOP GUI Basic mode E-field measurements*

recent values, older values will be discarded. To display the elapsed time instead of sample indexes for graphs' x-axis and graph length select the "Show Samples as time" check box. This setting can also be configured via the "View" menu. The plot can be paused and again un-paused using the space key or the "Pause Live View" entry in the "View" menu.

By way of the "File" menu the logging of continuously polled values and of the Trigger, Pulse, RPower, Sweep, Statistics, StatStep, Multiprobe data and Oversampling can be turned on and off individually. If enabled, newly arriving data of the specific subsystem gets immediately written to a log file. See Section 5.12 on page 88 for details. The "Export CSV" "File" menu entry offers a shortcut for the logging of the currently viewed data without previously having enabled the log feature. The "Export Image" and "Export PDF" "File" menu entries save the current graph as a PNG or PDF image to the set save path. To configure file prefix and save path for the different sub systems open the "Logging Configuration" dialog via the "Configure Log" "File" menu entry. The E-field probe identification string, a date and time string and a CSV file suffix will be appended to every newly created log file. See Section 13.1 on page 273 for file format details. Please note that the export of a PNG image creates a screenshot of the displayed graph. Therefore it is essential that the complete graph is visible at time of image creation.

Low pass filter settings are made through the numeric input fields in the "Filter and LHF Configuration" dialog opened via the "LPF/LHF" button in the "Control" toolbar or the "Filter" entry of the

Figure 41: *LUMILOOP GUI Live view*

"Settings" menu. The subdialog is shown in Figure 42. A value of zero disables low-pass filtering. A non-zero value sets the -3 dB cut-off frequency for the first order low-pass filter used for E-field and acceleration values, for example 10 Hz. When changing the frequency the E-field low-pass filter output value will be updated directly, i.e., low-pass filtered values will see a step response instead of a slewing of values.

The automatic software-based video bandwidth reduction can be disabled and enabled via the "Auto Set VBW-Filter" checkbox, see Section 3.1.4 for details. If disabled, the user can set the video bandwidth filter through the respective numeric input field. The transition frequency for switching between the low- and high-band detector in the interleaved modes 1 and for LSProbe 1.2/2.0 also mode 5 can be set in the corresponding numeric in put field. For example, the transition frequency in Figure 42, the transition frequency is set to 30 MHz.

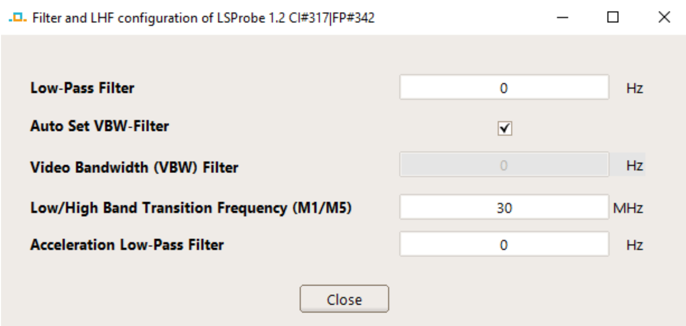


Figure 42: *LUMILOOP GUI Filter Configuration dialog*

The currently active device's factory and, if existing, accredited calibration date, the CI-250(+) device's firmware, the E-field probe's and, in case of optically powered measurement devices, the CI250's temperature are listed in the "Status toolbar" at the bottom. It can be hidden and shown again via it's respective entry in the "View" menu.

5.3.2 Continuous Measurements Using SCPI Commands

After setting the operating mode and frequency as described in Section 5.2.6, the E-field low-pass filter frequency is configured through »:MEASure[:FProbe][:Efield]:LPFrequency <Frequency>[,<MProbe>]«. A synchronized set of component values and magnitude can be queried through the »:ALL« variant of »:MEASure[:FProbe][:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]« . This is the recommended method ensuring that the values have been acquired at the same time. E-field values can also be queried individually through the »:X/:Y/:Z/:MAG« variants of the command.

The acceleration low-pass filter frequency is configured through »:MEASure[:FProbe]:ACCeleration:LPFrequency <Frequency>[,<MProbe>]«. Acceleration values can be queried through »:MEASure[:FProbe]:ACCeleration:X/Y/Z/ALL? [<MProbe>]« .

5.4 Triggered E-field Measurements

Triggered E-field measurements allow the user to take full advantage of the LSProbe's exceptionally high-speed measurements. Waveform acquisition can be triggered by software or by hardware. The edge-sensitive hardware trigger signals originate from the CI-250$^{(+)}$ device's BNC/RJ45 connectors or the signal level with a set threshold for field strength level triggering. The trigger system has a built-in dead-time of 100 µs, i.e., it can process up to 10,000 events per second.

5.4.1 E-field Waveform Acquisition Using the GUI

Figure 43 shows the LUMILOOP GUI in scope mode which is entered by selecting the "Scope" tab. In scope mode, the textual legend at the top shows the averaged, minimum and maximum x-, y-, z- and magnitude-value of the electric field strength for the displayed waveforms. Unchecking "Show Statistic data" in the "Graph" menu hides the minimum and maximum values.

All settings as well as the recording of a new waveform is handled via the settings and status frame on the left side. This frame can be minimized using the arrow button on its upper right corner. "Trigger State" displays the condition of the trigger system. "Progess" shows the number of samples already acquired for the current waveform, as well as the total number of samples of the waveform.

The LUMILOOP GUI trigger waveform acquisition behavior is set via the "Trigger Mode" drop-down menu. Automatic free-running triggering, normal event-based triggering and one-shot single triggering can be selected. The "Source" drop-down box is used for selecting rising or falling edge external BNC, external RJ45, x-, y-, z-axis E-field value or any of the axes' value triggering. For the E-field value triggering, the threshold value in V/m can be set via "X/Y/Z Level" . By changing "Trigger

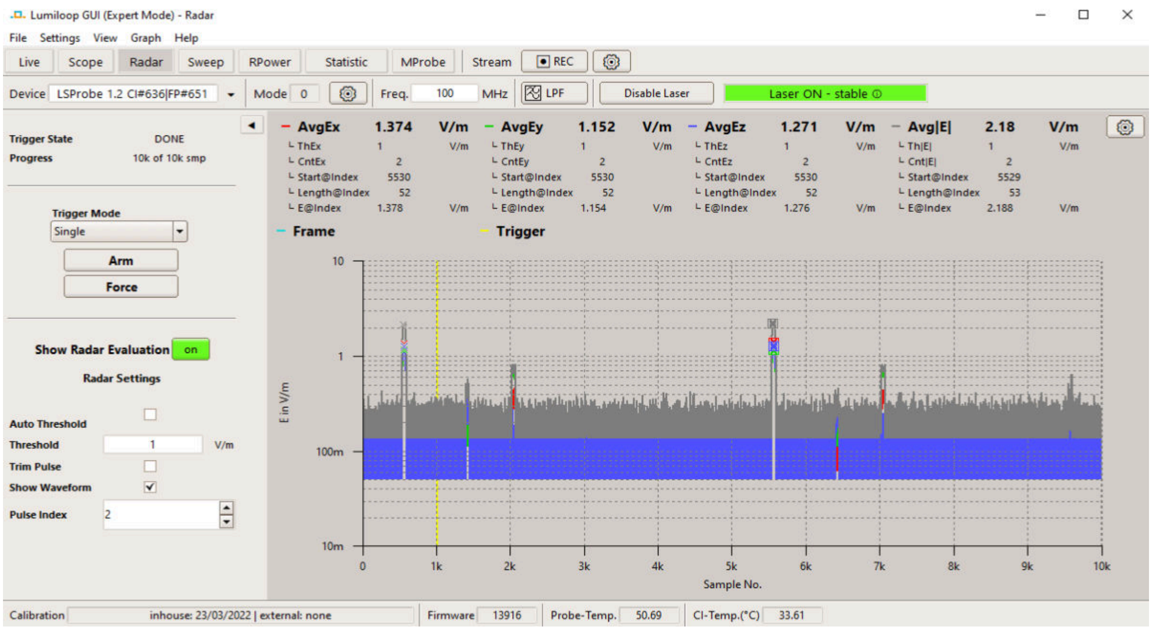


Figure 43: *LUMILOOP GUI, Scope tab*

Mode" automatic free-running triggering, normal event-based triggering and one-shot single triggering can be selected. The "Arm" and "Force" buttons serve to prepare the trigger system and to force triggering regardless of actual trigger events.

The length of the acquired waveform is determined by the "Length" numeric input field, setting the number of samples for each triggered waveform. "Offset" sets the start of the saved waveform relative to the position of the trigger event. "Offset", "Length" and the graph's x-axis can be displayed/entered as time values by selecting the "Show samples as time" check box in the "Scope Graph Configuration" or the respective "View" menu item. Time values are displayed according to the sampling rates in Table 1 to Table 3 on page 24 to page 27.

Point triggering enables recording of waveforms consisting of multiple sub-waveforms of equal size, based on multiple trigger events. Point triggering is enabled by selecting more than the default single trigger point in the "Points" input field. The number of total samples in the "Progress" field is updated according to the number of trigger points. After processing the set number of trigger points, the trigger state will reach DONE and the waveform will be displayed.

The "Source" drop-down box is used for selecting rising or falling edge external BNC, external RJ45, x-, y-, z-axis E-field value or any of the axes' E-field value triggering. For the E-field value triggering the threshold value in V/m can be set via "X/Y/Z Level".

The "BNC Trigger Output" and "RJ45 Trigger Output" drop-down menus are used to enable trigger signal output via the CI-250$^{(+)}$ device's BNC connector and "Ext1" RJ45 socket and set their respective signal polarities. Triggers can be output either when encountering a trigger event, including forced triggering, or for synchronization triggering as described in Section 12.6.31.

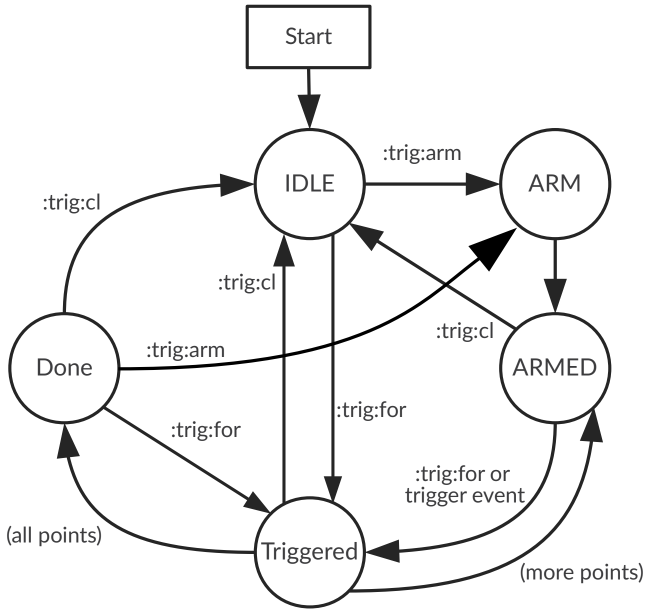


Figure 44: *Trigger system states and state transitions*

5.4.2 E-field Waveform Acquisition Using SCPI Commands

The state of the trigger system is queried using »:TRIGger:STATe? [<Timeout>,<MProbe>]«. The configuration of triggered measurements must take place in IDLE state. Waveform query must take place when the trigger system is in DONE state. The SCPI commands »:TRIGger:CLear [<MProbe>]«, »:TRIGger:ARM [<MProbe>]« and »:TRIGger:FORce [<MProbe>]« are used for directly manipulating the state of the trigger system. Figure 44 shows all valid trigger states and state transitions.

After receiving »:TRIGger:ARM [<MProbe>]«, the trigger subsystem first transitions to the ARM state before entering the state ARMED, readying the CI-250$^{(+)}$ device for trigger event processing. Since trigger events will only be processed in state ARMED, the queries »:TRIGger:STATe? [<Timeout>,<MProbe>]« or »:TRIGger:ARMed? [<Timeout>,<MProbe>]« must be used to verify the state ARMED before generating trigger events. Similarly, the command »:TRIGger:DONE? [<Timeout>,<MProbe>]« can be used to wait for the trigger subsystem to reach the DONE state. The progess of the current waveform acquisition can be checked using »:TRIGger:PROgress? [<MProbe>]«, for progress of point trigger acquisition »:TRIGger:PTProgress? [<MProbe>]«.

The trigger source and polarity are set using »:TRIGger:SOURce <Source>[,<MProbe>]« and »:TRIGger:FALLing <0/1>[,<MProbe>]«. If E-field value triggering is to be employed, the trigger level is set using »:TRIGger:LEVel <Level>[,<MProbe>]«. The trigger length is set using »:TRIGger:LENgth <Length>[,<MProbe>]« and »:TRIGger:BEGin <Index>[,<MProbe>]«. The corresponding query commands are »:TRIGger:LENgth? [<MProbe>]« and »:TRIGger:BEGin? [<MProbe>]«.

Trigger output is configured using »:TRIGger:OUTput <0/1>[,<MProbe>]«, »:TRIGger:INVert <0/1>[,<MProbe>]«, »:TRIGger:SYNC <0/1>[,<MProbe>]« for the BNC connector and »:TRIGger:BPOUTput <0/1>[,<MProbe>]«, »:TRIGger:BPINVert <0/1>[,<MProbe>]« and »:TRIGger:BPSYNC <0/1>[,<MProbe>]« for the RJ45 connector.

The number of trigger points is set via »:TRIGger:POINts <Points>[,<MProbe>]«, the number of recorded points is queried using »:TRIGger:PTProgress? [<MProbe>]«. The full length of the waveform for all trigger points can be queried using »:TRIGger:FLENght? [<MProbe>]«. The command »:TRIGger:PTTimes? [<MProbe>]« can be used to retrieve the relative timing of trigger events.

In DONE state the waveform values can be queried using »:TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]«. Averaged waveform values can be queried using »:TRIGger[:WAVeform][:Efield]:ALL? [<MProbe>]«. The »:TRIGger[:WAVeform][:Efield]:BINary? [<MProbe>]« command is available for fast and computationally efficient waveform readout in binary format.

5.4.3 Pulse Measurements Using the GUI

The LSProbe is able to scan a previously recorded E-field waveform for pulses in order to find their positions, lengths and averaged field strengths. See Section 5.4.1 for details regarding triggered value acquisition. In mode 0 and 2 pulses above a specified threshold can be detected if they are longer than 2 µs and at least 2 µs apart. In mode 4, 6, 8 and 10 pulses above a specified threshold can be detected if they are longer than 0.5 µs and at least 0.5 µs apart. Pulse measurements in other modes are not recommended due to their lower video bandwidths. Usage of interleaved modes, e.g. 1, is not recommended due to the rapid switching between high and low band detector.

Pulses can be evaluated with or without pulse trimming, use the "Trim Pulse" checkbox on the left side to enable pulse trimming. If pulse trimming is disabled, all samples above the pulse threshold will be treated as belonging to the pulse, as shown in Figure 45.

If pulse trimming is enabled, samples at the start and end of a pulse will be treated distinctly, this is useful for better accuracy of constant peak E-field strength evaluation of short pulses with short rise and fall times. Pulse trimming works as follows: for pulses containing one or two samples the pulse's E-field strength, the pulse's average value is defined as its largest sample value. For pulses containing at least three samples, the pulse's E-field strength is defined as the arithmetic mean of all but the first and last sample value of the pulse, Figure 46 depicts this behavior. Samples that are treated as belonging to a pulse are shown as squares. The start position of the pulse within the waveform and the indicated length of pulses are not affected by pulse trimming, i.e., they are calculated using all sample values above the pulse threshold.

Pulses starting before the beginning of a waveform or burst frame (in burst modes 4 or 7) will be ignored since their timing is unknown. The same applies for pulses that extend beyond the end of a waveform or burst frame.

In order to enable pulse detection and evaluation within the LUMILOOP GUI select the "Pulse" button in the "View" toolbar and enable "Show Data" as shown in Figure 47.

Pulse characteristics are presented independently for x, y, z and magnitude of the E-field probe above the graph. The averaged values over all pulses' field strength values of the current waveform

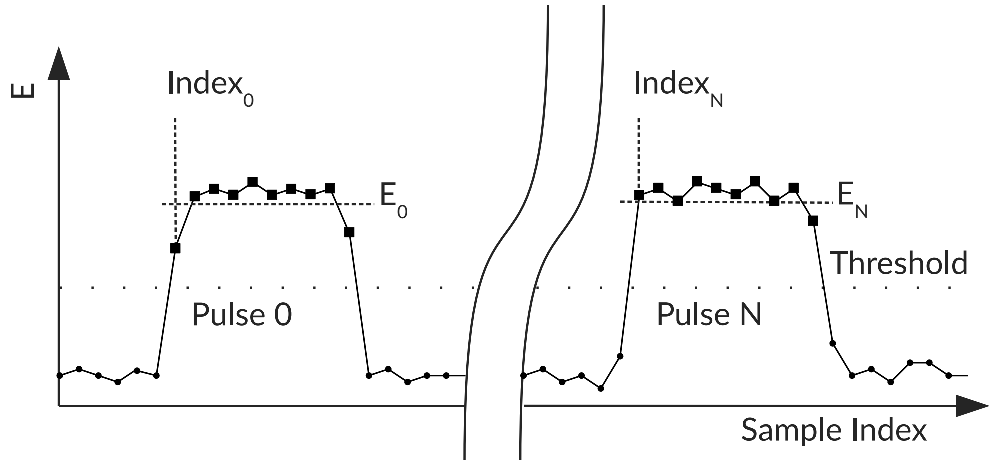


Figure 45: *Pulse detection when pulse trimming is disabled. All samples above the threshold are used for field strength calculation, leading to a lower average pulse field strength.*

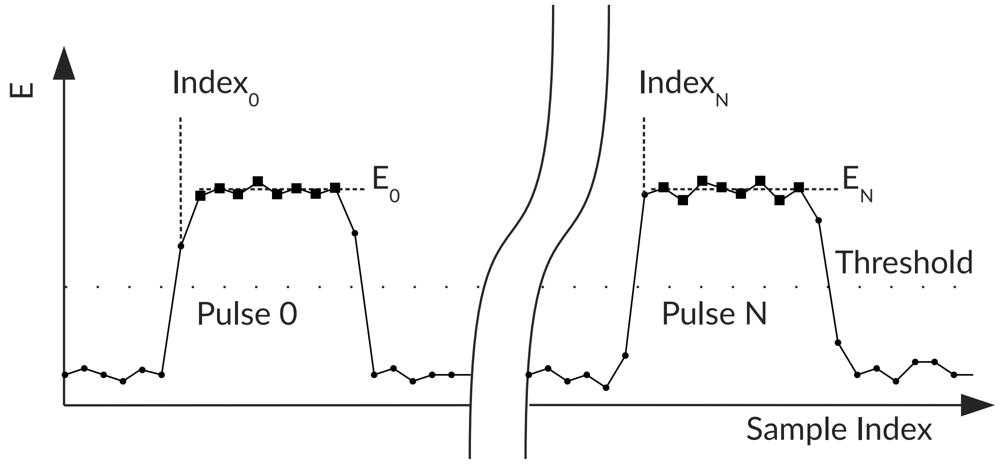


Figure 46: *Principle of pulse detection when pulse trimming is enabled*

"AvgE", the applied threshold value for pulse detection "ThE" and the resulting number of pulses "CntE" are shown on top.

When the pulse evaluation source waveform is set to **IND** via the "Source" drop-down menu, all waveforms are evaluated independently. In this case, the number of detected pulses can differ for each axis and magnitude waveform. When the waveform master for pulse evaluation is set to a value other than **IND**, the designated waveform will be used for pulse detection. The evaluation of all other waveforms will be performed using the pulse boundaries determined by the master waveform, ensuring the same pulse count and timing for all pulse characteristics.

Detailed information about individual pulses, stating the start position in the waveform ("Start@Index"), the length of individual pulses ("Length@Index") and the arithmetic mean of each individual pulse ("E@Index") are listed in the lower "Single pulse data" legend. Use "Pulse Index" on the lower left side to step through individual pulses, the first pulse has the index one. The start sample index is given relative to the first waveform sample and represents the first sample belonging to the selected pulse. An invalid index will remain empty for start index, sample index and averaged field strength. The currently selected pulse will be highlighted in the graph via boxes, as depicted in Figure 47 for pulse number two. If no pulses are detected, the averaged E-field values will display "NaN" and number of detected pulses will display "0". All other fields will be empty.

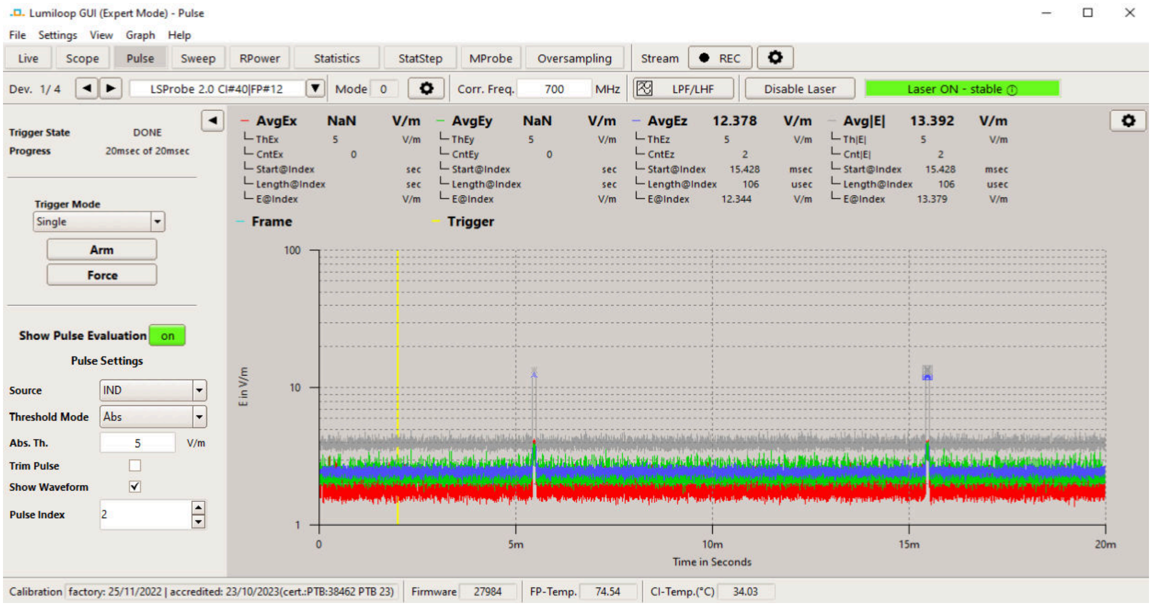


Figure 47: *LUMILOOP GUI, Pulse tab*

Waveform aquisition and configuration of pulse evaluation are set in the retractable frame on the left side. The "Trigger State" and "Progress" indicator fields, the "Trigger Mode" drop-down menu and the "Arm" and "Force" buttons are duplicated from the "Scope" tab to enable waveform acquisition and get trigger state information without switching to the "Scope" view. All trigger settings are performed via the "Scope" window. Pulse evaluation is repeated for every update of the E-field waveform and with every change in the pulse evaluation source waveform, threshold value and trim setting.

The threshold value for all E-field components is set via the "Threshold mode" drop-down menu, with the following options available:

AVG
: The pulse threshold is automatically set to the arithmetic mean of the maximum field strength value and minimum field strength value in the waveform for each x, y, z and magnitude separately. Minimum and maximum field strength value are accessible via the statistics subsystem, see Section 5.6.

ABS
: Pulse detection will use the fixed field strength value in V/m set via the "Abs. Th." entry field as the threshold.

The available threshold mode's entry field will become visible upon selecting the respective mode.

Figure 46 shows the relationship of E-field waveform values, pulse indices and pulse values.

Enabling the "Show Waveform" checkbox will display the trigger waveform in addition to the pulse points.

By selecting the "x-axis as time" check box the "Index" values of pulses and x-axis labels of the waveform graph will be displayed in seconds. If the pulse subsystem is turned off, the "Pulses" field will be set to zero and all other fields be cleared.

Both the "Statistic data" legend and "Single pulse data" legend can be hidden via their respective "Graph" menu entry, leaving only the averaged values over all pulses visible.

5.4.4 Pulse Measurements Using SCPI Commands

See Section 5.4.2 for the details of triggered value acquisition. Pulse detection requires the trigger system to be in DONE state.

Pulse trimming is enabled and disabled using »[:TRIGger]:RADar:TRIM <State>[,<MProbe>]«. Configuration of the source waveform used for pulse evaluation is done via »[:TRIGger]:RADar:SOURce <Source>[,<MProbe>]«. The pulse detection method is set using »[:TRIGger]:RADar:THMethod <Method>[<MProbe>]«, allowing for minimum/maximum-based threshold calculation and absolute threshold setting. The latter is configured using the command »[:TRIGger]:RADar:THreshold <Value>[,<MProbe>]«. The applied threshold values can be queried using »[:TRIGger]:RADar:THreshold:X/Y/Z/MAG/ALL? [<MProbe>]«. Pulse evaluation can be performed multiple times using different threshold values or radar source waveforms.

The number of detected pulses followed by triples of start sample index, pulse length in samples and maximum pulse field strength values can be obtained through the commands »[:TRIGger]:RADar:X/Y/Z/MAG? [<MProbe>]«. Individual properties can be queried using »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]«, »[:TRIGger]:RADar:STArt:X/Y/Z/MAG? [<MProbe>]«, »[:TRIGger]:RADar:LENgth:X/Y/Z/MAG?

[<MProbe>]« and »[:TRIGger]:RADar:Efield:X/Y/Z/MAG? [<MProbe>]«. Averaged pulse field strength values can be queried using »[:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]«. The »[:TRIGger]:RADar:BINary? [<MProbe>]« command is available for fast and computationally efficient pulse detection readout in binary format.

5.4.5 Sweep Measurements Using the GUI

The LSProbe is able to evaluate E-field waveforms containing a level or frequency sweep, thus enabling sped-up measurements. See Section 5.4.1 for details regarding triggered value acquisition. For sweep measurements the acquired waveform typically contains multiple sections of equal size, where each section is characterized by constant measurement conditions. Most commonly, the frequency setting of a setup is altered in a step-wise manner in order to measure the frequency-dependent power of a setup under test. In this case, each section of the E-field waveform will have a different, constant frequency associated with it. Sweep measurements return the averaged E-field value for each section of the waveform. Dead-times at the beginning and end of each section may be applied to account for the setting characteristics of the setup under test. Due to the high sampling rate of the LSProbe, waveform sections may be shorter than a millisecond, enabling the evaluation of more than a thousand distinct frequencies per second. This method is much faster than setting the frequencies individually and measuring E-field values via multiple discrete queries.

The sweep subsystem should be used in E-field probe modes 0, 2, 3, 8, 9 and 10 only. One or more sections of the waveform, which align with the sweep's steps, are analyzed independently, yielding a set of averaged E-field strength values for each section. Waveform sections have a uniform length and spacing relative to each other. They are spaced in such a way to guarantee stable conditions for each section and must take into account the switching and settling characteristics of the setup under test. In general the usage of point trigger waveforms is recommended due to unknown settling times of signal generators. Each individual waveform is triggered by the signal generator's signal stettled output for each frequency. Additionally waveform sections of different lengths and averaged sections can be configured to allow for utmost flexibility in the evaluation of an already recorded waveform.

In order to enable sweep evaluation within the LUMILOOP GUI select the "Sweep" tab and activate "Show Sweep Evaluation", as shown in Figure 48. Sweep evaluation requires the trigger system to be in DONE state. The "Trigger State" and "Progress" indicator fields, the "Trigger Mode" drop-down menu and the "Arm" and "Force" buttons are duplicated from the "Scope" tab. Frequency sweep re-evaluation is performed upon every change of any evaluation parameter and E-field waveform update.

The timing of the sweep is configured using the fields "Length@Step", "Begin@Step" and "End@Step". "Length@Step" specifies the length of each sweep step. "Step Begin" and "Step End" specify the first and the last sample index for averaging relative to the start index of each sweep step. Samples before "Step Begin" and samples after "Step End" will be discarded. Indexing starts at zero, evaluation starts with the first sample of the E-field waveform. I.e. to use all samples of a complete step of 1,000 samples for evaluation, "Begin@Step" has to be set to 0 and "End@Step" to 999. The E-field

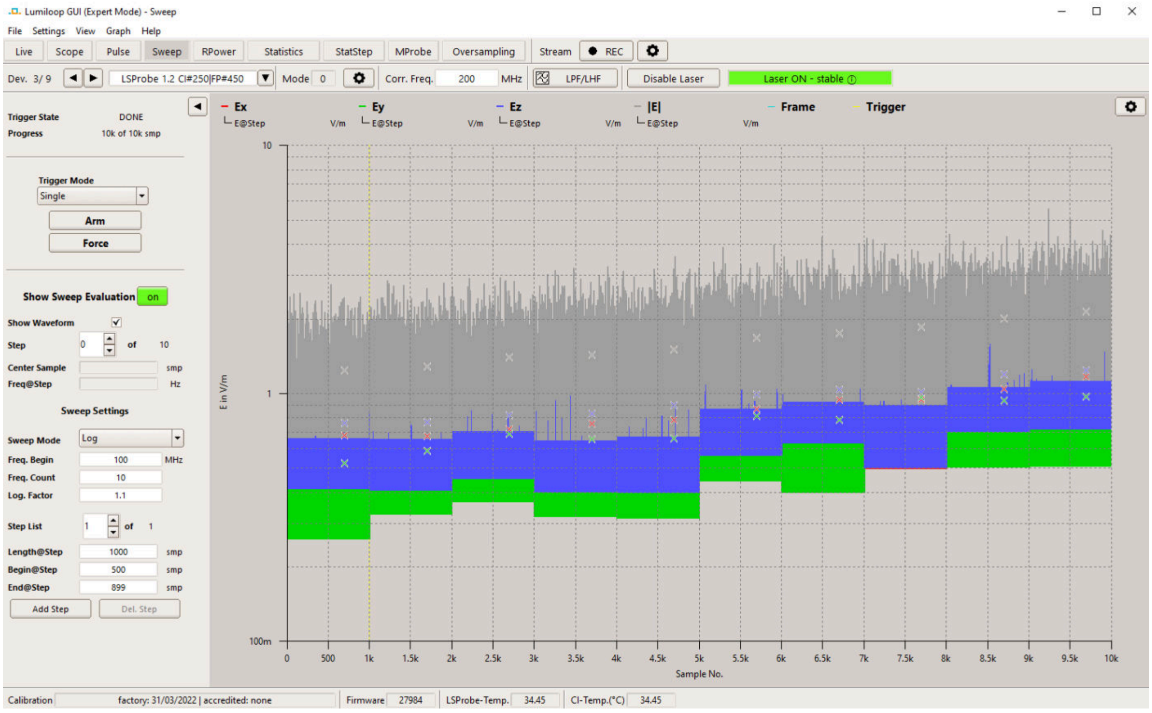


Figure 48: *LUMILOOP GUI, Sweep tab*

waveform is divided into as many sweep steps as will fit into the E-field waveform starting at its beginning. Note that the entire waveform can be shifted relative to the trigger signal by means of a different value for “Trigger Begin”in the “Scope” tab. To add arbirary sweep steps, use the “Add Step” button. Step trhough the “Step List” spinxbox in order to adjust single sweep step parameters. Use “Del. Step” to remove the currently visible step.

If the length of the waveform allows for more than the configured number of arbitrary sweep steps, the last sweep step will be used for continuing sweep evaluation of the remaining samples.

There are three frequency sweep modes selectable via the “Sweep Mode” drop-down menu, with the specific sweep mode dependent entry and indicator fields becoming visible upon selection:

LIN
: selects a linear frequency sweep, defined by its start frequency “Freq. Begin” in hertz, the number of frequency steps “Freq. Count” and the linear frequency increment “Freq. Step” in hertz.

LOG
: selects a logarithmic frequency sweep, defined by its start frequency “Freq. Begin” in hertz, the number of frequency steps “Freq. Count” and the incremental factor between two steps “Log. Factor”, e.g., 1.1 for increasing the by 10% from one step to the next.

LIST
: allows adding arbitrary frequency using the “Add” button to a list of frequency values. To step through the set arbitrary frequency list use the “Freq. List” spinbox. The set frequency for the respective sweep step is displayed in the “Freq.@Index” indicator field. The list can be reset

using the "Clear" button.

The selector field "Step" is used to select individual sweep steps, with the total number of sweep steps being displayed to its right side. The first step has the index one. The center of each step relative to the start of the waveform is displayed in the indicator field "Center Sample". The corresponding frequency is shown below in the "Freq@Step" indicator field. Averaged x-, y-, z-axis and magnitude E-field strength values for the selected sweep step are displayed in the concealable "Single Sweep Step data" legend above the graph. Selecting an invalid sweep step will display "NaN" for all corresponding values.

Enabling the "Show Waveform" checkbutton will display the frequency corrected trigger waveform in addition to the sweep points.

By setting the "Show samples as time", the waveform's x-axis as well as the fields "Length@Step", "Begin@Step", "End@Step" and "Center Sample" are expressed in seconds instead of samples.

5.4.6 Sweep Measurements Using SCPI Commands

See Section 5.4.2 for the details of triggered waveform acquisition. To set the sweep step length and start/end index of averaging within each step the SCPI commands »[:TRIGger]:SWeep:TStep <TStep>[,<MProbe>]«, »[:TRIGger]:SWeep:TBegin <TBegin>[,<MProbe>]« and »[:TRIGger]:SWeep:TEnd <TEnd>[,<MProbe>]« are used. Use »[:TRIGger]:SWeep:ADDTimes <TStep>,<TBegin>,<TEnd>[,<MProbe>]« to add additonal arbitrary sweep steps. Using one of the commands »[:TRIGger]:SWeep:TStep <TStep>[,<MProbe>]«, »[:TRIGger]:SWeep:TBegin <TBegin>[,<MProbe>]« or »[:TRIGger]:SWeep:TEnd <TEnd>[,<MProbe>]« will shorten the set sweep step list to a single step. Alternatively use »[:TRIGger]:SWeep:CLEARTimes [<MProbe>]« to delete all sweep steps except the first one. The sweep mode is set via »[:TRIGger]:SWeep:MODe <Mode>[,<MProbe>]«, choosing »LIN«, »LOG« or »LIST«. For linear and logarithmic sweeps, the start frequency, number of frequency steps and frequency increment is set via »[:TRIGger]:SWeep:BEGin <Freq>[,<MProbe>]«, »[:TRIGger]:SWeep:COUnt <Count>[,<MProbe>]« and »[:TRIGger]:SWeep:STEP <Step>[,<MProbe>]«. A list of arbitrary frequencies can be created incrementally via the »[:TRIGger]:SWeep:ARBAdd <Freq>[,<MProbe>]« command. »[:TRIGger]:SWeep:ARBClear [<MProbe>]« is used to clear the arbitrary frequency list. In any sweep mode, the command »[:TRIGger]:SWeep:LIST? [<MProbe>]« returns the list of frequencies in accordance with the selected sweep mode and waveform length.

The command »[:TRIGger]:SWeep:IDX? [<MProbe>]« returns the center sample indices of all sweep steps in the waveform. The averaged E-field and RSSI values for each step are queried using the commands »[:TRIGger]:SWeep[:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]« and »[:TRIGger]:SWeep:RSsi:X/Y/Z/ALL? [<MProbe>]«. Frequency corrected trigger waveforms can be obtained using »[:TRIGger]:SWeep:WEfield:X/Y/Z/MAG/ALL? [<MProbe>]«. The »:TRIGger[:WAVeform][:Efield]:BINary? [<MProbe>]« command is available for fast and computationally efficient value readout in binary format.

5.4.7 Remote Power Measurements Using the GUI

LSProbes may be employed for Effective Isotropic Radiated Power (EIRP) measurements if far-field conditions are observed and the distance between the LSProbe and the transmitter is known. Under these conditions, the EIRP may be calculated using the equation $P_{EIRP} = (E \cdot r)^2 / 30\Omega$, where E specifies the E-field strength in V/m, r specifies the distance between transmitter and field probe in meters and P_{EIRP} specifies the Effective Isotropic Radiated Power in Watts.

The remote power subsystem supports EIRP measurements in accordance with EN 300328 and EN 301893, including pulse detection, calculation of power values in dBm and generation of pulse statistics, including duty cycle and averaged pulse power. The standards require measurements at a sampling rate of at least 1 MSamples/s over relatively long continuous stretches of time, e.g., one second. In mode 8 the LSProbe 1.2 continuously measures the y-axis field strength only, operating at 2 MSamples/s. In mode 8,9 the LSProbe 2.0 continuously measures the y-axis field strength only, operating at 1 MSamples/s in mode 8, in mode 9 at 2 MSamples/s.

Figure 49: *LUMILOOP GUI, RPower tab*

In order to enable remote power measurements within the LUMILOOP GUI, select the "RPower" tab and activate "Show RPower Evaluation" as shown in Figure 49. Remote power measurements require the trigger system to be in DONE state. The "Trigger State" and "Progress" indicator fields, the "Trigger Mode" drop-down menu and the "Arm" and "Force" buttons are duplicated from the "Scope" tab. Remote power re-evaluation is performed upon any evaluation parameter change and E-field waveform update.

Pulses can be evaluated with or without pulse trimming, use the "Trim Pulse" checkbox to enable pulse trimming. If pulse trimming is disabled, all samples above the pulse threshold field strength will be treated as a part of the pulse. If pulse trimming is enabled, samples at the start and end of the pulse will be treated distinctly, as described in Section 5.4.3.

The distance between field probe and transmitter in meters is set via the "Distance" entry field. The "Threshold Mode" drop-down menu is used to set either absolute (ABS), relative (REL) or histogram-based (HIST) threshold calculation.

ABS
: Pulse detection will use the fixed power level set via the "Abs. Th." entry field as the threshold.

REL
: Pulse detection will use a power level relative to the maximum value found in the waveform as the threshold. The threshold level in dB relative to the maximum is set via the "Rel. Th." entry field. Figure 50 left demonstrates the principle – pulse 3 will be ignored because its peak power is too low.

HIST
: Pulse detection will use a histogram-based threshold value, based on the minimum of the power value distribution which is located between the probabilities of the noise floor and the active transmitter's power level, as shown in Figure 50 on the right. The histogram which is created in the background has a resolution of 1 dB.

  The "Clearance" entry field can be used to ensure that the threshold is located an integer-valued multiple of 1 dB away from the probability peaks of the probability distribution. This way a minimum signal-to-noise ratio can be guaranteed.

The specified theshold mode dependent entry fields becoming visible upon selection of the specific threshold mode.

The "MinLength" input field sets the minimum number of samples per pulse of the transmitter. All pulses that are shorter will be discarded, see pulse 2 shown in Figure 50. The "Moving AVG" input field sets the number of samples to use for a moving average filter of the waveform values. A value of one will disable the moving average filter, a value of two will calculate the moving average of two samples, thus reducing bandwidth and noise. A value of two for LSProbe 1.2 or for an LSProbe 2.0 device using mode 9 is most common for standards-compliant measurements which require at least 1 MSamples/s.

Results are presented independently for the three axes of the field probe, in field probe mode 8, 9 and 10 only the y-axis value is valid. The main legend indicates the arithmetic means of all pulses' power values. In the "Statistic data" legend below, the manually set or automatically calculated threshold values, the number of detected pulses that satisfy the "MinSamples" criteria, the maximum power values found in the entire waveform and the duty cycle, i.e., the ratio of the number of samples in the waveform belonging to valid pulses and the total number of samples in the waveform is displayed. If no valid data is available indicator fields will display "NaN".

The selector field "Pulse Index" can be used to step through individual pulses, the first pulse has the index one. The start sample index "Start@Index", pulse length "Length@Index" and pulse's power's averaged mean "Power@Index" of the selected pulse are depicted in the "Single pulse data" legend. An invalid index will remain empty for sample index, pulse length and power value. By selecting

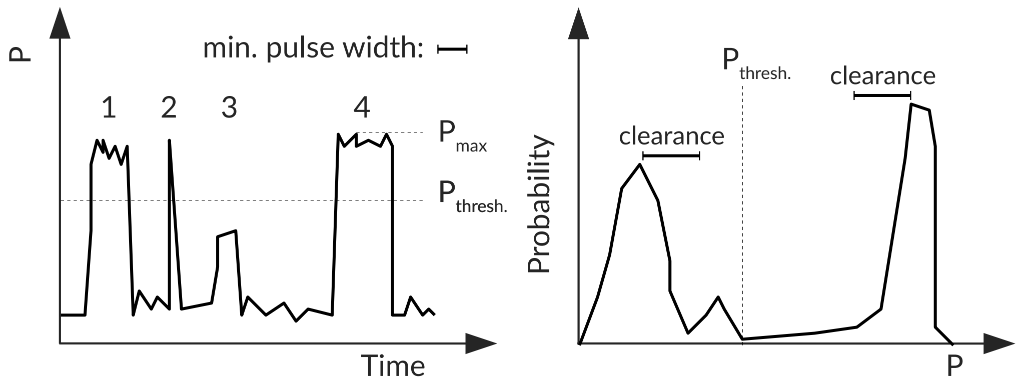


Figure 50: *Principle of remote power measurements' threshold calculation*

the "show samples as time" in the "View" menu, the "MinLength" setting, the x-axis labels of the waveform graph and the values "Start@Index" and "Length@Index" will be displayed in seconds, otherwise values are given as a number of samples.

5.4.8 Remote Power Measurements Using the SCPI Commands

See Section 5.4.2 for the details of triggered value acquisition. Remote Power Measurements require the trigger system to be in DONE state.

The distance between the transmitter and the LSProbe is set using the command »[:TRIGger]:RPower:DIST <Distance>[<MProbe>]«. Pulse trimming is enabled and disabled using »[:TRIGger]:RPower:TRIM <State>[,<MProbe>]«. The pulse detection method is set using »[:TRIGger]:RPower:THMethod <Method>[<MProbe>]«, the manual threshold is set using »[:TRIGger]:RPower:ATHold <Threshold>[<MProbe>]«, the relative threshold is set using »[:TRIGger]:RPower:RTHold <Threshold>[<MProbe>]« and the clearance for histogram-based threshold setting is set using »[:TRIGger]:RPower:CLEARance <Clearance>[<MProbe>]«. The threshold values can be queried using »[:TRIGger]:RPower:THold:X/[:Y]/:Z? [<MProbe>]«.

The moving average filter is configured using »[:TRIGger]:RPower:MAVG <Count>[<MProbe>]«, the minimum pulse length is set by »[:TRIGger]:RPower:MINSamples <MinS>[<MProbe>]«.

Remote power results for the entire waveform can be queried using the command »[:TRIGger]:RPower[:APOWer]:X/[:Y]/Z? [<MProbe>]« for averaged power values, »[:TRIGger]:RPower:COUNt:X/[:Y]/:Z? [<MProbe>]« for the number of pulses, »[:TRIGger]:RPower:DUTY:X/[:Y]/:Z? [<MProbe>]« for the duty cycle and »[:TRIGger]:RPower:MPOWer:X/[:Y]/:Z? [<MProbe>]« for the maximum power values.

Measurement results for individual pulses can be queried from the TCP server using »[:TRIGger]:RPower:PULses[:TIMe]:X/[:Y]/:Z? [<MProbe>]« for the combined start times, pulse lengths and pulse power values, times returned as seconds. Alternatively, »[:TRIGger]:RPower:PULses:STArt:X/[:Y]/:Z? [<MProbe>]«, »[:TRIGger]:RPower:PULses:LENgth:X/[:Y]/:Z? [<MProbe>]« and »[:TRIGger]:RPower:PULses:Power:X/[:Y]/:Z? [<MProbe>]« can be used to retrieve the these values individually, with times expressed as samples.

Power value waveforms can be retrieved from the TCP server using the command »[:TRIGger]:RPower:WPower:X/[:Y]/:Z? [<MProbe>]«. The »[:TRIGger]:RPower:BINary? <Wave>[,<MProbe>]« command is available for fast and computationally efficient remote power measurement readout in binary format.

5.5 Oversampling

The Oversampling feature enables recording of repetitive signals, e.g. pulses, with a higher resolution than during normal trigger waveform aquisition. This is especially of intereset for use cases, where the shifting signal is faster than the sampling rate of the LSProbe. For normal operating mode, the time resolution and therefore minimum pulse width and spacing is at least 2 us. Via the oversampling feature the granularity can be improved down to 3.3ns and a high resolution waveform generated.

During Oversampling, a repetitive signal is sampled multiple times with different phase correlation, each covering a part of the underlying signal curve. The time between the start of the repetitive signal and the sampling start of each waveform is random and denoted as phase. By sampling the signal multiple times, various waveforms with different phases are recorded. Each waveform with a certain phase represents a part of the signal. Superimposing the waveforms in the order of their phase reconstructs the acquired signal, see Figure 51.

To determine the start of the repetitive signal it is necessary to provide external trigger signal to the BNC trigger input at the rear of the CI-250(+) device, see Section 3.2 for more information regarding the hardware setup. The internal counter to determine the phase between the external trigger signal and ADC conversion begin enables the enhanced time resolution.

The ADC sampling counter runs asynchronous to the external trigger signal and for signal repetition rates different to the ADC sampling rate, the phase differs with every sampling event. The sampling event can occur either before or after a trigger signal. Sampling events occurring before the trigger signal need to be shifted by a full phase period. Since the correlation between the sampling event and the trigger signal depends on each individual measurement setup, the time span for the samples occurring before the trigger event is random and needs to be determined for each measurement. This span is denoted as the offset.

As multiple waveforms for a single phase can be received, the underlying structure of the complete oversampled waveform consists of histograms. I.e. for each point in the high resolution waveform a histogram labelled with a phase number and trigger waveform index is designated. The resolution of the histograms is 0.005 dB. The total length of the high resolution waveform is the length of the sub-waveform multiplied by the sampling-rate dependent number of phase values. Upon receiving

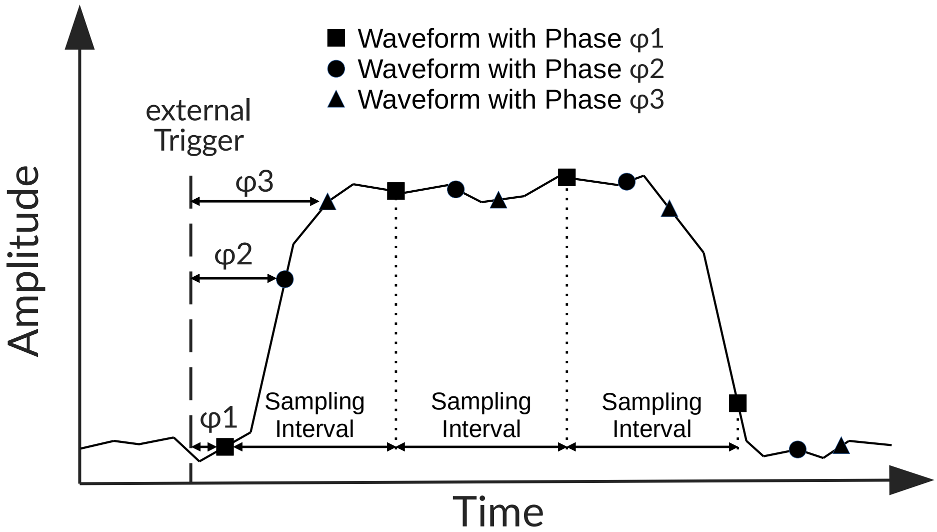


Figure 51: *Basic principle of oversampling feature*

multiple waveforms for a single phase, the values are superimposed to get the overall value for the overampling waveform. An averaged value with an adjustable confidence interval is computed, stating the final value of the oversampled waveform for the respective phase and sample index. Refer to Figure 52 for graphical depiction.

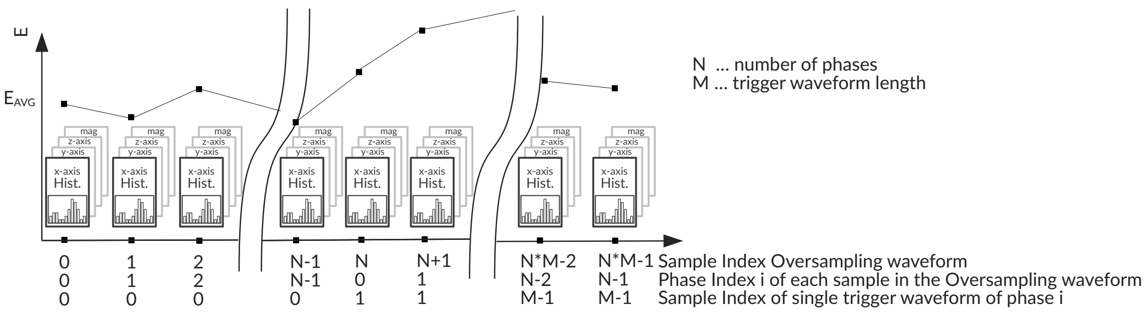


Figure 52: *Structure of Oversampling waveform*

5.5.1 Oversampling Using the GUI

In order to enable oversampled waveform aquisition within the LUMILOOP GUI select the "Oversampling" tab in the "View" toolbar and enable "Show Data" as shown in Figure 53. The waveform acquisition is configured in the retractable frame on the left side of GUI. At the top, the status of waveform acquisition is shown. "Trigger State" imparts the present state of the trigger system as described in Figure 44. During Oversampling enabled state, the trigger system will switch only between "Triggered" and "ARMED" states. "Waveforms" displays the number of sub-waveforms recorded, which are constituting the current oversampled waveform. The "Progress" indicator field denotes the percentual progression of the measurement. Its behavior depends on the stop criterium for the continuously recorded oversampled waveform. There are three options:

Sub-waveform count
: Automatical termination of oversampling upon obtaining a specific number of sub-waveforms. If the "WavCount" field is set to a value higher than zero, as soon as the specified number of waveforms is reached, the oversampled waveform acquisition will terminate and the trigger system reach "DONE" state. The "Progress" indicator field will mirror the percentual advancement of the defined number of sub-waveforms.

Phase count
: Automatical termination of oversampling upon obtaining a minimum number of sub-waveforms for each phase. If the "BinCount" field is set to a value higher than zero, as soon as at least the specified number of waveforms for each phase is reached, the oversampled waveform acquisition will terminate and the trigger system reach "DONE" state. The "Progress" indicator field will mirror the percentual advancement of the defined number of sub-waveforms for each phase. E.g. if four sub-waveforms per bin are required for a complete measurement and each bin contains a single waveform, the "Progress" field will show a progress of 25%. The same progress will be shown, if a quarter of all bins are filled with four bins and the rest is empty.

Continuous
: If phase count and sub-waveform count are both set to zero, termination of oversampled waveform recording is reached by manually disabling the recording of sub-waveforms by setting the "Enable" button to off. The "Progress" indicator field will show the same behaviour as if a phase count of one was set as termination criterion.

If both for sub-waveform count and phase count a value greater than zero is set, as soon as one of the conditions is met oversampled waveform acquisition will terminate. The distribution of the sub-waveforms among the phases is shown in the table "Bin Progress" at the bottom of the left frame. For each possible phase, the number of sub-waveforms corresponding to this phase is shown. If the minimum amount of sub-waveforms per phase as set in the "BinCount" field is reached or at least one if "BinCount" is set to zero, the corresponding row in the "Bin Progress" table is highlighted by a green background.

"Offset" and "Length" numeric input fields are duplicated from the "Scope" tab for comfort to configure the length of the sub-waveform and the start of the sub-waveforms relative to the position of the trigger event. Configuration of sub-waveform length and offset is ony allowed if oversampled waveform acquisition is disabled.

Figure 53: *LUMILOOP GUI, Oversampling tab*

After enabling the oversampled waveform recording by pressing the "Enable" button, the trigger subsystem is automatically configured to accept external trigger signals and the measurement starts immediately. I.e. the BNC trigger output is disabled, the trigger source is set to BNC trigger input and the trigger state is set to "ARM". The "Reset" button deletes all previously recorded sub-waveforms for the current measurements, starting the sub-waveform acqusition from the beginning. The "Show Data" button enables or disables the display of the oversampled waveform in the graph. The "Show Histogram" checkbox hides or shows the histogram of all sub-waveforms. Histogram values of the recorded sub-waveforms are displayed as a scatter plot, in the order of their corresponding phase of the sub-waveform. The "Show Waveform" checkbox hides or shows the oversampled waveform resulting from the individual sub-waveforms. The high resolution waveform is calculated by the arithmetic mean of the samples of all sub-waveforms for a specific phase. The averaged samples of the sub-waveforms is then plotted starting in the order of their corresponding phase. Averaging of the sub-waveform samples is controlled by the "Max Noise" field. The "Max Noise" value sets the maximum distance from a single sample value to the arithmetic mean. If the distance is greater than the set value, the sample is not considered for the calculation and the arithmetic mean is recalculated.

The "Phase Offset" slider sets the offset for shifting the waveforms captured before the trigger signal. The effect of the offset is applied immediately to the high resolution waveform. With the "Phase Offset Auto" button, the LUMILOOP TCP Server computes an offset in the following way: For each phase offset, the sum over the distance between neighboring values in the resulting oversampled waveform is computet and added for each x-, y-, z-axis E-field component and E-field strength magnitude waveform. The phase offset with the minimum sum is taken as the optimal phase offset.

Above the plot, E-field statistics of the oversampled waveform are displayed, namely the E-field average over the whole high resolution waveform, as well as its maximum and minimum recorded E-field value for each x-, y-, z-axis and magnitude.

5.5.2 Oversampling Using SCPI Commands

The measurement is configured via the »:TRIGger:LENgth <Length>[,<MProbe>]« command for the sub-waveform lenght and »:TRIGger:BEGin <Index>[,<MProbe>]« command for the sub-waveform offset known from the triggered measurements. To set the maximum number of waveforms to be recorded, use the »:TRIGger:OVERsampling:WAVCnt <Value>[,<MProbe>]« command. The minimum number of sub-waveforms per phase is set by the »:TRIGger:OVERsampling:BINCnt <Value>[,<MProbe>]« command. To verify the settings for a measurement use the query commands »:TRIGger:LENgth? [<MProbe>]«, »:TRIGger:BEGin? [<MProbe>]«, »:TRIGger:OVERsampling:WAVCnt? [<MProbe>]« and »:TRIGger:OVERsampling:BINCnt? [<MProbe>]«.

Using the »:TRIGger:OVERsampling:ENable <State>[,<MProbe>]« SCPI command will enable the oversampling subsystem. To query the status of the oversampling subsystem, use »:TRIGger:OVERsampling:ENable? [<MProbe>]«. The configuration of oversampling measurements must take place in OFF state, since activating the oversampling subsystem also immediately starts the measurement. During enabled state, »:TRIGger:OVERsampling:RESet [<MProbe>]« deletes the current measurement data.

The status of the oversampled waveform recording can be dertermined by querying the status of the trigger subsystem using the »:TRIGger:STATe? [<Timeout>,<MProbe>]« command. After the measurement is finished, either by using »:TRIGger:OVERsampling:ENable <State>[,<MProbe>]« with the parameter "0" or, if defined, either the sub-waveform count or sub-waveform per phase count termination condition was met, the trigger subsystem reaches the DONE state. To query the number of sub-waveforms recorded, use the »:TRIGger:OVERsampling:WAVProgress? [<MProbe>]« command. The percentage of phases satisfying the criteria is queried with the »:TRIGger:OVERsampling:PROgress? [<MProbe>]« command. A detailed distribution of the number sub-waveforms per phase can be obtained using the »:TRIGger:OVERsampling:BINStatus? [<MProbe>]« command. This command returns a comma-separated list with the amount of waveforms per phase, starting from phase index zero. The number of phases for the current sampling rate is queried by »:TRIGger:OVERsampling:PHCount? [<MProbe>]« For post processing of the sub-waveforms use the »:TRIGger:OVERsampling:MAXNoise <Value>[,<MProbe>]« command, for adjusting the maximum distance between a sample and the average value in dB. With the »:TRIGger:OVERsampling:PHOffset <Offset>[,<MProbe>]« command, the index of phase offset is set, a value between zero and the number of phases (»:TRIGger:OVERsampling:PHCount? [<MProbe>]«) minus one. The current phase offset is queried with the »:TRIGger:OVERsampling:PHOffset? [<MProbe>]« command and the auto phase offset detection is executed by using the »:TRIGger:OVERsampling:PHOffset:AUTO [<MProbe>]«.

To obtain the results from the measurement, either the averaged E-field oversampled waveform or the histogram of the measurement can be queried by using the »:TRIGger:OVERsampling:X/Y/Z/MAG/ALL? [<MProbe>]« or »:TRIGger:OVERsampling:HISTogram:X/Y/Z/MAG? [<MProbe>]« command.

5.6 E-field Statistics

Two types of E-field statistics are available for the LSProbe, continuous statistics as described in Section 5.6.1 and triggered statistics based on acquired waveforms as described in Section 5.6.3. Continuous statistics evaluate all measured E-field values from the time that statistics collection is enabled to the time that a statistics snapshot is created. Continuous statistics are collected in the background and can be performed over arbitrary periods of time. Triggered statistics evaluate only E-field values of waveforms in memory. Almost all SCPI commands of the statistics subsystem apply to both continuously collected and triggered E-field values.

5.6.1 Continuous E-field Statistics using the GUI

Statistics functions are controlled via the "Statistics" tab of the LUMILOOP GUI, see Figure 54. See Section 2.7 for an explanation of the operating principle.

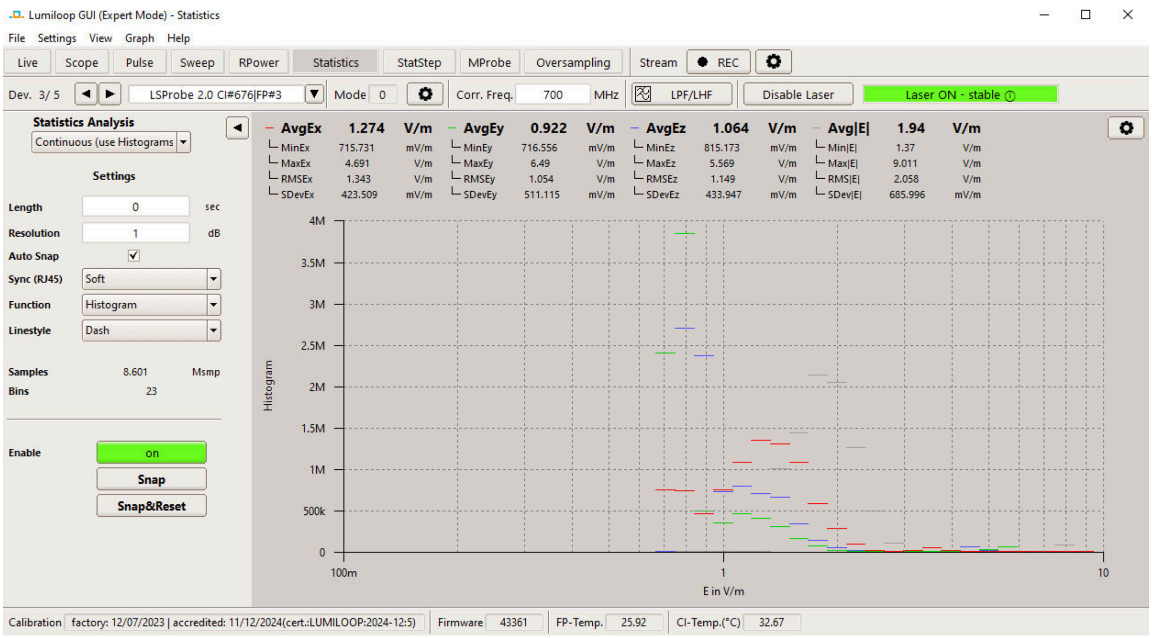


Figure 54: *LUMILOOP GUI, Statistics tab*

All enumerated LSProbe devices will be configured automatically as software controlled, independent units. In case of synchronized continuous E-field statistics, one master computer interface must be set, all other devices must be configured as statistics slaves. As explained in Section 3.3 synchronized continuous E-field statistics use the RJ45 socket of the CI-250$^{(+)}$ device for synchronized enabling of statistics collection and snapshot creation. For a single LSProbe system the LSProbe can be configured to either master or software controlled.

A computer interface may be configured as the statistics master via the "Sync (RJ45)" drop-down list. If multiple devices are set to master at the same time, the "Synchronization Setup" dialog as depicted in Figure 55 will open, for verifying the current setting. Setting multiple devices which are connected via their RJ45 socket to master state can cause unexpected behaviour. Setting multiple devices as master is possible, if the different Multi Device Systems have no connection among each other, only among themselves.

In order to enable continuous statistics in the LUMILOOP GUI, select "Continuous (use Histograms)" from the "Statistics Analysis" drop-down list. This will enable additional controls for continuous statistics.

The "Enable" button is used to enable and disable continuous E-field statistics collection via the statistics master computer interface and/or for all software controlled devices. Continuous statistics data can be viewed in the form of statistics snapshots as described in Section 5.6. A statistics

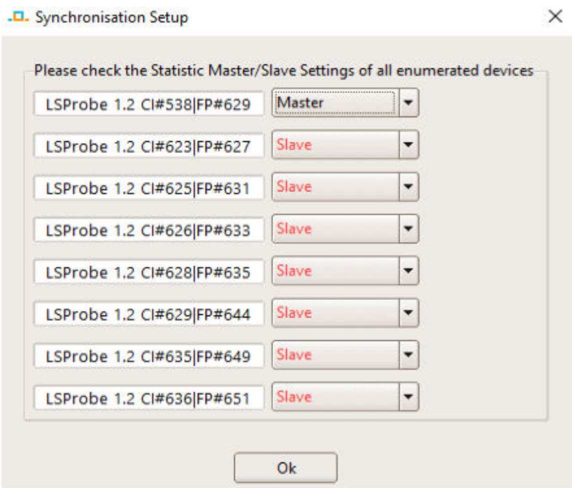


Figure 55: *LUMILOOP GUI, Statistics "Synchronization Setup" dialog*

snapshot can be created manually by clicking on the "Snap" button. A statistics snapshot will also be created when statistics collection is disabled via the "Enable" button. Automatic statistics snapshot creation is enabled via the "Auto Snap" check box, instructing the GUI to trigger a new statistics snapshot after each update of the statistics display. The total number of samples used for the most recent statistics snapshot is displayed in the "Samples" display field. For Multi Device Systems this number may vary slightly due to minimally different local clock frequencies of each device. To collect a specific number of E-field samples, set the "Length" numeric input field to this number. If set to zero, continuous statistics collection runs until manually disabled again.

All output is based on the most recent statistics snapshot. See the SCPI command reference in Section 12.11 for a detailed description of scalar and histogram-like statistics values.

The plot legend above the plot lists all scalar statistics values of the currently selected LSProbe. The histogram-like statistics include arithmetic mean, minimum, maximum, root mean square and standard deviation for the x-, y- and z-components of the E-field and its magnitude.

Histogram-like statistics are selected via the "Function" drop-down list. Available choices are histogram, discrete relative probability distribution, discrete cumulative probability distribution and discrete complementary cumulative probability distribution. Histogram-like statistics are displayed in the main plot area.

The style of the displayed graphs is adjustable via the "'Linestyle" drop-down list. If "Dash" is selected, dashes stretching each power level bin will be displayed, in case of "Point" one point will be plotted for every power level bin mid point. Point size and dash line width can be adapted using the "Statistics Graph Configuration".

The E-field strength resolution in dB can be set via the "Resolution" input field, determining the size of the E-field strength bins. Its smallest permissible value, yielding the maximum E-field strength resolution, is 0.005 dB. The number of bins resulting from the set resolution and E-field strength distribution is shown in the "Bins" display field.

5.6.2 Continuous E-field Statistics using SCPI Commands

Continuous statistics and triggered statistics are accessible using a common set of SCPI commands. An SCPI command's function is determined by the parameter "Triggered". If set to "0" an SCPI command applies to continuous statistics, if set to "1" an SCPI command applies to triggered statistics. For most commands the parameter "Triggered" is optional, making the SCPI command default to continuous statistics.

The continuous statistics synchronization is set by using »:STATistics:MAster <State>[,<MProbe>]« with the parameters "soft", "slave" or "master". The continuous statistics master computer interface must be set by first selecting it using »:SYSTem:CISerial <Value>«, followed by setting its master status to "1" or "master" using »:STATistics:MAster <State>[,<MProbe>]«. Statistics slave or software based statistics can be set for multiple devices at once using the MProbe parameter as described in Section 12.1. The statistics synchronization status of any computer interface may be queried using »:STATistics:MAster? [<MProbe>]«.

Continuous E-field statistics collection is started by issuing »:STATistics:ENable <State>[,<MProbe>]« with the parameter "State" set to "1" for the statistics master computer interface or all software controlled devices. To set the maximum number of samples to be collected, use the »:STATistics:LENgth <Length>[,<MProbe>]« command. If set to a non-zero number statistics collection will terminate automatically after reaching the maximum number of samples. Statistics snapshots will be generated on receiving either »:STATistics:SNAPshot [<Triggered>][,<MProbe>]« or »:STATistics:ENable <State>[,<MProbe>]« with the parameter "State" set to "0". The snapshot counter will be incremented by one for every new snapshot, the counter(s) can be queried using »:STATistics:COUnt? [<MProbe>]«. Using this query enables snapshot synchronization, since snapshot query and execution are inherently asynchronous for continuous E-field statistics. Enabling continuous statistics will reset the snapshot counter to zero. »:STATistics:SAMples? [<Triggered>][,<MProbe>]« returns the number of samples used for the most recent statistics snapshot.

Scalar statistics values can be read using the commands described in Section 12.11.14 through 12.11.18. Histogram-like statistics values are returned by the commands described in Sections 12.11.20 through 12.11.23.

The resolution for histogram-like values is set using »:STATistics:RESolution <Resolution>[,<MProbe>]«. The resulting number of bins, the offset of the bin with the smallest E-field strength and the center E-field strength of each bin can be queried via »:STATistics:HISTogram:SIZe? [<Triggered>][,<MProbe>]«, »:STATistics:HISTogram:OFFset? [<Triggered>][,<MProbe>]« and »:STATistics:Efield? [<Triggered>][,<MProbe>]« respectively. All statistics values are also available in binary format, see »:STATistics:BINary? [<Triggered>][,<MProbe>]« for details.

5.6.3 Triggered Statistics using the GUI

Triggered statistics use waveform data for building the scalar and histogram-like values discussed in the previous section. See Section 5.4.1 for a description of waveform acquisition. Triggered E-field statistics do not rely on the physical connections required for continuous synchronized E-field statistics. For triggered E-field statistics there is no statistics master, slave or soft state, no statistics enable function and no hardware-based snapshot feature.

In order to access triggered E-field statistics in the LUMILOOP GUI select "Triggered (use Waveforms)" from the "Statistics Analysis" drop-down list, this will enable additional controls for triggered E-field statistics.

A statistics snapshot based on the most recently acquired waveforms can be created manually by clicking on the "Snap" button. Automatic statistics snapshot creation is enabled via the "Auto Snap" button, making the GUI take a new triggered snapshot upon receiving a new E-field waveform. The "Arm" and "Force" buttons are provided for ease of use and are identical in function to the buttons described in Section 5.4.

Triggered statistics data is viewed in the form of statistics snapshots as described in Section 5.6. All scalar and histogram-like values are controlled and displayed as described in the previous sections.

5.6.4 Triggered Statistics using SCPI Commands

Triggered statistics SCPI commands require the parameter "Triggered" to be set to "1" for all related SCPI commands. Statistical evaluation requires a valid set of triggered waveforms, see Section 5.4.2 for details about waveform acquisition.

To enable the statistics commands generate a snapshot histogram using »:STATistics:SNAPshot [<Triggered>][,<MProbe>]«. This snapshot will be based on the most recently acquired waveforms. There is no trigger snapshot counter. Instead, triggered snapshot generation is performed synchronously making statistics values available immediately after issuing the SCPI snapshot command.

Scalar and histogram-like statistics values can be obtained using the same SCPI commands as described in Section 5.6.2 with the parameter Triggered set to "1" at all times.

5.7 E-field Step-Wise Statistics

Step-Wise Statistics allows for reduction of the LSProbe's sampling rate by creating statistics over a user specified number of samples. The minimum. maximum and averaged E-field value for each step is computed for x-, y-, z-axis E-field component and E-field strength magnitude. Via a FIFO-buffer up to 1024 past samples can be queried. Step-Wise statistics make use of the continuous statistics subsystem's enable and snapshot function as well as the synchronization if required. Due to minimally different local clock frequencies of each device, step-wise statistics over multiple devices is dispersing after a short amount of time. For this reason a "Reset" on Snapshot signal can be used to reset all devices to zero.

5.7.1 Step-Wise Statistics using the GUI

In order to enable Step-Wise Stastistics within the LUMILOOP GUI select the "StatStep" button in the "View" toolbar and enable "Show StatStep Analysis" as shown in Figure 56.

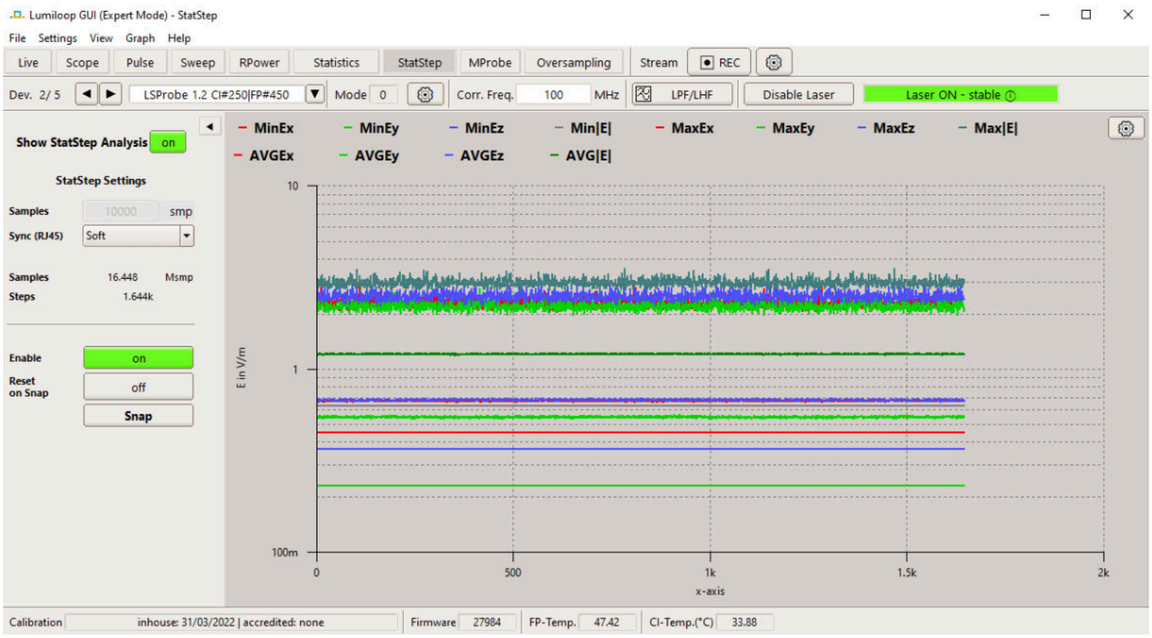


Figure 56: *LUMILOOP GUI, StatStep tab*

The "Samples" entry field sets the number of samples over which step-wise statistic is performed. It can only be edited during Statisics disabled state. To disable Step-Wise Statistics set the value to zero. The "Sync (RJ45)" drop-down menu, the "Enable" and "Snap" buttons are provided for ease of use and are identical in function to the buttons described in Section 5.6.1.

The "Samples" and "Steps" indicator fields state the number of samples and the resulting number of steps since Statistics enable or the last reset command. For synchronized measurements to reset the Step-Wise statistics during statistics collection and start for all devices from the beginning again enable the "Reset on Snap" button and create a snapshot via pressing "Snap" afterwards. "Samples" and "Steps" indicator fields will reset to zero.

5.7.2 Step-Wise Statistics using SCPI commands

To set the number of samples for step-wise statistics evaluation use 12.11.25. Enabling and disabling statistics collection is done via the scpi command 12.11.3 using the parameter "1" or "0". Refer to Section 5.6.2 for details on synchronization and continuous statistics collection. To reset step-wise statistics collection first the reset flag has to be set via 12.11.32 followed by a continuous snapshot command, e.g. 12.11.7 with the "Triggered" parameter set to zero.

Use 12.11.31 and 12.11.30 to query the processed number of samples or steps since last statistics collection enable or reset. 12.11.29 returns the number of available step-wise statistic value sets which are currently in the value FIFO available, at maximum 1024 values.

Step-wise statistics encompasses minimum, maximum and averaged E-field value for x-, y-, z-axis and magnitude. Results are queried using 12.11.34. To disable output of certain statistics and/or E-field components use the command described in Sections 12.11.27. Therefore the command returns at max four times three values, at least a single value. The "greedy" parameter of the command 12.11.34 denotes if the returned values are deleted from the value fifo, meaning that other clients can only query future values.

The »:STATistics:STEPwise:BINary? [<Greedy>,<MProbe>]« command is available for fast and computationally efficient step-wise value readout in binary format.

5.8 Stream Recording

The LSProbe supports recording field strength values at the E-field probe's full sampling rate for virtually unlimited durations of time. Recording time is only limited by the disk space available.

Stream files are stored in the path specified by the `LUMILOOP.ini` configuration file setting `SAVE_PATH` and adhere to the naming convention in Section 13.1.8. File names start with an arbitrary prefix string followed by the E-field probe's serial number and version and, if optically powered, the computer interface's serial number, ending with a unique time stamp. A new set of stream files, containing an updated time stamp, will be created every 1,000,000,000 samples.

The stream recording feature stores field strength data in a binary format in order to reduce both disk space and CPU load. The binary file format is detailed in Section 13.1.8. Binary stream files can be converted into CSV files using the "Bin2Csv" conversion tool described in Section 13.1.9.

Alternatively, the binary stream data can also be send to a user specified client connection. See Section 13.1.9 for a detailed description on realization and format.

5.8.1 Stream Recording Using the GUI

All stream configurations are done via the "Stream configuration" dialog, opened by the button showing a gear next to the stream recording button in the "View" toolbar, see Figure 58. Set the synchronization i.e. "Master" or "Slave", status of the CI-250$^{(+)}$ device using the "Master" drop-down list. Per default all computer interfaces are set to slave after enumeration. The synchronization source can be selected via the "Synchronization" drop-down list. If set to "OFF", stream recording is software controlled. If "External BNC" or "External RJ45" synchronziation is to be used, make sure to connect the appropriate signal lines as described in Section 3.2 and perform the settings either for all devices individually or enable the "Apply settings to all" flag. If multiple devices are set to streaming master at the same time, the "Synchronization Setup" dialog as depicted in Figure 57 will open, for verifying the current setting. Setting multiple devices which are connected via their BNC or RJ45 socket to master state can cause unexpected behaviour. Setting multiple devices as master is possible, if the different Multi Device Systems have no connection among each other, only among themselves.

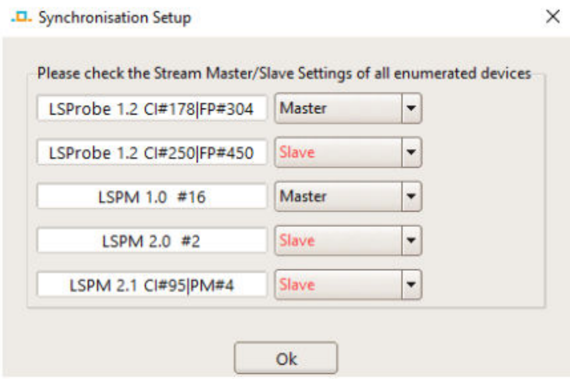


Figure 57: *LUMILOOP GUI, Stream "Synchronization Setup" dialog*

To record a specific number of E-field samples, set the "Length" numeric input field to this number. If set to zero, stream recording runs until manually disabled again. The number of E-field values to be skipped after every recorded sample is set via the "Skip Count" numeric input field. E.g. setting the "Skip Count" to three, after every recorded sample, three samples are omitted, reducing the effective sampling rate to a quarter. The stream file prefix is set via the "Prefix" input field. The content of the data stream can be either written into a file or send to a TCP port. The IP-address and port is set in the corresponding entry fields below the "Output"choice box.

Stream recording is enabled via the "Enable" button in the stream configuration dialog or via the "REC" button in the LUMILOOP GUI's "View" toolbar. When activated, the "Enable" button in the stream configuration dialog turns green and the "Rec" button in the main window turns red, see Figure 58. If the "Length" input field is set to a non-zero value, streaming will be terminated automatically once the desired number of samples to be streamed is reached. A stream recording may be terminated via the "Enable" button before the set number of samples has been reached. If the "Length" input field is set to "0", stream recording must be terminated manually via the "Enable" or "REC" button. Manual termination of a stream recording can lead to stream files containing a disparate number of samples. The current number of recorded samples is displayed in the "Progress" field.

5.8.2 Stream Recording Using SCPI Commands

Stream synchronization can be configured using the »:STReam:SYNC <Sync>[,<MProbe>]« SCPI command. When synchronization is disabled, the stream master CI-250$^{(+)}$ device can be changed by setting the former master CI-250$^{(+)}$ device to slave, selecting the new device and setting it to stream master using »:SYSTem:CISerial <Value>«, for selecting the new device and the »:STReam:MAster <State>« with the parameter "1" to set it to stream master.

To set the maximum number of samples to be recorded, use the »:STReam:LENgth <Length>[,<MProbe>]« command. If set to a non-zero number stream recording will terminate automatically after reaching the maximum number of samples.

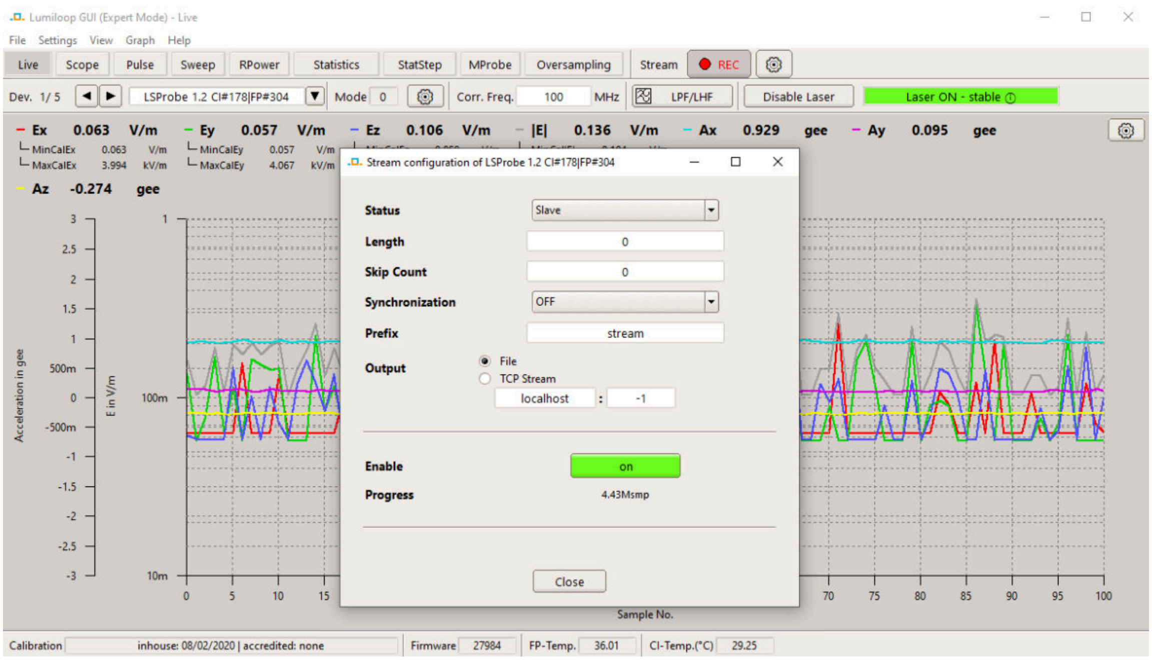


Figure 58: *LUMILOOP GUI and "Stream configuration" dialog of the current selected*

The stream data rate can be reduced using the »:STReam:SKIp <SkipCnt>[,<MProbe>]« command, specifying the number of skipped samples following each stored sample. The »:STReam:PREfix <String>[,<MProbe>]« command can be used to change the stream files' prefix string.

To change the output directory of the stream data use »:STReam:OUTput <OUT>[,<MProbe>]«. If set to "FILE", the binary stream data is written to binary file, this is the default. To set the output to a TCP Server cient, a string parameter with quotes specifying the host and port, separated by a ":" , e.g. setting "localhost:10005", will send the binary data to port 10005 on the local computer.

Stream recording is initiated and terminated using the »:STReam:ENable <State>[,<MProbe>]. The progress of stream recording can be monitored using the »:STReam:PROgress? [<MProbe>]« command.

5.9 Multiprobe Statistics Analysis

Mulitprobe analysis for a set of LSProbe 1.2/1.4/2.0 E-field probes is only supported for LSProbe 1.2/1.4/2.0 E-field probes enumerated by the same LUMILOOP TCP Server. Multiple sets with an arbitrary number of LSProbe devices can be defined. For Multiprobe setups the statistics SCPI command subsystem is used to calculate statistics values as described in Section 5.6. Multiprobe statistics can be calculated from continuous and triggered E-field statistics in the same manner as all other statistics values.

5.10 Multiprobe Systems Using the GUI

Multiprobe evaluation is controlled via the "MProbe" tab of the LUMILOOP GUI, see Figure 60.

The GUI offers three predefined ISO standard setups for the demonstration of Multiprobe functionality. These three setups are accomplished by defining special cases of a more generalized Multiprobe system using the Multiprobe SCPI command subsystem. This subsystem is also employed for calculating statistics based on the statistics of multiple E-field probes.

As Mulitprobe analysis for a set of LSProbe 1.2/1.4/2.0 E-field probes is only supported for LSProbe 1.2/1.4/2.0 E-field probes enumerated by the same TCP Server client, if the LUMILOOP GUI is communicating with multiple LSProbe TCP Server clients, the desired client connection can be chosen via the "LSProbe TCP Server" drop-down list. The LUMILOOP GUI supports loading and saving of Multiprobe Configurations by name, e.g. different setups of a single Multiprobe setup type can be managed. As configurations are stored in the user's `LUMILOOP.ini` file, this functionality is restricted to the computer and user running the LUMILOOP GUI.

Multiprobe statistics can be calculated from continuous and triggered E-field statistics in the same manner as all other statistics values. In order to enable continuous or triggered Multiprobe analysis in the LUMILOOP GUI select "Continuous (use Histograms)" or "Triggerd (use Waveforms)" from the "Multiprobe Analysis" drop-down list, this will enable additional controls for continuous or triggered Multiprobe E-field statistics.

Accordingly, the GUI mirrors functionality of the "Statistics" tab in the "MProbe", see Figure 60. The drop-down list "Multiprobe Analysis", the buttons "Enable", "Auto Snap", "Arm", "Force" and "Snap" have the same function as described in Section 5.6.1 and are not detailed in this section. In "Continuous (use Histograms)" analysis mode, the "Configure Synchronization" button replaces the selection ring "Stats Master" of the "Statistics" frame. It will open the dialog window "Synchronization Setup" as depicted in image Figure 59 for configuring the synchronization of all set devices of the selected Multiprobe setup.

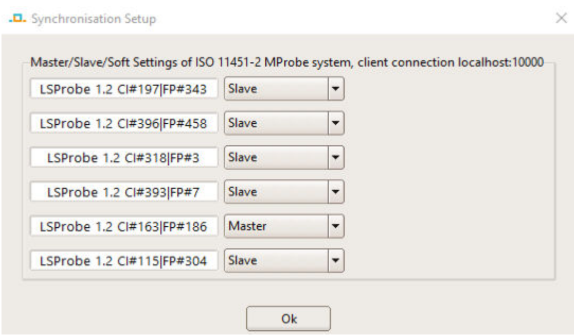


Figure 59: *LUMILOOP GUI, "Synchronization Setup" dialog window*

5.10.1 Single, Three, Four or Six Probe Setups according to ISO 11451-2

In accordance with the ISO standard the arithmetic mean of the E-field strength magnitude at a given reference point is calculated over a user defined period of time. The reference point can be compromised of a single E-field probe or of four LSProbe 1.2/1.4/2.0 E-field probes, placed on a reference line. Two control probes may be included in the system, thus extending the single or four probe setup to form a three or six probe setup, see Figure 60.

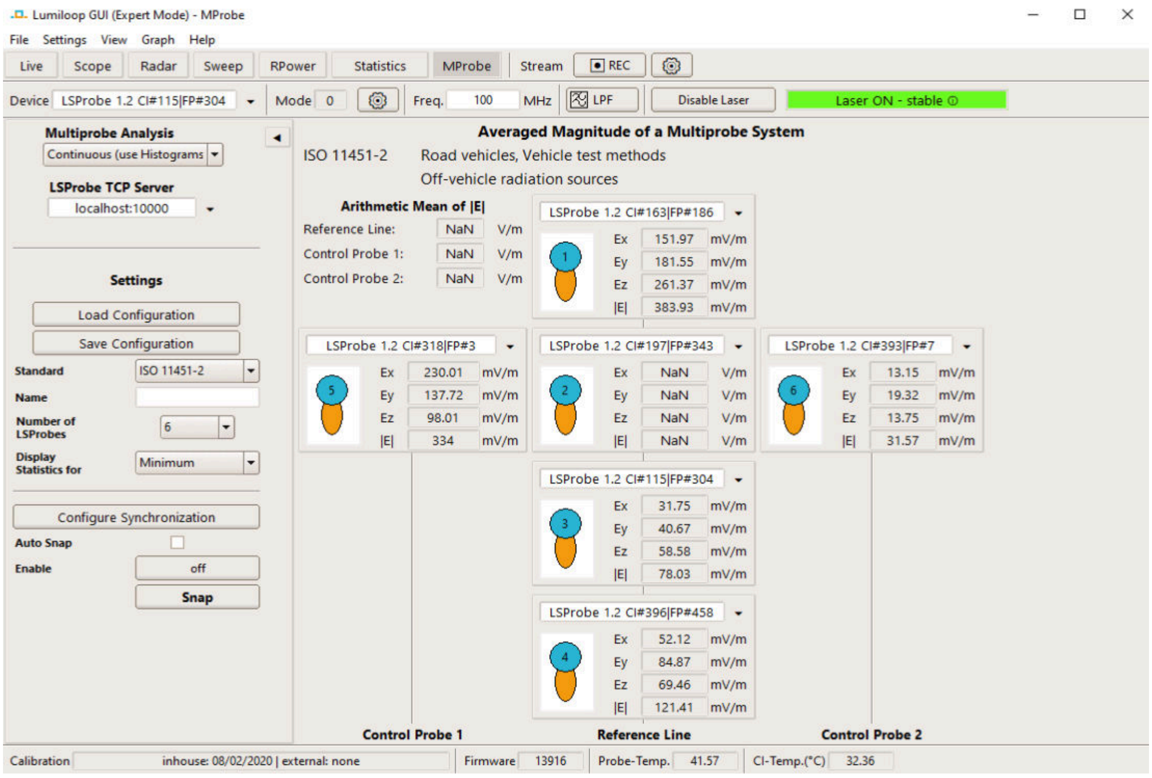
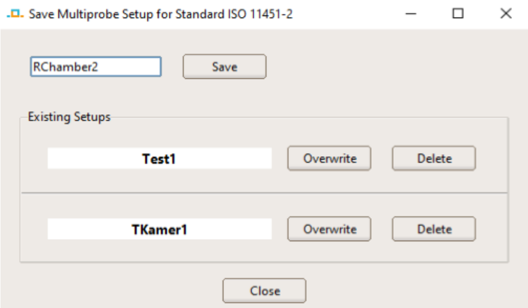


Figure 60: *LUMILOOP GUI, Multiprobe tab for ISO 11451-2*

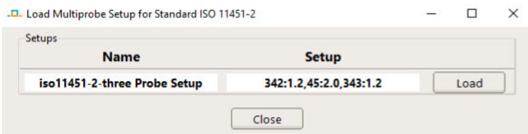
Set the "Standard" dropdown list to "ISO 11451-2". Configure the number of probes to be used via the "Number of Probes" drop-down list.

Multiprobe setup, results and single probe status are displayed in the right pane normally used for waveforms. At the top a short summary of the statistical evaluation over the E-field probes of the setup and ISO standard application is given. The Multiprobe results for the reference point or reference line and the control probes are shown on the upper left-hand side. The values give the arithmetic mean of the E-field strength magnitude for the reference point or line and the optional two control probes. With the number of set probes for the ISO 11451-2 setup, single device status frames will become visible and arranged accordingly. For each device frame the active device can be set via the arrow down button or by clicking in the red indicator field. Changing these settings will reconfigure the Multiprobe setup immediately. For each device the current single statistical data is shown in accordange with the setting "Display Statistics for" on the left site.

To save a Multiprobe setup enter the name in the "Name" entry field on the left site and press “Save Configuration”. The “Save Multiprobe Setup for Standard ISO 11451-2” will open with an overview over all existing setups for the current standard. Either create a new setup or overwrite an exisiting one. Additionally, an existing setup can be deleted via its dedicated “Delete” button. To load an existing standard configuration, click on the “Load Configuration” button to open the “Load Multiprobe Setup for Standard ISO 11451-2” dialog with an overview over all saved setups for the current standard with its name and set LSProbe 1.2/1.4/2.0 E-field probes serial numbers and versions.



(a) Multiprobe Setup Save Dialog



(b) Multiprobe Setup Load Dialog

Figure 61: *Multiprobe setup save and load dialog for currently observed standard*

5.10.2 Eight Probe Setup according to ISO 11452-11 / IEC 61000-4-21

Eight probe setups define a probe for the corners of a cube, this is also approximated in the layout of the GUI, see Figure 62. Although the ISO standard is defined with eight points, for utmost flexibility setups with down to a single probe can be configured. Scalar statistics values for each probe are displayed in the bottom pane in the single device frames in the same fashion as described in Sections 5.10.1 All other controls operate in the same way as described in the previous sections.

5.10.3 Probe Setup According to ISO 11451-5

The LUMILOOP GUI allows configurations of the ISO 11451-5 setup up to twelve LSProbes. Configuration is done in the “Select LSProbes” tab on the right lower panel. Scalar statistics values for each probe are also depicted in this tab, as shown in Figure 63. To view the Multiprobe evaluation over all selected devices got to the “Results” tab as shown in Figure 64. The represented multiprobe evaluation encompasses the arithmetic mean over all arithmetic mean of field strength values of the single LSProbes (“MEAN_P(MEAN_t)”), the arithmetic mean over all maximum field strength values of the single LSProbes (“MEAN_P(MAX_t)”), the quotient of maximum and arithmetic mean of E-field strength averaged over all field probes (“MEAN_P(MAX_t)/MEAN_P(MEAN_t)”), E-field value where the discrete cumulative probability distribution exceeds the parameter “CDF Threshold” for all E-field probes (“CDP_P(E)>=CDF_Th”).

All other controls operate in the same way as described in the previous sections.

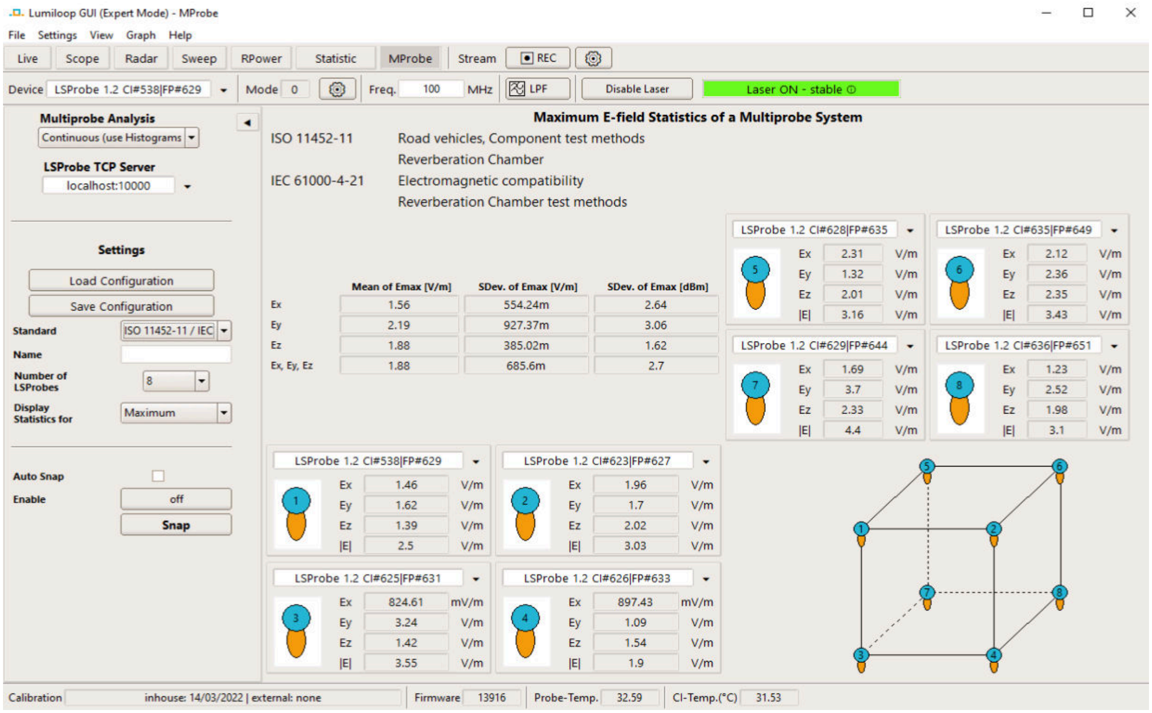


Figure 62: *LUMILOOP GUI, Multiprobe tab ISO 11452-11 / IEC 61000-4-21 setups*

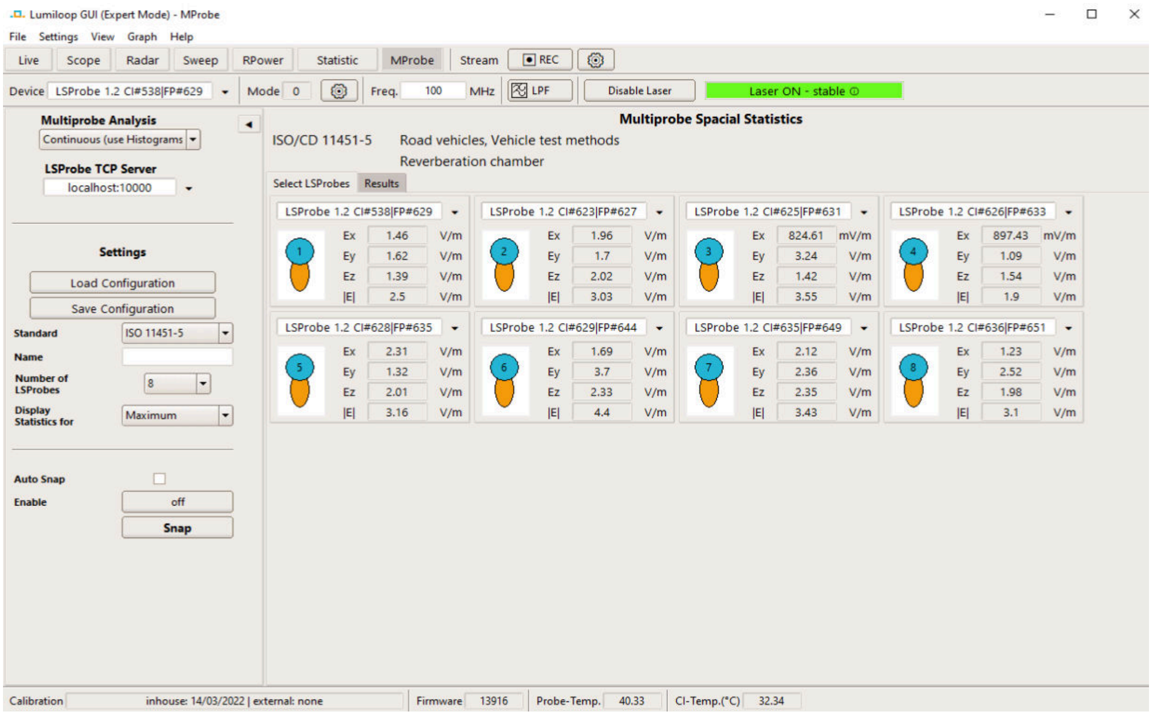


Figure 63: *LUMILOOP GUI, Multiprobe ISO 11451-5 configuration tab "Select LSProbes"*

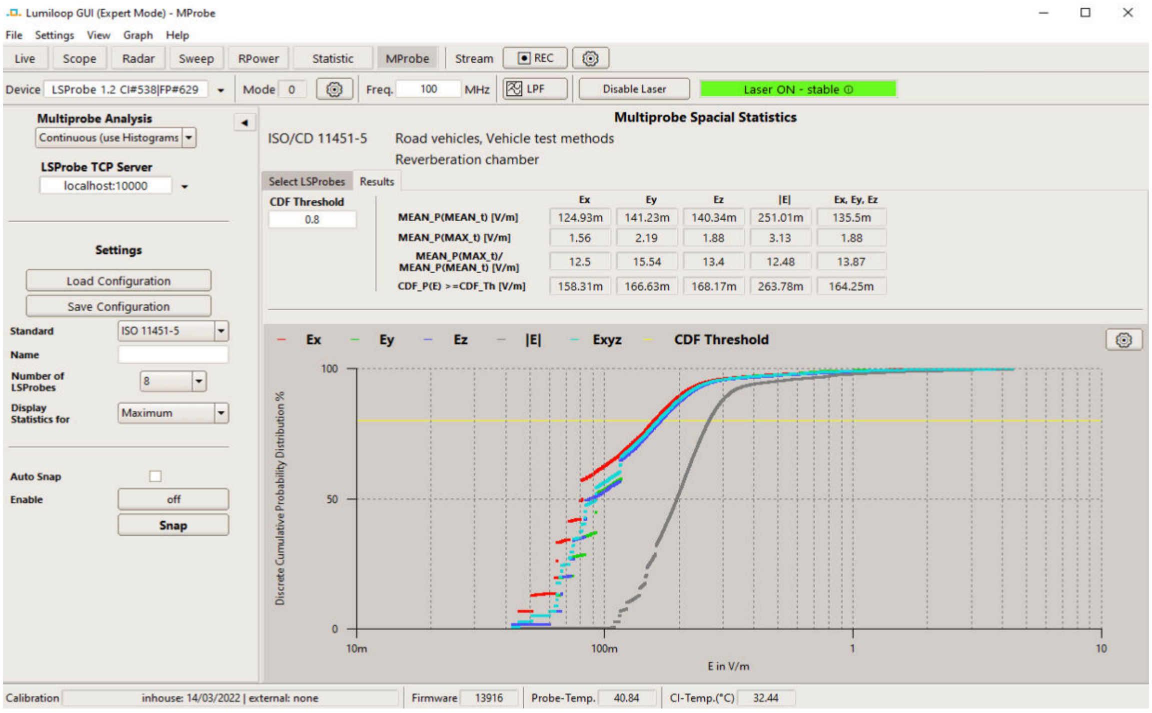


Figure 64: *LUMILOOP GUI, Multiprobe tab ISO 11451-5 setups*

5.10.4 Multiprobe Setups Using SCPI Commands

Multiprobe setups can be defined by specifying a list of E-field probe serial numbers using »:MProbe:FPSerial <MProbe>,<Probe1>[,<Probe2>,...,<ProbeN>]« or by giving a list of CI-250(+) Computer Interface serial numbers using »:MProbe:CISerial <MProbe>,<Ci1>[,<Ci2>,...,<CiN>]«. Multiprobe setup definition by LSProbe 1.2/1.4/2.0 E-field probe serial numbers requires the respective E-field probes to be active, definition by computer interface serial numbers only requires the specified CI-250 Computer Interfaces to be enumerated by the TCP server.

Multiprobe setups may contain any number of field probes and may contain individual E-field probes multiple times, this is especially useful for testing Multiprobe setup with fewer E-field probes than required. The MProbe parameter may be set to any integer value greater than zero and serves as a unique Multiprobe setup identifier. Multiprobe setups can be queried using »:MProbe:FPSerial? <MProbe>« and »:MProbe:CISerial? <MProbe>«. To query the list of all configuret Multiprobe setup names use the SCPI command »:MProbe:SETS?«.

Statistics data covering more than one E-field probe is calculated using the »:MProbe:AMAGnitude? <Triggered>,<MProbe>[,<RProbe>]« and »:MProbe:MAXStatistics? <Triggered>,<MProbe>«. »:MProbe:AMAGnitude? <Triggered>,<MProbe>[,<RProbe>]« returns the averaged E-field magnitudes of a Multiprobe setup. »:MProbe:MAXStatistics? <Triggered>,<MProbe>« returns the E-field maximum values of a Multiprobe system, including arithmetic mean, standard deviation and standard deviation expressed in decibel.

Use »:MProbe:TPStat:X/Y/Z/MAG/E3/ALL? <TSpec>,<PSpec>,<T.>,<MPr.>« for evaluation of statistics of multiple probes individually in time domain with subsequent statistic evaluation across these probes, for minimum, maximum, or arithmetic mean in any combination. The the quotient of maximum and arithmetic mean of E-field strength, averaged over multiple field probes is returned by »:MProbe:RATIO:X/Y/Z/MAG/E3/ALL? <Triggered>[,<MProbe>]«. To query the discrete cumulative probability distribution of the E-field strength for all E-field probes of the stated Multi-probe System use »:MProbe:CDF:WAVEFORM:X/Y/Z/MAG/E3/ALL? <Triggered>,<MProbe>«, »:MProbe:PDF:X/Y/Z/MAG/E3/ALL? <Triggered>,<MProbe>« returns the discrete relative probability distribution of the E-field strength for all E-field probes of the stated Multi-probe System. Use »:MProbe:Efield? <Triggered>,<MProbe>« to query center field strengths of bins used by all Mulitprobe distribution queries. »:MProbe:CDF[:AT]:X/Y/Z/MAG/E3/ALL? <Probability>,<Trig.>,<MProbe>« is used to query the E-field value where the discrete cumulative probability distribution exceeds a given probability for all E-field probes of the stated Multi-probe System.

5.11 Shutting Down LUMILOOP TCP Server and LUMILOOP GUI

5.11.1 Shutting Down Using the LUMILOOP GUI

Click on the "Disable Laser" button to disable the supply laser. The orange "Laser on" and blue "Data Link" indicators will turn off. Close the LUMILOOP GUI window and shut down the LUMILOOP TCP Server by typing "Ctrl-C" in the server window. The green "Power" indicator will change from constant on to flashing. After this set the power switch to OFF for each device. In case of LSProbe1.4 devices unplug the USB cable.

5.11.2 Shutting Down Using SCPI Commands

The supply laser is turned off using the »:SYSTem:LASer:ENable <Value>[,<MProbe>]« command with "0" as value. Terminate the TCP session and close the LUMILOOP TCP Server as described above.

5.12 Saving Log Files using the GUI

The "File" menu contains the item "Configure Log", which will open the "Logging Configuration" dialog as depicted in Figure 65. File name prefix settings and additional log columns of LUMILOOP GUI log files are configured in this dialog. The prefix applies to both one-shot and continuous logging. Separate log files are created for the "Live", "Scope", "Pulse", "Sweep", "RPower", "Statistics", "Statstep" and "Oversampling" subsystems. One-shot log files are created using the "Export CSV" "File" menu entry or the keyboard shortcut ctrl+s. A new log file for the currently active tab and E-field probe of the LUMILOOP GUI will be created. If the "Apply settings for all devices" option is enabled, the log file is created for all connected devices. Continuous logging is enabled in the "File" menu using the "Start ... Log" entries. It saves the respective data for all enumerated E-field probes to disk. For "Scope", "Sweep" and "Oversampling" logging every new set of data will be written to a separate file.

For all other log data continuous logging will append new sets of data to the respective log file as long as continuous logging is enabled.

Log files are stored by default in the path specified by the configuration file setting `SAVE_PATH`. Upon saving a file the status line will display the filename and its' save path for five seconds. Log file name conventions are detailed in Section 13.

Logging of RSSI values i.e., raw ADC sample values for x-, y- and z-axis, can be enabled by selecting the "include RSSI" check box. The feature is available for "Live" and "Scope" log files.

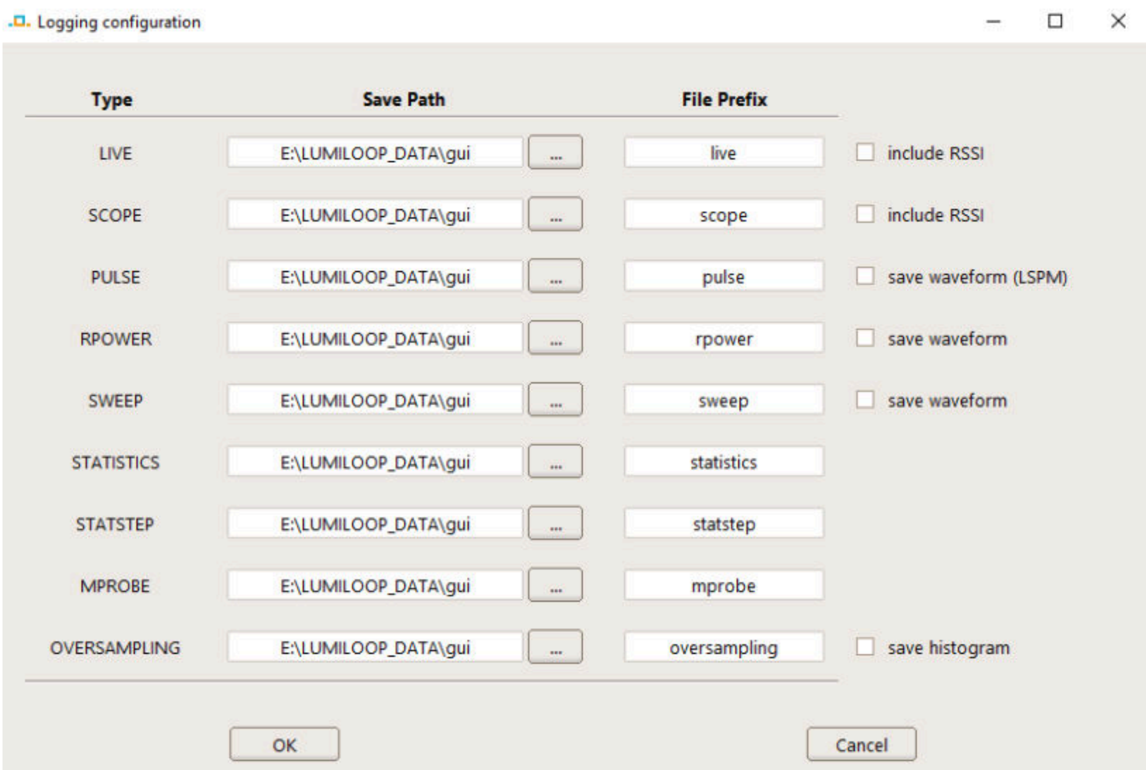


Figure 65: *LUMILOOP GUI, Data Logger tab*

5.13 Opening Log Files using the GUI

The LUMILOOP GUI is able to reload and display its own live, scope and sweep waveform log files, described in Section 13.1.1, 13.1.2 and 13.1.5. Additionally, all stream files created by the LUMILOOP TCP Server and converted to csv-files via the "Bin2Csv.exe" tool can be opened. If files from other sources are to be viewed, refer to Section 13.1.10 for file conventions. The file data remains open and can be selected again via its "View" menu entry as long as the file has not been closed via the respective "File" menu entry, refer to Figure 67

Take note that for big files, i.e. stream files with millions of values, the loading time can take tens of seconds up to minutes.

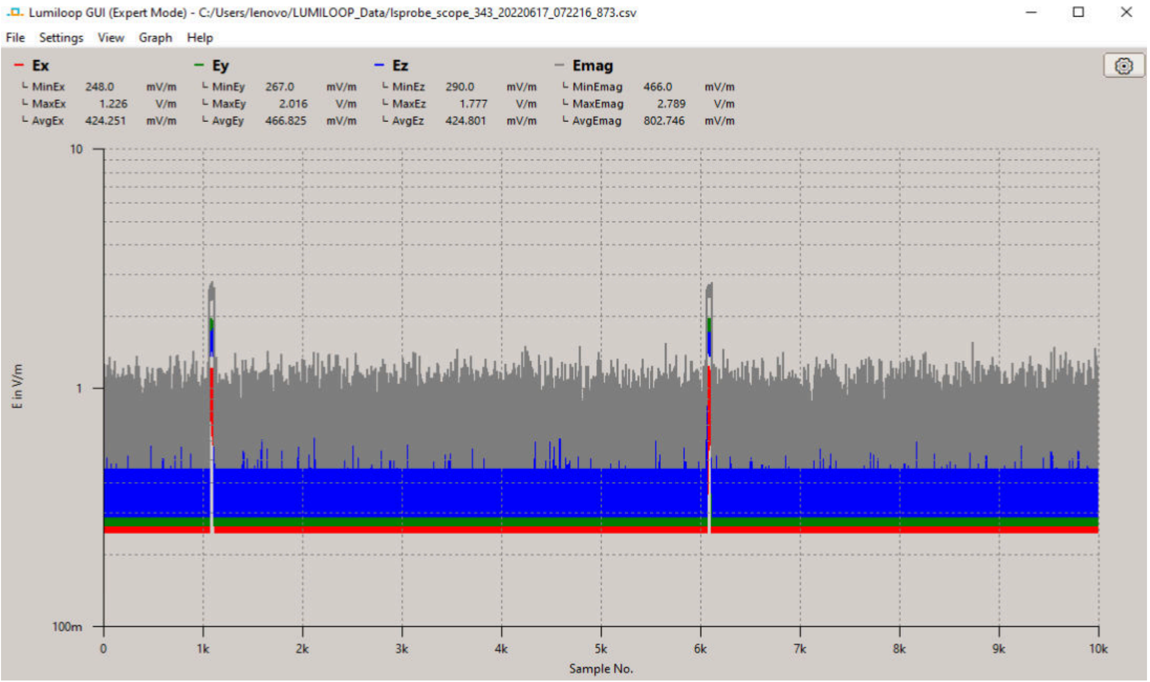
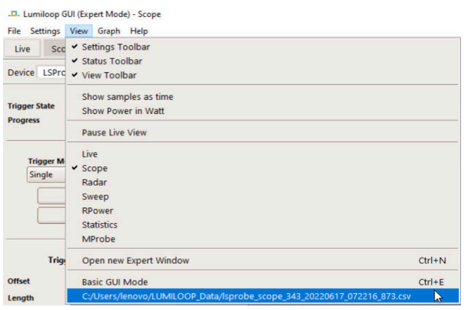
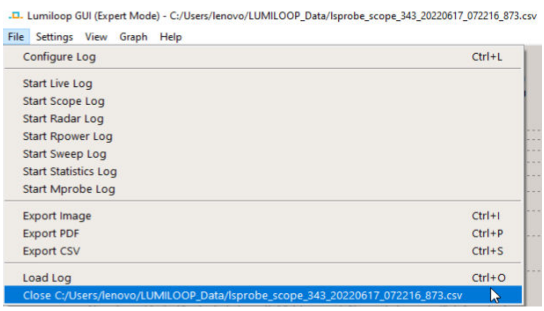


Figure 66: *LUMILOOP GUI, Data Load view*



(a) Reselect loaded file



(b) Close opened file

Figure 67: *Menu entries for loaded file*

6 Stand-Alone CI-250⁺

6.1 Software

The software preinstalled on "**+**" Device systems consists of:

- the Debian 10, GNU Linux operating system
- the LUMILOOP TCP Server,
- the LUMILOOP Graphical User Interface (GUI) and
- the Plus Device Manager GUI.

After turning on the "**+**" Device, the LUMILOOP TCP Server and "**+**" Device GUI are started automatically. The "**+**" Device GUI is run on the default graphical display, the LUMILOOP TCP Server is executed in a text terminal in the background. Both LUMILOOP TCP Server and "**+**" Device GUI will be automatically restarted if terminated. "**+**" Device systems are delivered with pre-installed calibration data.

Since "**+**" Device systems employ a standard Linux operating system they can can be accessed and operated as such both locally and remotely. See Section Section 6.6.4 on page 103 for a detailed description of local and remote system administration.

The default network settings are a static IP address of `10.0.0.42` and and a subnet mask of `255.255.255.0`. See Section 6.5.1 for details on network configuration.

Calibration data and software updates are handled by the Plus Device Manager, see Section 6.5.1.

The "**+**" Device GUI running on the "**+**" Device is derived from the desktop version of the LUMILOOP GUI and runs in basic mode. Expert mode as described in Section 5 can be used from a remote computer running the LUMILOOP GUI which connects to the "**+**" Device as described in Section 5.2.3 on page Section 47 and Figure 32.

6.2 Getting ready to Measure

6.2.1 Making Optical Connections

If the optical fibers have already been installed make sure that there is no apparent damage to the fibers and that there are no sharp bends or pinches. **Warning: Never switch the CI-250⁺ device on with no E-field probe being connected to it!**

Sacrificial optical cables are supplied with each LSProbe 1.2/2.0 . Always use the E2000 connectors shown in Figure 68 for breaking and making the optical connection. The E2000 connectors of the sacrificial cable assembly include automatic shutters preventing contamination and resulting optical fiber burn-in. Nevertheless, all optical connectors must be kept in a perfectly clean condition at all times.

Figure 68: *E2000 coupler of sacrificial optical cable assembly*

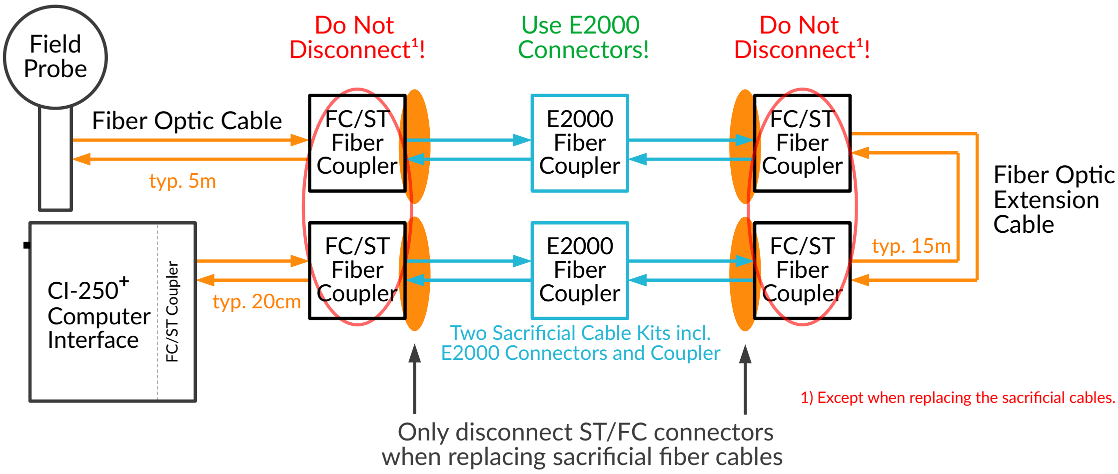


Figure 69: *Principle of sacrificial optical cable assembly*

The principle of the sacrificial cable assembly is explained in Figure 69. In case of a fiber connector burn-in only **a pair** of sacrificial cables need to be replaced, allowing for rapid and cost-effective fault recovery without requiring external service.

For optical fiber installation using the ST/FC connectors, e.g., when replacing a pair of sacrificial cables, carefully follow the steps below for one optical fiber at a time, starting with the ST Data connector (black bend protection):

1. Remove the dust caps.
2. Check the ceramic ferrules, i.e., the white ceramic cylinder at the front of the fiber connector, for apparent damage.
3. Always clean the fiber connectors before plugging! This is essential for preventing dust-induced fiber burn-in. Use a lint-free tissue, moistened with isopropyl alcohol (IPA) or a fiber optic connector cleaner, and gently wipe the front surface of the ceramic ferrules.
4. Plug in the ST Data connector (black bend protection) and lock the bayonet nut connector.
5. Plug in the FC laser supply connector (red bend protection) and tighten its nut. Make sure that the connectors key slides into the corresponding notch, see Figure 70 for the correct alignment.

When unplugging fiber optics, **always** place the supplied dust caps **immediately** on all four fiber

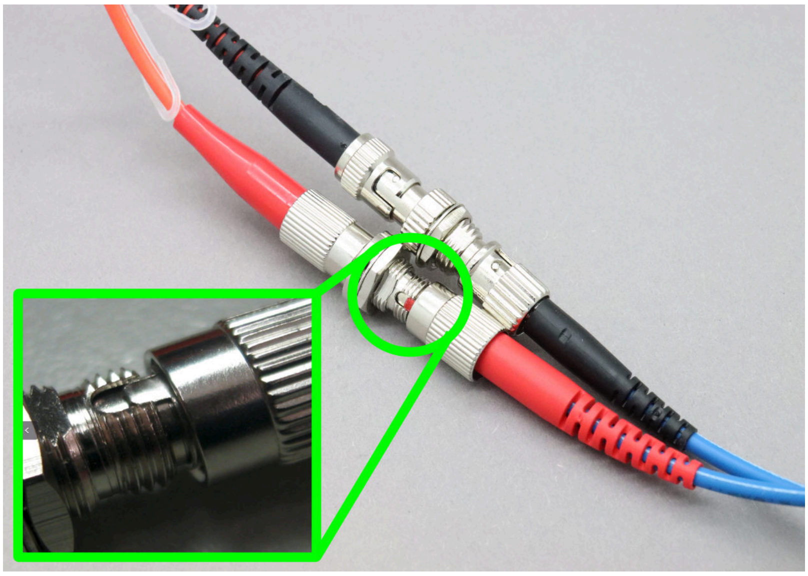


Figure 70: *FC fiber connector alignment*

cable connectors. Purchasing a fiber optics cleaning kit is strongly recommended.

6.2.2 Making Electrical Connections

When installing the LUMILOOP "**+**" Device system for the first time make the following electrical connections:

1. Connect the supplied mains adapter.
2. Optionally, connect additional LUMILOOP LSProbe and/or LSPM devices via USB.
3. Optionally, connect the computer interface to any trigger sources or sinks via the BNC/RJ45 trigger connector.
4. Optionally, connect the "**+**" Device to a network via the RJ45 Ethernet connector.

Switch on the "**+**" Device, setting the front panel switch to "1" and observe the green power LED starting to flash and the system booting up. After approximately 30 seconds the green power LED will be continuously on and the "**+**" Device GUI will start in fullscreen mode as depicted in Figure 71.

6.3 "+" Device GUI

6.3.1 General Notes on the "+" Device GUI

The "**+**" Device GUI, as depicted in Figure 80, is able to handle multiple USB devices. This includes the built-in CI-250 Computer Interface and additional, externally connected CI-250 Computer Interfaces and LSPM 1.0/2.0 power meters. "**+**" Devices can also connect to remote LUMILOOP TCP Servers via the "TCP Server Connections" dialog, see Section 6.5.2 on page 100 for details. Only

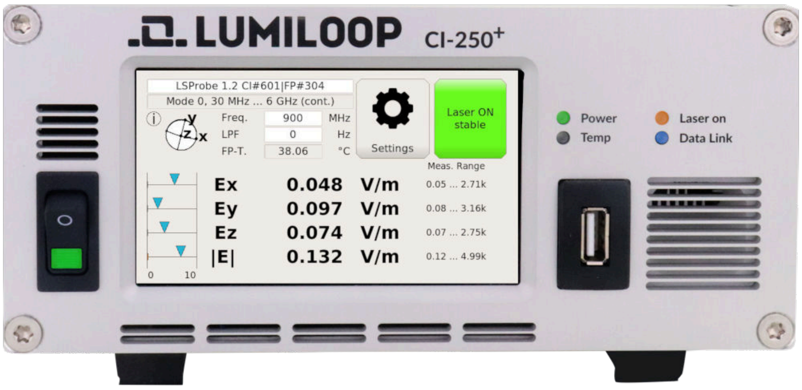


Figure 71: *"+" Device after start up*

one device is displayed on the touch display at a time. If more than one device are connected to the "+" Device, a scrollbar will be shown at the right edge of the screen, as depicted in Figure 72. The number of the currently displayed and the total number of connected devices are shown on the scrollbar, e.g., "2/5" indicates the second device of five available LSProbe and/or LSPM devices. The arrow buttons of the scrollbar switch between available devices.

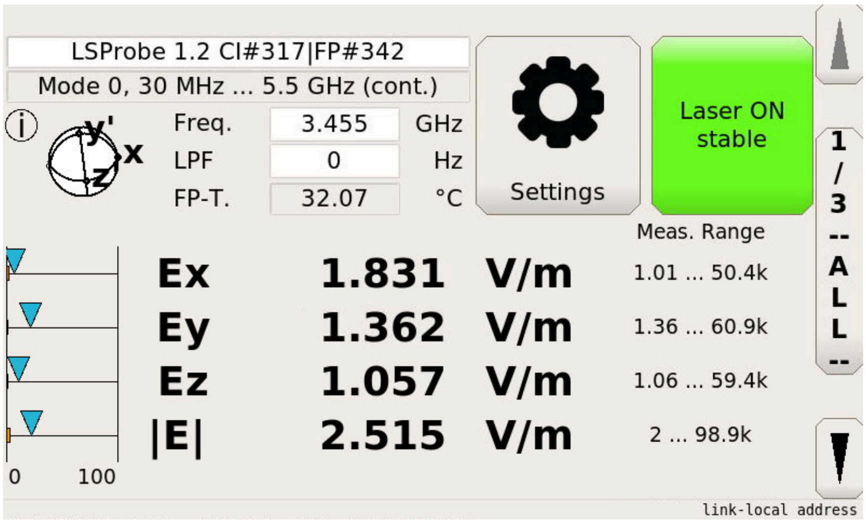


Figure 72: *"+" Device GUI appearance while managing multiple devices*

Press the middle button of the scrollbar to switch between "Basic" and "Table" mode. The "Table" mode, as shown in Figure 73, displays all connected devices in a table format and is available if at least two devices are connected. The device identification string, operating mode, operating frequency and the current measurement values are shown. No settings can be changed. Press anywhere on the screen to switch back to "Basic" view.

Note that by default, changing the operating mode, operating frequency and low-pass filter settings will result in changes to all connected devices, since these settings are normally identical for a given

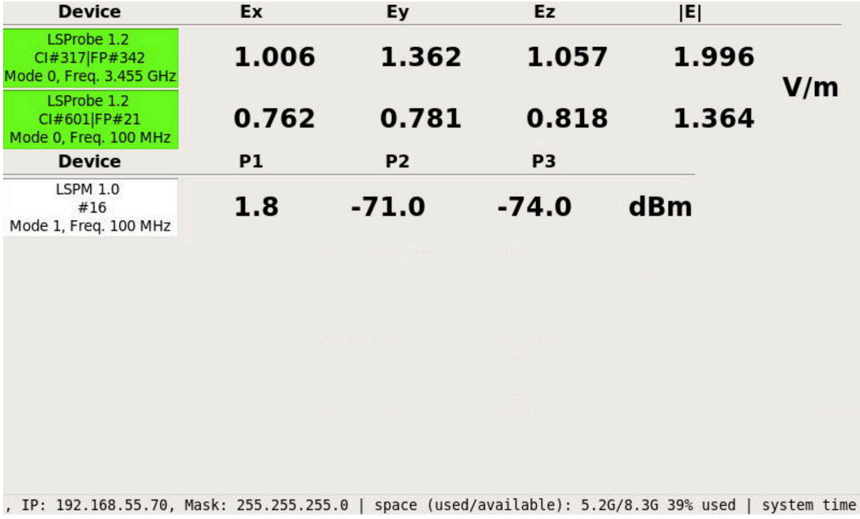
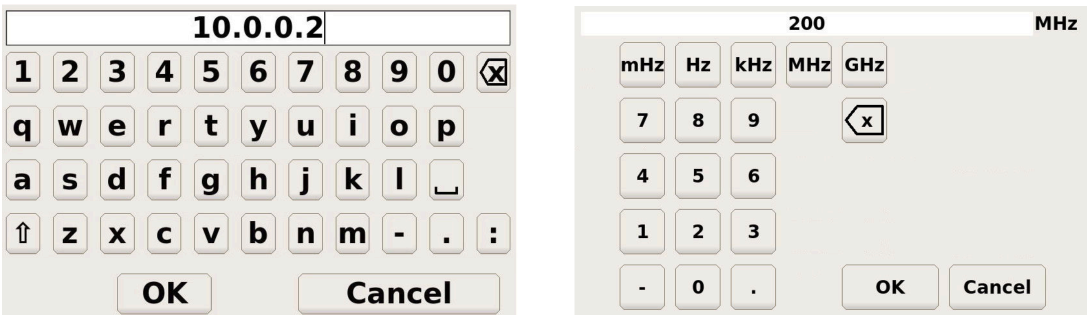


Figure 73: *"+" Device GUI table mode*

setup. To disable this behaviour, click on "Apply Settings to all Devices" in the "Settings" dialog, as shown in Figure 81 (a).

For settings requiring numeric or text input, an on-screen keyboard is displayed in the appropriate mode, as depicted in Figure 74.



(a) Generic appearance

(b) Numeric appearance

Figure 74: *"+" Device GUI screen keyboards*

A ticker text at the bottom of the main GUI displays the current network configuration, software revision, system time and all active connections including the number of connected clients.

6.3.2 Enabling the Supply Laser Using the "+" Device GUI

Clicking on the button labeled "Laser OFF" in the upper right corner of the screen activates the supply laser and sets the E-field probe to the selected mode of operation. The orange "Laser on" indicator LED at the front of the CI-250^{+} Computer Interface will show the activity of the supply laser. **Warning: When the orange LED is flashing, Automatic Power Reduction (APR) is disabled.**

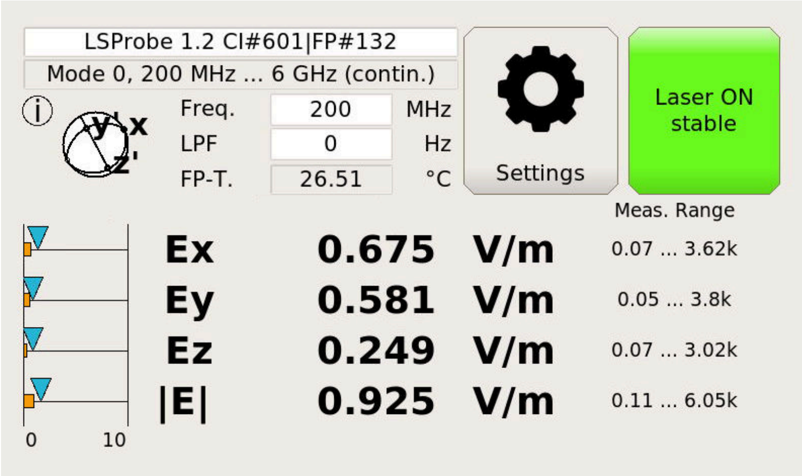


Figure 75: *"+" Device GUI with enabled laser*

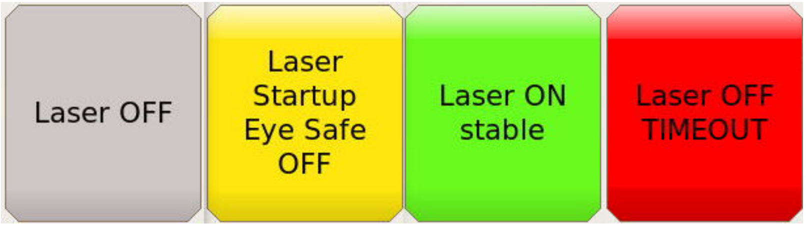


Figure 76: *"+" Device GUI laser indicator when off, during start-up, in safe operation and upon encountering a time-out error*

Interrupting optical connections is dangerous! The +GUI's "Laser Status" indicator will turn yellow and display "Laser Startup - Eye Safe OFF" to warn the user of this fact (see Figure 76).

As soon as both the orange "Laser on" indicator and the blue "Data Link" indicator are continuously on, Automatic Power Reduction is active and the laser connection is eye-safe. If any of the optical fibers gets interrupted, the supply laser will be switched off within ten milliseconds and the +GUI will present the red indicator shown in Figure 76.

Clicking on the image of the E-field probe in the top left of the screen will open the dialog shown in Figure 77. It contains the status of the laser link, including temperatures and the operating conditions of optically powered devices.

6.3.3 Mode Selection Using the "+" Device GUI

For accurate E-field strength measurements, the field's frequency must be specified using the "Freq." input field. Values are entered in Hertz, SI unit prefixes may be used, e.g., "1.8G" for 1.8 GHz. The decimal separator is "." (decimal point). Frequency values outside a mode's supported frequency range will result in undefined E-field values, i.e., "NAN". Note that changing the operating mode when the frequency setting is outside of the new mode's frequency range, will result in the frequency being set to the closest valid value, e.g., the minimum or maximum frequency of the new mode.

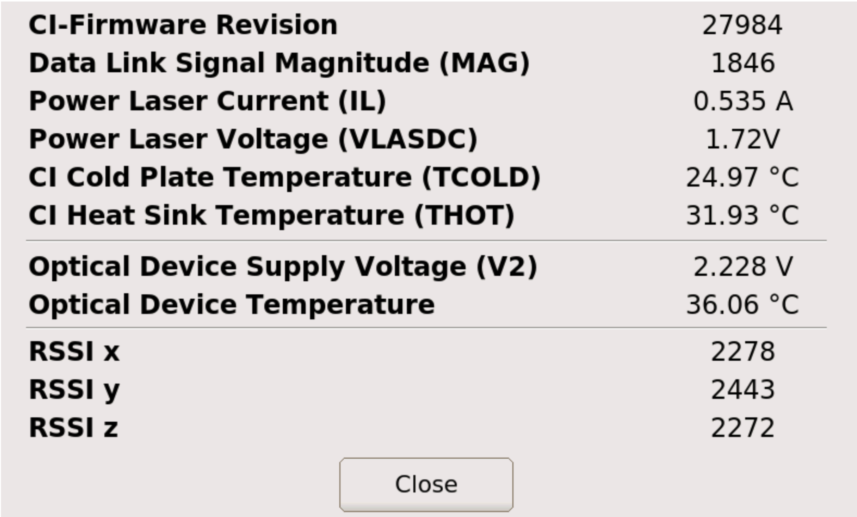


Figure 77: *"**+**" Device GUI Laser Link Status window*

To reduce the noise of the measured E-field strength values, a software-based low-pass filter can be set via the "LPF" field. A value of "0" disables low-pass filtering, while a non-zero value sets the -3 dB cut-off frequency for the low-pass filter used for E-field strength values.

The operating frequency or low-pass filter can either be set by touching the respective entry fields in the main window or by selecting the corresponding buttons in the "Settings" dialog. The temperature of the E-field probe is shown below the low-pass filter field in the main window.

To change the mode, open the dialog shown in Figure 78. It is opened via the "Mode" button in the "Settings" dialog shown in Figure 81.

The "Mode" dialog cycles through all supported modes of the current device using the left/right arrow buttons at the top, the selected mode is shown in a bold black font. The properties of each mode, i.e., calibrated frequency ranges, video bandwidths, sampling rate and detector type are shown in the table below.

For the interleaved modes 1 and 5 the frequency for detector change-over can be changed within the overlapping frequency range, using the right field highlighted in white in the "Minimum Frequency" column of the respective mode, see Figure 78. Alternatively, press the "M1/M5 Transition Freq." button in the "Settings" dialog on the right side of the second button row, see Figure 81. If the field probe is off or if there is no calibration data, "?" will be displayed in fields that depend on calibration data and device version of the LSProbe. If the laser is enabled, frequency range and supported modes are shown as supported by the LSProbe revision, mode and calibration data. If a mode is not supported by an LSProbe device, the "Set" buttons will be disabled. The displayed values are a device-specific version of the values shown in Table 1 to Table 3 on page 24 to page 27.

For information about the calibration dates of factory and accredited calibration data, click on the top left device identification string indicator highlighted in white. A dialog as shown in Figure 79 will open. If accredited calibration data are available, its certificate string will be displayed.

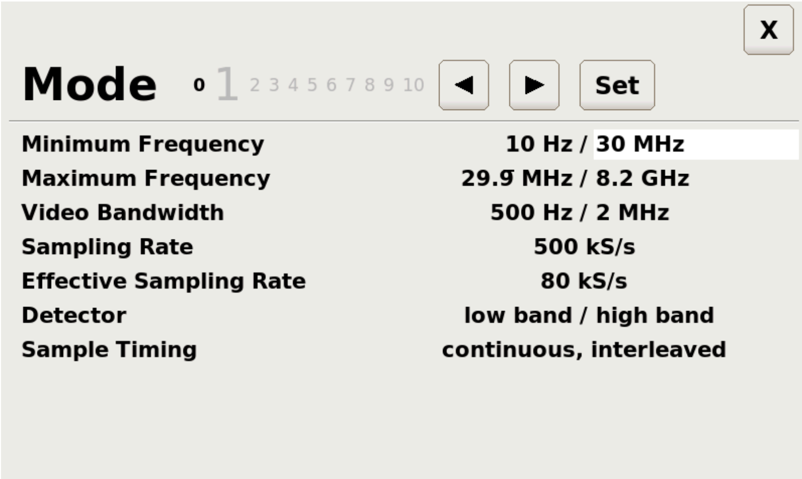


Figure 78: *"**+**" Device GUI Operating Mode configuration dialog*

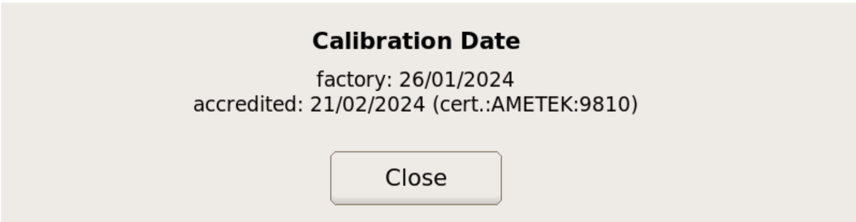


Figure 79: *"**+**" Device GUI Calibration dates dialog of current LSProbe*

6.4 Continuous E-field Measurements Using the +GUI

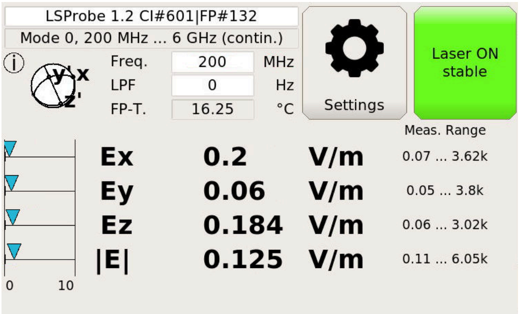
While LSProbes are capable of exceptionally high speed measurements, they are also able to perform high precision measurements of quasi-static signals. For continuous E-field measurements, the TCP server receives all E-field strength values, applies calibration data and performs low-pass filtering if configured accordingly.

X/y/z axis acceleration data are recorded and optionally low-pass filtered as well. The orientation of the LSProbe is shown in the "**+**" Device GUI in the top left of the screen.

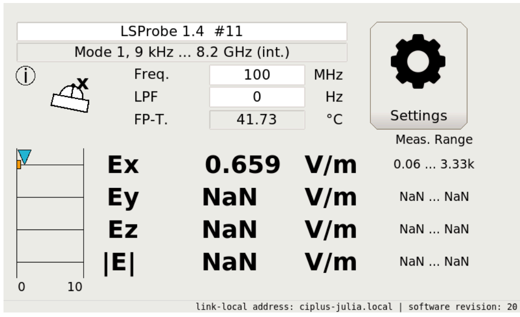
At the top of the "**+**" Device GUI the measurement device identification string, the current operating mode, the calibrated frequency range, the operating frequency, the low-pass filter setting and the E-field probe temperature are displayed. Upon clicking on the device identification string, a dialog containing the factory and accredited calibration date is shown, see Figure 79, "none" indicates missing or invalid calibration data.

For optically supplied devices, a laser status and enable/disable toggle button are located next to the "Settings" button.

As shown in Figure 80, the "**+**" Device GUI displays the measured E-field values for the x/y/z axis E-field components and the E-field magnitude in the lower half of the display. In the bottom left of the display, the measured values are shown as a bar graph. The orange bars represent the instan-



(a) "**+**" Device GUI LSProbe 1.2



(b) "**+**" Device GUI LSProbe 1.4

Figure 80: *"**+**" Device GUI LSProbe devices connected*

taneous E-field values, the blue triangles serve as peak markers with a built-in decay. A numerical representation of the instantaneous E-field strength values is shown in the bottom center of the display. The available measuring range for the present temperature and operating frequency is shown in the bottom right of the display.

6.5 "Settings" Dialog

The "Settings" dialog is opened by pressing its button in the "**+**" Device GUI. It gives access to all LSProbe settings, including operating mode, frequency and network configuration. The dialog will first open as depicted in Figure 81 (a), see Section 6.3.3 and 6.4 for details of the available settings. The button labeled "Apply settings to all Devices" will, if turned on, apply all device settings, such as mode and operating frequency, to all devices enumerated by the "**+**" Device GUI. If turned off, settings will be applied to the current device only.

The "System" button on the bottom of the screen brings up the system settings dialog as shown in Figure 81 (b).

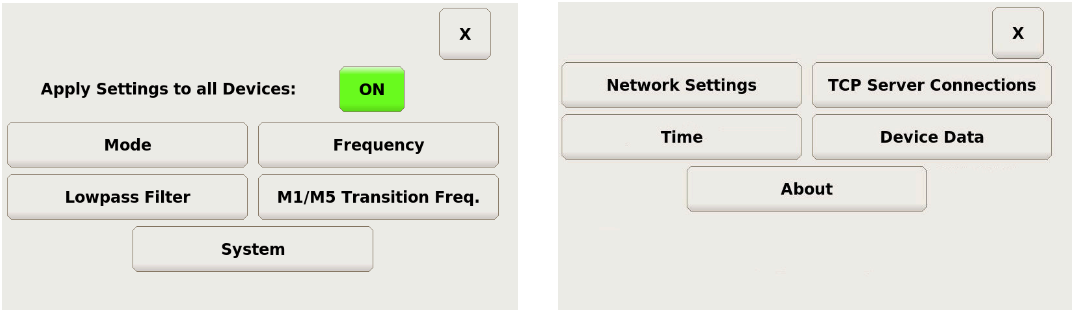
The "Device Data" button will open the "Plus USB Interface" as described in Section 6.6. It provides functionality for viewing and altering calibration data, LUMILOOP TCP Server log files and software updates.

The "About" button will display the current software revision as depicted in Figure 82.

The details of the dialogs associated with the "Network Settings", "TCP Server Connections" and "Time" buttons are explained in the following subsections.

6.5.1 Network Configuration

The "Network Configuration" dialog, shown in Figure 83, is accessed via the "Settings" Dialog→"System"→"Network Settings". The default network configuration is a static IP address of `10.0.0.48` with a subnet mask of `255.255.255.0`. Press "DHCP" followed by "Apply" to switch



(a) Device Settings (b) System Settings

Figure 81: "**+**" *Device GUI "Settings" Dialog*

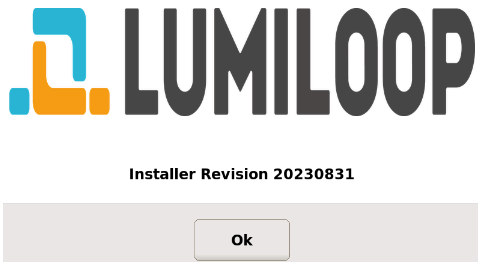


Figure 82: "**+**" *Device GUI About Dialog with Installer Revision*

to automatic network configuration, this will take a few seconds. The active configuration is highlighted in green. The active IP address and subnet mask are displayed in the lower part of the dialog.

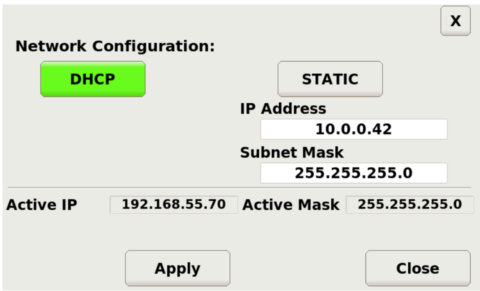


Figure 83: "**+**" *Device GUI Network Configuration Dialog*

6.5.2 TCP Server Client Connections

The dialog, shown in Figure 84, for configuring TCP Server client connections is opened via the "Settings" Dialog→"System"→"TCP Server Connections". The default client connections are "localhost" port `10000` for LSProbe devices and "localhost" port `10001` for LSPM devices. To add connections to TCP Servers running on another machine, use the host and port entry fields highlighted in white in the lower part of the dialog and press "Add Connection". Use the up and down arrows on the right side of the screen to browse the list of configured TCP Server client connections. Use the "x" button to delete a client connection entry. Each entry can be enabled and disabled using the check-buttons on the left side of the screen.

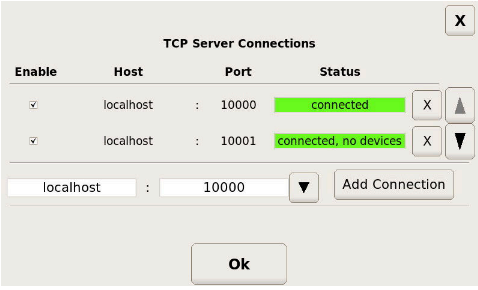


Figure 84: *"**+**" Device GUI Active TCP Server Client Connections Dialog*

6.5.3 System Time

System time can be set either manually or automatically using the network time protocol (NTP) as shown in Figure 85. The default is to use NTP. The current system date and time are displayed at the top of the screen. For manual configuration use the associated entry fields and press "Set" to apply. Network time can be obtained from an NTP server given by its IP address or host name. Press the "Set" button to apply the configuration. The default NTP server, `debian.pool.ntp.org`, is set by pressing the "Set" button on the bottom of the screen.

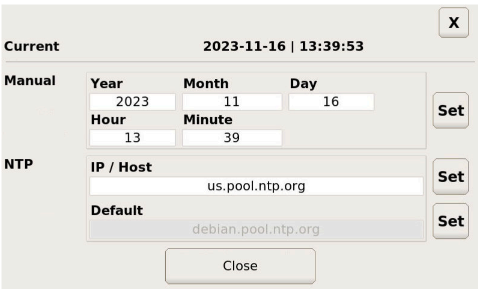


Figure 85: *"**+**" Device GUI System Time Setting Dialog*

6.6 Plus Device Manager

The Plus Device Manager is shown in Figure 86. It is opened automatically when a USB thumb drive is plugged in and will be closed when the thumb drive is disconnected or the "Close" button is pressed. Alternatively, the Plus Device Manager can be brought up via the "Settings" Dialog of the "**+**" Device GUI as described in Section 6.5. The Plus Device Manager allows for easy file transfer to and from the Plus device, calibration data management and the installation of software updates.

Figure 86: *Plus Device Manager Main Window*

6.6.1 Managing Files and Folders

Press the "Manage Files" button to copy files onto or off the Plus device, to create directories or delete files/directories on either the "**+**" Device or the USB thumb drive.

Only two directories are user-accessible on the "**+**" Device: the calibration data folder "cal" and the data folder "lumiloop_data". Figure 86 shows the dialog when a USB thumb drive is present. Use the "Calibration Update" functionality described in the following section for adjusting calibration data on the "**+**" Device. Manual modification of calibration data is both cumbersome and prone to error and therefore discouraged.

To copy files onto the USB thumb drive, first click on the "USB" button in the top right corner and navigate to the desired directory of the thumb drive. The current path is displayed below the "USB" button. Next, click on the "Device" button and select the files and/or folders to be copied. Finally, click on the "Copy" button at the bottom of the screen to copy all selected files to the chosen directory on the USB thumb drive. For copying files onto the Plus device follow the procedure above with "Device" and "USB" reversed.

If no USB thumb drive is connected, only files and folders on the "**+**" Device can be managed.

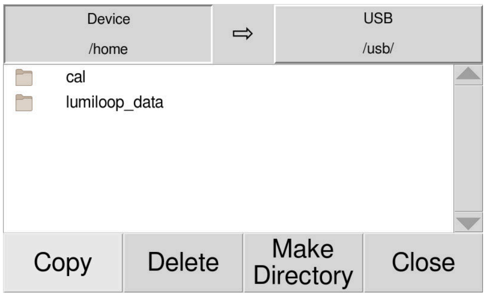


Figure 87: *USB Device Manager, Files Window*

6.6.2 Managing Calibration Data

In order to add or update calibration data on the "**+**" Device, copy the calibration data onto a USB thumb drive. Calibration data can be supplied as either a zip file or a folder. They must be comprised of all factory and accredited calibration files.

After connecting the thumb drive, choose "Manage Calibration Data" in the USB device manager's main menu. The "**+**" Device and the USB thumb drive will be searched for available calibration data sets, this may take several seconds. All found calibration data sets will be listed, including information about their device type, serial number and calibration date, as shown in Figure 88. Calibration data sets found on the thumb drive are shown above the calibration data sets on the "**+**" Device.

Select data sets on the thumb drive using the check-buttons on the left of the screen and press "Install" to add or update calibration data on the "**+**" Device. Select individual or all data sets marked as installed and press "Delete" in the lower left corner of the screen to remove calibration data sets. The TCP Server on the "**+**" Device will be reset after modification of calibration data upon pressing the "Close" button. When the update is complete, the main dialog will be shown.

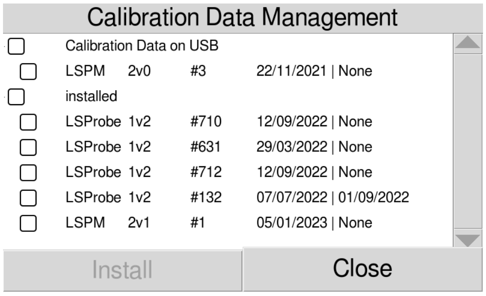


Figure 88: *USB Device Manager, Calibration Update Dialog*

6.6.3 Managing Software Updates

Software updates are provided as ZIP files and need to be copied into the root folder of a USB thumb drive first. "**+**" Device software updates can be managed by choosing "Software Updates" in the USB device manager's main menu. Both upgrading and downgrading of the software is supported. The thumb drive will be searched, which may take a few seconds. Thereafter, all found software updates will be listed. Select the desired software update and press "Update" for installation.

Please note that the process of updating the software includes a restart of the "**+**" Device. Do not turn off the device during software updates!

After "**+**" Device restart, the installed software revision can be verified in the "About" window in the "Settings" dialog.

6.6.4 Plus Device System Administration

A secure shell (SSH) client can be used for remote access of the "**+**" Device. The user name is `lumiloop` and default password `qwer1234`. Please change the password if required for system security.

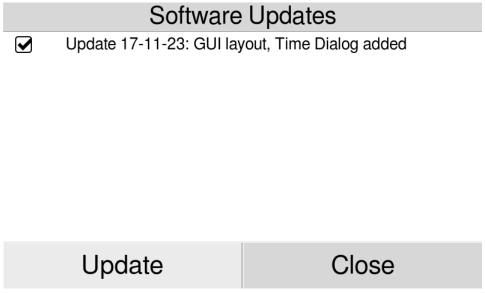


Figure 89: *USB Device Manager, Software Update Dialog*

The LUMILOOP software is located in the `bin` directory of the user's home directory, i.e., `/home/lumiloop/bin` and requires root privileges for modification. Calibration data are located in the `cal` directory, LUMILOOP TCP Server log files are stored in the `log` directory of the user, i.e., `/home/lumiloop/cal` and `/home/lumiloop/log`.

To access the LUMILOOP TCP Server running in the background, connect a USB keyboard to the "**+**" Device and switch from graphic terminal to virtual text terminal No. 8 by pressing `Ctrl+Alt+F8`. To switch back to the graphical terminal use `Ctrl+Alt+F7`.

7 Third Party EMC Software

This section describes the setup of the LSProbe 1.2/1.4/2.0 E-field probe in third party EMC test automation software. Third party support files are installed in separate directories of the `lib` sub-directory of the LUMILOOP software install path.

Before running any third party EMC test automation software follow the hardware setup instructions detailed in Section 5.1 on page 43 and start the TCP server as described in Section 5.2.1 on page 45.

The LUMILOOP GUI is not required when using third party EMC test automation software, with the notable exception of enabling the supply laser and setting the mode. However, the LUMILOOP GUI may be run in parallel as long as it is used solely for monitoring and no settings are changed using the GUI, i.e., the user must not modify any LUMILOOP GUI controls, e.g., mode, frequency, low-pass filter frequency, etc. The LUMILOOP GUI is designed in such a way that it will not apply any settings on its own.

When using different versions of the LSProbe, e.g. version 1.2 and version 2.0, please mind the difference of the mode dependent frequency ranges as described in table 1 and table 3.

7.1 Rohde & Schwarz – EMC32

LUMILOOP recommends using the most recent version of the R&S EMC32 measurement software since EMC32 integration is always tested against the most recent EMC32 release. The LSProbe 1.2/1.4/2.0 E-field probe is supported by EMC32 version 10.0 and later. Field probes which support operating mode 1 may be operated in this mode, requiring only a single E-field probe entry.

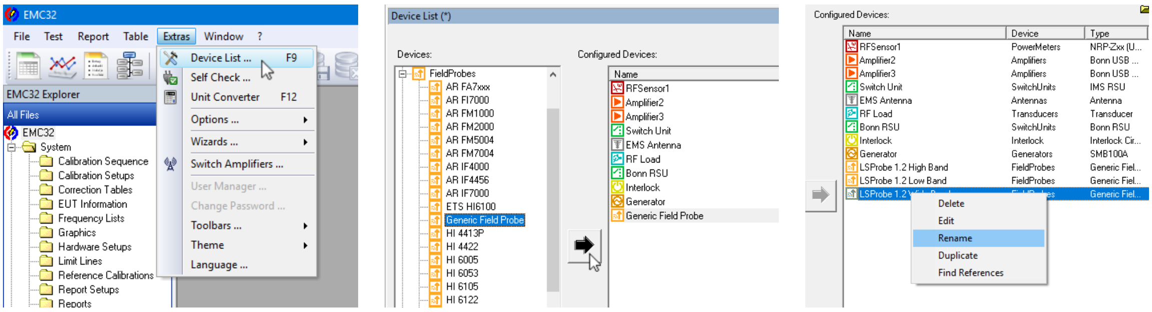
Newer versions of EMC32 come with the required dynamic link library (DLL) `FpGeneric.dll` already installed in the EMC32 installation path's `Execute\Devices` sub-directoy. A typical location is `C:\Program Files\Rohde-Schwarz\EMC32\Execute\Devices`. If the EMC32 installation does not already contain the `FpGeneric.dll` file, please contact LUMILOOP with your EMC32 version number so that the appropriate DLL file can be provided.

Please copy all device configuration files ending in `DeviceConfiguration` from the `EMC32` sub-directory of the LUMILOOP installation path's `lib` directory to the EMC32 program data path's `Configuration\Others` sub-directoy, a typical location is `C:\ProgramData\EMC32\Configuration\Others`.

7.1.1 CW fields using LSProbe 1.2 Field Probes

To set up the LSProbe 1.2/1.4/2.0 E-field probe in EMC32 run the LUMILOOP TCP Server and enable the supply laser, as described in Sections 5.1 and 5.2.1 through 5.2.6, then start EMC32.

Open the EMC32 Device List via "Extras→Device List" in the menu bar as shown in Figure 90(a). In the "Device List" window select "Generic Field Probe" from the "Devices:" list's "FieldProbes" category and create a new "Configured Device" by clicking on the right-pointing arrow in the center as shown in Figure 90(b). This will create a new entry named "Generic Field Probe". Click the right-pointing arrow again to add a second "Generic Field Probe" entry. One LSProbe 1.2 field probe will be used for low band E-fields from 10 kHz to 400 MHz. The other will be used for high band E-fields from 30 MHz to 6 GHz. Rename the first "Generic Field Probe" entry to "LSProbe 1.2 High Band" and the second entry to "LSProbe 1.2 Low Band", use "right-click→Rename" as shown in Figure 90(c). For LSProbe 1.2 devices supporting operating mode 1 add a third and fourth entry named "LSProbe 1.2 Wide Band 30MHz detector switch" resp. "LSProbe 1.2 Wide Band 400MHz detector switch". In modes 1 the high band and low band envelope detectors are active in an interleaved fashion. Depending on the operating frequency the data of only one detector is processed. For the first Mode 1 device configuration the low band detector will be used up to 30 MHz at which point the change over to the the high band detector data will occur. For the second Mode 1 device configuration the switch appens at 400 MHz.



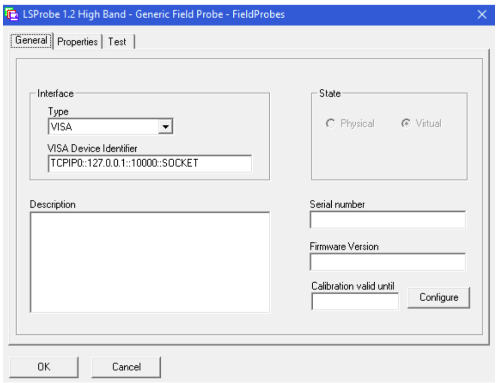
(a) Opening the Device List (b) Adding Generic Field Probes (c) Renaming Field Probes

Figure 90: *Adding the LSProbe 1.2/1.4/2.0 E-field probe in EMC32*

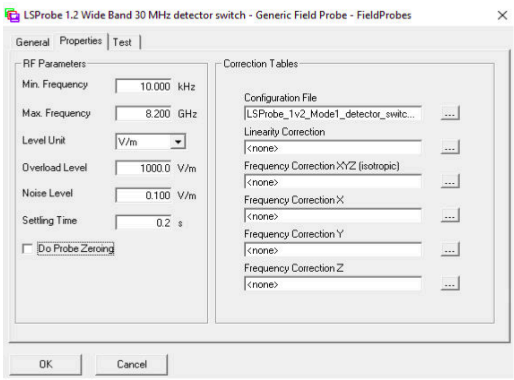
Use "right-click→Edit" to open the Generic Field Probe's settings. In the "General" tab shown in Figure 91(a) edit "VISA Device Identifier" to configure the IP address and TCP port of the LUMILOOP TCP Server. The identifier string has the generalized format "TCPIP0::<IP address>::<TCP Port>::SOCKET". Usually the LUMILOOP TCP Server is run on the same computer and listening to the default TCP port 10,000. Consequently, the default identifier string is "TCPIP0::127.0.0.1::10000::SOCKET". All other settings in the "General" tab are optional and may be left unchanged.

Select the "Properties" tab shown in Figure 91(b) through (d), edit all parameters as detailed in Table 4. Select the appropriate file for "Configuration File" located in `...\ProgramData\EMC32\Configuration\Others`. The settling time of 200 ms is chosen in such a way that it guarantees settling of the field strength values with a margin of less than one percent when used with the supplied `.DeviceConfiguration` files. The low pass filter value in the `.DeviceConfiguration` files can be adjusted by the user to accommodate longer or shorter settling times. LSProbe 1.2 does not require any correction files to be set as all correction is handled transparently by the LUMILOOP TCP Server. Make sure all correction values are set to "<none>". Click "OK" when you are done.

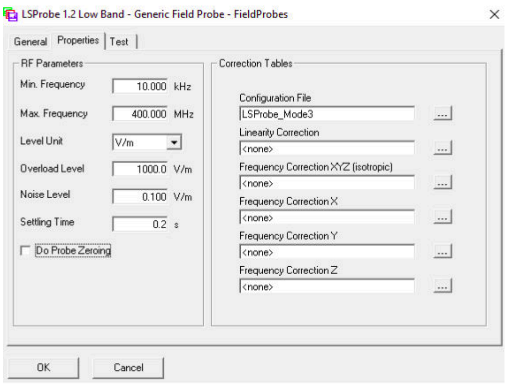
To finish the setup restart EMC32 and open the EMC32 Device List via "Extras→Device List". Use "right-click→Edit" for the "LSProbe 1.2" entry appropriate for the measurement task and change



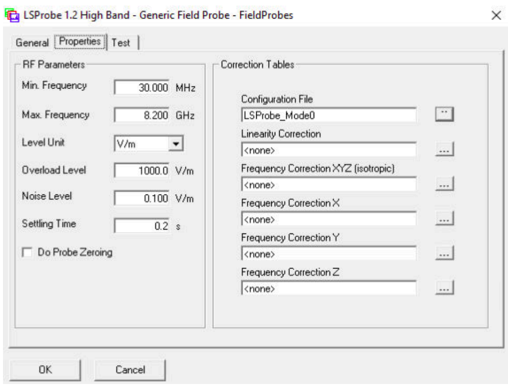
(a) General Settings



(b) Wide Band Properties



(c) Low Band Properties



(d) High Band Properties

Figure 91: *Configuring LSProbe 1.2 Field Probes for Wide, Low and High Band in EMC32*

"State" from "Virtual" to "Physical". This will prompt EMC32 to connect to the LUMILOOP TCP Server. After establishing the correct mode the "Serial number" value turns blue, this is also indicated by the CI-250$^{(+)}$ Computer Interface's LEDs as detailed in Section 3.1.5. Only one "LSProbe 1.2" entry may be set to "Physical" at a time, when changing from Low Band to High Band or vice-versa set the "Physical" device to "Virtual" first and set the other device to "Physical" after that.

7.1.2 CW fields using LSProbe 2.0 Field Probes

To set up the LSProbe 2.0 proceed as described in the preceding Section 7.1.1. Start the LUMILOOP TCP Server and add three "Generic Field Probe" entries to the EMC32 device list. One device will be used for low band E-fields from 9 kHz to 1 GHz, the second for high band E-fields from 700 MHz to 18 GHz, the third for wide band operation from 9 kHz to 18 GHz. Rename the first "Generic Field Probe" entry to "LSProbe 2.0 Low Band", the second entry to "LSProbe 2.0 High Band", and the third to "LSProbe 2.0 Wide Band 700MHz detector switch". Adjust the connection settings in the "General" tab of the field probe settings as described in the prvious section and depicted in Figure 91(a) and (b).

Table 4: *EMC32 Properties tab values for Low and High Band*

Setting	Wide Band	Low Band	High Band
Min. Frequency	10.000 kHz	10.000 kHz	30.000 MHz
Max. Frequency	8.200 GHz	400.000 MHz	8.200 GHz
Level Unit	V/m	V/m	V/m
Overload Level	1000	1000	1000
Noise Level	0.1	0.1	0.1
Settling Time	0.2	0.2	0.2
Do Probe Zeroing	unchecked	unchecked	unchecked
Configuration File	LSProbe_1v2_Mode1_detector_switch_[30/400]MHz.Device-Configuration	LSProbe_Mode3.Device-Configuration	LSProbe_Mode0.Device-Configuration
Correction Settings	<none>	<none>	<none>

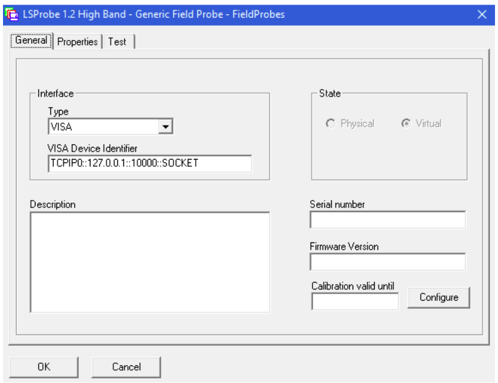
Use "right-click→Edit" to open the Generic Field Probe's settings. and edit the connection settings as described in the previous section and depicted in Figure 92(a)

Select the "Properties" tab shown in Figure 92(b) through (d), edit all parameters as detailed in Table 5. Select the appropriate file for "Configuration File" located in `...\ProgramData\EMC32\Configuration\Others`. The settling time of 200 ms is chosen in such a way that it guarantees settling of the field strength values with a margin of less than one percent when used with the supplied `.DeviceConfiguration` files. The low pass filter value in the `.DeviceConfiguration` files can be adjusted by the user to accommodate longer or shorter settling times. As with the LSProbe 1.2, the LSProbe 2.0 does not require any correction files to be set as all correction is handled transparently by the LUMILOOP TCP Server. Make sure all correction values are set to "<none>". Click "OK" when you are done.

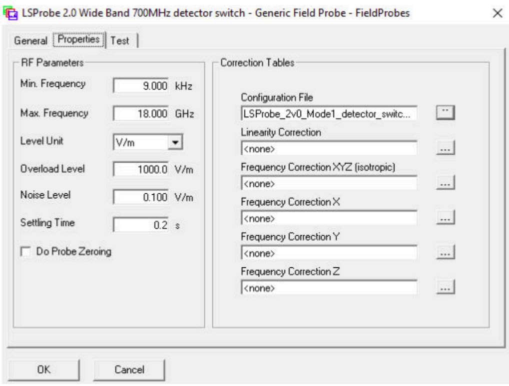
To finish the setup restart EMC32 and open the EMC32 Device List via "Extras→Device List". Use "right-click→Edit" for the "LSProbe" entry appropriate for the measurement task and change "State" from "Virtual" to "Physical". This will prompt EMC32 to connect to the LUMILOOP TCP Server. After establishing the correct mode the "Serial number" value turns blue, this is also indicated by the CI-250$^{(+)}$ Computer Interface's LEDs as detailed in Section 3.1.5. Only one "LSProbe [1.2/2.0]" entry may be set to "Physical" at a time, when changing from Low Band to High Band or vice-versa set the "Physical" device to "Virtual" first and set the other device to "Physical" after that.

7.1.3 Pulsed fields LSProbe 1.2

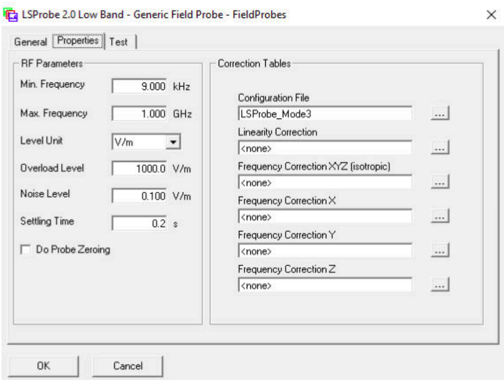
For pulsed field strength measurements with the LSProbe 1.2 add two more generic field probe entries to the EMC32 Device List, following the steps described in Section 7.1.1. Rename



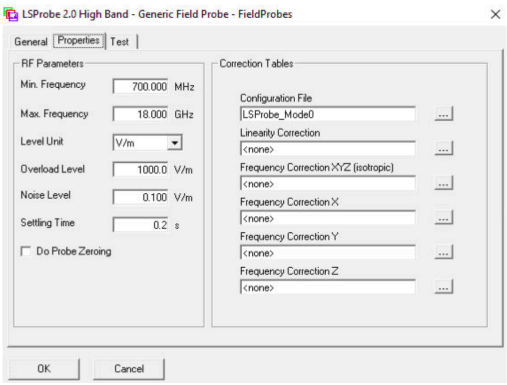
(a) General Settings



(b) Wide Band Properties



(c) Low Band Properties



(d) High Band Properties

Figure 92: *Configuring LSProbe 2.0 Field Probes for Wide, Low and High Band in EMC32*

the two entries to "LSProbe 1.2 Pulse Continuous" and "LSProbe 1.2 Pulse Burst". Use the high band settings from Table 4 for both entries. Substitute "Mode0.Device-Configuration" for "LSProbe_Mode0_Radar" and "LSProbe_Mode4_Radar_Burst" respectively. Mode 0 corresponds to the entry "LSProbe 1.2 Pulse Continuous" and mode 4 corresponds to the entry "LSProbe 1.2 Pulse Burst" as shown in Figure 94.

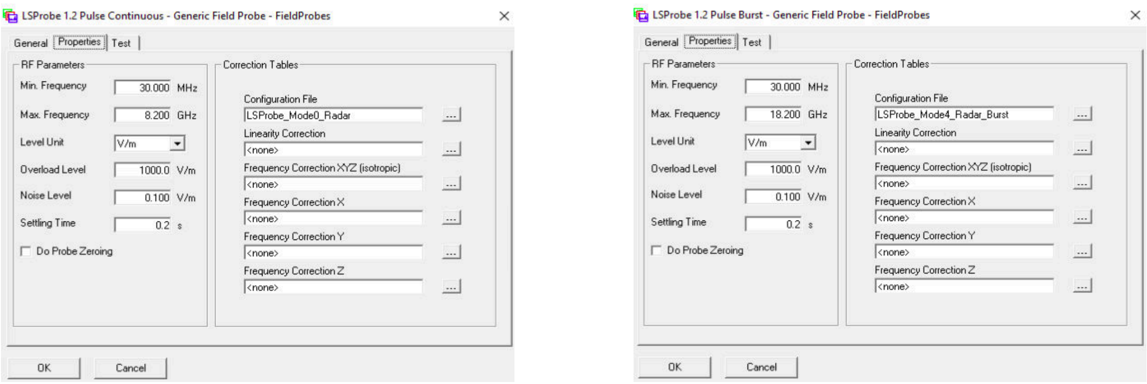
The default setting of both device configuration files is suitable for the GMW-3097 standard. It will use the x-axis field strength for triggering at 10 V/m, record 100,000 samples and retrieve the averaged pulse field strength magnitude and x-, y- and z-axis values. The trigger parameters can be modified by editing the respective device configuration files in lines 49 through 53. See Section 5.4.2 for more information about the trigger subsystem's SCPI commands.

7.1.4 Pulsed fields with LSProbe 2.0

For pulsed field strength measurements with the LSProbe 2.0 add two more generic field probe entries to the EMC32 Device List, following the steps described in Section 7.1.1. Rename the two entries to "LSProbe 2.0 Pulse Continuous" and "LSProbe 2.0 Pulse Burst". Use the

Table 5: *EMC32 Properties tab values for Low and High Band*

Setting	Wide Band	Low Band	High Band
Min. Frequency	9.000 kHz	9.000 kHz	9.000 MHz
Max. Frequency	18.000 GHz	1.000 GHz	18.000 GHz
Level Unit	V/m	V/m	V/m
Overload Level	1000	1000	1000
Noise Level	0.1	0.1	0.1
Settling Time	0.2	0.2	0.2
Do Probe Zeroing	unchecked	unchecked	unchecked
Configuration File	LSProbe_2v0_Mode1_detector_switch_700MHz.Device-Configuration	LSProbe_Mode3.Device-Configuration	LSProbe_Mode0.Device-Configuration
Correction Settings	<none>	<none>	<none>

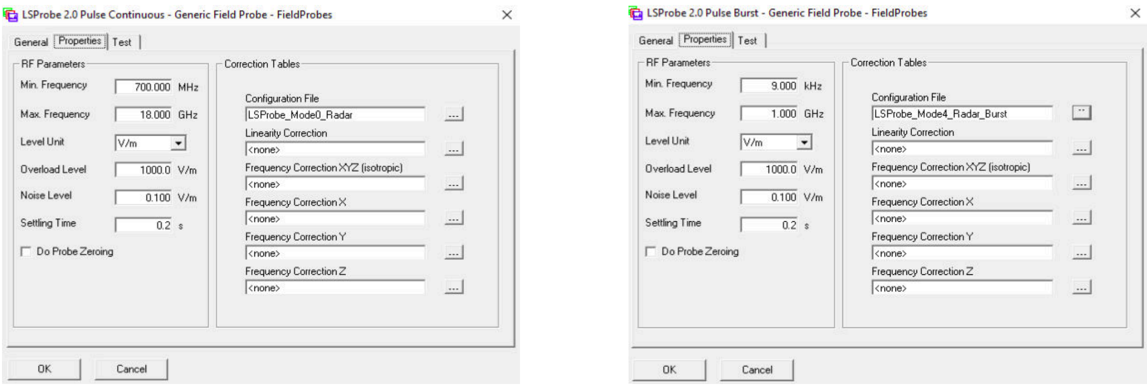


(a) Mode 0 Pulse (Continuous) (b) Mode 4 Pulse (Burst)

Figure 93: *Configuring LSProbe 1.2/1.4/2.0 E-field probes for pulse measurements in EMC32*

high band settings from Table 4 for both entries. Substitute "Mode0.Device-Configuration" for "LSProbe_Mode0_Radar" and "LSProbe_Mode4_Radar_Burst" respectively. Mode 0 corresponds to the entry "LSProbe 2.0 Pulse Continuous" and mode 4 corresponds to the entry "LSProbe 2.0 Pulse Burst" as shown in Figure 94.

The default setting of both device configuration files is suitable for the GMW-3097 standard. It will use the x-axis field strength for triggering at 10 V/m, record 100,000 samples and retrieve the averaged pulse field strength magnitude and x-, y- and z-axis values. The trigger parameters can be modified by editing the respective device configuration files in lines 49 through 53. See Section 5.4.2 for more information about the trigger subsystem's SCPI commands.



(a) Mode 0 Pulse (Continuous) (b) Mode 4 Pulse (Burst)

Figure 94: *Configuring LSProbe 2.0 for pulse measurements in EMC32*

7.2 Nexio – BAT-EMC

The BAT-EMC test automation software supports CW and pulsed E-field measurements. BAT-EMC requires a DLL file, make sure that "FieldP_Lumliloop_LS12.dll" is present in the BAT-EMC directory `...\BAT-EMC\BAT-EMS`.

Please import the provided E-field Fieldmeter equipment models listed in Table 6 by right-clicking on "Fieldmeter" inside the "Equipment" tree structure as shown in Figure 95.

Table 6: *BAT-EMC equipment model files for CW and pulsed fields*

CW	Pulsed
LSProbe_CW.xml	LSProbe_Pulse.xml
LSProbe_CWX.xml	LSProbe_PulseX.xml
LSProbe_CWY.xml	LSProbe_PulseY.xml
LSProbe_CWZ.xml	LSProbe_PulseZ.xml

If the IP address and/or the port number of the LSProbe 1.2/1.4/2.0 E-field probe connection differ from the default values of localhost and port 10,000 go to the "Equipment" subsection and change the "Address" input field appropriately, see also Figure 95. Additionally adjust the "Start Freq." and "Stop Freq." accordingly as depicted in Figure 95 exemplary for an LSProbe 1.2 device.

BAT-EMC requires the LSProbe 1.2/1.4/2.0 E-field probe to be enabled and configured before performing measurements. Before starting BAT-EMC start the LUMILOOP TCP Server and optionally LUMILOOP GUI, enable the supply laser, and set the desired field probe mode as described in Sections 5.2.1 through 5.2.6.

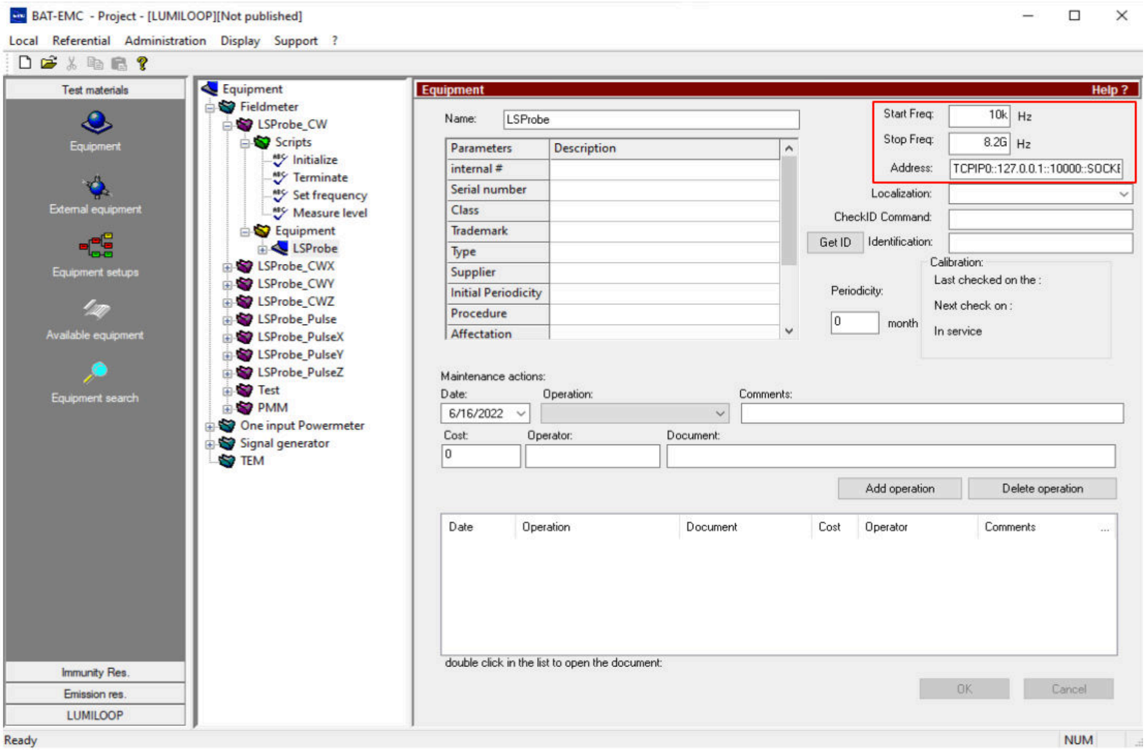


Figure 95: *BAT-EMC Equipment editor, network and frequency range configuration*

7.2.1 CW E-Field measurements

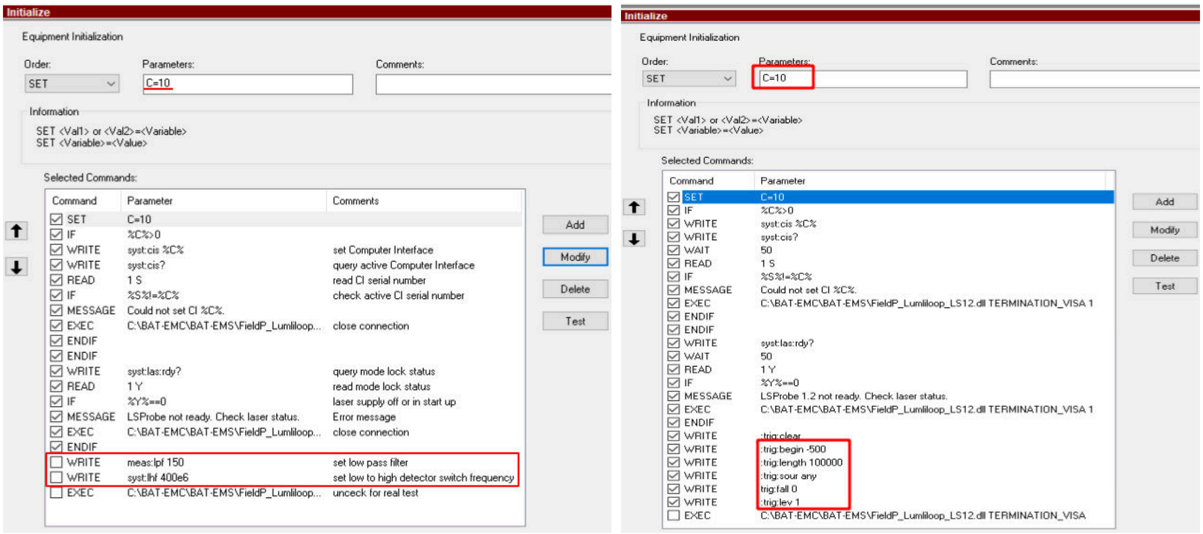
The Fieldmeter model "LSProbe_CW" can be used for LSProbe 1.2 as well as for LSProbe 2.0 devices. It handles all communication including checking the supply laser's status, setting the operating frequency as well as retrieving isotropic, x-, y- and z-axis field strength values. Optionally a low pass filter can be set via enabling the "meas:lpf 150" command depicted in Figure 96 (a). If a different low pass filter is to be set, replace the value 150 accordingly. Operating an LSProbe 1.2 device in mode 1 where the low band detector is to be used up to 400 MHz, enable the "syst:lhf 400e6" command directly below the low pass filter command. Per default the low to high detector frequency switching point is 30 MHz.

The Fieldmeter model returns the isotropic field strength value and stores the field strength of the individual axes in the global variables named "AX", "AY" and "AZ". The three Fieldmeter models "LSProbe_CW[X/Y/Z]" retrieve the global variables and return the respective axis' field strength values. When measuring x-, y- and z-axis field strengths the "LSProbe_CW" Fieldmeter model must be called first.

7.2.2 Pulsed E-Field measurements

The Fieldmeter model "LSProbe_Pulse" handles all communication including checking the supply laser's status, setting the operating frequency as well as retrieving isotropic, x-, y- and z-axis field strength values. Additionally, the Fieldmeter model includes commands for trigger subsystem configuration, trigger detection and radar pulse property retrieval. The Fieldmeter returns the isotropic field strength value and stores the field strength of the individual axes using global variables named "PX", "PY" and "PZ". The three Fieldmeter models "LSProbe_Pulse[X/Y/Z]" read these global variables and return the respective axis' field strength values. When measuring x-, y- and z-axis field strengths the "LSProbe_Pulse" Fieldmeter model must be called first.

The trigger subsystem's configuration can be modified via the Fieldmeter model's "Initialize" script, the relevant commands are shown inside the red frame in Figure 96(b). See Section 5.4.2 for more information about the trigger subsystem's SCPI commands.



(a) LSProbe_CW Initalize script (b) LSProbe_Pulse Initalize script

Figure 96: *Configuring the Initialize scripts for LSProbe 1.2/1.4/2.0 E-field probe CW and pulse measurements in BAT-EMC*

Figure 97 shows the "Measure level" script of the "LSProbe_Pulse" Fieldmeter model. Every call to the "Measure level" script arms the trigger subsystem, waits for the trigger subsystem to acquire a waveform, checks the number of pulses and queries the averaged pulsed field strengths.

The default setting of the "LSProbe_Pulse" Fieldmeter model is suitable for the GMW-3097 standard. It will record 100,000 samples (see the trigger length setting in Figure 96(b)), verify that there are a total of 50 pulses (see the topmost red frame in Figure 97) and retrieve the averaged pulse field strength magnitude and x-, y- and z-axis values. The trigger source, trigger length and expected pulse count can be modified by editing the respective scripts. Pulse count checking can be disabled by unchecking all boxes in the two lower red frames in Figure 97.

If more than one CI-250$^{(+)}$ Computer Interface are attached to the host computer, set the variable CI in Figure 96 to a value other than zero. Doing so will enable the setting and verification of the computer interface's serial number. The Figure 96 demonstrates setting the computer interface serial number to 10, the serial number must be changed to match the desired CI-250$^{(+)}$ Computer Interface's serial number. The variable is available for both CW and pulsed Fieldmeter models.

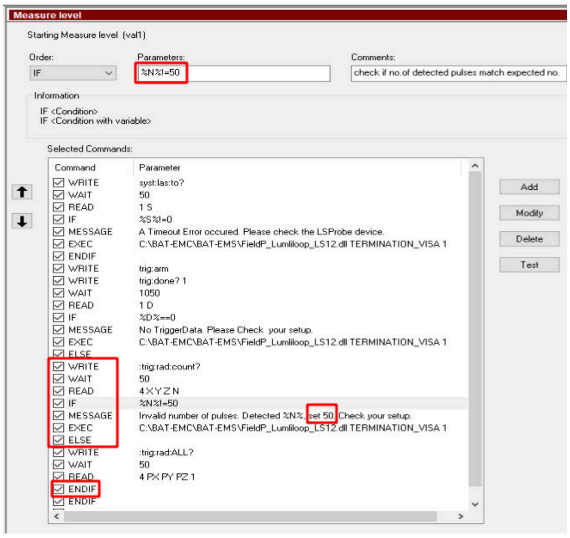


Figure 97: *Configuring the Measure level script for LSProbe 1.2/1.4/2.0 E-field probe pulse measurements in BAT-EMC*

For monitoring multiple CI-250 Computer Interfaces in parallel create a copy of all Fieldmeter models by right-clicking on the Fieldmeter models and choosing "duplicate". Adjust all model names and computer interface serial number variable settings appropriately.

7.3 Techno Science Japan – TEPTO-RS

LUMILOOP recommends using the most recent version of the TSJ Tepto-RS measurement software. The LSProbe 1.2/1.4/2.0 E-field probe driver has been included since 2019.

Before using the LSProbe 1.2/1.4/2.0 E-field probe in Tepto-RS run the LUMILOOP TCP Server, enable the laser supply and select the desired mode as described in Sections 5.2.1, 5.2.4 and 5.2.5.

To configure the LSProbe 1.2/1.4/2.0 E-field probe as the field probe in Tepto-RS select "Hardware Setting" from the "Option" menu as shown in Figure 98.

Click on "E-Field Sensor" to bring up the detailed field probe setup. Select "LSProbe(LUMILOOP)" from the list of available Models. Ignore all other settings and click on "Monitor view" to verify that the field probe is working correctly as shown in Figure 99.

Tepto-RS will connect to the local machine on the default TCP port.

7.4 AR – emcware

LUMILOOP recommends using the most recent version of the AR emcware measurement software. An LSProbe 1.2/1.4/2.0 E-field probe driver, supporting emcware 4.1 and above is included in the LUMILOOP installer.

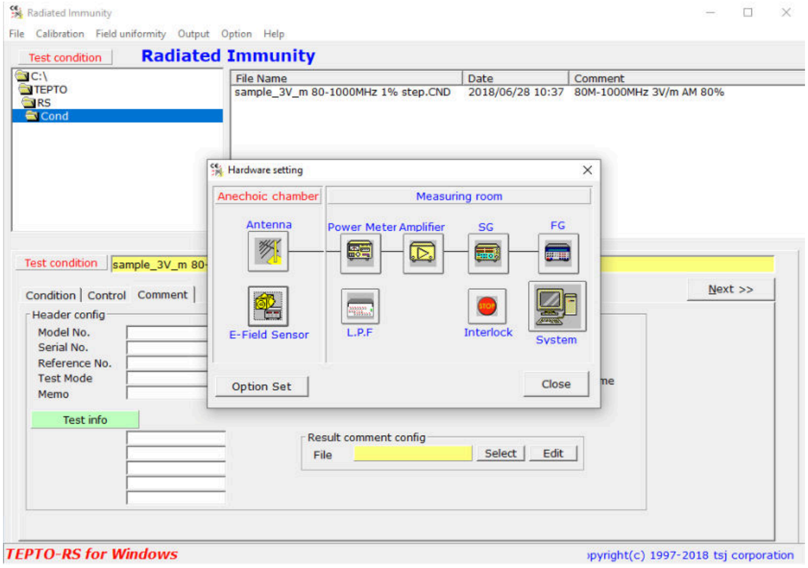


Figure 98: *Hardware setup in TSJ Tepto-RS*

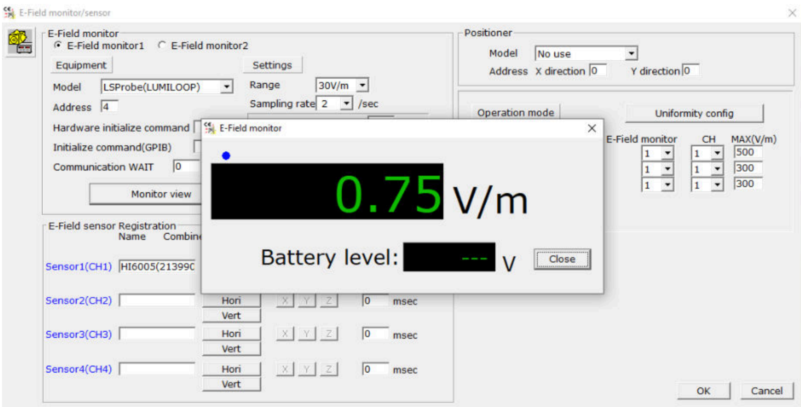


Figure 99: *Testing the LSProbe 1.2/1.4/2.0 E-field probe in TSJ Tepto-RS*

Before using the LSProbe 1.2/1.4/2.0 E-field probe in emcware, copy `LSProbe.dll` from the `lib` sub-directory of the LUMILOOP software installation directory into the `FM` sub-directory of the `Equipment Drivers` directory of the emcware installation path. Moreover, run the LUMILOOP TCP Server, enable the laser supply and select the desired mode as described in Sections 5.2.1, 5.2.4 and 5.2.5. Emcware will change neither the supply laser nor the field probe mode setting.

In order to add the LSProbe 1.2/1.4/2.0 E-field probe to the equipment list, start emcware, open the "Equipment List Manager", select "Field Monitor" and click the "New" button to bring up the configuration window as shown in Figure 100.

Select "LSProbe.dll" as the "Driver". Edit "Address" to configure the IP address and TCP port of the LUMILOOP TCP Server. The identifier string has the generalized format "TCPIP0::<IP address>::<TCP Port>::SOCKET". Usually the LUMILOOP TCP Server is run on the same computer and listening to the default TCP port 10,000. Consequently, the default identifier string is

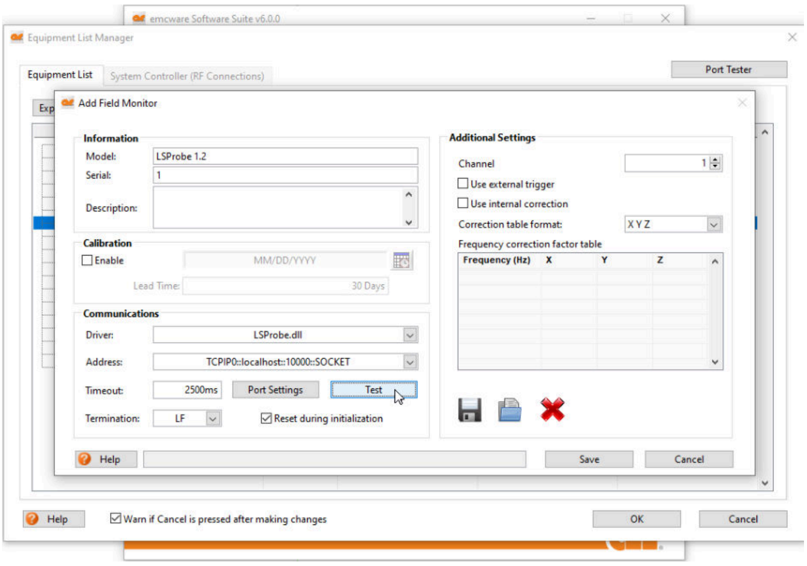


Figure 100: *Adding an LSProbe 1.2/1.4/2.0 E-field probe in AR emcware*

"TCPIP0::127.0.0.1::10000::SOCKET". Make sure that "Termination" is set to "LF". All other parameters may be left at their default values. Make sure that there is no calibration table since the LUMILOOP TCP Server will handle all correction factors.

Click on "Test" to verify that the field probe is working correctly as shown in Figure 101. This will open the window shown in Figure 101. Clicking "Test" will connect to the specified LUMILOOP TCP Server, set the correction frequency and read out a set of field strength values.

The driver communicates only with the first enumerated CI-250(+) Computer Interface.

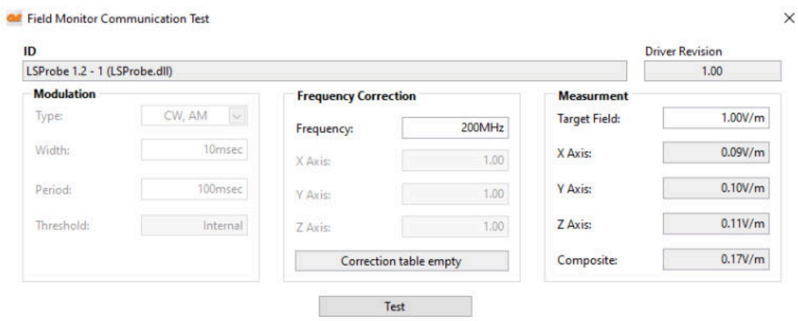


Figure 101: *Testing the LSProbe 1.2/1.4/2.0 E-field probe in AR emcware*

7.5 Raditeq – RadiMation

LUMILOOP recommends using the most recent version of the Raditeq RadiMation measurement software. The LSProbe 1.2/1.4/2.0 E-field probe driver has been included in the RadiMation drivers package since March 2017. The latest version of the RadiMation software and its device drivers package can be downloaded from `https://wiki.radimation.com/wiki/index.php/Main_Page`.

Before using the LSProbe 1.2/1.4/2.0 E-field probe in RadiMation run the LUMILOOP TCP Server, enable the laser supply and select the desired mode as described in Sections 5.2.1, 5.2.4 and 5.2.5. RadiMation will change neither the supply laser nor the mode setting.

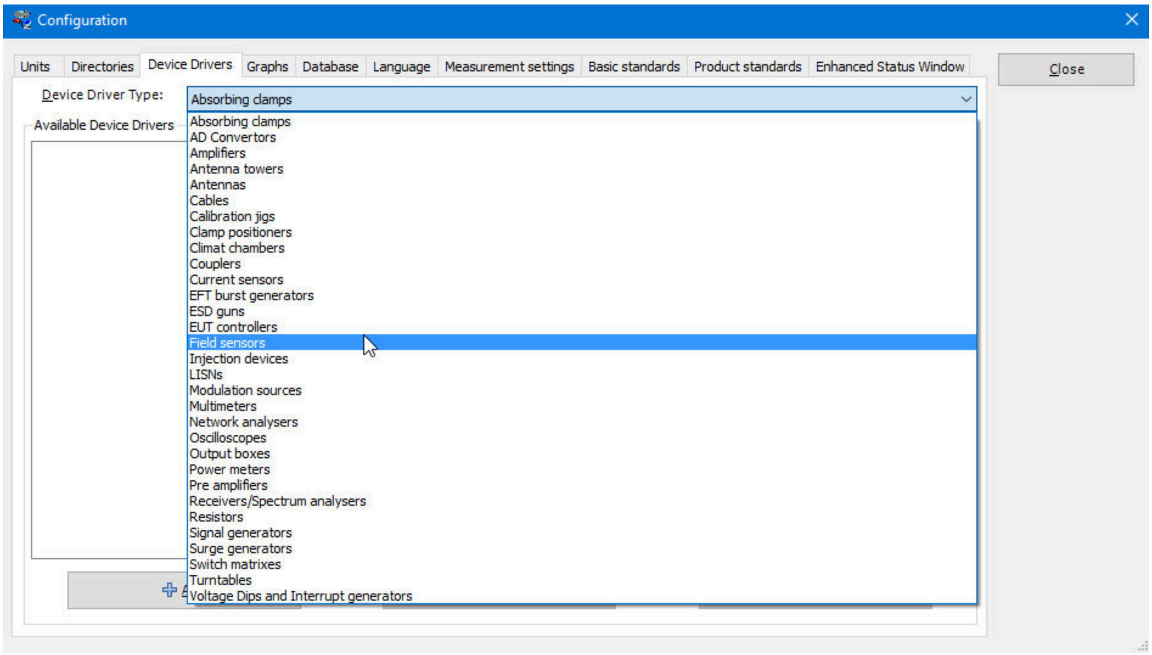


Figure 102: *Choosing field sensors in RadiMation configuration*

Every newly connected LSProbe 1.2/1.4/2.0 E-field probe needs to be added to the RadiMation device list choosing it from the RadiMation device driver list. Open the "Configuration" window via "Configuration→Configuration" in the menu bar. Inside the "Device Drivers" tab choose "Field sensors" as the "Device Driver Type" as shown in Figure 102

As shown in Figure 103 click the "Add" button and select "LUMILOOP LSProbe 1.2" from the list. Next click the "New" button and enter a description of the field probe, e.g., "LUMILOOP LSProbe 1.2", finish by clicking "Ok".

A "Device Driver Settings" window will open as shown in Figure 104. Click the "Advanced" button and select the "Settings tab". Enter the correct CI-250$^{(+)}$ Computer Interface number of the E-field probe to be connected. To determine the serial number of the computer interface type the SCPI command »:SYSTem:CISerial? [<MProbe>] 0« in the TCP-Server window, which will return the list of all connected CI-250$^{(+)}$ Computer Interface serial numbers or refer to the Computer Interface Device Summary table output by the TCP-server as shown in Figure 105(a). Alternatively, open the LUMILOOP GUI, select the "Connection" tab and find the "CI SerNo" indicator field as shown in Figure 105(b).

The low-pass filter frequency is also adjustable in this window. Click "Ok" to close the advanced setting window and the "Device Driver Settings" window. The TCP host and port can be configured using the "Communication" tab.

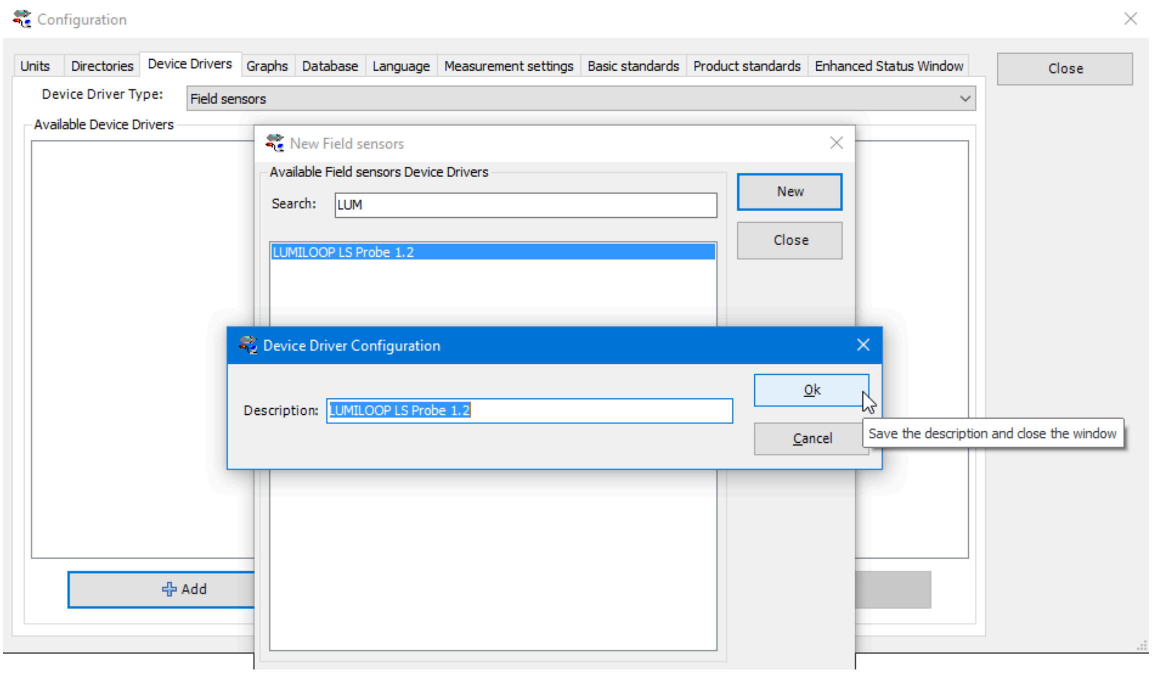


Figure 103: *Adding a new LSProbe 1.2 field sensor in RadiMation*

The newly created field probe device can be selected available via "Devices→Field sensors" as shown in Figure 106.

Figure 107 shows the window used for connecting to and testing the LSProbe 1.2 field sensor. Use the "Connect" button for establishing the connection and the "Trigger" button for obtaining field strength readings for the operating frequency set via the "Carrier frequency" control.

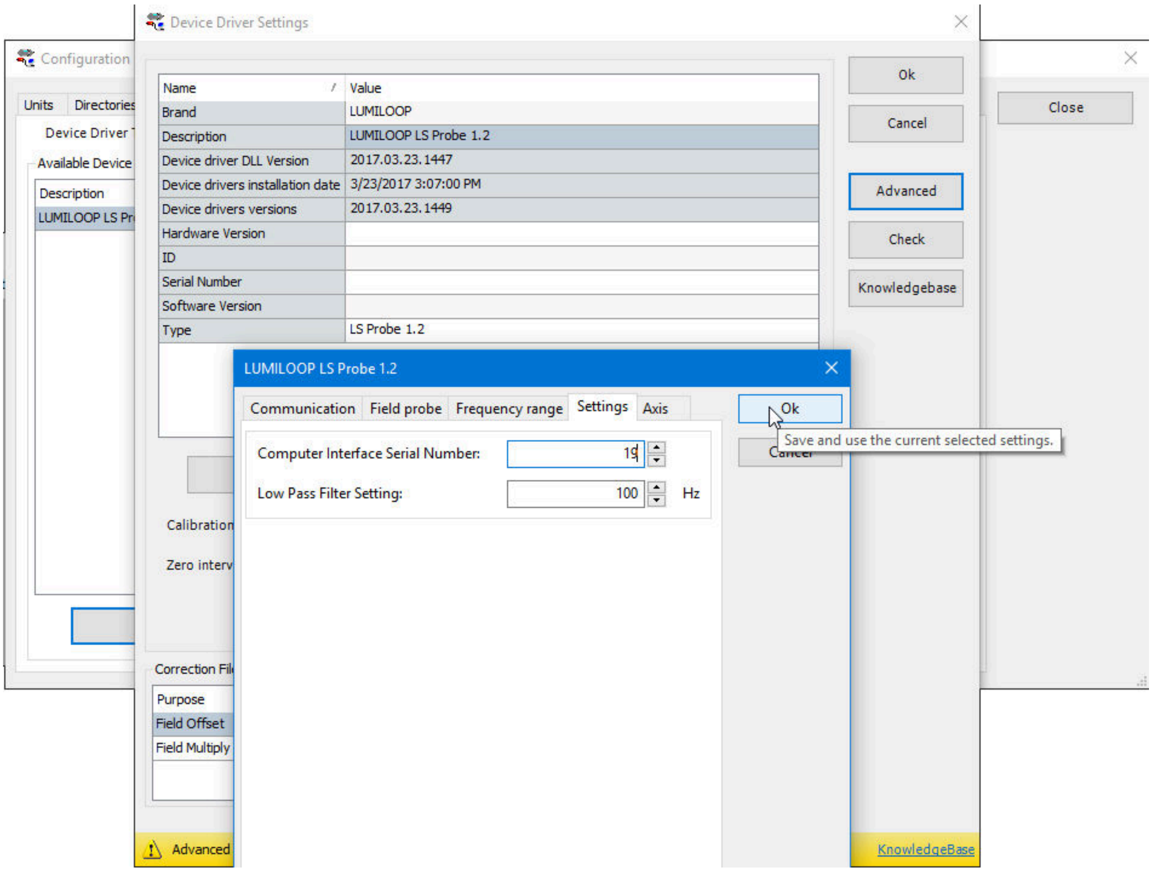
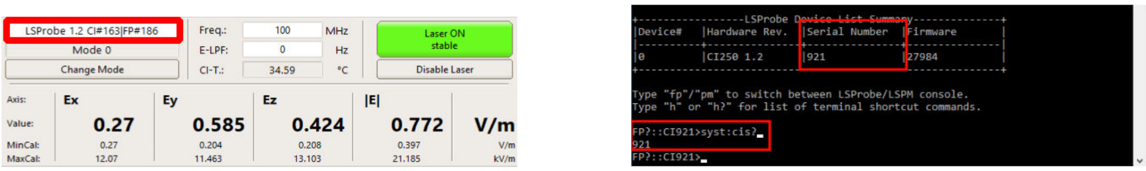


Figure 104: *Configuring LSProbe 1.2 field sensor in RadiMation*



(a) LUMILOOP GUI (b) TCP-Server

Figure 105: *Acquiring the computer interface serial number*

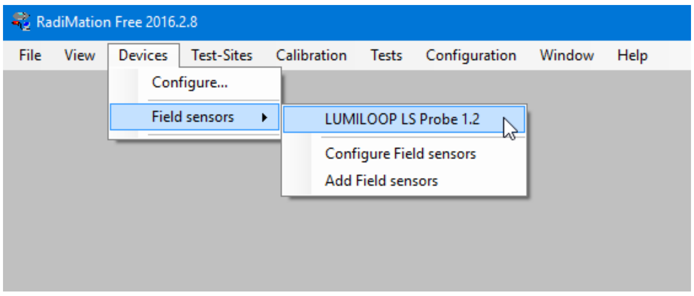


Figure 106: *Selecting new field sensor in RadiMation*

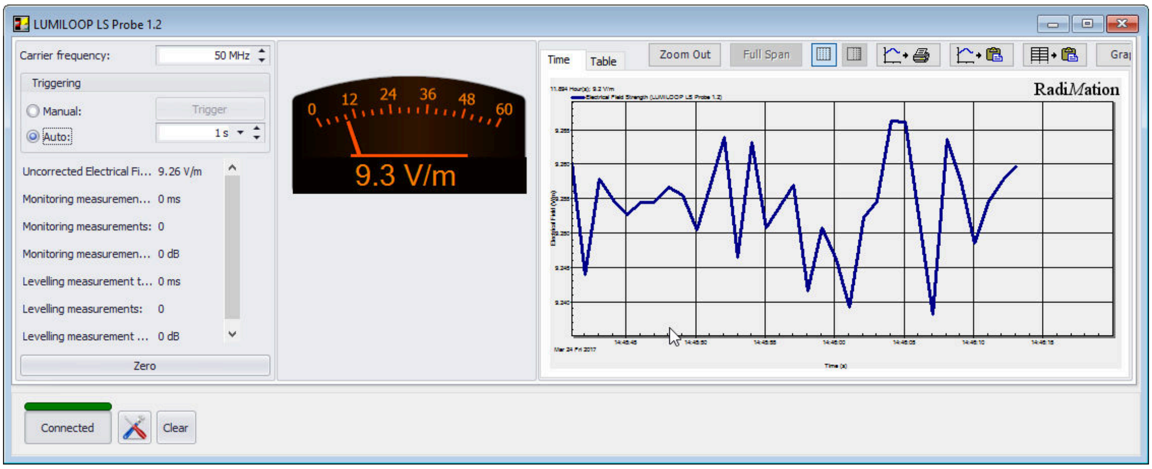


Figure 107: *Connecting and testing LSProbe 1.2 field sensor in RadiMation*

7.6 Teseq – Win6000

The LSProbe 1.2/1.4/2.0 E-field probe is supported by Win6000 version 1.35 and later.

Start Win6000 and install the packages `drv_LSProbe1.2_Ver2017-03-27.zip` and `LUMILOOP_LSProbe2.1_Test2.zip` contained in the `lib\Win6000` subdirectory of the LSProbe installation path. As shown in Figure 108 use "Packages→Install Package" in the menu bar for both packages.

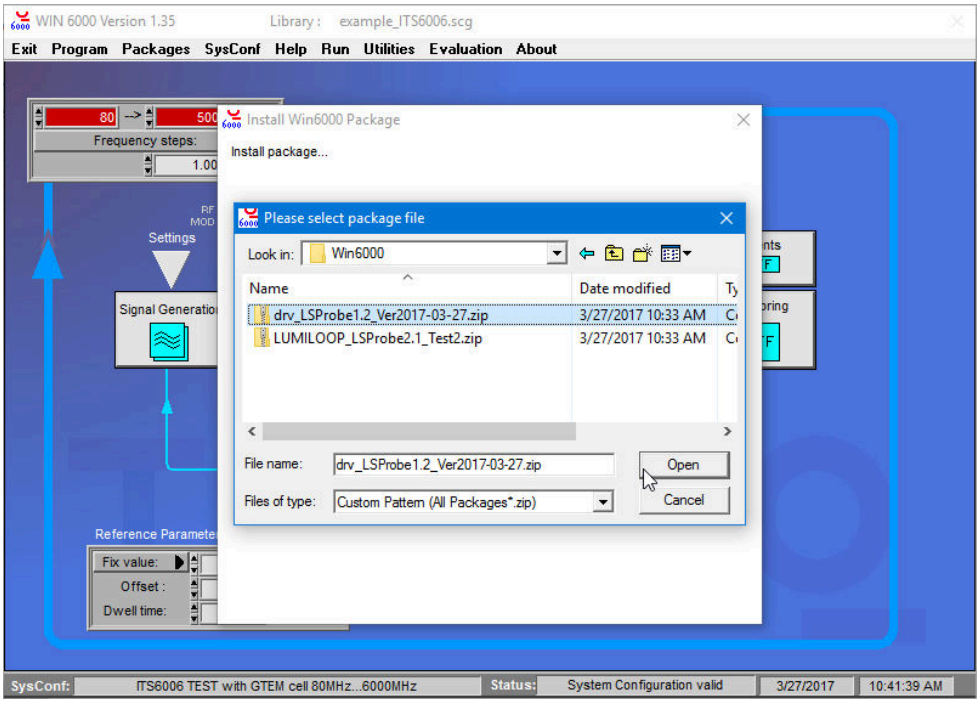


Figure 108: *Installing Win6000 driver and test setup packages*

By default Win6000 will connect to port 10,000 of an LUMILOOP TCP Server running on the same host. To change the host or TCP port setting open `LSProbe1.2.drv` typically located in `C:\Teseq\Teseq\Devices`. In line 20 of `LSProbe1.2.drv` change "127.0.0.1" to the desired TCP host and "10000" to the desired TCP port number.

Before using the LSProbe 1.2/1.4/2.0 E-field probe in Win6000 run the LUMILOOP TCP Server. Open the test setup via "SysConf→Open" and select the "LUMILOOP_LSProbe" setup's subsection "using as device of monitoring system" as shown in Figure 109.

Within the test setup shown in Figure 110, click on "Monitoring" to configure the channels to be recorded.

Choose "LSProbe 1.2" from the list of available devices, name the channel and open the channel's settings dialog as shown in Figure 111. Select the desired mode, sensor type (E-field x-, y-, z-axis magnitude or temperature) and low-pass filter cut-off frequency. Choose whether calibration information is to be shown. Close the configuration by clicking "OK".

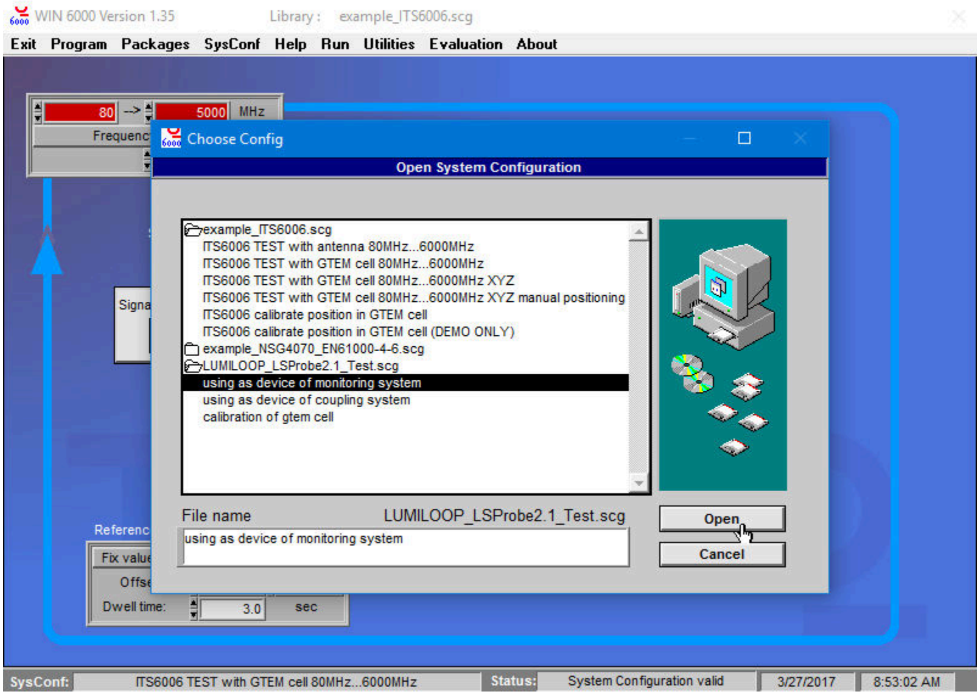


Figure 109: *Loading Win6000 LSProbe 1.2 test setup in Win6000*

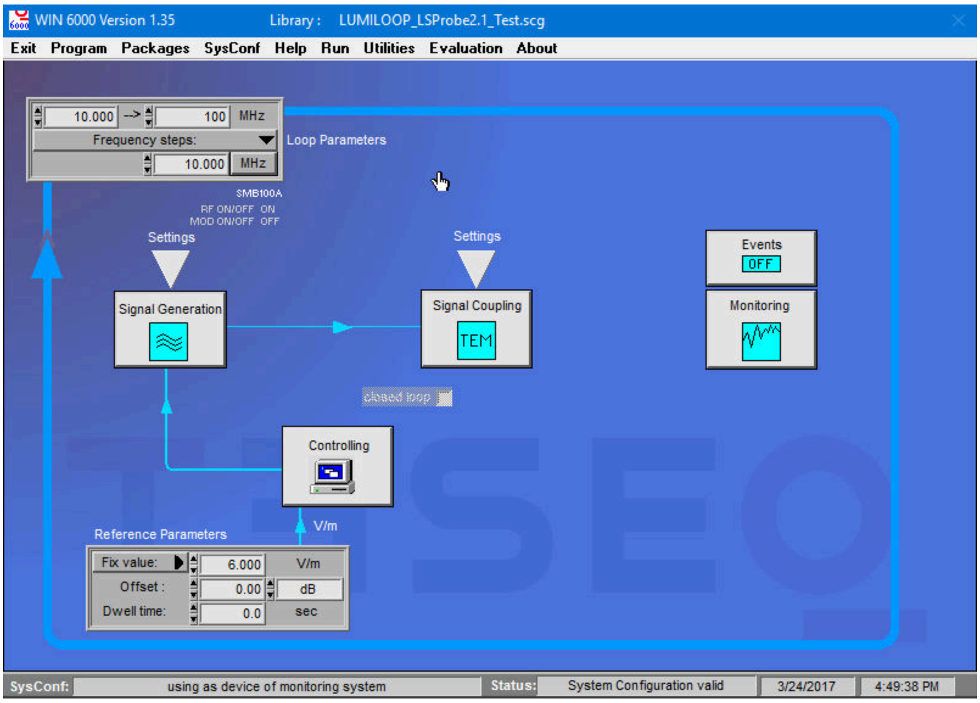


Figure 110: *Configuring LSProbe 1.2 test setup in Win6000*

Start the measurement via "Run→ Start Automatic Test Execution" in the menu bar. Fill in the following dialogs to configure the recording of measurement data appropriately. Figure 112 shows a

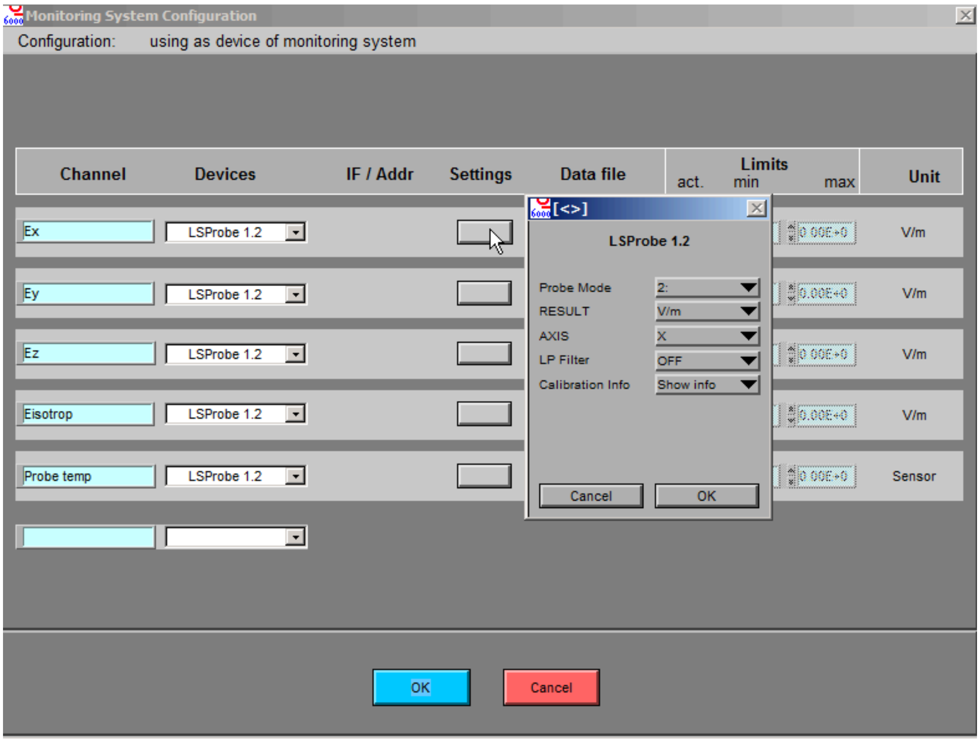


Figure 111: *Selecting LSProbe 1.2 mode, axis and low-pass filter in Win6000*

measurement run, note that Win6000 will display wait messages when performing mode switching.

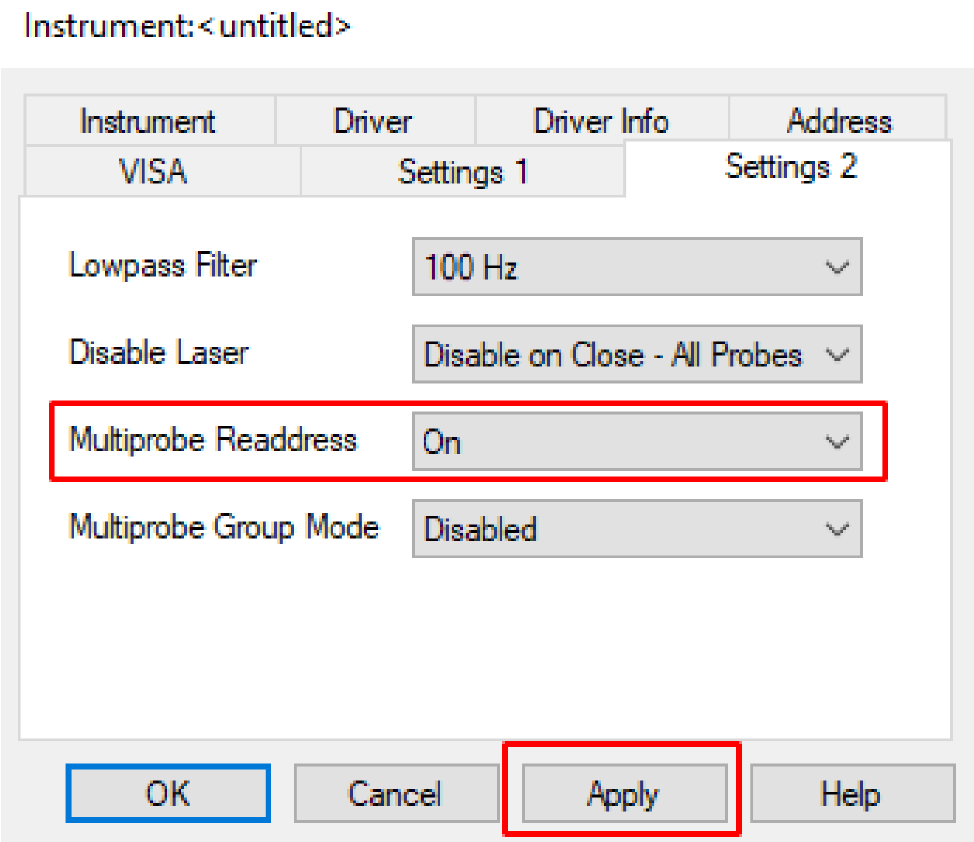
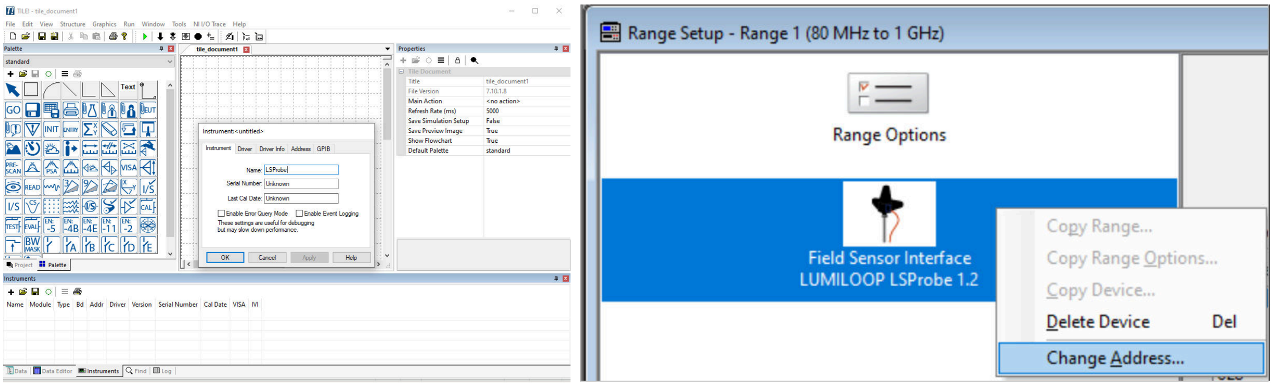


Figure 112: *Measurement run in Win6000*

7.7 ETS-Lindgren – TILE!

The LSProbe 1.2/1.4/2.0 E-field probe is supported by TILE! version 7.6.0.5 and later. Example profiles for LSProbe setups in TILE! are located in the installations path's `lib\TILE` directory. In order to add an LSProbe 1.2/1.4/2.0 E-field probe as a TILE! instrument, use the "+" button and select `Lumiloop_LSProbe.ins` as the device driver as shown in Figure 113.



(a) (b)

Figure 113: *Adding the LSProbe driver to to TILE!*

As shown in Figure 114(a), the "VISA Resource Name" can be set in the "VISA" tab, specifying the host name and TCP port of the LUMILOOP TCP Server. The identifier string has the generalized format "TCPIP0::<IP address>::<TCP Port>::SOCKET". Usually the LUMILOOP TCP Server is run on the same computer and listening to the default TCP port 10,000. Consequently, the default identifier string is "TCPIP0::127.0.0.1::10000::SOCKET" or "TCPIP0::localhost::10000::SOCKET".

As shown in Figure 114(b), additional settings are accessible via the "Settings 1" tab:

axis
: Select single axis or magnitude for readout. To read out multiple axes, instantiate multiple instruments.

Mode
: Set the field probe operating mode.

Enable Laser
: Let TILE! enable the laser on initialization or enable laser by hand, the latter is recommended.

Run LUMILOOP TCP Server
: Run TCP server from TILE! on driver load, initialization or not at all, the latter is recommended.

Run LUMILOOP GUI
: Run GUI from TILE! on driver load, initialization or not at all, the latter is recommended.

As shown in Figure 114(c), further settings are accessible via the "Settings 2" tab:

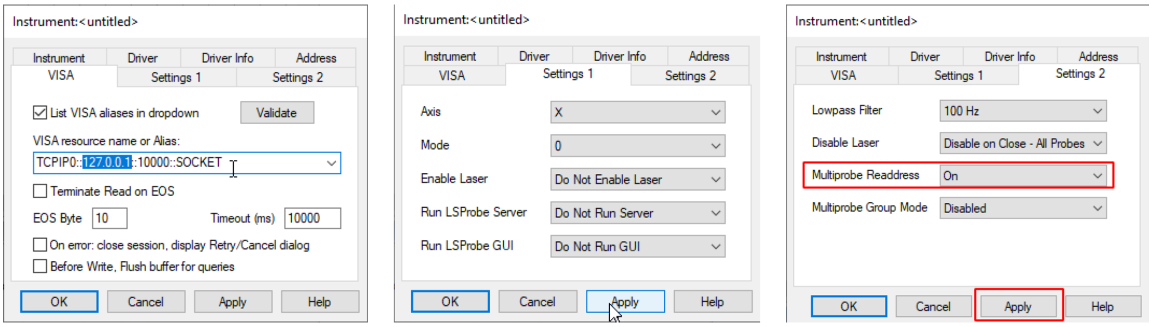
Lowpass Filter
: Set the lowpass filter cut-off frequency or disable lowpass filtering.

Disable Laser

Let TILE! disable the laser when closing one probe, all probes or not at all, the latter is recommended.

Multiprobe Readdress

Set to "On" if more than one LSProbe device is to be used. Create one instrument for each LSProbe device. Additionally, in the "Probe CI" serial number entry field in the property frame, the serial number of the Computer Interface has to be entered



(a) (b) (c)

Figure 114: *Configuring LSProbe driver in TILE!*

When using more than one LSProbe 1.2/1.4/2.0 E-field probe, set the CI-250(+) Computer Interface serial number via the "Probe CI#" property of the field probe instance as shown in Figure 115. To use multiple field probes create multiple driver instances with distinct identifiers and computer interface serial numbers.

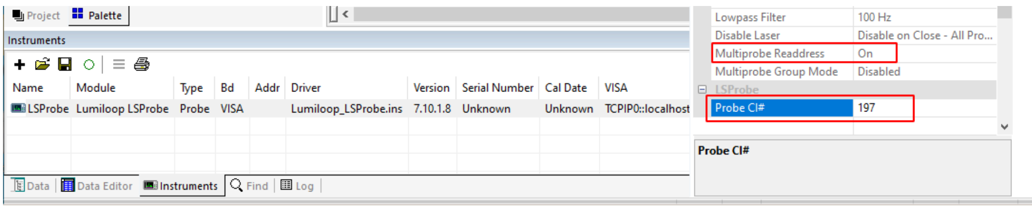


Figure 115: *Setting LSProbe CI number in TILE!*

To test the field probe, place one "INIT" and one "READ" action on the TILE! flow chart. Associate both actions with the LSProbe driver instance. Enable monitoring for the "READ". Enabling monitoring for the "READ" action, will display field strengths readings upon running the "READ" action, as shown in Figure 116.

7.8 Ametek – Compliance Immunity 6

LSProbe 1.2/1.4/2.0 E-field probes are supported by AMETEK CTS Compliance Immunity since version 6.01.0. For the previous version i.e. Complience 5 there is no device driver available. LSProbe devices can only be used in the way as described in Section 8.

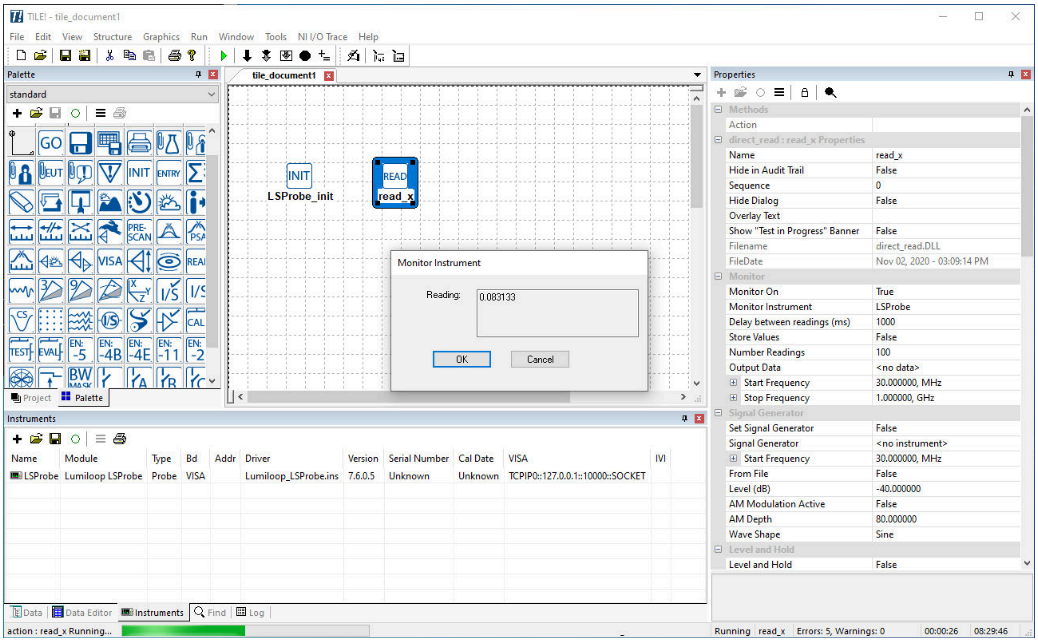


Figure 116: *Testing LSProbe instance in TILE!*

The LSProbe 1.2/1.4/2.0 Compliance 6 Device Driver requires an installed VISA library, e.g., from National Instruments (NI) and allows to us the VISA TCP socket connection. For application of LSProbe 1.2/1.4/2.0 E-field probes with CI6, the LUMILOOP TCP Server has to be started. The laser of the system has to enabled using the LUMILOOP TCP Server or LUMILOOP GUI, respectively.

The LSProbe 1.2/1.4/2.0 Device Driver is not supported by Compliane 5 Immunity (C5I), as C5I does not support VISA functionality. As a workaround for the application of LSProbe 1.2/1.4/2.0 E-field probes with C5I, the LUMILOOP TCP Server allows to emulate the serial protocol of the PMM EP60x E-field probe series. The LSProbe 1.2/1.4/2.0 Device Driver is provided directly with the CI6 Software. The Device Files `_Lumiloop_LS_Probe_1.2.edv` and `_Lumiloop_LS_Probe_1.2.jpg` can be found in the Driver Directory `C:\TESEQ\RF_Software\DriversSystem\Drivers\`. The Device Driver is listed in the Device Driver Library which can be found under menue item Tools. General information about the CI6 Device Drivers is given the CI6 Help menue. Specific information about the LSProbe 1.2/1.4/2.0 Device Driver is provided directly by AMETEK CTS from version 6.2 on. Until then, the driver information `Lumiloop_LSProbe1.2.pdf` can be requested using software.rf.cts@ametek.com, a copy of will be distributed with the LUMILOOP Software Installer.

7.9 Rohde & Schwarz – ELEKTRA

The LUMILOOP devices can be used with the ELEKTRA software. For this please make sure that you have the newest ELEKTRA version above 5.0 installed.

To create an LSProbe configuration got to "Device List->Field Probe->Lumiloop Probes" and select the correct LSProbe version as depicted in Figure 117.

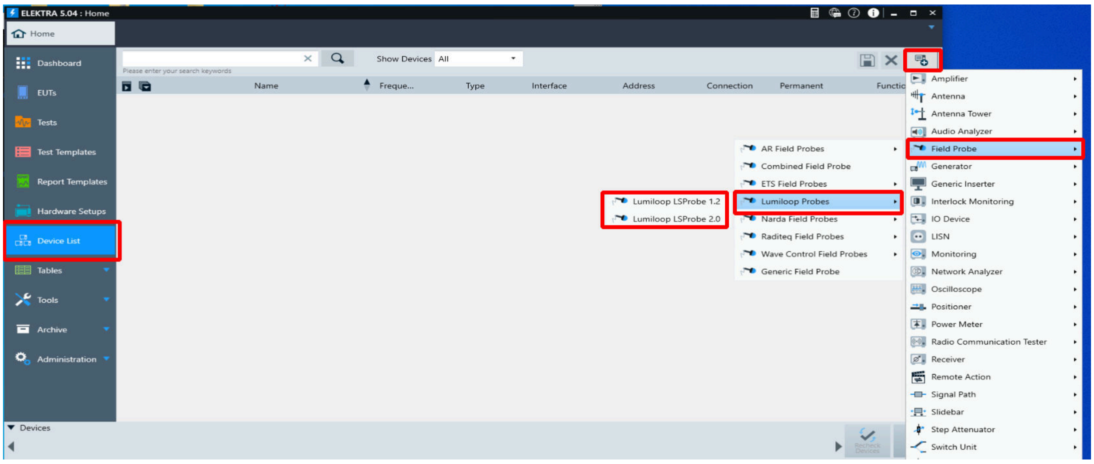


Figure 117: *Adding an LSProbe device to ELEKTRA's device list*

Go to the "Connection" tab to set the IP address and the port of the LUMILOOP TCP Server as shown in Figure 118.

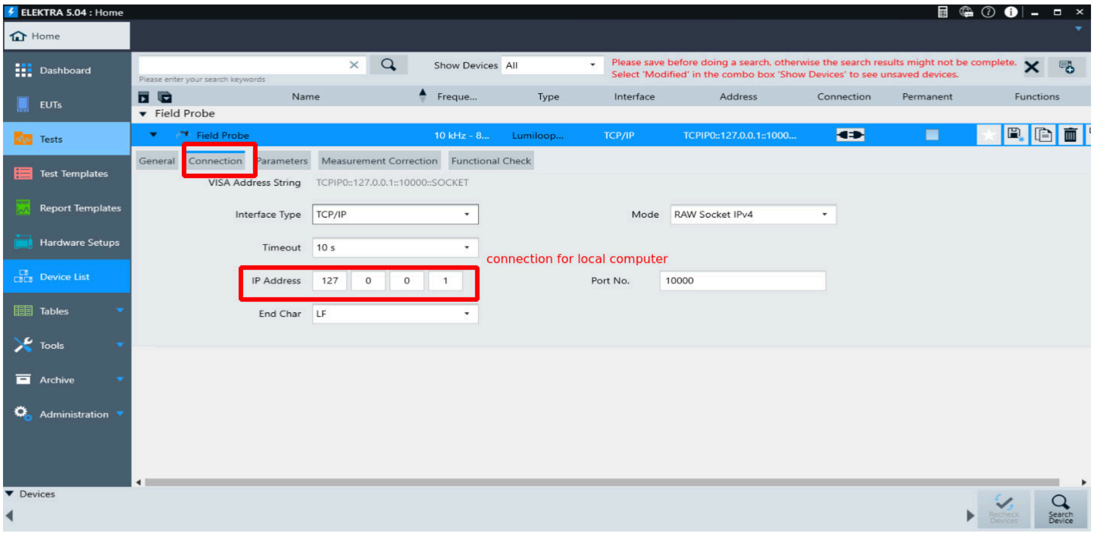


Figure 118: *Setting the IP address and port of the LUMILOOP TCP Server in ELEKTRA*

In the "Parameters" tab the number of LSProbe devices as well as their respective Computer Interface serial number(s) have to be specified. Please refer to Figure 119. If only one LSProbe is used, set the "Number of Channels" to 1 and enter its CI serial number in the "Computer Interface ID for Channel 1" entry field and check the "Actice" box.

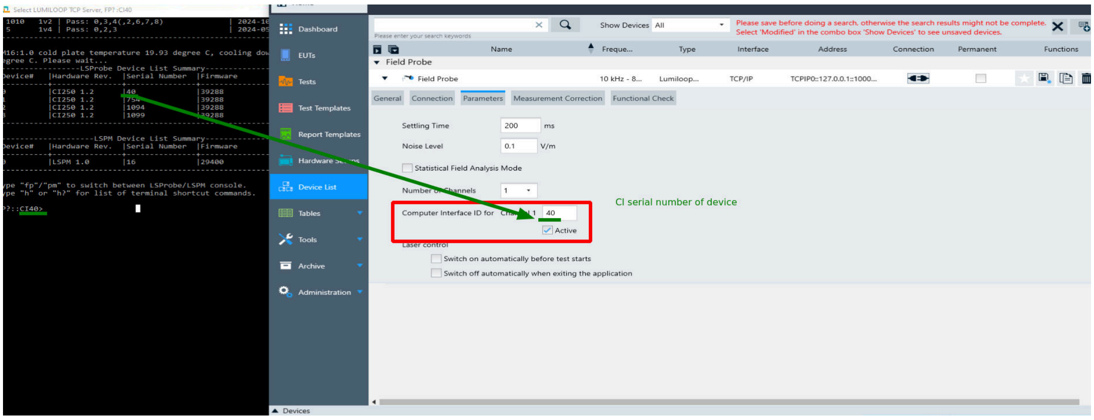


Figure 119: *Specifying the Computer Interface serial number(s) in ELEKTRA*

For validation of the connection and correct setup, go to the "Functional Check" tab as shown in Figure 120. Set the measurement mode and frequency accordingly and press on "Measurement". E-field values will be displayed in the "Meaurment Result XYZ/X/Y/Z" fields.

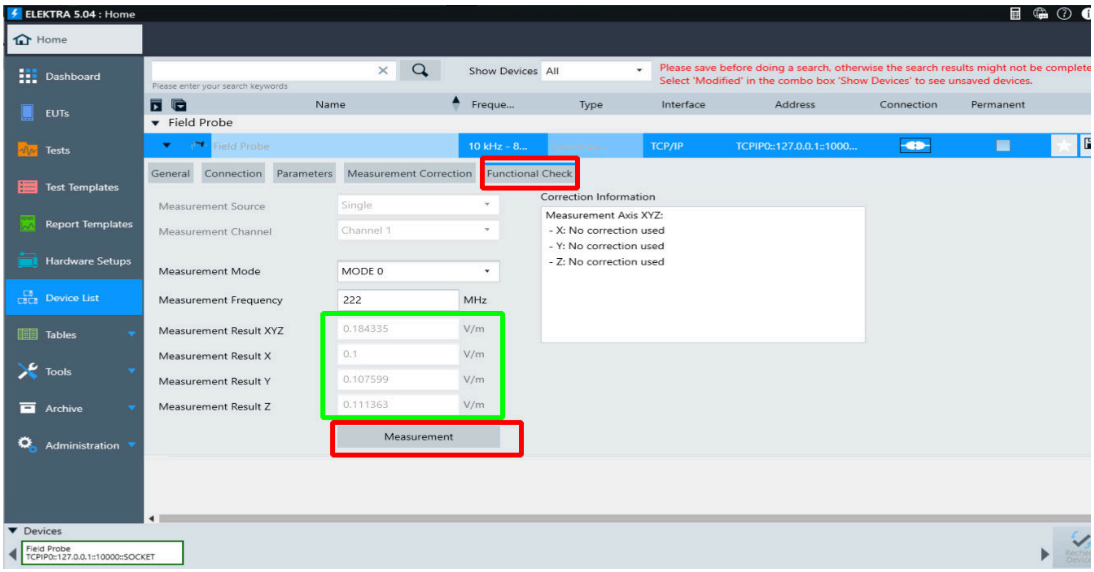


Figure 120: *Functional check of the LSProbe device in ELEKTRA*

7.10 Frankonia – ProveEMC

7.11 TOYO - VI5RS and IM5RS

7.12 TDK RF Solutions – Radiated Immunity Lab

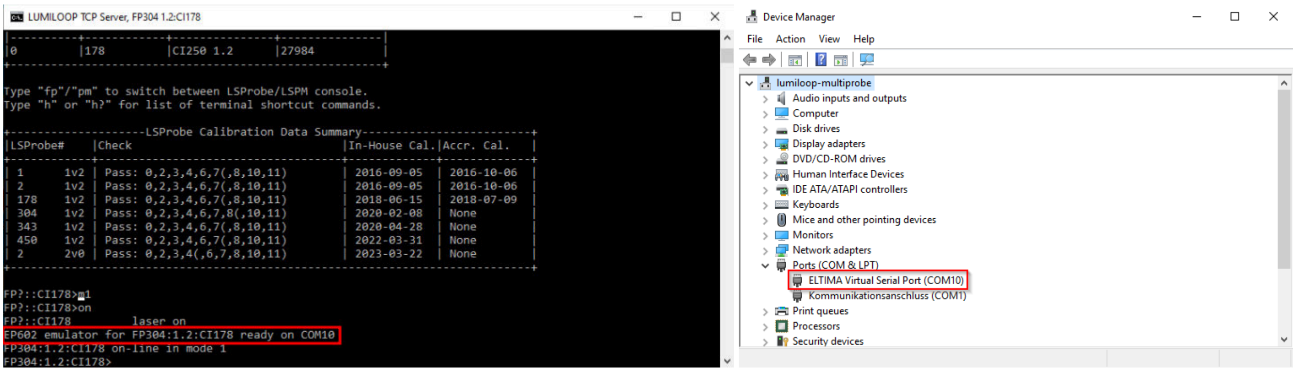
For LSProbe 2.0 devices proceed in the same way.

For further more detailed information regarding the available settings and options, refer to the TDK Radiated Immunity Lab User Manual's chapter 14, "How to Set Up the Field Sensor Interface".

8 Serial Port Protocol Emulation

The LUMILOOP TCP Server is capable of closely emulating the serial protocol of the PMM EP60x E-field probe series. This enables the seamless integration into a wide range of existing test setups and third party EMC software without requiring a dedicated device driver. The serial port protocol emulation provides basic asynchronous read-out and filtering of x-, y-, z-axis E-field values and E-field magnitude values. Advanced features such as high speed waveform acquisition, triggering, pulse detection, statistics and Multiprobe setups require a dedicated device driver.

On entering mode 1, which supports the complete operating frequency range, the LUMILOOP TCP Server will create a virtual serial port and indicate the COM port number as shown in Figure 121. Virtual serial port numbers start from the value set by the configuration file setting '`COM_PORT`'. The default value is COM10. The LUMILOOP TCP Server reserves the lowest available COM number to offer serial command access. The virtual serial port is configured to use 9600 baud, no parity, one stop bit and no flow control. Different settings, especially baud rates will normally not affect communication over the virtual serial port as the virtual serial line's settings are not enforced strictly.



(a) LUMILOOP TCP Server (b) Device Manager

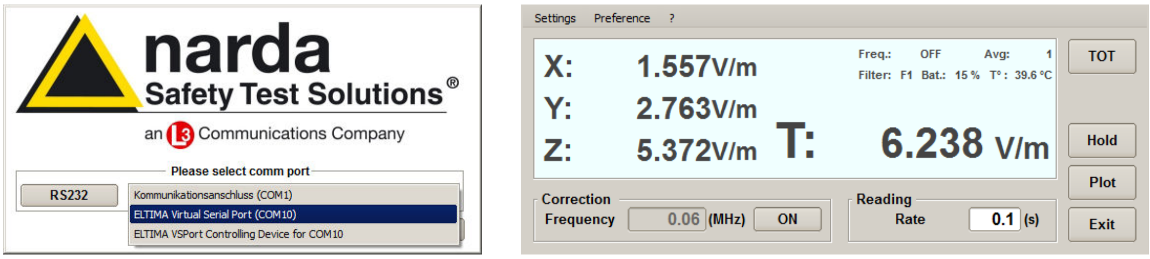
Figure 121: *Virtual serial port for EP60x emulation in mode 1*

8.1 Using LSProbe 1.2/2.0 via the WinEP600 Software

Use the LUMILOOP GUI to enable the supply laser and set the mode to 1 as described in Sections 5.2.4 and 5.2.5. Optionally, close the GUI afterwards.

Run WinEP600 and select the virtual COM port indicated by the LUMILOOP TCP Server as shown in Figure 122(a). Do **not** use the COM port containing the string "VSPort Controlling Device". Click "RS232" to open the connection.

Figure 122(b) shows the WinEP600 software communicating with the LUMILOOP TCP Server. Note that setting frequency correction to "OFF" will in fact not disable frequency correction but set the correction frequency to 10 kHz. The indicated battery voltage is the E-field probe's optically generated supply voltage, the displayed temperature is the E-field probe's internal temperature, which is



(a) Serial Port Section (b) Main Window

Figure 122: *Using WinEp600*

always significantly higher than its ambient temperature. The E-field probe's serial number is available through the help menu under "? → Info → Serial" indicated before the "S" character of the displayed text.

The filter setting is handled in such a fashion that the cut-off frequency will be emulated. The notch characteristics will be ignored. Note that on closing WinEP600 the E-field probe will not be shut down even if commanded to. The E-field probe can be shut down using the GUI as described in Section 5.11.1.

8.2 Serial Command Reference

All serial commands are case-sensitive, start with a "#" character and end with a "*" character. The two characters following "#" indicate the field probe's address between "00" and "99". An address of "00" will be accepted regardless of the serial number set using the commands "@c" and "@la", detailed below.

The supported command strings between serial number and "*" are explained in the following sections.

8.2.1 ?v

Query version string, consisting of emulated field probe type, pseudo firmware version and the calibration date. If available, the accredited calibration date will be used rather than the factory calibration date. E.g., the query "#00?v*" will return "vEP602:1.12 11/16;" for a field probe calibrated in November of 2016.

8.2.2 ?p

Query calibration date string of the emulated field probe. If available, the accredited calibration date will be used rather than the factory calibration date. E.g., the query "#00?p*" will return "p11/16;" for a field probe calibrated in November of 2016.

8.2.3 ?b

Query E-field probe's optically generated supply voltage in V, encoded as a two byte, big endian encoded, 16 bit unsigned integer value. E.g., the query "#00?b*" will return "b" followed by two bytes encoding the voltage code n. The battery voltage can be calculated as $V_{bat} = 4.8\,\mathrm{V}\,\frac{n}{1024}$.

8.2.4 ?t

Query E-field probe's internal temperature in °C, encoded as a two byte, big endian encoded, 16 bit unsigned integer value. E.g., the query "#00?t*" will return "t" followed by two bytes encoding the temperature code t. The temperature can be calculated as $T_{int} = 281.7\,^{\circ}\mathrm{C}\left(\frac{1.6t}{1024} - 0.986\right)$.

8.2.5 ?s

Query E-field probe's serial number string consisting of a total of 33 characters. E.g., the query "#00?s*" will return "s0001S00000" followed by 22 zero-valued bytes for an E-field probe with the serial number 1. The Serial number is contained in the four characters preceding "S".

8.2.6 ?T

Query the square of the E-field strength's magnitude in V^2/m^2, encoded as a four byte, little endian, single-precision IEEE floating-point number. E.g., the query "#00?T*" will return "T" followed by four bytes containing the squared field strength magnitude.

8.2.7 ?A

Query x-, y- and z-axis components of the E-field strength in V/m, each encoded as a four byte, little endian, single-precision IEEE floating-point number. E.g., the query "#00?A*" will return "A" followed by three times four bytes containing the field strength value for x-, y- and z-axis.

8.2.8 kf

Set the operating frequency expressed in multiples of 10 kHz. The command returns the character "k" followed by four bytes encoding the operating frequency in MHz as a four byte, little endian, single-precision IEEE floating-point number. E.g., the command "#00k10000*" will set the operating frequency to 100 MHz and return the character "k" followed by four bytes containing the operating frequency in MHz. If the set frequency is outside the E-field probe's calibrated frequency range e-field queries will return NAN.

8.2.9 fn

Set the low-pass filter characteristic. Settings between 0 and 7 are allowed. The command contains a single ASCII-coded number giving the filter number n. The values 0 through 7 correspond to low-pass filter cut-off frequencies of 28, 24, 8, 4.7, 4, 4, 3.2 and 2.3 Hz. Note that the notch characteristics of the original EP60x filter is not implemented by the emulation. The command returns the character “f” followed by one byte echoing the set mode number between 0 and 7. E.g., the command “#00f0*” will select the first filter characteristic having a 28 Hz cut-off frequency and return “f0”.

8.2.10 et

The command contains a single ASCII-coded number giving the time in seconds t. Originally, the command is used to set the time before the EP60x field probe switches off automatically. Since the LSProbe 1.2/1.4/2.0 E-field probe is laser-powered, the command serves no useful purpose for emulation. The input of the command is therefore ignored and always acknowledged. E.g., the command “#00e 300*” for setting the timeout to five minutes will be ignored and be acknowledged by a single “e” character.

8.2.11 !

Originally, the command is used to switch the EP60x field probe off. Since the LSProbe 1.2/1.4/2.0 E-field probe is laser-powered, the command serves no useful purpose for emulation. The command is therefore ignored. The command returns no reply.

8.2.12 @c

Enter address-storing mode for the next second. The command returns no reply. E.g., “#00@c*” will enter address-storing mode.

8.2.13 @la

When in address-storing mode, set the field probe address to a value between 0 and 99. The command consists of the two characters “@l” followed by the parameter a, two ASCII characters stating an address between “00” and “99”. The command returns “ERR” if not in storing mode and “l” followed by two bytes echoing the set address if in storing mode. E.g., “#00@l11*” will set the address to 11 and return “l11”.

9 Virtual E-Field Probes

The LUMILOOP TCP Server is capable of instantiating virtual LSProbe devices including the simulation of arbitrary E-field patterns.

Virtual E-field probes can replace physical ones and signal generators during measurement setup preparation, feature demonstration, third party EMC software development and off-line signal analysis, including setups using multiple E-field probes.

The following virtual computer interface and E-field probe properties can be configured:

- Computer interface serial number ,
- Computer interface supply laser state ,
- E-field probe version,
- E-field probe serial number,
- E-field probe temperature in °C and / or LSB ,
- E-field probe x-, y- and z-axis acceleration and
- E-field probe x-, y- and z-axis E-field strength for version 1.2, or xa-, ya-, za-, xb-, yb- and zb-axis E-field strength for field probe version 2.0, see pattern description below.

Virtual computer interface serial numbers and E-field probe serial numbers must be unique, i.e., must not duplicate the serial numbers of any physical or virtual units. Virtual E-field probe version and serial number must be configured before enabling the virtual supply laser. LSProbe 1.2 E-field patters for x-, y-, and z-axis, or xa-, ya-, za, xb-, yb-, and zb-axis for LSProbe 2.0 are simulated by summing up RSSI patterns of the following types:

CW (continuous wave)
: Generates constant RSSI values.

Noise
: Generates random RSSI values with a configurable maximum amplitude whose time-average is zero.

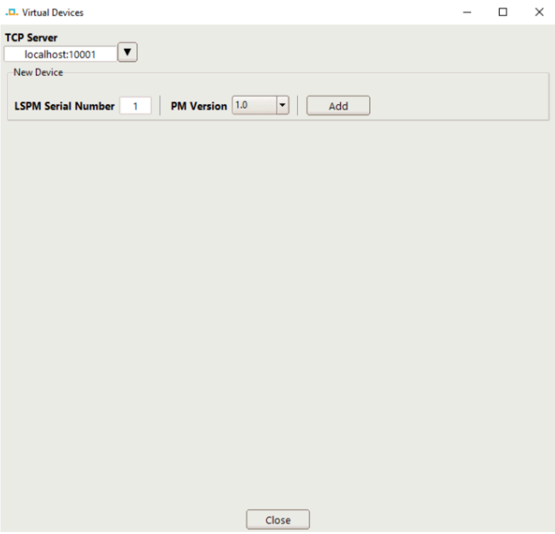
Pulse
: Generates periodically pulsed RSSI values whose OFF-value is zero and whose ON-value is configurable for each axis. The pattern's ON-time and period are configurable and apply to all axes.

List
: Generates a sequence of arbitrary RSSI values, optionally calculated from a list of E-field values, using the present mode, operating frequency and temperature. The sequence is repeated indefinitely.

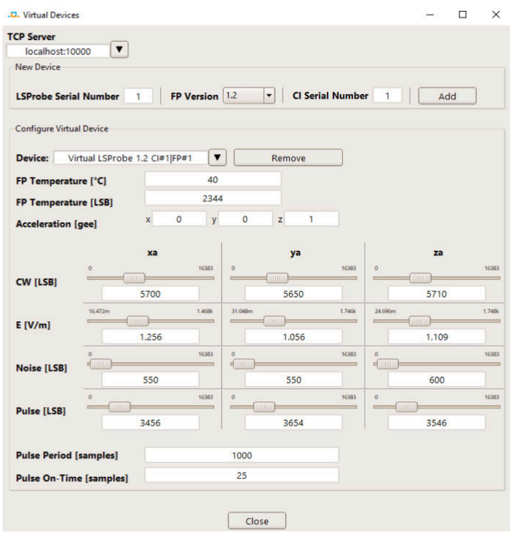
Virtual E-field probes support all operating modes. Triggering is supported with the exception of external trigger input and output. Virtual E-field probes support the collection of continuous statistics with the exception of synchronized continuous statistics. Note that a virtual statistics master E-field probe cannot control physical statistics slave E-field probes, only virtual ones.

9.1 Controlling Virtual E-Field Probes Using the GUI

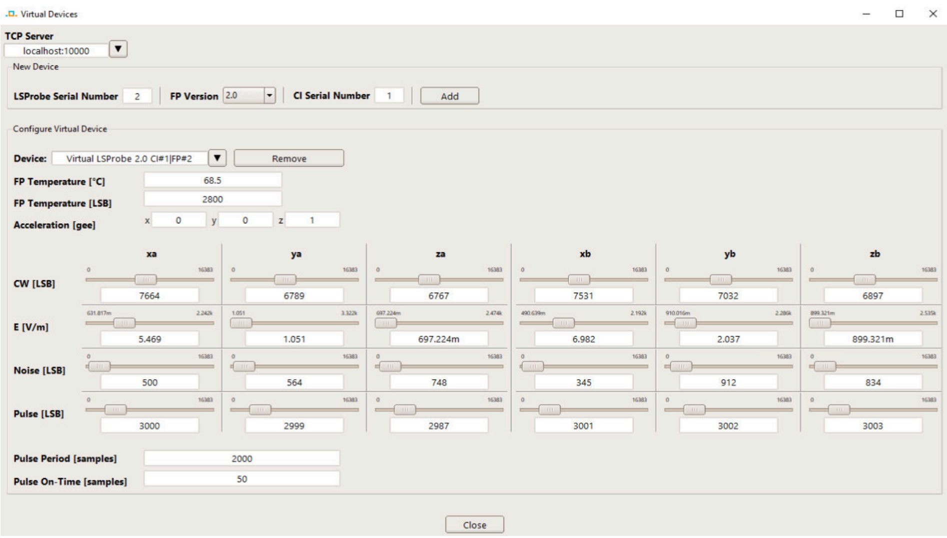
To open the "Virtual Devices" dialog go to "Expert Mode" of the LUMILOOP GUI and select the "Virtual Devices" item in the "Settings" menu. Alternatively press `Ctrl+M`. A dialog as depicted in Figure 123(a) will be opened.



(a) Virtual Devices Dialog



(b) Virtual Devices Dialog - LSProbe 1.2



(c) Virtual Devices Dialog - LSProbe 2.0

Figure 123: *Virtual Devices Dialog of the LUMILOOP GUI*

If the LUMILOOP GUI is connected to mutliple TCP Servers, select the active LUMILOOP TCP Server for which a new virtual device is to be added on the top left. Specify the new E-field probe serial number, E-field probe version and CI serial number.

Click the "Add" button to add the configured virtual device. If a virtual device is available, the virtual device configuration dialog will change it's layout as depicted in Figure 123(b) and (c) and show additional controls. The "Device" drop down menu lists all connected virtual LSProbes of the selected TCP Server client with their associated E-field probe's serial numbers and versions. Click the "Remove" button to disconnect the currently selected virtual device.

The selected virtual LSProbe device can be configured using the controls in the frame below. Virtual E-field probe temperature in degree C, E-field probe temperature in LSB, acceleration and field strength pattern components are set using the controls inside the frame. Settings take effect as soon as they are entered. "FP Temperature [°C]" and "FP Temperature [LSB]" are interconnected, i.e. access the same base value. As soon as one value is adapted the other is automatically updated. "E [V/m]" controls are interconnected with the underlying "CW [LSB]" values and can only be used if the virtual E-field probe's laser is enabled . E-field values are set to the nearest calibrated value for the current mode and frequency and temperature setting, i.e. changing frequency, mode or temperature setting will yield to different E-field values while the set RSSI values remain the same.

9.2 Controlling Virtual E-Field Probes Using SCPI Commands

Virtual LSProbes are added using »:VIRTual:CONnect [<CI>]«. The added device can be defined via the command's parameter in the following ways:

empty
: An LSProbe 1.2 with E-field probe an CI-250 serial number 1 is added.

integer value X
: An LSProbe 1.2 with E-field probe serial numer 1 an CI-250 serial number X is added.

device string "C:X.Y" or "C:XvY"
: An LSProbe X.Y with E-field probe serial numer 1 an CI-250 serial number C is added.

device string "P:X.Y:C" or "P:XvY:C"
: An LSProbe X.Y with E-field probe serial numer P an CI-250 serial number C is added.

»:VIRTual:CISerial?« lists the serial numbers of all virtual computer interfaces. The currently selected virtual device can be removed using »:VIRTual:DISConnect« The virtual E-field probe's serial number, version, temperature, supply voltage, acceleration values and parametric field strength patterns are set/queried using the following SCPI commands:

- »:VIRTual:FPSerial <Value>« / »:VIRTual:FPSerial?«,
- »:VIRTual:FPVersion« / »:VIRTual:FPVersion?«,
- »:VIRTual:TEMPerature <Temperature>« / »:VIRTual:TEMPerature?« ,
- »:VIRTual:ACCeleration <ACCx>,<ACCy>,<ACCz>« / »:VIRTual:ACCeleration?« ,
- »:VIRTual:CW <RSSIxa>,<RSSIya>,<RSSIza>[,<RSSIxb>,<RSSIyb>,<RSSIzb>]« / »:VIRTual:CW?«,
- »:VIRTual:NOIse <NOISExa>,<NOISEya>,<NOISEza>[,<NOISExb>, <NOISEyb>,<NOISEzb>]« / »:VIRTual:NOIse?« and
- »:VIRTual:PULse <RSSIxa>,<RSSIya>,<RSSIza>,[<RSSIxb>,<RSSIyb>, <RSSIzb>],<T>,<Ton>« / »:VIRTual:PULse?«.

Arbitrary E-field values are appended to the virtual E-field probe's list using »:VIRTual:LIST <RSSIxa1>,<RSSIya1>,<RSSIza1>,<RSSIxb1>,<RSSIyb1>, <RSSIzb1>[,...,<RSSIzbN>]« for arbitrary RSSI, »:VIRTual:ELIST <Exa1>,<Eya1>,<Eza1>,[<Exb1>, <Eyb1>,<Ezb1>][,...,<EzbN>]« for arbitrary E-field values. The complete list of RSSI values is queried using »:VIRTual:LIST?«. »:VIRTual:LCNt?« returns the number of samples in the list. »:VIRTual:LCLear« clears the list of values.

10 E-Field Probe Calibration

LSProbe 1.2/1.4/2.0 E-field probes use data from factory and, optionally, accredited calibration for calculating accurate field strength values based on the ADC values for each of the E-field probe's antennas, see Figures 7, 8 and 9 on pages 23, 25 and 26 for principle block diagrams of the different E-field probes. This data are stored in factory calibration files and accredited correction factor files.

10.1 Factory Calibration

Factory calibration records the digitized output voltage of the logarithmic RF detector circuits, covering all antennas, modes, temperatures, frequencies and E-field strength levels.

Linearity, frequency and temperature compensation files, or LFT files for short, resulting from factory calibration contain the relationship between field strength detector input power and measured ADC value. The file format is detailed in Section 13.4.1. The LUMILOOP TCP Server interpolates between these recorded data points to obtain a linearity-compensated and temperature-compensated detector characteristic for each antenna and mode.

Factory E-field calibration files, or FE files for short, contain the ADC values for a constant E-field strength and operating temperature (typically room temperature). The file format is detailed in Section 13.4.2. FE files cover all antennas, modes and frequencies. The LUMILOOP TCP Server uses the detector characteristics generated from LPF files in combination with the values contained in the FE files to generate the factory-calibrated E-field strength.

Table 7 and Table 8 list the default factory calibration frequency steps. The input power level of the detectors, which is proportional to the E-field strength, is adjusted between their noise floor and their level of saturation in 1 dB steps. For LSProbe 1.2, calibration is performed at 15, 30, 45 and 60 °C. For LSProbe 1.4 and LSProbe 2.0, calibration is performed at 10, 30, 50 and 70 °C.

For LSProbe 1.2, calibration is performed in modes 0, 3 and 4, see Table 7. For LSProbe 1.4, calibration is performed in modes 0 and 3, see Table 7. For LSProbe 2.0 calibration is performed in modes 0, 2, 3 and 4, see Table 8.

All other modes are implicitly covered by these calibration results since the operating conditions of the RF detectors and ADCs are identical.

- Modes 2, 6, 7 and 10 use the calibration data obtained in mode 3.
- Modes 8 and 9 use the calibration data obtained in mode 4.
- Mode 1 uses the combined calibration data obtained in modes 0 and 3.
- Mode 5 uses the combined calibration data obtained in modes 3 and 4.

The reference field strength for the factory E-field calibration is established using a transfer standard, i.e., a reference E-field probe. For LSProbe 1.2/1.4 the standard factory calibration E-field strength is 50 V/m, for LSProbe 2.0 it is 20 V/m. Factory calibration is performed in a custom setup and is not accredited. Therefore, the LSProbe 1.2/1.4/2.0 E-field probe systems support the inclusion of externally generated correction factors which are typically produced by an accredited calibration.

Table 7: *LSProbe 1.2/1.4: Frequency steps used for factory calibration*

Mode (and Variant)	Calibration Frequency Steps
3 (F)	10 Hz, 15 Hz, 22 Hz, 33 Hz, 47 Hz, 68 Hz, 100 Hz, 150 Hz, 220 Hz, 330 Hz, 470 Hz, 680 Hz, 1 kHz, 1.5 kHz, 2.2 kHz, 3.3 kHz, 4.7 kHz, 6.8 kHz
3	9 kHz, 10 kHz, 15 kHz, 22 kHz, 47 kHz, 68 kHz, 100 kHz, 150 kHz, 220 kHz, 470 kHz, 680 kHz, 1 MHz, 1.5 MHz, 2.2 MHz, 4.7 MHz, 6.8 MHz, 10 MHz, 20 MHz to 80 MHz in 20 MHz steps, 100 MHz to 400 MHz in 50 MHz steps
0, 4	30 MHz, 40 MHz to 180 MHz in 20 MHz steps, 200 MHz to 400 MHz in 100 MHz steps, 600 MHz to 5400 MHz in 200 MHz steps, 5500 MHz to 8200 MHz in 100 MHz steps

10.2 Accredited Calibration

Accredited calibration of LSProbe 1.2/1.4/2.0 E-field probes must be performed in mode 0 and 3 to cover the entire frequency range of their low- and high-band detectors. The frequency ranges of mode 0 and 3 overlap. Note that the indicated E-field values in the overlapping frequency range can differ due to the properties of the factory calibration. Consequently, both modes must be calibrated over their full frequency ranges. Since identical E-fields are used during factory calibration, correction factors obtained in mode 0/3 are applied to all modes using the high/low band detectors by default. If required, accredited calibration can be performed for modes other than 0 and 3 as well.

Correction factor files, or CF files for short, contain the E-field value correction factors in decibel for a defined calibration field strength, a constant operating temperature and a desired number of frequencies. The file format is detailed in Section 13.4.3. If required, accredited calibration can be performed at multiple calibration field levels.

10.2.1 Calibration Conditions

Calibration must be performed using linear polarization, successively aligning each of the three orthogonal axes (x, y, z) with the field. This ensures that the frequency characteristics of all antennas and their detectors are measured independently with high accuracy. LSProbe 1.2/2.0 must not be calibrated using the magnitude of the indicated E-field strength. For LSProbe 2.0 the two antennas (a, b) of each axis can be measured at the same time. Table 9 gives a summary of the antennas for the different field probes.

It is recommended to use the factory calibration frequencies detailed in Table 7 for accredited field

Table 8: *LSProbe 2.0: Frequency steps used for factory calibration*

Mode	Calibration Frequency Steps
2, 3	9 kHz, 10 kHz, 20 kHz, 40 kHz, 60 kHz, 80 kHz 100 kHz, 200 kHz, 400 kHz, 1 MHz, 4 MHz, 10 MHz, 30 MHz, 40 MHz, 50 MHz, 70 MHz, 90 MHz 100 MHz to 1000 MHz in 40 MHz steps
0, 4	700 MHz to 950 MHz in 50 MHz steps, 975 MHz, 1 GHz to 18 GHz in 100 MHz steps

Table 9: *Antennas requiring calibration for LSProbe 1.2/1.4/2.0 E-field probes*

Field probe	high band antennas	low band antennas
LSProbe 1.2	x; y; z	x; y; z
LSProbe 1.4	x	x
LSProbe 2.0	xa, xb; ya, yb; za, zb	x; y; z

strength calibration. A different set of frequencies can be used but may increase the uncertainty of measurements due to the error introduced by interpolation. For older factory calibrations, frequency steps and frequency range may differ. Since the LUMILOOP TCP Server will interpolate the correction factors as needed, the standard frequency steps can be employed regardlessly. The LUMILOOP TCP Server will limit the usable frequency range to the one used for accredited calibration. Therefore, the lowest and highest frequency of the factory calibration should always be included in the accredited calibration.

The SCPI commands »`:SYSTem:FREQuency:MINimum?`« and »`:SYSTem:FREQuency:MAXimum?`« can be used to retrieve the frequency bounds for the currently active mode of an LSProbe 1.2/1.4/2.0 E-field probe. The frequency bounds of the factory calibration can be determined by disabling accredited calibration data by issuing the SCPI command »`:CALibration:CORRfactor 0`« first.

Please contact LUMILOOP (calibration@lumiloop.de) if a different frequency range is required. If there are no other requirements, nominal calibration field strength values, typically between 10 V/m and 50 V/m, are used.

Figure 124 shows the standard orientation of the field probe during calibration in an anechoic chamber or GTEM cell relative to the calibration E-field. The correct orientation reduces errors caused by field probe anisotropy. Note that, for regular measurements, the best precision is achieved if the probe is set up in the orientation as was used during calibration.

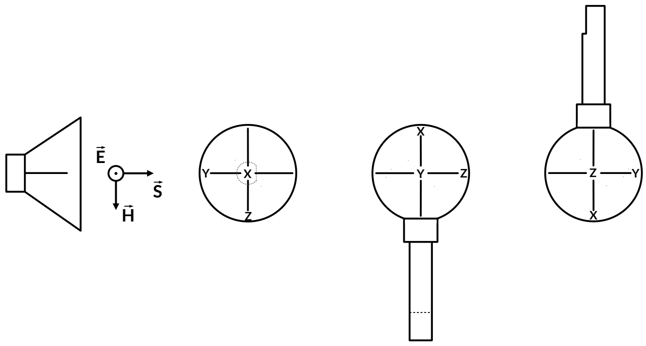


Figure 124: *Top view of field probe alignment during calibration for x-, y- and z-axis (left to right), using electric-field polarization orthogonal to the plane*

10.2.2 Measurement and Meta Data

The calibration certificate must contain all correction factors, all measurement values which these factors are based on and additional information, i.e., meta data, obtained during calibration.

For LSProbe 1.4/1.2/2.0 one/three/six correction factors are required for each calibration step. The calculation of these factors is based on the calibration field-strength and the indicated field-strength for each antenna. Thus, sets of $E_{disp}(f)$ and $E_{cal}(f)$ in V/m must be aquired for each axis, frequency and mode of the accredited calibration. Each set results in a linear and/or logarithmic correction factor $CF_{lin}(f)/CF_{log}(f)$.

The following meta data are required as well:

- serial number or identifier of the calibration certificate
- date of the accredited calibration
- date of the factory calibration
- name of the calibration laboratory
- nominal calibration field strength
- device type, e.g., LSProbe 1.2
- serial number of field probe
- serial number of Computer Interface for LSProbe 1.2/2.0

For automatic calibration data import, these data must be provided in a machine-readable format. It is recommended to use the CSV file format described in Section 13.3. This format combines measurement data and meta data in an easily processible format.

10.2.3 SCPI-Commands for Calibration

Correction factors must be disabled during calibration using »`:CALibration:CORRfactor 0`«, since calibration and recalibration are performed relative to the field probe's factory calibration data. Enabling prior correction factors would result in the generation of erroneous correction factors.

Calibration logging of measurement commands should be enabled using the command »:CALibration:LOGging 1«.

To reduce measurement noise and thus uncertainty, a low-pass filter of 100 Hz should be set using »:MEASure[:FProbe][:Efield]:LPFrequency 100«. This requires a minimum dwell time of 20 ms for each measurement. Note that a different low-pass filter setting also requires a different dwell time.

After enabling the laser using »:SYSTem:LASer:ENable 1«, the probe's readiness must be queried using »:SYSTem:LASer:RDY?« until 1 is returned. For a minimum measurement uncertainty, a warm-up time of 15 minutes is advised after enabling the laser. The probe's temperature can be queried using »:MEASure[:FProbe]:ATEMPerature?«.

The operating mode is set/changed using »:SYSTem:MODe <Mode>«, the mode must be queried using »:MEASure[:FProbe]:MODe?« until the desired mode is returned.

Use »:MEASure[:FProbe][:Efield]:CALL?« to query the displayed field strength of all antennas at the same time.

At the end of the calibration it is recommended to check if the application of correction factors is still deactivated, using »:CALibration:CORRfactor?«.

Table 10 gives a summary of the recommended SCPI commands during calibration. Please refer to the SCPI command reference in chapter 12 on page 152 for more information on the commands mentioned above. Refer to Section 5.4.6 to set up frequency-swept Measurements for use during calibration.

Table 10: *Recommended SCPI commands during LSProbe 1.2/1.4/2.0 E-field probe calibration.*

Get factory calibration date	»:CALibration:DATE?«
Disable correction factors	»:CALibration:CORRfactor 0«
Enable calibration logging	»:CALibration:LOGging 1«
Set low-pass filter	»:MEASure[:FProbe][:Efield]:LPFrequency 100«
Set mode	»:SYSTem:MODe <Mode>«
Enable laser	»:SYSTem:LASer:ENable 1«
Wait for laser ready state	»:SYSTem:LASer:RDY?«
Measurement	»:MEASure[:PRObe]:Efield:CALL?«
Check correction factors	»:CALibration:EXTernal?«

10.2.4 Log Files

If enabled as described above, measurement results are logged together with ADC values, temperatures, frequencies, operating modes, etc. Log files can be used by the CalImport calibration import tool, detailed in Section 10.2.5 on page 145, to perform a sanity check of calibration results. This helps to avoid the most common issues during calibration. Logging helps to ensure that the LSProbe 1.2/1.4/2.0 E-field probe is operating correctly during calibration and enables faster, more efficient service in case of any issues.

The LUMILOOP TCP Server logs the results and additional data for the commands »`:MEASure[:PRObe]:Efield:X/Y/Z/MAG/ALL?`«, »`:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB?`« and »`:MEASure[:FProbe][:Efield]:CALL?`«. Log files are stored in the directory defined by the `SAVE_PATH` setting in the `LUMILOOP.ini` configuration file. If a CI-250+ device is used for calibration, log files can be retrieved using a USB thumb drive, see Section 6.6.1 an page 102 for details. A description of the calibration log file format can be found in Section 13.2 on page 292.

10.2.5 Calibration Data Import

As shown in Figure 125, LUMILOOP has enhanced the calibration data flow by supplying the calibration data import tool *CalImport* as part of the LUMILOOP Installer. CalImport automatically generates checksum-protected CSV files for the LUMILOOP TCP Server. These correction factor (CF) files contain the correction factors for each frequency and antenna (LSProbe) or measurement channel (LSPM) in decibel (dB). Multiple correction factor files can be generated to accommodate different calibration field-strengths (LSProbe) or reference power levels (LSPM) and additional modes.

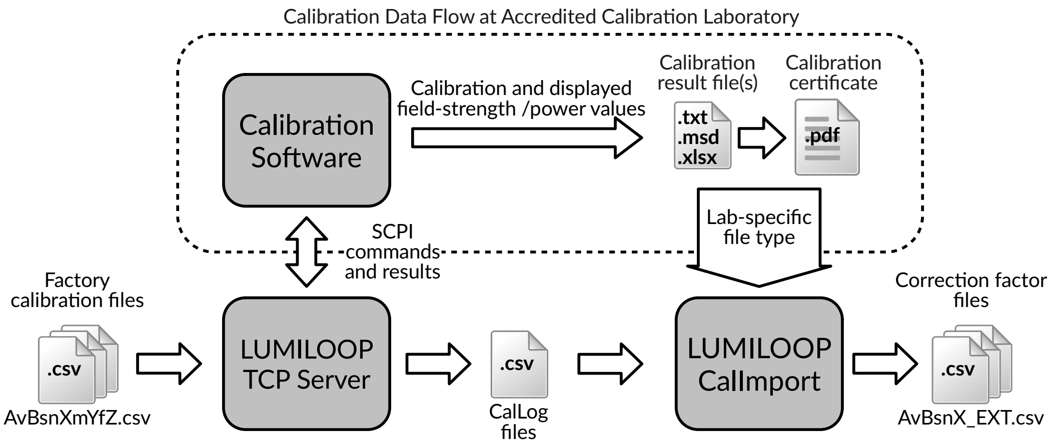


Figure 125: *Enhanced calibration data flow*

Conventionally, calibration laboratories generate calibration result files in a format of their choosing. These files contain at least the calibration frequency, the calibration field-strength or power level and the displayed field-strength or power level. Calibration certificates are provided to customers based on this data. Customers are required to incorporate the appropriate correction factors into their setups on their own – this step is known to be both cumbersome and especially prone to human error.

CalImport supports the import of calibration data files for several accredited calibration laboratories.

Please contact calibration@lumiloop.de if your calibration lab is not supported yet. LUMILOOP recommends using the generic calibration data CSV file format, specified in Section 13.3 on page 296. If using CalImport is not an option, make sure to provide the correction factors to the LUMILOOP TCP Server, using the file format specified in Section 13.4.3 in the LSProbe or LSPM User's Manual. Doing so will ensure that all clients of the LUMILOOP TCP Server will receive results based on the same calibration data.

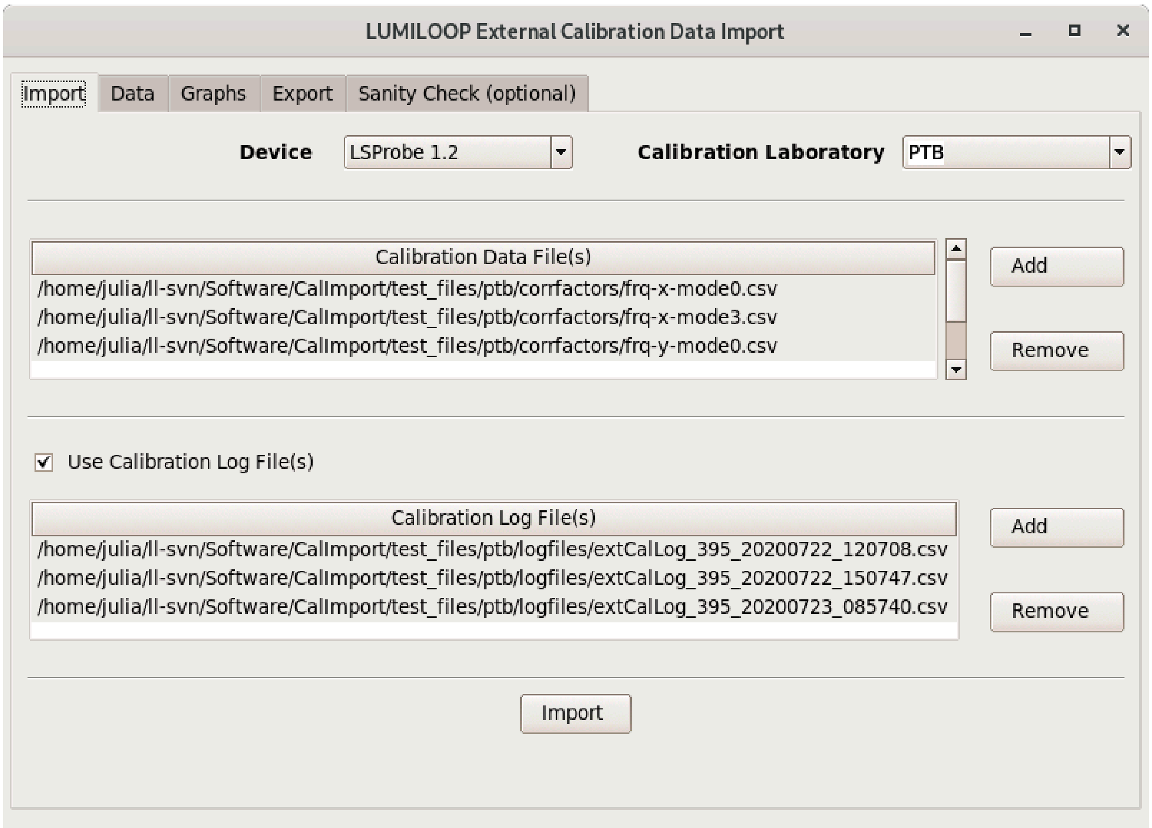


Figure 126: *Using the calibration data import tool CalImport*

Import the calibration data using the following steps:

1. Run CalImport as shown in Figure 126.
2. Select the appropriate device.
3. Select the appropriate calibration laboratory.
4. Choose calibration data files and calibration log files, if available.
5. Import all calibration data by clicking the `Import` button.
6. Review the correction factors and graphs presented in the tab `Data` and `Graphs`.
7. Export the accredited calibration files to the appropriate calibration data folder in the `CAL_PATH` directory. If calibration data are stored as ZIP files, extract the files to a temporary folder, add the CF files to this folder and create a new ZIP file replacing the original one.
8. Restart or reset the LUMILOOP TCP Server using »`*RST`« and check the calibration data summary table for errors.

9. If calibration log files are available, execute the sanity check in the tab `Sanity Check`.

Using the LUMILOOP TCP Server's calibration log files with CalImport is strongly recommended. It allows CalImport to perform data sanity checks to avoid a number of common data handling errors and will ensure that all calibration data files are consistent with the calibration log files.

11 SCPI Communication Basics

The LUMILOOP TCP Server provides a convenient text command-based interface to E-field probe measurement data, it supports up to 32 concurrent TCP/IP client connections. All commands sent to the TCP server are ASCII text commands which terminated by a newline (\n), carriage return (\r) or semicolon (;) character or any combination thereof. Replies sent by the TCP server in reply to queries are single lines of text terminated by a carriage return character followed by a newline character (\r\n). Binary replies deviate from this convention, see the individual commands' descriptions in Section 12 for further details.

This section gives examples of communication with the TCP server using standard libraries and utilities.

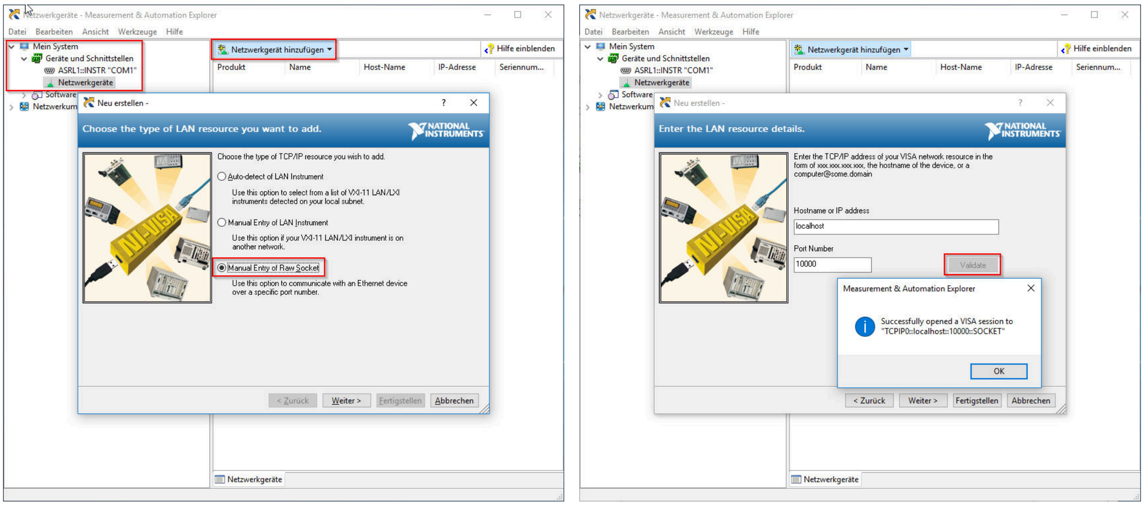
11.1 National Instruments VISA

NI VISA is a cross-platform library for unified communication with measurements connected via GPIB, serial port, network socket, etc. NI VISA handles all low-level configuration and provides buffered bidirectional I/O streams. This sections explains how to configure a socket connection to the LUMILOOP TCP Server using the debug tool provided with the NI VISA library and how to test it. NI VISA needs be downloaded from the "National Instruments" homepage and installed first.

Open the NI VISA Measurement and Automation Explorer (NI MAX). Add a new network device by selecting the subsection "Network devices" of "Devices and Interfaces" next click on "Add Network Device". As shown in Figure 127(a), select "Manual Entry of Raw Socket" and click "Next". As shown in Figure 127(b) enter the correct "Hostname or IP" the TCP "Port Number", click "Validate" to connect to the LUMILOOP TCP Server. Both NI MAX and the TCP server's output will indicate a successful connection. Click "OK" and "Finish" to return to the NI MAX main window.

Right-click on the newly created network device and select "OPEN VISA Test Panel" as shown in Figure 128. No changes are required in the "TCP/IP Settings" tab. Set "Enable Termination Character" in the "I/O Settings" tab, click "Apply Changes" and observe the return data output as shown in Figure 129(a). This step needs to be repeated for every NI VISA Input/Output debug session. The "View Attributes" tab in Figure 129(b) shows shows the VISA parameters "VI_ATTR_TERMCHAR_EN" set to "VI_TRUE" and the "VI_ATTR_TERMCHAR" attribute set to "0xA". When using the NI VISA library for connecting to the LUMILOOP TCP Server make sure to set all VISA parameters identically.

Click on "Input/Output" to start testing NI VISA communication. Clicking "Query" will retrieve the identification string using the "*idn?\n" command, see Figure 130(a). As shown in Figure 130(b) the laser is enabled by entering and writing the "syst:las:en 1" command . As shown in Figure 130(c), the frequency is set to a specific value by entering and writing the "syst:freq 1e9\n" command. After the E-field probe is operational, set the command "meas:e:all?"and click "Query" to obtain four E-field values. Make sure no errors are produced at any time.



(a) (b)

Figure 127: *Connection to LUMILOOP TCP Server through NI MAX*

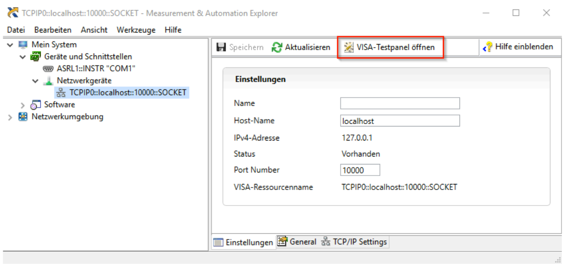
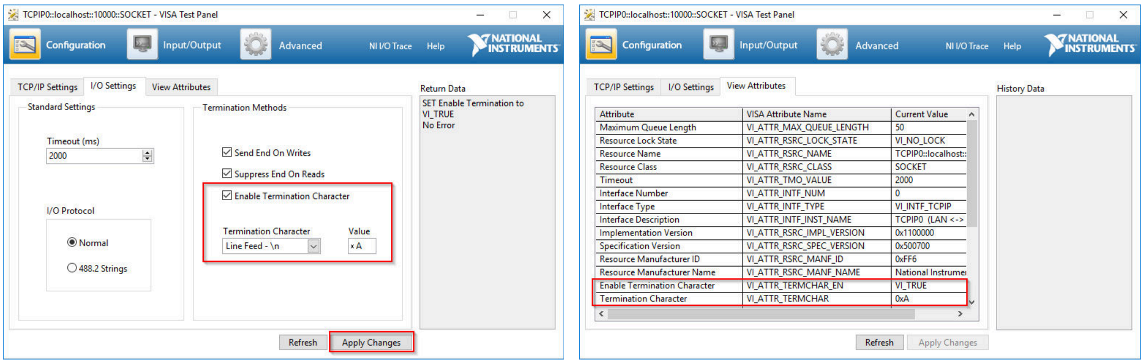
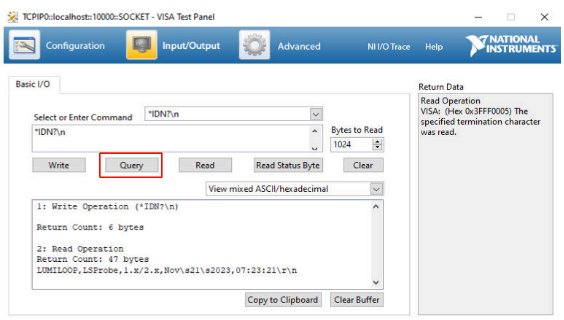


Figure 128: *Starting NI VISA Test Panel*

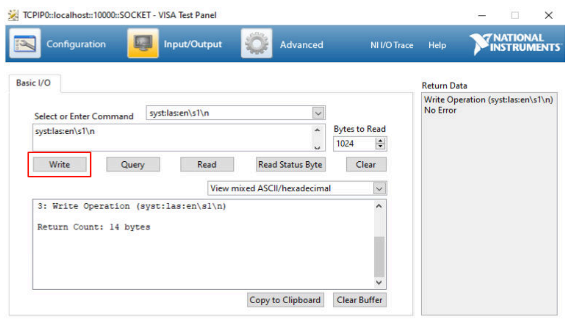


(a) (b)

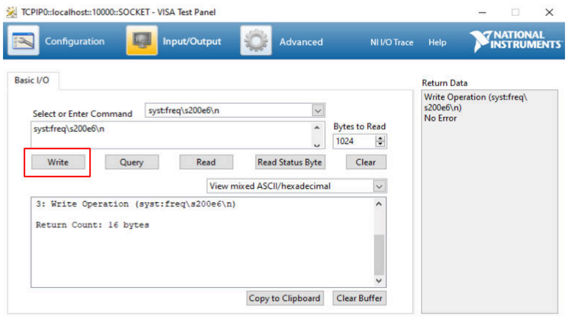
Figure 129: *Configuring VISA TCP/IP socket parameters*



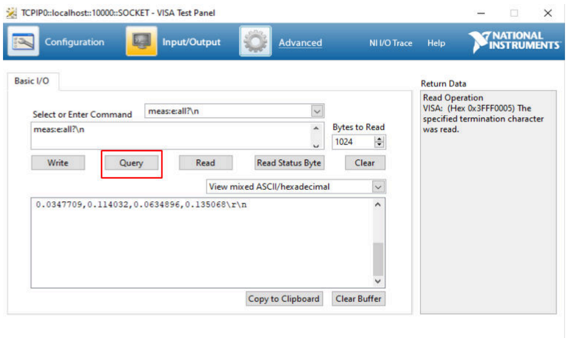
(a) Identification string query



(b) Enabling the supply laser



(c) Setting the frequency

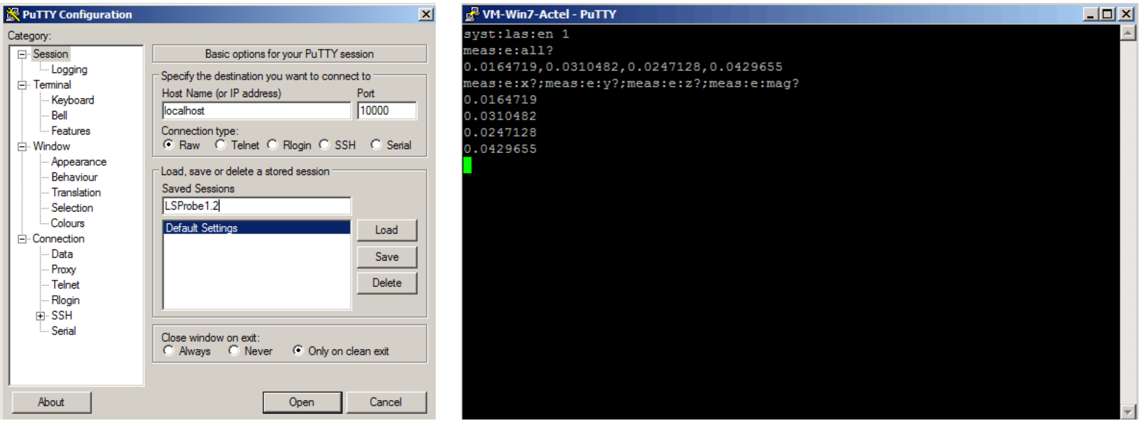


(d) E-field value query

Figure 130: *Testing NI VISA LUMILOOP TCP Server writes and queries*

11.2 Raw TCP socket communication using PuTTY

Run PuTTY and enter the host name or IP address and the TCP port number. Set "Connection type" to "Raw" as shown in Figure 131(a). Optionally, save the session configuration for later use. Click "Open" to start the terminal session. Figure 131(b) shows the terminal window. Enter commands and press Return when done. Query commands will generate one reply line each. Multiple commands may be sent in rapid succession by separating them by semicolons.



(a) Session settings

(b) LUMILOOP TCP Server session

Figure 131: *Using PuTTY*

12 SCPI Command Reference

This section contains a list of all SCPI commands supported by the LUMILOOP TCP Server, grouped by sub-system. Each command is given with its mandatory, short-form syntax in upper-case letters. The long-form syntax is given by a combination of upper and lower-case letters. Optional parts of the command are enclosed in square brackets, i.e., []. Parameters are are enclosed in angular brackets, i.e., <>.

12.1 Multiprobe Behavior

Most SCPI commands support the optional MProbe parameter determining the Multiprobe behavior of the respective command. The following MProbe parameters are available:

empty
: If the MProbe parameter is omitted the command will only be executed for the presently active CI-250$^{(+)}$ Computer Interface.

0
: If the MProbe parameter is set to zero the command is executed for all enumerated CI-250 Computer Interfaces. CI-250 Computer Interfaces will be enumerated and displayed sorted by their serial numbers starting with the smallest value.

N
: If the MProbe parameter is set to a number N that is greater than zero the command will be executed for all CI-250 Computer Interfaces of the specified Multiprobe setup, see :MProbe:FPSerial? <MProbe> and :MProbe:CISerial? <MProbe> for the order of E-field probe and computer interface serial numbers.

When any SCPI command is executed for more than one field probe, i.e., the MProbe parameter refers to multiple CI-250 Computer Interfaces, the command behaves as if executed for each computer interface of the specified Multiprobe system successively. The order of execution is the same as the serial numbers returned by »:MProbe:FPSerial? <MProbe>« and »:MProbe:CISerial? <MProbe>«. All output will be joined on a single line by replacing line breaks between the output of different CI-250 Computer Interfaces with commas. For the sake of brevity the return value descriptions in the following sections do not explicitly state the return values for Multiprobe calls if they conform to the format explained above.

12.2 Generic Commands

12.2.1 *CLS

Clear all status registers and structures, e.g., error queue.

12.2.2 *ESE <ESR>

Set event status enable register. This feature is currently not implemented.

Parameters:
Integer value for event status register.

12.2.3 *ESE?

Query event status enable register. This feature is currently not implemented.

Return value:
Returns the integer value of the event status register.

12.2.4 *ESR?

Query the most recent error status register value. The error will be removed from error queue.

Return value:
Value of most recent errors in error queue.

12.2.5 *IDN?

Query TCP server identification string.

Return value:
Comma-separated string, consisting of maker, product name, supported product versions, TCP server build date and TCP server build time, e.g., "LUMILOOP,LSProbe,1.x/2.x,Sep 2 2023,08:07:06".

12.2.6 *OPC

Set operation complete flag after the completion of the previously sent command. This feature is currently not implemented.

12.2.7 *OPC?

Query operation complete flag. This feature is currently not implemented.

Return value:
Always 1.

12.2.8 *RST

Reset LSProbe TCP server. This will close all previously opened CI-250 Computer Interfaces, rescan the USB hardware and open all detected CI-250 Computer Interfaces. This will perform a power-on reset of all CI-250 Computer Interfaces.

The TCP server will print enumeration status information to its standard error output.

12.2.9 *SRE <int>

Set service request enable register. This feature is currently not implemented.

Parameter:
: Integer value of service request enable register.

12.2.10 *SRE?

Query service request enable register. This feature is currently not implemented.

Return value:
: Always 0.

12.2.11 *STB?

Query status byte. Note that only bit 2 is currently implemented.

Return value:
: The returned eight bit integer value contains the following status flags:

  Bit 0
  : Unused bit

  Bit 1
  : Protection event flag, currently not implemented

  Bit 2
  : Error/Event queue message available

  Bit 3
  : Questionable status, currently not implemented

  Bit 4
  : Message available, currently not implemented

  Bit 5
  : Standard event status register, currently not implemented

Bit 6
: Service request, currently not implemented

Bit 7
: Operation status flag, currently not implemented.

12.2.12 *TST?

Initiate self test and return test result. This feature is currently not implemented.

Return value:
: 0 on failing and 1 on passing the self test.

12.2.13 *WAI

Wait for the completion of the previously issued command. This feature is currently not implemented.

12.3 :SYSTem Commands

12.3.1 :SYSTem:RUNTime?

Query runtime of LUMILOOP TCP Server in seconds.

Return value:
: The command returns an unsigned integer value containing the runtime since start of the LUMILOOP TCP Server in seconds.

12.3.2 :SYSTem:WAIT <Sec>

Pause processing of LSProbe SCPI commands for Sec seconds.

12.3.3 :SYSTem:ERRor[:NEXT]?

Query most recent entry in system error queue and remove this entry from error queue. If an overflow has occured for the error queue, i.e., more than sixteen errors have accumulated without a query of the error queue, the seventeenth error will replace the most recent entry in the error queue.

Return value:
: Returns comma-separated numeric error code and an error message string enclosed in quotes, e.g., "0,"No error"."

12.3.4 :SYSTem:ERRor:COUNt?

Query number of entries in system error queue. The maximum number is seventeen.

Return value:
Number of values in error queue.

12.3.5 :SYSTem:AUTOCONnect <State>

Enable/disable polling for new CI-250 Computer Interfaces.

Parameter:
Setting State to 1 activates polling for new CI-250 Computer Interfaces, setting State to 0 disables polling.

By default, device polling is enabled. Disabling device polling can be useful if it is suspected or found to interfere with other USB devices.

12.3.6 :SYSTem:AUTOCONnect?

Query status of new device polling.

Return value:
The command returns an unsigned integer value containing the status of polling for new CI-250 Computer Interfaces. If disabled, the command returns 0, if enabled 1.

12.3.7 :SYSTem:CLIENTS?

Query number of clients connected to server.

Return value:
The command returns an unsigned integer value giving the number of clients connected to the server.

12.3.8 :SYSTem:SERial <Value>

Select active LSProbe by LSProbe serial number.

Parameter:
One serial number out of the list returned by :MEASure[:FProbe]:SERialnumber? [<MProbe>] with the MProbe parameter set to 0 or string stating the serial number and version string separated by a ":", e.g. "3:1.4" for setting the active device to LSProbe 1.4 with serial number 3. If there are devices with identical serial numbers and different versions connected to the LUMILOOP TCP Server, the string notation is mandatory.

12.3.9 :SYSTem:SERial? [<MProbe>]

Query serial number of one or multiple LSProbe 1v4 devices.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
: Unsigned integer-valued serial number of selected LSProbe 1v4. If the selected device is not an LSProbe 1v4 device, the command will return NAN.

12.3.10 :SYSTem:CISerial <Value>

Select active CI-250 Computer Interface by serial number. The old syntax »:SYSTem:SNUMber:SET <Value>« remains supported.

Parameter:
: One serial number out of the list returned by »:SYSTem:CISerial? [<MProbe>]« with the MProbe parameter set to 0.

12.3.11 :SYSTem:CISerial? [<MProbe>]

Query serial number of one or multiple CI-250 Computer Interfaces . The old syntax »:SYSTem:SNUMber:GET? [<MProbe>]« remains supported.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
: Unsigned integer-valued serial number of selected CI-250(+) Computer Interface. NAN will be returned for LSProbe 1v4. If no CI-250 Computer Interfaces have been enumerated, the command will return NAN.

12.3.12 :SYSTem:COUnt?

Query number of enumerated LSProbe devices.

Return value:
: Unsigned integer-valued number of enumerated CI-250 Computer Interfaces and LSProbe 1v4 devices.

12.3.13 :SYSTem:MAKer? [<MProbe>]

Query maker identification string of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
Name string of the device maker, e.g., “LUMILOOP”.

12.3.14 :SYSTem:DEVice? [<MProbe>]

Query identification string of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
Name string of the device, e.g., “LSPROBE”.

12.3.15 :SYSTem:VERSion? [<MProbe>]

Query device version string of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
Version string of the device, e.g., “1.2”. If the version string is unknown, e.g. optically powered devices with turned off laser, “?.?” is returned.

12.3.16 :SYSTem:FVERSion? [<MProbe>]

Query device version as a float number of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
Float valued version of the device, e.g., 1.2. If the device version is unknown 0.0 is returned.

12.3.17 :SYSTem:REVision? [<MProbe>]

Query firmware revision of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: An unsigned integer value indicating the firmware's revision number is returned.

12.3.18 :SYSTem:FWUPdate?

Query firmware revision provided by TCP server.

Return value:
: Unsigned integer value specifying the firmware revision number provided by the TCP server.

12.3.19 :SYSTem:DEBUG <Value/Flag1[,Flag2]...>

Set value of debug flags in debug register, in order to make the TCP server output debug information to standard error.

Parameter:
: Integer value whose individual bits are used to enable/disable the output of debugging information. Setting a flag to 1 enables debug output, setting a flag to 0 disables debug output. The bit positions of the debug flags are defined below.

  Alternatively, a comma-separated list of strings can be supplied, as defined below.

  Bit 0, Value 1, String "MEM"
  : Information about memory usage

  Bit 1, Value 2, String "TIM"
  : Timing information

  Bit 2, Value 4, String "SCPII"
  : Echo of all incoming TCP server messages

  Bit 3, Value 8, String "SCPIO"
  : Echo all outgoing TCP server messages

  Bit 4, Value 16, String "FIFO"
  : Information about USB burst and FIFO function calls

  Bit 5, Value 32, String "USB"
  : Information about timing and data throughput of USB communications

  Bit 6, Value 64, String "CALDATA"
  : Information about the read-in of calibration data

Bit 7, Value 128, String "CORR"
: Information on the processing timing and interpolation of calibration data

Bit 8, Value 256, String "TRIG"
: Information about trigger events

Bit 9, Value 512, String "RADAR"
: Information about radar evaluation

Bit 10, Value 1024, String "EMU"
: Information about EP602 emulation

Bit 11, Value 2048, String "STREAM"
: Information about data streaming

Bit 12, Value 4096, String "STAT"
: Information about statistics collection and processing

Bit 13, Value 8192, String "CALLOG"
: Information about the logging of calibration data

Bit 14, Value 16384, String "POL"
: Information about CI-250(+) Computer Interface polling

Bit 15, Value 32768, String "FW"
: Information about firmware programming

Bit 16, Value 65536, String "LUT"
: Information about processing of E-field look-up-tables

Bit 17, Value 131072, String "STRLUT"
: Information about processing of look-up-tables for stream saving

Bit 18, Value 262144, String "RP"
: Information about calculation of threshold values for remote power subsystem

Bit 19, Value 524288, String "VBW"
: Information about software-based RSSI value filtering to reduce video bandwidth

Bit 20, Value 1048576 , String "TRLUT"
: Information about buffer of look-up-tables of the trigger system.

Bit 21, Value 2097152 , String "INIFILE"
: Information about the ini file path

Bit 22, Value 4194304 , String "TIMEOUT"
: Information about communication time-out events.

Bit 23, Value 8388608 , String "ISO"
: Information about isotropy interpolation (LSProbe 2v0 only).

Bit 24, Value 16777216 , String "ACC"
: Information about accredited calibration data interpoaltion.

Bit 25, Value 33554432 , String "LOGCORLUT"
Enable/disable logging of correction lookup tables to file.

Bit 26, Value 67108864 , String "TEMP"
Information about Compuer Interface temperature regulation.

Bit 27, Value 134217728 , String "LASER"
Information about laser regulation and optimization.

Bit 28, Value 268435456 , String "LASLOG"
Enable/disable logging of status information to file during laser regulation.

Bit 29, Value 536870912 , String "OTRIG"
Information about oversampling events

Bit 30, Value 1073741824 , String "CALLOAD"
Information about oversampling events

Bit 31, Value 2147483648 , String "SWEEP"
Information about sweep evaluation

E.g., to trace incoming and outgoing SCPI commands issue ":syst:debug 12", alternatively ":syst:debug scpii,scpio".

12.3.20 :SYSTem:DEBUG?

Query value of debug register, containing all debug flags.

Return value:
Unsigned integer value containing all debug flags. See »:SYSTem:DEBUG <Value/Flag1[,Flag2]...>« for the description of the individual debug flags and their values.

12.3.21 :SYSTem:DFLags?

Query mnemonic strings of all set debug flags in debug register

Return values:
List of string values for all set debug flags in the debug register. See »:SYSTem:DEBUG <Value/Flag1[,Flag2]...>« for the description of individual debug flags, their strings and their numeric values.

12.3.22 :SYSTem:LASer:ENable <Value>[,<MProbe>]

Enable or disable supply laser of one or multiple CI-250 Computer Interfaces.

Parameters:
Enable laser(s) by setting Value to 1, disable laser(s) by setting value to 0.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.3.23 :SYSTem:LASer:ENable? [<MProbe>]

Query status of supply laser of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value indicating the laser supply status will be returned. If a laser is off the return value is 0, if it is on the return value will be 1. NAN will be returned for LSProbe 1v4.

12.3.24 :SYSTem:LASer:RDY? [<MProbe>]

Query laser ready status of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value of 1 indicates that the system is ready to operate in the configured mode, a value of 0 indicates that the laser supply is either off or in start-up. NAN will be returned for LSProbe 1v4.

12.3.25 :SYSTem:LASer:TOut? [<MProbe>]

Query laser timeout status of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value of 1 indicates that the laser has been turned off non-nominally, e.g., by the safety turn-off function, a value of 0 indicates normal operation. NAN will be returned for LSProbe 1v4.

12.3.26 :SYSTem:MODe <Mode>[,<MProbe>]

Set operating mode of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameters:
The unsigned integer parameter Mode specifies the E-field probe operating mode as described in Table 1 on page 24 for LSProbe 1.2 devices, Table 3 on page page 27 for LSProbe 2.0 devices and Table 2 on page page 26 for LSProbe 1.4 devices. Valid values are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 for LSProbe 1.2/2.0 and 0,1,2,3 and 4 for LSProbe 1.4 devices.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.3.27 :SYSTem:MODe? [<MProbe>]

Query operating mode of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameter:
  The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
  An unsigned integer mode value as described in Table 1 on page 24, resp. Table 3 on page page 27 will be returned.

12.3.28 :SYSTem:FREQuency <Frequency>[,<MProbe>]

Set frequency for frequency-compensated operation of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameters:
  The first double-precision, floating-point valued parameter sets the desired frequency. If the frequency exceeds the calibrated frequency range for the mode set via »:SYSTem:MODe <Mode>[,<MProbe>]« all E-field queries will return NAN.

  The second, optional unsigned integer parameter MProbe is described in Section 12.1. »:syst:freq 1e9,0« will set the compensation frequency to 1 GHz for all enumerated CI-250 Computer Interfaces, »:syst:freq 2e9« will set the compensation frequency to 2 GHz for the currently selected CI-250$^{(+)}$ Computer Interface.

12.3.29 :SYSTem:FREQuency? [<MProbe>]

Query frequency for frequency-compensated operation of one or multiple CI-250 Computer Interfaces.

Parameter:
  The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
  A double-precision, floating-point value in hertz indicating the set compensation frequency will be returned. The value may have up to three decimal places.

12.3.30 :SYSTem:FREQuency:MINimum? [<MProbe>]

Query lowest calibrated frequency for frequency-compensated operation of one or multiple CI-250 Computer Interfaces.

Parameter:
  The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A double-precision, floating-point value, indicating the lowest calibrated compensation frequency of the current operating mode will be returned. NAN will be returned if the field probe is turned off or calibration data is missing.

12.3.31 :SYSTem:FREQuency:MAXimum? [<MProbe>]

Query highest calibrated frequency for frequency-compensated operation of one or multiple CI-250 Computer Interfaces.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A double-precision, floating-point value, indicating the highest calibrated compensation frequency of the current operating mode will be returned. NAN will be returned if the field probe is turned off or calibration data is missing.

12.3.32 :SYSTem:LHFrequency <Frequency>[,<MProbe>]

Set transition frequency for interleaved Modes 1 and 5 and between low-band and high-band detector for one or multiple CI-250 Computer Interfaces.

Parameters:

The first double-precision, floating-point valued parameter sets the desired transition frequency.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.3.33 :SYSTem:LHFrequency? [<MProbe>]

Query transition frequency for interleaved Modes 1 and 5 between low-band and high-band detector for one or multiple CI-250 Computer Interfaces.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A double-precision, floating-point value in hertz indicating the set transition frequency for interleaved modes will be returned. The value may have up to three decimal places.

12.3.34 :SYSTem:RDY? [<MProbe>]

Query ready status of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value of 1 indicates that the system is ready to operate, a value of 0 indicates that the laser is not (yet) stable.

12.3.35 :SYSTem:SRAte? [<MProbe>]

Query current sampling rate of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value indicating the current sampling rate of the CI-250(+) Computer Interface resulting from the mode value that can be queried via »:MEASure[:FProbe]:MODe? [<MProbe>]«.

12.3.36 :SYSTem:ESRAte? [<MProbe>]

Query current effective sampling rate of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value indicating the current sampling rate of the CI-250(+) Computer Interface resulting from the mode value that can be queried via »:MEASure[:FProbe]:MODe? [<MProbe>]«.

12.4 :CALibration Commands

12.4.1 :CALibration:DATA:LIST? [<Serno>]

Query available calibration data sets for single device.

Parameter:
An optional integer valued serial number or string "SN:X.Y" denoting the serial number and version of a field probe.

Return values:

A list of string values of all available calibration data sets for the specified field probe is returned. The value “default” denotes the standard calibration data. If no calibration data is available for the currently active or specified or provided field probe, “undefined” will be returned.

12.4.2 :CALibration:DATA:SELect <NAME>

Set active calibration data set by name.

Parameter:

Name of calibration data set with quotes out of list returned by »:CALibration:DATA:LIST? [<Serno>]«, e.g., “:cal:data:set "default"”.

12.4.3 :CALibration:DATA:SELect? [<MProbe>]

Query name of currently selected calibration data set for one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Return values:

A string indicating the name of the active calibration data set, “default” is returned for the standard calibration data set, “undefined” if no calibration data is available.

12.4.4 :CALibration:LOGging <Value>

Enable or disable logging of status information when receiving measurement commands from current TCP session for active device.

Parameter:

Enable logging of status information for the current TCP session by setting Value to 1, disable logging by setting Value to 0.

When logging is enabled, »:MEASure[:FProbe][:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«, »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]« and »:MEASure[:FProbe][:Efield]:CALL? [<MProbe>]« SCPI queries will log one line to the external calibration log.

See Section 13.2 for details about the log file format. Log files are located in the directory specified by the SAVE_PATH setting in the LUMILOOP.ini configuration file. There is one log file for every active field probe.

12.4.5 :CALibration:LOGging?

Query state of logging of status information when receiving measurement commands from current TCP session.

Return value:

An unsigned integer value indicating if logging is enabled. The command returns 1 if logging is enabled and 0 otherwise.

12.4.6 :CALibration:LOGging:GLObal <Value>

Enable or disable logging of status information when receiving measurement commands from any TCP session.

The command is identical to »:CALibration:LOGging <Value>« except for the fact that logging will take place for all existing and new TCP sessions, as well as commands sent to the console of the LUMILOOP TCP Server.

12.4.7 :CALibration:LOGging:GLObal?

Query state of global logging of status information when receiving measurement commands from any TCP session.

Return value:

An unsigned integer value indicating if logging is enabled. The command returns 1 if logging is enabled and 0 otherwise.

12.4.8 :CALibration:ISOtropy <Value>[,<MProbe>]

Enable or disable application of isotropy calibration data of one or multiple E-field probes. The application of isotropy calibration data is enabled by default.

Parameters:

Enable application of isotropy calibration data by setting Value to 1, disable application by setting Value to 0, in which case averaging will be applied.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.4.9 :CALibration:ISOtropy? [<MProbe>]

Query application of isotropy calibration data of one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

An unsigned integer value indicating if isotropy calibration data is being applied or not will be returned. If isotropy calibration data is being applied the command returns 1, otherwise zero will be returned. NAN will be returned if the E-field probe is off.

12.4.10 :CALibration:CORRfactor <Value>[,<MProbe>]

Enable or disable application of accredited calibration data of one or multiple CI-250 Computer Interfaces. The application of accredited calibration data is enabled by default.

The old syntax »:CALibration:EXTernal <Value>[,<MProbe>]« remains supported.

Parameters:

Enable application of accredited calibration data by setting Value to 1, disable application by setting Value to 0.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.4.11 :CALibration:CORRfactor? [<MProbe>]

Query application of accredited calibration data of one or multiple CI-250 Computer Interfaces.

The old syntax »:CALibration:EXTernal? [<MProbe>]« remains supported.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

An unsigned integer value indicating if accredited calibration data is being applied or not will be returned. If accredited calibration data is being applied the command returns 1, otherwise zero will be returned. NAN will be returned if the E-field probe is off.

12.4.12 :CALibration:CERTificate? [<MProbe>]

Query accredited calibration certificate string of one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

An accredited calibration certificate string as given in the accredited calibration data CSV file will be returned. If the accredited calibration data CSV file does not contain a certificate string, the E-field probe is off or there is no valid accredited calibration data "undefined" will be returned.

12.4.13 :CALibration:TStamp? [<MProbe>]

Query factory and accredited calibration time stamps of one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A pair of unsigned integer values indicating the time stamp of factory calibration and accredited calibration will be returned. If time stamps differ the largest timestamp is returned. Time stamps are expressed as the number of seconds since Jan 1 1904 00:00:00. NAN will be returned if the probe is off or there is no valid factory or accredited calibration data. NAN will also be returned for the accredited calibration time stamp if accredited calibration data has been disabled using »:CALibration:CORRfactor <Value>[,<MProbe>]«.

12.4.14 :CALibration:DATe? [<MProbe>]

Query factory and accredited calibration dates of one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A pair of date strings indicating the date of factory calibration and accredited calibration will be returned. Date formate is YYYY-MM-DD. NAN will be returned if the probe is off or there is no valid factory or accredited calibration data. NAN will also be returned for the accredited calibration date if accredited calibration data has been disabled using »:CALibration:CORRfactor <Value>[,<MProbe>]«.

12.5 :MEASure Commands

12.5.1 :MEASure:CInterface:TCold? [<MProbe>]

Query the cold side temperature of the laser's thermoelectric heater/cooler for one or multiple CI-250 Computer Interfaces. The cold side temperature is controlled within 15 to 25 °C by the thermoelectric heater/cooler for safe long-time laser operation.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the float-valued laser temperature in °C.

12.5.2 :MEASure:CInterface:THot? [<MProbe>]

Query the hot side temperature of the laser's thermoelectric heater/cooler for one or multiple CI-250 Computer Interfaces. The temperature is measured at the CI-250$^{(+)}$ Computer Interface's tubular heat sink. The temperature value is close to the thermoelectric heater/cooler's hot side temperature when the laser is being cooled. In the rare case that the laser is being heated this temperature will be lower than the laser's temperature returned from »:MEASure:CInterface:TCold? [<MProbe>]«.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the float-valued laser heat sink temperature in °C.

12.5.3 :MEASure:CInterface:VPeltier? [<MProbe>]

Query thermoelectric heater/cooler voltage for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the float-valued thermoelectric heater/cooler voltage in volt.

12.5.4 :MEASure:CInterface:IPeltier? [<MProbe>]

Query thermoelectric heater/cooler current for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns the float-valued thermoelectric heater/cooler current in ampere.

12.5.5 :MEASure:CInterface:VSWLaser? [<MProbe>]

Query switching supply voltage for laser supply for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns the float-valued voltage value of step-down voltage controller in volt. This supply rail is approximately 200 mV higher than the laser's supply voltage and serves to improve laser supply efficiency.

12.5.6 :MEASure:CInterface:VLINLaser? [<MProbe>]

Query linear regulator voltage for laser supply for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns the float-valued voltage value of linear voltage regulator in volt. This voltage is the laser's supply voltage.

12.5.7 :MEASure:CInterface:ILaser? [<MProbe>]

Query laser supply current for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns the float-valued laser supply current in ampere.

12.5.8 :MEASure:CInterface:MAGnitude? [<MProbe>]

Query magnitude of optical receiver received signal strength for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns an unsigned integer valued magnitude of the data link receiver in arbitrary units.

12.5.9 :MEASure[:FProbe]:VERsion? [<MProbe>]

Query field probe version string of one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
Version string of the field probe, e.g., "1.2" or "2.0". NAN will be returned if the field probe is off.

12.5.10 :MEASure[:FProbe]:FWVERsion? [<MProbe>]

Query field probe firmware version of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

Integer valued of the field probe version, e.g., 3 for LSProbe 2.0 devices. NAN will be returned if the field probe is off.

12.5.11 :MEASure[:FProbe]:ICapable? [<MProbe>]

Query interleaved mode capability of one or multiple LSProbe 1.2/1.4/2.0 E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

If the commands returns an integer value of 1, the field probe supports operation in mode 1, 5 and 9. If zero is returned, mode 1, 5 and 9 are not available. This applies to early LSProbe 1.2/1.4/2.0 E-field probe variants and variants optimized for low frequencies, e.g., 10 Hz, since they do not support rapid alternation between low-band and high-band detectors. NAN will be returned if the field probe is turned off or if calibration data is missing.

12.5.12 :MEASure[:FProbe]:TIMer? [<MProbe>]

Query E-field probe activity timer for one or multiple CI-250 Computer Interfaces.

The old syntax »:MEASure[:PRObe]:TIMer? [<MProbe>]« remains supported.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer value approximating the E-field probe's operating time in seconds. The counter runs over after reaching 4095. NAN will be returned if the field probe is off or in start-up.

12.5.13 :MEASure[:FProbe]:SERial <Value>

Select active device by field probe serial number.

Parameter:

One serial number out of the list returned by :MEASure[:FProbe]:SERialnumber? [<MProbe>] with the MProbe parameter set to 0 or string stating the serial number and revision string separated by a ":", e.g. "3:2.0" for setting the active device LSProbe 2.0 of serial number 3. In case of enumerated devices with the same serial number but different revisions, e.g. LSProbe 1.2 #3 and LSProbe 2.0 #3 the string containing the serial number and revision has to be given.

12.5.14 :MEASure[:FProbe]:SERialnumber? [<MProbe>]

Query E-field probe serial number for one or multiple devices. The old syntax »:MEASure[:PRObe]:SERialnumber? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer value giving the field probe's serial number. NAN will be returned if the field probe is off or in start-up.

12.5.15 :MEASure[:FProbe]:REVision? [<MProbe>]

Query field probe firmware revision of one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PRObe]:REVision? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value indicating the field probe's firmware's revision number is returned. NAN will be returned if the field probe is off or in start-up.

12.5.16 :MEASure[:FProbe][:Efield]:ANTennas <ANTENNAs>[,<MProbe>]

Activate xa-, ya-, za-axes or xb-, yb-, zb-axes or both sets for LSProbe 2.0 devices.

Parameter:
String parameter without quotes specifying the active antennas, valid values are A, B and AB. When set to A only xa-, ya- and za-axis will be used for all E-field computation and return values. When set to B only xb-, yb- and zb-axis will be used for all E-field computation and return values. When set to AB the isotropic efield value is computed out of each a and b axis and will be used for all subsequent E-ield evaluation and return values for all subsystems. The command will be ignored for LSProbes 1.2 devices.

The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.5.17 :MEASure[:FProbe][:Efield]:ANTennas? <ANTENNAs>[,<MProbe>]

Query active field probe axes for one or multiple devices.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
Refer to »:MEASure[:FProbe][:Efield]:ANTennas <ANTENNAs>[,<MProbe>]« for a list of return values and description.

12.5.18 :MEASure[:FProbe]:MODe? [<MProbe>]

Query E-field probe mode for one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PRObe]:MODe? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer value giving the E-field probe's operating mode. Valid modes are 0, 1, 2, 3, 4, 6, 7, 8 and 9. NAN will be returned if the E-field probe is off or in start-up.

12.5.19 :MEASure[:FProbe]:TEMPerature? [<MProbe>]

Query E-field probe internal temperature for one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PRObe]:TEMPerature? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the probe temperature in °C. This temperature is typically 15 to 20 °C above the probe's ambient temperature. If the probe is off or in start-up, returned values are nonsensical.

12.5.20 :MEASure[:FProbe]:ATEMPerature? [<MProbe>]

Query low-pass filtered E-field probe internal temperature for one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PRObe]:ATEMPerature? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a low-pass filtered value as described in »:MEASure[:FProbe]:TEMPerature? [<MProbe>]«. A 10 Hz first oder low-pass filter is used. NAN will be returned if the E-field probe is off or in start-up.

12.5.21 :MEASure[:FProbe]:ADCTemperature? [<MProbe>]

Query E-field probe internal temperature for one or multiple CI-250 Computer Interfaces in LSB. The old syntax »:MEASure[:PROBe]:ADCTerature? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the ADC probe temperature in LSB. -1 will be returned if the E-field probe is off or in start-up.

12.5.22 :MEASure[:FProbe]:VOLTage? [<MProbe>]

Query E-field probe supply voltage for one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PROBe]:VOLTage? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the float-valued E-field probe supply voltage value in Volts. NAN will be returned if the E-field probe is off or in start-up.

12.5.23 :MEASure[:FProbe]:RDY? [<MProbe>]

Query ready state for query of measruement data.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer value indicating that calibration data was found and in case of optically powered LSProbe 1.2 and 2.0 devices the laser has reached ready state.

12.5.24 :MEASure[:FProbe][:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]

Query E-field for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component value,

:MAGnitude?
E-field magnitude,

:ALL?
: all four results above as a list.

The old syntax »:MEASure[:PRObe]:Efield:X/Y/Z/MAG? [<MProbe>]« remains supported.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns a float-valued field strength in V/m. Values are low-pass filtered as described in »:MEASure[:FProbe][:Efield]:LPFrequency <Frequency>[,<MProbe>]«. If ALL values are queried, a list of four values is returned. NAN will be returned if the E-field probe is off, in start-up or if there is no valid calibration data.

12.5.25 :MEASure[:FProbe][:Efield]:MIN X/Y/Z/MAG/ALL? [<MProbe>]

Query minimum value of E-field range for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:MINX?/:MINY?/:MINZ?
: x-, y- or z-axis E-field component value,

:MINMAGnitude?
: E-field magnitude,

:MINALL?
: all four results above as a list.

The old syntax »:MEASure[:PRObe]:Efield:MIN X/Y/Z/MAG/ALL? [<MProbe>]« remains supported.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns a float-valued field strength in V/m. If ALL values are queried, a list of four values is returned. NAN will be returned if the E-field probe is off, in start-up or if there is no valid calibration data.

12.5.26 :MEASure[:FProbe][:Efield]:MAX X/Y/Z/MAG/ALL? [<MProbe>]

Query maximum value of E-field range for one or multiple CI-250 Computer Interfaces.

See »:MEASure[:FProbe][:Efield]:MIN X/Y/Z/MAG/ALL? [<MProbe>]« for a description of parameter and return values.

12.5.27 :MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]

Query single axis antennae E-field value for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:XA?/:YA?/:ZA?
: xa-, ya-, za-axis E-field component value for LSProbe 2.0, x-, y-, z-axis E-field component value for LSProbe 1.2,

:XB?/:YB?/:ZB?
: xb-, yb-, zb-axis E-field component value, NAN for LSProbe 1.2 or for modi where the axes are not active for LSProbe 2.0, e.g. Mode 3.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns a float-valued field strength in V/m. Values are low-pass filtered as described in »:MEASure[:FProbe][:Efield]:LPFrequency <Frequency>[,<MProbe>]«. If ALL values are queried, a list of four values is returned. NAN will be returned if the antennae does not exists (LSProbe 1.2 has no xb, yb, zb antennae) or is not active (LSProbe 2.0 xb, yb, zb antennae only active in modes 0, 4 and 8), if the E-field probe is off, in start-up or if there is no valid calibration data.

12.5.28 :MEASure[:FProbe][:Efield]:MIN XA/YA/ZA/XB/YB/ZB/RAWALL? [<MProbe>]

Query minimum value of E-field range for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:MINXA?/:MINYA?/:MINZA/:MINXB?/:MINYB?/:MINZB?
: xa-, ya-, za-, xb-, yb- or zb single antennae E-field component value,

:MINRAWALL?
: all six results above as a list.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns a float-valued field strength in V/m. If RAWALL values are queried, a list of six values is returned. NAN will be returned if the antennae does not exists (LSProbe 1.2 has no xb, yb, zb antennae) or is not active (xb, yb, zb antennae only active in modes 0, 4 and 8), if the E-field probe is off, in start-up or if there is no valid calibration data.

12.5.29 :MEASure[:FProbe][:Efield]:MAX XA/YA/ZA/XB/YB/ZB/RAWALL? [<MProbe>]

Query maximum value of E-field range for one or multiple CI-250 Computer Interfaces.

See »:MEASure[:FProbe][:Efield]:MIN XA/YA/ZA/XB/YB/ZB/RAWALL? [<MProbe>]« for a description of parameter and return values.

12.5.30 :MEASure[:FProbe][:Efield]:CALL? [<MProbe>]

Query detailed E-field output for one or multiple CI-250 Computer Interfaces.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns 10 float-valued field strength values in V/m:

xa-antennae E-field value,

ya-antennae E-field value,

za-antennae E-field value,

xb-antennae E-field value or -1 if not active/existing,

yb-antennae E-field value or -1 if not active/existing,

zb-antennae E-field value or -1 if not active/existing,

x-axis E-field component value,

y-axis E-field component value,

z-axis E-field component value,

E-field magnitude,

All values are low-pass filtered as described in »:MEASure[:FProbe][:Efield]:LPFrequency <Frequency>[,<MProbe>]«. NAN will be returned if the E-field probe is off, in start-up or if there is no valid calibration data.

12.5.31 :MEASure[:FProbe][:Efield]:LPFrequency <Frequency>[,<MProbe>]

Set E-field low-pass filter -3 dB cut-off frequency for one or multiple CI-250 Computer Interfaces.

The old syntax »:MEASure[:PRObe]:Efield:LPFrequency <Frequency>[,<MProbe>]« remains supported.

Parameter:

Float value specifying the -3 dB cut-off frequency for the first order E-field low-pass filter in hertz. The filter is applied to calibrated and uncalibrated field strength values. Setting the value to 0 Hz disables low-pass filtering.

The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.5.32 :MEASure[:FProbe][:Efield]:LPFrequency? [<MProbe>]

Query E-field low-pass filter -3 dB cut-off frequency for one or multiple CI-250 Computer Interfaces.

The old syntax »:MEASure[:PROBe]:Efield:LPFrequency? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a float value specifying the -3 dB cut-off frequency for the first order E-field low-pass filter in hertz. A value of 0 indicates that low-pass filtering is disabled.

12.5.33 :MEASure[:FProbe][:Efield]:AUTOVBW <State>[,<MProbe>]

Enable or disable automatic, frequency-dependent setting of the software-defined video bandwidth

Parameters:
If the unsigned integer parameter State is set to 1 the LUMILOOP TCP Server will apply a low-pass filter with a frequency response suitable for the set operating frequency to avoid aliasing when the video bandwidth of the low-band detector is too large, i.e. video bandwidth low-pass filter is set to a tenth of the set operating frequency. Frequency-dependent video bandwidth is applied for LSProbe 1.2 devices below 200 kHz for mode 2 and below 800 kHz for mode 6, for LSProbe 2.0 devices below 200 kHz for mode 2 and below 3 MHz for mode 6. For LSProbe 1.2 Variant F, software-based video bandwidth reduction is always applied below 9 kHz. If the parameter State is set to 0 the bandwidth set by the SCPI command »:MEASure[:FProbe][:Efield]:VBW <Frequency>[,<MProbe>]« will be used.

The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.5.34 :MEASure[:FProbe][:Efield]:AUTOVBW? [<MProbe>]

Query state automatic, frequency-dependent setting of the software-defined video bandwidth

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
If automatic software-defined video bandwidth setting is enabled, the command returns 1, otherwise the command returns 0.

12.5.35 :MEASure[:FProbe][:Efield]:VBW <Frequency>[,<MProbe>]

Set software-defined video bandwidth

Parameter:

The float-valued parameter Frequency sets the -3 dB cut-off frequency in hertz for the software-based first-order RSSI filter. If set to zero, software-based video bandwidth filtering is disabled.

The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.5.36 :MEASure[:FProbe][:Efield]:VBW? [<MProbe>]

Query software-defined video bandwidth

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a float value specifying the -3 dB cut-off frequency for the software-based first-order RSSI filter in hertz. A value to 0 indicates that low-pass filtering is disabled.

12.5.37 :MEASure[:FProbe]:RSsi:X/Y/Z/ALL/XA/YA/ZA/XB/YB/ZB? [<MProbe>]

Query RSSI value for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:X?/:Y?/:Z?

x-, y- or z-axis RSSI component value for LSProbe 1.2 devices, xa-, ya- or za-axis RSSI component value for LSProbe 2.0 devices,

:XA?/:YA?/:ZA?

xa-, ya- or za-axis RSSI component value for LSProbe 2.0 devices, x-, y- or z-axis RSSI component value for LSProbe 1.2 devices,

:XB?/:YB?/:ZB?

xb-, yb- or zb-axis RSSI component value for LSProbe 2.0 devices,

:ALL?

for LSProbe 1.2 three results, x-, y-, z-axis RSSI component values are returned as a list, for LSProbe 2.0 six results, xa-, ya-, za, xb-, yb-, zb-axis RSSI component values are returned as a list,

The old syntax »:MEASure[:PRObe]:RSsi:X/Y/Z? [<MProbe>]« remains supported.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns an unsigned integer value representing the uncalibrated 14 bit ADC value acquired by the respective axis' RSSI chip, i.e., received signal strength indicator, used to determine the electrical field strength. The value is low-pass filtered using the same low-pass filter as described in »:MEASure[:FProbe][:Efield]:LPFrequency <Frequency>[,<MProbe>]« and »:MEASure[:FProbe][:Efield]:VBW <Frequency>[,<MProbe>]«. If ALL values are queried, a list of three values for LSProbe 1.2 devices and six values for LSProbe 2.0 devices is returned. NAN will be returned if the E-field probe is off or in start-up.

12.5.38 :MEASure[:FProbe]:ACCeleration:X/Y/Z/ALL? [<MProbe>]

Query E-field probe acceleration value for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis acceleration value,

:ALL?
: all three results above as a list.

The old syntax »:MEASure[:PRObe]:ACCeleration:X/Y/Z? [<MProbe>]« remains supported.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
: The command returns a float value of the respective acceleration in g, i.e., multiples of 9.81 m/s^2. A value of one g will be returned if an axis is pointing straight up, minus one g will be returned if an axis is pointing straight down. If ALL values are queried, a list of three values is returned. NAN will be returned if the E-field probe is off or in start-up.

12.5.39 :MEASure[:FProbe]:ACCeleration:LPFrequency <Frequency>[,<MProbe>]

Set acceleration low-pass filter -3 dB cut-off frequency for one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PRObe]:ACCeleration:LPFrequency <Frequency>[,<MProbe>]« remains supported.

Parameters:
: Float value specifying the -3 dB cut-off frequency for the first order acceleration low-pass filter in Hz. Setting the value to 0 Hz disables low-pass filtering.

: The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.5.40 :MEASure[:FProbe]:ACCeleration:LPFrequency? [<MProbe>]

Query acceleration low-pass filter -3 dB cut-off frequency for one or multiple CI-250 Computer Interfaces. The old syntax »:MEASure[:PRObe]:ACCeleration:LPFrequency? [<MProbe>]« remains supported.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a float value specifying the -3 dB cut-off frequency for the first order acceleration low-pass filter in hertz. A value to 0 indicates that low-pass filtering is disabled.

12.6 :TRIGger Commands

12.6.1 :TRIGger:BEGin <Index>[,<MProbe>]

Set index of first sample of E-field waveform for one or multiple E-field probes. The command is only accepted if trigger state »:TRIGger:STATe? [<Timeout>,<MProbe>]« is IDLE, set via »:TRIGger:CLear [<MProbe>]«.

Parameters:
The first parameter is the integer-valued position of the beginning of the E-field waveform relative to the position of the trigger. E.g., ":trig:beg 0" will record samples starting at the trigger position, ":trig:beg -100" will record samples starting 100 samples before the trigger position, ":trig:beg 100" will record samples starting 100 samples after the trigger position.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.2 :TRIGger:BEGin? [<MProbe>]

Query index of first sample of E-field waveform for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an integer-valued position of the beginning of the E-field waveform relative to the position of the trigger, corresponds to the first parameter of »:TRIGger:BEGin <Index>[,<MProbe>]«.

12.6.3 :TRIGger:LENgth <Length>[,<MProbe>]

Set length of the E-field waveform per trigger point for one or multiple E-field probes. The command is only accepted if trigger state »:TRIGger:STATe? [<Timeout>,<MProbe>]« is IDLE, set via »:TRIGger:CLear [<MProbe>]«.

Parameters:
The unsigned integer-valued parameter of the command specifies the length of an E-field waveform per trigger point. E.g., »:trig:len 100« will record 100 samples starting at the sample index specified by »:TRIGger:BEGin <Index>[,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.4 :TRIGger:LENgth? [<MProbe>]

Query number of samples in E-field waveform per trigger point for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer-valued length of the E-field waveform per trigger point, corresponding to the length set by »:TRIGger:LENgth <Length>[,<MProbe>]«.

12.6.5 :TRIGger:POINts <Points>[,<MProbe>]

Set number of the trigger points for one or multiple E-field probes. The command is only accepted if trigger state »:TRIGger:STATe? [<Timeout>,<MProbe>]« is IDLE, set via »:TRIGger:CLear [<MProbe>]«.

Parameters:
The unsigned integer-valued parameter Points specifies the number of trigger points, i.e., the number of trigger events required for a full waveform. Consequently, reaching the trigger state DONE requires Points valid trigger events. The number of samples per sub-waveforms is specified using »:TRIGger:LENgth <Length>[,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.6 :TRIGger:POINts? [<MProbe>]

Query number of the trigger points for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of trigger points, corresponding to the value set by »:TRIGger:POINts <Points>[,<MProbe>]«.

12.6.7 :TRIGger:FLENght? [<MProbe>]

Query full number of samples in an E-field waveform for all trigger points, for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued full length of the E-field waveform for all trigger points, expressed as a number of samples. The return value equals the number of samples per trigger point, returned by »:TRIGger:LENgth? [<MProbe>]« multiplied by the number of trigger points returned by »:TRIGger:POINts? [<MProbe>]«.

12.6.8 :TRIGger:PROgress? [<MProbe>]

Query progress of waveform acquisition for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of samples that have been recorded to the E-field waveform buffer. Upon reaching the trigger state DONE the return value equals the number returned by »:TRIGger:FLENght? [<MProbe>]«.

12.6.9 :TRIGger:PTProgress? [<MProbe>]

Query progress of point trigger acquisition for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of point trigger events that have been processes by the trigger sub-system. Upon reaching the trigger state DONE the return value equals the number returned by »:TRIGger:POINts? [<MProbe>]«.

12.6.10 :TRIGger:PTTimes? [<MProbe>]

Query point trigger sample offsets for a full waveform for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a list of unsigned 64 bit integer-valued offset values, expressed as the number of samples relative to the first trigger point. The list has one element less than the there are trigger points. E.g., for an LSProbe 1.2 E-field probe operating in mode 0, for three

trigger points whose trigger events are 1 ms apart, the command will return a list consisting of two values, 500 and 1000, indicating that the second trigger event occured 1 ms after the first trigger event and that the third trigger event occured 2 ms after the first trigger event. NAN will be returned if the trigger system is not in DONE state or if there is only one trigger point.

12.6.11 :TRIGger:EVCNT? <Samples>[,<MProbe>]

Query the number of hardware-detected trigger events for one or multiple E-field probes for given number of samples.

Parameter:

The first mandatory unsigned integer parameter Samples defines the number of samples for which the trigger events are counted. The detection of trigger evenents is independent of the trigger state. Every trigger event increments the counter by one.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

An integer-valued number of hardware-detected trigger events is returned.

12.6.12 :TRIGger:STATe? [<Timeout>,<MProbe>]

Query the state of the trigger system for one or multiple E-field probes.

Parameter:

The first optional float-valued parameter Timeout sets the maximum number of seconds to wait for the trigger state DONE. The command will return immediately if the trigger state is DONE or IDLE, if Timeout is set to zero, or if Timeout is omitted.

The second optional unsigned integer parameter MProbe is described in Section 12.1. The second parameter always requires the first parameter to be set.

Return value:

The command returns a string value giving the state of the trigger system, valid return values are IDLE, ARM, ARMED, TRIGGERED, DONE. See Figure 44 on page 59 for reference.

12.6.13 :TRIGger:CLear [<MProbe>]

Clear trigger, the trigger system will change state from any other trigger state to IDLE for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.14 :TRIGger:ARM [<MProbe>]

Arm trigger, the trigger system will change state to ARMED if in IDLE or DONE state for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.15 :TRIGger:ARMed? [<Timeout>,<MProbe>]

Query if the trigger system is in state ARMED for one or multiple E-field probes.

Parameter:

The first optional float-valued parameter Timeout sets the maximum number of seconds to wait for the state ARMED. The command will return immediately if the trigger state is ARMED, if Timeout is set to zero, or if Timeout is omitted.

The second optional unsigned integer parameter MProbe is described in Section 12.1. The second parameter always requires the first parameter to be set.

Return value:

The command returns an unsigned integer value indicating if the trigger state is ARMED. If the trigger state is ARMED,the return value is 1, otherwise it is 0.

12.6.16 :TRIGger:FORce [<MProbe>]

Force trigger, the trigger system will change state to TRIGGERED independent of the trigger source set by »:TRIGger:SOURce <Source>[,<MProbe>]« for one or multiple E-field probes. This command is used for software triggering.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.17 :TRIGger:DONE? [<Timeout>,<MProbe>]

Query if the trigger system is in state DONE for one or multiple E-field probes.

Parameter:

The first optional float-valued parameter Timeout sets the maximum number of seconds to wait for the state DONE. The command will return immediately if the trigger state is DONE or IDLE, if Timeout is set to zero, or if Timeout is omitted.

The second optional unsigned integer parameter MProbe is described in Section 12.1. The second parameter always requires the first parameter to be set.

Return value:

The command returns an unsigned integer value indicating if the trigger state is DONE. If the trigger state is DONE,the return value is 1, otherwise it is 0.

12.6.18 :TRIGger:COUnt? [<MProbe>]

Query number of detected trigger events for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

An integer-valued number of trigger events recorded is returned.

12.6.19 :TRIGger:SOURce <Source>[,<MProbe>]

Set trigger source for triggered operation for one or multiple E-field probes.

Parameter:

String parameter without quotes specifying the trigger source, valid values are SOFT, EXT, EXT2, X, Y, Z and ANY. When set to SOFT triggering must occur by means of the »:TRIGger:FORce [<MProbe>]« command. When set to EXT triggering uses the external trigger input configured by »:TRIGger:INVert <0/1>[,<MProbe>]«, »:TRIGger:SYNC <0/1>[,<MProbe>]« and »:TRIGger:OUTput <0/1>[,<MProbe>]«. EXT refers to the trigger signal of the BNC connector. EXT2 refers to the trigger signal of the Ext1 RJ45 socket of the respective CI-250(+) Computer Interface and is configured by »:TRIGger:BPINVert <0/1>[,<MProbe>]«, »:TRIGger:BPSYNC <0/1>[,<MProbe>]« and »:TRIGger:BPOUTput <0/1>[,<MProbe>]«. When set to either X-, Y or Z the field strength value of the selected axis is used for triggering, »:TRIGger:LEVel <Level>[,<MProbe>]« and »:TRIGger:FALLing <0/1>[,<MProbe>]« are used for configuration. When set to ANY, X-, Y and Z the field strength value of all the axes are taken into account. The first axis, where the E-field value passes the set trigger level is used for triggering. For LSProbe 2.0 E-field probes field strength triggering considers bot A- and B-axes equally, if the active antennaes was not adapted via »:MEASure[:FProbe][:Efield]:ANTennas <ANTENNAs>[,<MProbe>]« . E.g. for operating Mode 0, if the field level is set to 10 V/m with X field strength value as the selected trigger axis, as soon as as either XA- axis or XB-axis exceeds the trigger threshold a trigger event is prompted. Field level triggering ist not supported for operating Modes 1, 5 and 9.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.20 :TRIGger:SOURce? [<MProbe>]

Query trigger source for triggered operation for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a string value without quotes specifying the trigger source, see »:TRIGger:SOURce <Source>[,<MProbe>]« for more details.

12.6.21 :TRIGger:LEVel <Level>[,<MProbe>]

Set the trigger field strength for X, Y and Z triggering for one or multiple E-field probes.

Parameter:
Float parameter specifying the field strength in V/m. Triggering occurs when the field strength crosses the set value. For LSProbe 2.0 devices field triggering is done for the marked xa-, ya- and za-axis. In some circumstances the Level value has to be fitted to the respective axis field value and set slightly lower.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.22 :TRIGger:LEVel? [<MProbe>]

Query the trigger field strength for X, Y and Z triggering for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns the trigger level as a float-valued field strength value in V/m.

12.6.23 :TRIGger:FALLing <0/1>[,<MProbe>]

Set the direction for external, X, Y and Z triggering for one or multiple E-field probes.

Parameters:
Boolean value of either 0 or 1. If set to 0 the the rising edge of the external trigger signal or passing the threshold value in rising direction will bring the trigger system from the state ARMED to TRIGGERED. If set to 1 the falling edge will be used for triggering.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.24 :TRIGger:FALLing? [<MProbe>]

Query the direction for external, X, Y and Z triggering for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the boolean value giving the trigger edge direction, see »:TRIGger:FALLing <0/1>[,<MProbe>]« for details.

12.6.25 :TRIGger:RELay <0/1>[,<MProbe>]

Enable or disable the output of a received hardware trigger signal via the CI-250(+) Computer Interface's BNC connector or RJ45 connector to the RJ45 connector or BNC connector for one or multiple E-field probes.

Parameters:

Boolean value of either 0 or 1. If set to 0 trigger relay is disabled and the CI-250(+) Computer Interface's BNC or RJ45 hardware trigger signal will not be output on the other connector. If set to 1 trigger relay is enabled and inc ase of receiving a hardware trigger via the the CI-250(+) Computer Interface's BNC connector a signal is output on the RJ45 connector and vice versa. Relay from BNC o RJ45 will be immediately, relay from RJ45 to BNC take 2 clock cycles, i.e. 30 nsec.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.26 :TRIGger:RELay? [<MProbe>]

Query status of trigger relay for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a boolean value giving the state of the CI-250 Computer Interfaces trigger relay setting, see »:TRIGger:RELay <0/1>[,<MProbe>]« for details.

12.6.27 :TRIGger:OUTput <0/1>[,<MProbe>]

Enable or disable the output of a trigger signal via the CI-250(+) Computer Interface's BNC connector for one or multiple E-field probes.

Parameters:

Boolean value of either 0 or 1. If set to 0 trigger output is disabled and the CI-250(+) Computer Interface's BNC connector can be used for trigger input. If set to 1 trigger output is enabled and the CI-250(+) Computer Interface's BNC connector cannot be used for trigger input.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.28 :TRIGger:OUTput? [<MProbe>]

Query status of trigger output for one or multiple E-field probes.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
: The command returns a boolean value giving the state of the CI-250 Computer Interfaces BNC trigger connector, see »:TRIGger:OUTput <0/1>[,<MProbe>]« for details.

12.6.29 :TRIGger:INVert <0/1>[,<MProbe>]

Set the polarity for trigger output via the CI-250(+) Computer Interface's BNC trigger connector for one or multiple E-field probes.

Parameters:
: Boolean value of either 0 or 1. If set to 0 trigger output uses a rising edge logic signal. If set to 1 a falling edge logic signal will be generated.

: The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.30 :TRIGger:INVert? [<MProbe>]

Query the polarity for trigger output via the CI-250(+) Computer Interface's BNC trigger connector for one or multiple E-field probes.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
: The command returns a boolean value of either 0 or 1. See »:TRIGger:INVert <0/1>[,<MProbe>]« for details.

12.6.31 :TRIGger:SYNC <0/1>[,<MProbe>]

Enable or disable synchronization trigger output using the CI-250(+) Computer Interface's BNC trigger connector for one or multiple E-field probes. This function is useful for synchronizing signal generators or transmitters with the E-field probe.

Parameters:
: Boolean value of either 0 or 1. If set to 0 and external trigger output is enabled, output trigger signal as described in »:TRIGger:OUTput <0/1>[,<MProbe>]« and »:TRIGger:INVert <0/1>[,<MProbe>]«. If set to 1 and trigger output is enabled, a logic edge will be generated

synchronously with E-field value acquisition. In mode 0, 2 and 3 a 1 µs long pulse will be generated once every 2 µs. In mode 4, 6 and 7 a 1 µs long pulse is generated for the first value of a burst frame. In mode 8, 10 and 11 a 250 ns long pulse will be generated once every 500 ns. Mode 1, 5 and 9 only a subset of sample values is made available by TCP server.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.32 :TRIGger:SYNC? [<MProbe>]

Query synchronization trigger output for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a boolean value of either 0 or 1. See »:TRIGger:SYNC <0/1>[,<MProbe>]« for details.

12.6.33 :TRIGger:BPOUTput <0/1>[,<MProbe>]

Enable or disable the output of a trigger signal via the CI-250$^{(+)}$ Computer Interface's upper RJ45 connector for one or multiple E-field probes. See »:TRIGger:OUTput <0/1>[,<MProbe>]« for parameters.

12.6.34 :TRIGger:BPOUTput? [<MProbe>]

Query status of trigger output via the CI-250$^{(+)}$ Computer Interface's upper RJ45 connector for one or multiple E-field probes. See »:TRIGger:OUTput? [<MProbe>]« for parameter and return value.

12.6.35 :TRIGger:BPINVert <0/1>[,<MProbe>]

Set the polarity for trigger output via the CI-250$^{(+)}$ Computer Interface's upper RJ45 connector for one or multiple E-field probes. See »:TRIGger:INVert <0/1>[,<MProbe>]« for parameters.

12.6.36 :TRIGger:BPINVert? [<MProbe>]

Query the polarity for trigger output via the CI-250$^{(+)}$ Computer Interface's upper RJ45 connector for one or multiple E-field probes. See »:TRIGger:INVert? [<MProbe>]« for parameter and return value.

12.6.37 :TRIGger:BPSYNC <0/1>[,<MProbe>]

Enable or disable synchronization trigger output via the CI-250(+) Computer Interface's upper RJ45 connector for one or multiple E-field probes. See »:TRIGger:SYNC <0/1>[,<MProbe>]« for parameters.

12.6.38 :TRIGger:BPSYNC? [<MProbe>]

Query the configuration of the synchronization trigger output via the CI-250(+) Computer Interface's upper RJ45 connector for one or multiple E-field probes. See »:TRIGger:SYNC? [<MProbe>]« for parameter and return value.

12.6.39 :TRIGger:OVERsampling:ENable <State>[,<MProbe>]

Enable or disable high resolution waveform acquisition for one or multiple E-field probes.

Parameters:

Setting State to 1 activates high resolution waveform acquisition, setting State to 0 disables oversampled high resolution waveform acquisition for one or multiple E-field probes. Changing the state from disabled to enabled will reset and start sub-waveform collection. The BNC trigger output will be disabled, the trigger source will be set to BNC and the trigger system will be armed, same as issuing the commands »:TRIGger:OUTput <0/1>[,<MProbe>]« with parameter "0", »:TRIGger:SOURce <Source>[,<MProbe>]« with Parameter "EXT" and »:TRIGger:ARM [<MProbe>]«. A dedicated signal source has to be connected to the CI-250 Computer Interfaces's BNC connector for synchronization purposes. For each sample of the sub-waveform length N set by »:TRIGger:LENgth <Length>[,<MProbe>]«, a mode and device type dependent number of phase values M is recorded, i.e. the waveform length of the high resolution waveform amounts to NxM samples. The resolution for each histogram is 0.005 dB. See Section 5.5 on page 70 for further details.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.40 :TRIGger:OVERsampling:ENable? [<MProbe>]

Query status of high resolution waveform acquisition for one or multiple E-field probes. During oversampling enabled state all commands for changing the trigger state and trigger settings are disabled.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns an unsigned integer value containing the status of high resolution waveform acquisition. A value of 1 is returned when high resolution waveform acquisition is enabled, 0 is returned if high resolution waveform acquisition is disabled. Disabled state can either be reached via issuing »:TRIGger:OVERsampling:ENable <State>[,<MProbe>]« with parameter "0" or if at least one of the termination criterion »:TRIGger:OVERsampling:BINCnt <Value>[,<MProbe>]« resp. »:TRIGger:OVERsampling:WAVCnt <Value>[,<MProbe>]« was configured and subsequently reached.

12.6.41 :TRIGger:OVERsampling:RESet [<MProbe>]

Reset high resolution waveform acquisition for one or multiple E-field probes. All recorded data will be cleared and the progress set to 0, same as if issuing »:TRIGger:OVERsampling:ENable <State>[,<MProbe>]« first with parameter "0" and then "1".

Parameters:

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.42 :TRIGger:OVERsampling:BINCnt <Value>[,<MProbe>]

Set termination criterion of minimum number of samples per sample histogram of the high resolution waveform, i.e. number of sub-waveforms for each phase for one or multiple E-field probes.

Parameters:

The unsigned integer-valued parameter Value specifies the number of samples for each waveform histogram, i.e., the number of sub-waveforms for each phase required for a full high resolution waveform. Consequently, reaching the trigger state DONE, resp. oversampling waveform aquisiton state disabled, requires at least <Value> waveforms per phase.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.43 :TRIGger:OVERsampling:BINCnt? [<MProbe>]

Query minimum number of required number of sub-waveforms for each phase for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued number of sub-waveforms for each phase, corresponding to the value set by »:TRIGger:OVERsampling:BINCnt <Value>[,<MProbe>]«.

12.6.44 :TRIGger:OVERsampling:WAVCnt <Value>[,<MProbe>]

Set termination criterion of number of sub-waveforms overall independet on their respective phases, forming the high resolution waveform for one or multiple E-field probes.

Parameters:

The unsigned integer-valued parameter <Value> specifies the overall number of sub-waveforms to be recorded for the high resolution waveform. This criterion for stopping the high resolution waveform aquisition does not take into account the phase of each recorded waveform, i.e. the final high resolution histogram may not be fully populated. Consequently, reaching the trigger state DONE, resp. oversampling waveform aquisiton state disabled, requires <Values> sub-waveforms.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.45 :TRIGger:OVERsampling:WAVCnt? [<MProbe>]

Query number of required sub-waveforms for the high resolution waveform for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued number of sub-wavefoms per high resolution waveform, corresponding to the value set by »:TRIGger:OVERsampling:WAVCnt <Value>[,<MProbe>]«.

12.6.46 :TRIGger:OVERsampling:PHOffset:AUTO [<MProbe>]

Automatically compute phase offset for current high resolution waveform for one or multiple E-field probes. For each phase as a start index, the sum of the absolute distances between consecutive samples are computed. The phase with the smallest sum is set as the phase offset. The phase offset denotes the starting phase index for each waveform.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.47 :TRIGger:OVERsampling:PHOffset <Offset>[,<MProbe>]

Set phase offset manually for current high resolution waveform for one or multiple E-field probes.

Parameters:

The unsigned integer-valued parameter Offset specifies the phase offset. Offset must be smaller than the number of phases returned by »:TRIGger:OVERsampling:PHCount? [<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.48 :TRIGger:OVERsampling:PHOffset? [<MProbe>]

Query phase offset of current high resolution waveform for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued number of the set phase offset, i.e. the start phase index for each sub-waveform sample. The value corresponds to the value set by »:TRIGger:OVERsampling:PHOffset <Offset>[,<MProbe>]« or computed by »:TRIGger:OVERsampling:PHOffset:AUTO [<MProbe>]«.

12.6.49 :TRIGger:OVERsampling:MAXNoise <Value>[,<MProbe>]

Set confidence interval for each sample histogram of the high resolution waveform for one or multiple E-field probes.

Parameters:

The floating point valued parameter <Value> specifies the maximum noise parameter for average computation of the E-field value for each sample histogram of the current high resolution waveform.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.6.50 :TRIGger:OVERsampling:MAXNoise? [<MProbe>]

Query maximum noise for average computation for each sample histogram of the high resolution waveform for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued number specifying the maximum noise for computing the averaged histogram values for each sample of the high resolution waveform, corresponding to the value set by »:TRIGger:OVERsampling:MAXNoise <Value>[,<MProbe>]«.

12.6.51 :TRIGger:OVERsampling:PHCount? [<MProbe>]

Query number of phases for current high resolution waveform for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of phases of the current high resolution waveform. The value depending on the current sampling rate and device type. If there is no high resolution waveform data, zero is returned.

12.6.52 :TRIGger:OVERsampling:BINStatus? [<MProbe>]

Query number of recorded sub-waveforms for each phase bin for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a separated list of N unsigned integer-values, stating the number recorded sub-waveforms for each phase, with N denoting the number of phases returned by »:TRIGger:OVERsampling:PHCount? [<MProbe>]«. The first value refers to the number of sub-waveforms corresponding to the first phase, et cetera. NAN will be returned if the laser is off or there is no valid calibration data.

12.6.53 :TRIGger:OVERsampling:PROgress? [<MProbe>]

Query acquisition of high resolution waveform progress on a range between zero and one for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a single precision float-valued progress stating the trigger process with zero denoting no trigger waveform was recorded. One is returned if one of the termination cirterias »:TRIGger:OVERsampling:BINCnt <Value>[,<MProbe>]« resp. »:TRIGger:OVERsampling:WAVCnt <Value>[,<MProbe>]« was set and met or if both termination criterias are set to zero, for each phase at least one waveform was recorded.

12.6.54 :TRIGger:OVERsampling:WAVProgress? [<MProbe>]

Query number of recorded sub-waveforms forming the high resolution waveform for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of recorded sub-waveforms that form the high resolution waveform.

12.6.55 :TRIGger:OVERsampling:X/Y/Z/MAG/ALL? [<MProbe>]

Query high resolution E-field waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component values,

:MAGnitude?
E-field magnitude values.

:ALL?
E-field component values and E-field magnitude values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns a comma-separated list of float-valued E-field waveform values in V/m. E-field value for samples with multiple recorded values are obtained via computing the averaged value out of the histogram of the respective sample in compliance with the set confidence interval via »:TRIGger:OVERsampling:MAXNoise <Value>[,<MProbe>]«. For phase samples missing a recorded sub-waveform, NAN is returned for all samples belonging to this phase. The sequence of the E-field values is in accordance with the phase offset returned by »:TRIGger:OVERsampling:PHOffset? [<MProbe>]« NAN will be returned if the E-field probe is off, in start-up, if there is no valid calibration or high resolution waveform data.

12.6.56 :TRIGger:OVERsampling:HISTogram:X/Y/Z/MAG? [<MProbe>]

Query histogram data for each sample of the high resolution waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component histogram values,

:MAGnitude?
E-field magnitude histogram values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns a comma-separated list of three values. The first unsigned integer valued number denotes the sample index of the high resolution waveform of following two values in accordance with the phase offset returned by »:TRIGger:OVERsampling:PHOffset? [<MProbe>]«. The second single precision float-valued value denotes E-field value in V/m of the next non-empty histogram bin of the stated sample index. The third unsigned 64 bit integer value states the number of samples of a field strength falling into the stated field strength bin of the sample index.

NAN will be returned if the E-field probe is off, in start-up, if there is no valid calibration or high resolution waveform data.

12.7 :TRIGger[:WAVeform] Commands

12.7.1 :TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]

Query E-field waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component values,

:MAGnitude?
E-field magnitude values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns a comma-separated list of float-valued E-field waveform values in V/m. NAN will be returned if the E-field probe is off, in start-up, if there is no valid calibration data or if the trigger system state is not equal to DONE.

12.7.2 :TRIGger[:WAVeform][:Efield]:ALL? [<MProbe>]

Query E-field component values and E-field magnitude averaged over the present E-field waveform for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of four float values giving the x-axis E-field component, y-axis E-field component, z-axis E-field component and E-field magnitude, i.e., isotropic E-field strength, in this order. NAN will be returned if the E-field probe is off, in start-up, if there is no valid calibration data or if the trigger system state is not equal to DONE.

12.7.3 :TRIGger[:WAVeform]:FRame? [<MProbe>]

Query frame indicator values of E-field waveform for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of integer values indicating the burst frame index inside a E-field waveform. Valid values are 0 and 1. In mode 0, 2, 3, 8, 10 and 11 the transition from 0 to 1 or vice versa indicates the acquisition of new LF sample values, there is no gap between field strength or RSSI values. In mode 1, 4, 5, 6, 7 and 9, the transition from 0 to 1 or vice versa indicates the beginning of a burst frame and thus a gap between field strength resp. RSSI values. NAN will be returned if the E-field probe is off, in start-up or if the trigger system state is not equal to DONE.

12.7.4 :TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]

Query RSSI values of a waveform, for one or multiple E-field probes. Using :X?/:Y?/:Z?/:XA?/:YA?/:ZA?/:XB?/:YB?/:ZB?, return result for either x-, y- or z-axis for LSProbe 1.2 devices, resp. xa-, ya-, za-, xb-, yb- or zb-axis for LSProbe 2.0 devices.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a list of unsigned integer values representing the uncalibrated 14 bit ADC value acquired by the RSSI detector chip, i.e., received signal strength indicator, used to detect the electrical field strength. NAN will be returned if the E-field probe is off, in start-up or if the trigger system state is not equal to DONE.

12.7.5 :TRIGger[:WAVeform]:ACCeleration:X/Y/Z? [<MProbe>]

Query E-field probe's acceleration waveform values for one or multiple E-field probes. Using :X?/:Y?/:Z?, return result for either x-, y- or z-axis acceleration.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of float-valued acceleration values in g, i.e., multiples of 9.81 m/s^2, within an E-field waveform. A value of one g will be returned if the axis is pointing straight up, minus one g will be returned if the axis is pointing straight down. Since the sampling rate of acceleration values is 1.3 kHz and asynchronous to E-field strength sampling the number of samples is much smaller than »:TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]« and can vary by one value for a constant E-field waveform length. NAN will be returned if the E-field probe is off, in start-up or if the trigger system state is not equal to DONE.

12.7.6 :TRIGger[:WAVeform]:TEMPerature? [<MProbe>]

Query E-field probe's internal temperature values for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of float-valued temperature values in °C within a waveform. See »:TRIGger[:WAVeform]:ACCeleration:X/Y/Z? [<MProbe>]« for further details about the return value format.

12.7.7 :TRIGger[:WAVeform]:VOLTage? [<MProbe>]

Query E-field probe's supply voltage values of a waveform for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of float-valued voltage values in volt within a waveform. See »:TRIGger[:WAVeform]:ACCeleration:X/Y/Z? [<MProbe>]« for further details about the return value format.

12.7.8 :TRIGger[:WAVeform][:Efield]:BINary? [<MProbe>]

Query E-field component values, E-field magnitude values and trigger frame values of E-field waveform in binary format for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

Binary data block followed by a carriage return, newline sequence. The first four bytes specify the number of bytes of the binary data block which will be returned following the first four bytes.

For each probe P a chunk of binary data will be sent, one for each referenced E-field probe. All values are encoded in little endian format. Data is ordered as follows:

CI number
: 32 bit unsigned integer value giving the serial number of the corresponding CI-250(+) Computer Interface. If the probe P is not defined the CI-250(+) Computer Interface serial number, probe serial number, probe version and sample count is set to zero and the binary data block ends.

probe number
: 32 bit unsigned integer value giving the serial number of the corresponding E-field probe. If the E-field probe is off or in start-up the probe serial number, probe version and sample count is set to zero and the binary data block ends.

probe version
: 32 bit single-precision, floating-point value giving the version of the corresponding E-field probe.

sample count
: 32 bit unsigned integer value giving the number of samples S in the waveform of the corresponding E-field probe. The following binary data will contain S values for each of the following values. If there is no valid calibration data or if the trigger system state is not equal to DONE the number of samples, S, is set to zero and the binary data block ends.

waveform count
: 32 bit unsigned integer value giving the number of the following waveforms N. The following binary data will contain N*S values for each of the following values.

x-axis
: S 32 bit single-precision, floating-point values giving a list of x-axis E-field values in V/m of the E-field waveform, see »:TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]«.

y-axis
: S 32 bit single-precision, floating-point values giving a list of y-axis E-field values in V/m of the E-field waveform, see »:TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]«.

z-axis
: S 32 bit single-precision, floating-point values giving a list of z-axis E-field values in V/m of the E-field waveform, see »:TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]«.

magnitude
: S 32 bit single-precision, floating-point values giving a list of E-field magnitude values in V/m of the E-field waveform, see »:TRIGger[:WAVeform][:Efield]:X/Y/Z/MAG? [<MProbe>]«.

frame indicator
: S 32 bit single-precision, floating-point values giving a list of E-field frame indicator values as described in »:TRIGger[:WAVeform]:FRame? [<MProbe>]«,

x-axis RSSI
: S 16 bit unsigned integer values, encoded as 32 bit single-precision, floating-point values, giving a list of x-axis RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]«.

y-axis RSSI
: S 16 bit unsigned integer values, encoded as 32 bit single-precision, floating-point values, giving a list of y-axis RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]«.

z-axis RSSI
: S 16 bit unsigned integer values, encoded as 32 bit single-precision, floating-point values, giving a list of z-axis RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]«.

xb-axis RSSI, LSProbe 2.0 only
: S 16 bit unsigned integer values, encoded as 32 bit single-precision, floating-point values, giving a list of x-axis RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]«.

yb-axis RSSI, LSProbe 2.0 only
: S 16 bit unsigned integer values, encoded as 32 bit single-precision, floating-point values, giving a list of y-axis RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]«.

zb-axis RSSI, LSProbe 2.0 only
: S 16 bit unsigned integer values, encoded as 32 bit single-precision, floating-point values, giving a list of z-axis RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:X/Y/Z/XA/YA/ZA/XB/YB/ZB? [<MProbe>]«.

12.7.9 :TRIGger[:WAVeform][:Efield]:BINWait? [<Timeout>,<MProbe>]

Query E-field component values, E-field magnitude values and trigger frame values of E-field waveform in binary format for one or multiple E-field probes. If data is available for all queried probes a »:TRIGger:CLear [<MProbe>]« and »:TRIGger:ARM [<MProbe>]« will be sent automatically.

Parameter:

The first optional float-valued parameter Timeout sets the maximum number of seconds to wait until encountering a DONE state. If the trigger state is equal to DONE, if Timeout is set to zero, or if Timeout is omitted the command will return immediately.

The second optional unsigned integer parameter MProbe is described in Section 12.1. The second parameter always requires the first parameter to be set.

Return values:

See »:TRIGger[:WAVeform][:Efield]:BINary? [<MProbe>]« for a description of the command's return values.

12.7.10 :TRIGger[:WAVeform][:Efield]:BINReduced? [<MProbe>]

Query E-field component values and E-field magnitude values in binary format for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

See »:TRIGger[:WAVeform][:Efield]:BINary? [<MProbe>]« for a description of the command's return values. RSSI and frame indicator waveforms are not returned.

12.8 [:TRIGger]:RADar, Commands

12.8.1 [:TRIGger]:RADar:SOURce <Source>[,<MProbe>]

Set pulse evaluation source waveform for one or multiple E-field probes.

Parameter:

The string parameter **Source**, without quotes, specifies the waveform master for pulse evaluation. Valid values are IND (default), X, Y, Z and MAG. When set to IND, X-, Y- Z- and e-field magnitude waveforms are evaluated independently, yielding potentially different pulse counts and pulse characteristics. When set to a value other than IND, the designated waveform will be used for pulse detection. The evaluation of all other waveforms will be performed using the pulse boundaries determined by the master waveform, ensuring the same pulse count and timing for all pulse characteristics.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.8.2 [:TRIGger]:RADar:SOURce? [<MProbe>]

Query pulse evaluation source waveform for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a string value without quotes specifying the pulse evaluation source, see »[:TRIGger]:RADar:SOURce <Source>[,<MProbe>]« for more details.

12.8.3 [:TRIGger]:RADar:TRIM <State>[,<MProbe>]

Enable/disable pulse trimming for one or multiple E-field probes.

Parameter:

The mandatory first unsigned integer parameter State controls the trimming of pulse edges. If set to 0 all samples exceeding the pulse threshold will be treated as belonging to a pulse. If set to 1, the first and last sample of the pulse, which exceed the threshold will be trimmed, i.e., will not be used for computation of the arithmetic mean of the pulse. If a pulse contains only one or two values, the pulse's average value is defined as its largest sample value. Pulse length and start position are not affected by pulse trimming.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.8.4 [:TRIGger]:RADar:TRIM? [<MProbe>]

Query state of pulse trimming for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

An unsigned integer value indicating state of pulse edge trimming, see »[:TRIGger]:RADar:TRIM <State>[,<MProbe>]«.

12.8.5 [:TRIGger]:RADar:THreshold:AUTO <State>[,<MProbe>]

Enable/disable automatic calculation of the threshold value for radar pulse detection for one or multiple E-field probes. The command mirrors behaviour of »[:TRIGger]:RADar:THMethod <Method>[<MProbe>]« with parameters AVG, resp. ABS.

Parameters:

If set to 1 the arithmetic mean of minimum and maximum field strength in the waveform will be used as the pulse detection threshold. If set to 0 the threshold set via »[:TRIGger]:RADar:THreshold <Value>[,<MProbe>]« will be used.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.8.6 [:TRIGger]:RADar:THreshold:AUTO? [<MProbe>]

Query state of automatic calculation of the threshold value for radar pulse detection for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
See »[:TRIGger]:RADar:THreshold:AUTO <State>[,<MProbe>]« for return value.

12.8.7 [:TRIGger]:RADar:THMethod <Method>[<MProbe>]

Set the method for setting the pulse threshold for one or multiple E-field probes.

Parameter:
The mandatory string value Method sets the method of threshold detection. Parameters are given without quotation marks, valid methods are:

AVG, max/min-based threshold
When set to AVG, the pulse threshold is set to the arithmetic mean of the maximum E-field value and minimum E-field value in the waveform. This is the default method.

ABS, absolute threshold
When set to ABS, the threshold set by the SCPI command »[:TRIGger]:RADar:THreshold <Value>[,<MProbe>]« is used.

The optional second unsigned integer parameter MProbe is described in Section 12.1.

12.8.8 [:TRIGger]:RADar:THMethod? [<MProbe>]

Query the method for setting the pulse threshold for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
A string value indicating the set pulse threshold method, see »[:TRIGger]:RADar:THMethod <Method>[<MProbe>]« for details.

12.8.9 [:TRIGger]:RADar:THreshold <Value>[,<MProbe>]

Set radar pulse detection threshold value if automatic threshold setting is disabled for one or multiple E-field probes.

Parameters:
Float value specifying the threshold for radar pulse detection for E-field component values and E-field magnitude in V/m. The value applies to the SCPI commands »[:TRIGger]:RADar:X/Y/Z/MAG? [<MProbe>]«, »[:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]« and »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]«. The default threshold value is 1 V/m. The threshold value will only be used if automatic threshold setting is disabled via »[:TRIGger]:RADar:THreshold:AUTO <State>[,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.8.10 [:TRIGger]:RADar:THreshold? [<MProbe>]

Query radar pulse detection threshold value for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a floating-point value indicating the absoluethe pulse detection threshold, set by »[:TRIGger]:RADar:THreshold <Value>[,<MProbe>]«, in V/m.

12.8.11 [:TRIGger]:RADar:THreshold:X/Y/Z/MAG/ALL? [<MProbe>]

Query radar pulse detection threshold for one or multiple E-field probes for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component values,

:MAGnitude?
E-field magnitude values,

:ALL?
a list of the four thresholds above.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the field strength threshold used for radar pulse detection. If ALL thresholds are queried, a list of four values is returned. NAN will be returned if the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.12 [:TRIGger]:RADar:X/Y/Z/MAG? [<MProbe>]

Query number of pulses in addition to sample index, pulse length and radar E-field component values or magnitude values of all radar pulses in the current a waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component values,

:MAGnitude?
E-field magnitude values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list, starting with the unsigned integer number of detected pulses, followed by index/length/field strength pairs giving the sample position, length in samples and averaged field strength value of each detected radar pulse. The first value of each triple gives the sample index after crossing the threshold value in a rising fashion relative to the start of the waveform. The second value of each triple gives the length of the pulse expressed as samples. The third value of each triple gives the arithmetic mean of the field strength of the respective pulse. The number of pulses will be returned as zero and no index/length/-field strength triples be returned, if no pulses could be detected, the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.13 [:TRIGger]:RADar:STArt:X/Y/Z/MAG? [<MProbe>]

Query radar pulse start positions in the current waveform for one or multiple E-field probes for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component values,

:MAGnitude?
: E-field magnitude values.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of unsigned integer numbers. The values gives the sample indexes after crossing the threshold value in a rising fashion relative to the start of the waveform.

NAN will be returned if no pulses could be detected, the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.14 [:TRIGger]:RADar:LENgth:X/Y/Z/MAG? [<MProbe>]

Query radar pulse lengths in the current waveform for one or multiple E-field probes for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component values,

:MAGnitude?
: E-field magnitude values.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns a comma-separated list of unsigned integer numbers giving the length of all radar pulses, expressed as samples. NAN will be returned if no pulses could be detected, the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.15 [:TRIGger]:RADar:Efield:X/Y/Z/MAG? [<MProbe>]

Query radar pulse field-strength values in the current waveform for one or multiple E-field probes for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component values,

:MAGnitude?
E-field magnitude values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns a comma-separated list of float-valued field strength values, giving the arithmetic mean of the field strength of each radar pulse. NAN will be returned if no pulses could be detected, the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.16 [:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]

Query averaged component values and magnitude of field strength for all radar pulses in the present waveform for one or multiple E-field probes.

Parameters:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns a comma-separated list of four float values giving arithmetic mean of all pulses found for the x-axis, y-axis, z-axis and magnitude, i.e., isotropic, E-field strength waveforms. This is equivalent to calculating the arithmetic means of »[:TRIGger]:RADar:Efield:X/Y/Z/MAG? [<MProbe>]«.

NAN will be returned if no pulses could be detected, the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.17 [:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]

Query number of detected pulses in the current waveform for one or multiple E-field probes for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component values,

:MAGnitude?
: E-field magnitude values,

:ALL?
: a list of the four pulse counts above.

Parameters:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns an unsigned integer number giving the number of detected pulses for one axis or the field strength magnitude. If ALL pulse counts are queried, a list of four values is returned. NAN will be returned if the E-field probe is off, the probe is in start-up, there is no valid calibration data or the trigger system state is not equal to DONE.

12.8.18 [:TRIGger]:RADar:BINary? [<MProbe>]

Query radar pulse detection results present waveform in binary format for one or multiple E-field probes.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: Binary data block followed by a carriage return, newline sequence. The first four bytes specify the number of bytes of the binary data block which will be returned following the first four bytes.

For each probe P a chunk of binary data will be sent, one for each referenced E-field probe. All values are encoded in little endian format. If the field probe P is not defined, the computer interface serial number, probe serial number and version and sample count are set to zero and the binary data block ends. Data are ordered as follows:

serial number
: 32 bit unsigned integer value giving the serial number of the corresponding CI-250(+) Computer Interface for optically powered LSProbe devices. In case of directly powered devices the LSProbe serial number.

OPD number
: 32 bit signed integer value giving the serial number of the corresponding optically powered field probe. In case of directly powered LSProbe devices the OPD serial number is set to minus one.

probe version
: 32 bit single-precision, floating-point value giving the revision of the corresponding field probe.

sample count
: 32 bit unsigned integer value giving the number of samples in the waveform of the corresponding field probe.

x-axis threshold value
: 32 bit single-precision, floating-point value giving the x-axis threshold value for pulse detection, see »[:TRIGger]:RADar:THreshold:X/Y/Z/MAG/ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

y-axis threshold value
: 32 bit single-precision, floating-point value giving the y-axis threshold value for pulse detection, see »[:TRIGger]:RADar:THreshold:X/Y/Z/MAG/ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

z-axis threshold value
: 32 bit single-precision, floating-point value giving the z-axis threshold value for pulse detection, see »[:TRIGger]:RADar:THreshold:X/Y/Z/MAG/ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

magnitude threshold value
: 32 bit single-precision, floating-point value giving the magnitude threshold value for pulse detection, see »[:TRIGger]:RADar:THreshold:X/Y/Z/MAG/ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

x-axis averaged radar E-field value
: 32 bit single-precision, floating-point value giving the arithmetic mean of all x-axis radar pulses in the present waveform, see »[:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

y-axis averaged radar E-field value
: 32 bit single-precision, floating-point value giving the arithmetic mean of all y-axis radar pulses in the present waveform, see »[:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

z-axis averaged radar E-field value

32 bit single-precision, floating-point value giving the arithmetic mean of all z-axis radar pulses in the present waveform, see »[:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

E-field magnitude averaged radar value

32 bit single-precision, floating-point value giving the arithmetic mean of all magnitude radar pulses in the present waveform, see »[:TRIGger]:RADar[:AVG]:ALL? [<MProbe>]«. If there is no valid calibration data or if the trigger system state is not equal to DONE the value is set to NAN.

x-axis radar pulse count

32 bit unsigned integer value giving the number of detected x-axis radar pulses Rx, see »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no x-axis radar pulses detected above the set threshold Rx is set to zero.

y-axis radar pulse count

32 bit unsigned integer value giving the number of detected y-axis radar pulses Ry, see »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no y-axis radar pulses detected above the set threshold Ry is set to zero.

z-axis radar pulse count

32 bit unsigned integer value giving the number of detected z-axis radar pulses Rz, see »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no z-axis radar pulses detected above the set threshold Rz is set to zero.

magnitude radar pulse count

32 bit unsigned integer value giving the number of detected magnitude radar pulses Rm, see »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are radar pulses detected above the set threshold Rm is set to zero.

start of x-axis pulse

Rx 32 bit unsigned integer values giving the start positions of all x-axis radar pulses expressed in samples relative to the beginning of the waveform.

length of x-axis pulses

Rx 32 bit unsigned integer values giving the length of all x-axis radar pulses expressed in samples.

arithmetic mean of x-axis pulses

Rx 32 bit single-precision, floating-point values giving the arithmetic mean of each x-axis radar pulse's field strength.

start of y-axis pulses
: Ry 32 bit unsigned integer values giving the start positions of all y-axis radar pulses expressed in samples relative to the beginning of the waveform.

length of y-axis pulses
: Ry 32 bit unsigned integer values giving the length of all y-axis radar pulses expressed in samples.

arithmetic mean of y-axis pulses
: Ry 32 bit single-precision, floating-point values giving the arithmetic mean of each y-axis radar pulse's field strength.

start of z-axis pulses
: Rz 32 bit unsigned integer values giving the start positions of all z-axis radar pulses expressed in samples relative to the beginning of the waveform.

length of z-axis pulses
: Rz 32 bit unsigned integer values giving the length of all z-axis radar pulses expressed in samples.

arithmetic mean of z-axis pulses
: Rz 32 bit single-precision, floating-point values giving the arithmetic mean of each z-axis radar pulse's field strength.

start of E-field magnitude pulses
: Rm 32 bit unsigned integer values giving the start positions of all magnitude radar pulses expressed in samples relative to the beginning of the waveform.

length of E-field magnitude pulses
: Rm 32 bit unsigned integer values giving the length of all magnitude radar pulses expressed in samples.

arithmetic mean of E-field magnitude pulses
: Rm 32 bit single-precision, floating-point values giving the arithmetic mean of each magnitude radar pulse's field strength.

12.9 [:TRIGger]:SWeep, Commands

12.9.1 [:TRIGger]:SWeep:TStep <TStep>[,<MProbe>]

Set number of samples per sweep step for one or multiple E-field probes.

Parameters:

The unsigned, integer-valued parameter of the command specifies the number of samples per sweep step within the E-field waveform, dividing it into as many sections as will fit into the waveform, starting with the first sample of the waveform. If set to zero automatic sweep computation during trigger recording is disabled.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.2 [:TRIGger]:SWeep:TStep? [<MProbe>]

Query number of samples per sweep step for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of samples per sweep step, corresponding to the value set via »[:TRIGger]:SWeep:TStep <TStep>[,<MProbe>]«, the default value is 1000 samples. If executed for multiple CI-250 Computer Interfaces the command returns a list of values for each E-field probe of the respective list.

12.9.3 [:TRIGger]:SWeep:TCNT? [<MProbe>]

Query number of sweep steps for present E-field waveform for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of sweep steps for the present E-field waveform, corresponding to the length of the full waveform queried via »:TRIGger:FLENght? [<MProbe>]« divided by the sweep step length set via »[:TRIGger]:SWeep:TStep <TStep>[,<MProbe>]«. If executed for multiple CI-250 Computer Interfaces the command returns a list of values for each E-field probe of the respective list.

12.9.4 [:TRIGger]:SWeep:TBegin <TBegin>[,<MProbe>]

Set the index of the first sample of the averaged portion of each sweep step for one or multiple E-field probes.

Parameters:
The unsigned integer-valued parameter of the command sets the index of the first value used for averaging in each sweep step.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.5 [:TRIGger]:SWeep:TBegin? [<MProbe>]

Query the index of the first sample of the averaged portion of each sweep step for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued index of the first sample used for averaging in each sweep step, corresponding to the length set via »[:TRIGger]:SWeep:TBegin <TBegin>[,<MProbe>]«, the default value is 500. If executed for multiple CI-250 Computer Interfaces the command returns a list of indexes for each E-field probe of the respective list.

12.9.6 [:TRIGger]:SWeep:TEnd <TEnd>[,<MProbe>]

Set the index of the last sample of the averaged portion of each sweep step for one or multiple E-field probes.

Parameters:

The unsigned integer-valued parameter of the command sets the index of the last value used for averaging in each sweep step.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.7 [:TRIGger]:SWeep:TEnd? [<MProbe>]

Query the index of the last sample of the averaged portion of each sweep step for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued index of the last sample used for averaging in each sweep step, corresponding to the length set via »[:TRIGger]:SWeep:TEnd <TEnd>[,<MProbe>]«, the default value is 899. If executed for multiple CI-250 Computer Interfaces the command returns a list of indexes for each E-field probe of the respective list.

12.9.8 [:TRIGger]:SWeep:ADDTimes <TStep>,<TBegin>,<TEnd>[,<MProbe>]

Append single sweep step to the list of sweep steps for one or multiple E-field probes.

Parameters:

The first unsigned, non-zero integer-valued parameter of the command specifies the number of samples for the nexz sweep step within the E-field waveform. The second unsigned integer-valued parameter of the command sets the index of the first value used for averaging in the respective sweep step. The third unsigned integer-valued parameter of the command sets the index of the last value used for averaging in the respective sweep step.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.9 [:TRIGger]:SWeep:CLEARTimes [<MProbe>]

Reduce list of sweep steps to first step for or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.10 [:TRIGger]:SWeep:TIMes? [<MProbe>]

Query list of sweep steps for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns one or multiple sets of three integer values.
The first value indicates the number of samples of the sweep step. The second value gives the index of the first sample of the averaged portion of the sweep step. The third value indicates the index of the last sample of the averaged portion of the sweep step.

12.9.11 [:TRIGger]:SWeep:ATCNT? [<MProbe>]

Query number of arbitrary sweep steps for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns the unsigned integer-valued number of sweep steps configured.

12.9.12 [:TRIGger]:SWeep:MODe <Mode>[,<MProbe>]

Set frequency sweep mode for E-field waveform evaluation for one or multiple E-field probes.

Parameter:
String parameter without quotes specifying the sweep mode, valid values are LIN, LOG and LIST. When set to LIN or LOG the sweep must be parametrized via the SCPI commands »[:TRIGger]:SWeep:BEGin <Freq>[,<MProbe>]«, »[:TRIGger]:SWeep:STEP <Step>[,<MProbe>]« and »[:TRIGger]:SWeep:COUnt <Count>[,<MProbe>]«. When set to LIST an arbitrary frequency list with a non-zero number of frequencies must be set via the SCPI command »[:TRIGger]:SWeep:ARBAdd <Freq>[,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.13 [:TRIGger]:SWeep:MODe? [<MProbe>]

Query frequency sweep mode for E-field waveform evaluation for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a string value without quotes specifying the sweep mode, see »[:TRIGger]:SWeep:MODe <Mode>[,<MProbe>]« for more details. If executed for multiple CI-250 Computer Interfaces the command returns a list of modes of all E-field probes of the respective list.

12.9.14 [:TRIGger]:SWeep:BEGin <Freq>[,<MProbe>]

Set frequency of first sweep step for linear and logarithmic frequency sweeps for one or multiple E-field probes.

Parameters:

The double-precision, floating-point valued parameter of the command specifies the frequency of the first sweep step for linear and logarithmic sweeps in hertz.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.15 [:TRIGger]:SWeep:BEGin? [<MProbe>]

Query frequency of first sweep step for linear and logarithmic frequency sweeps for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the double-precision, floating-point valued frequency of the first sweep step in hertz with up to three decimal places for the sweep modes LIN and LOG, corresponding to the value set by »[:TRIGger]:SWeep:BEGin <Freq>[,<MProbe>]«, the default value is 100 MHz. If executed for multiple CI-250 Computer Interfaces the command returns a list of floating-point values indicating the frequency of the first sweep step for each E-field probes.

12.9.16 [:TRIGger]:SWeep:COUnt <Count>[,<MProbe>]

Set number of frequency steps for linear and logarithmic frequency sweeps for one or multiple E-field probes.

Parameters:

The unsigned integer-valued parameter of the command specifies the number of frequency steps of the frequency sweep.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.17 [:TRIGger]:SWeep:COUnt? [<MProbe>]

Query number of frequency steps for linear and logarithmic frequency sweeps for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued number of frequency steps for the sweep modes LIN and LOG, set via »[:TRIGger]:SWeep:COUnt <Count>[,<MProbe>]«, the default is 10 steps. If executed for multiple CI-250 Computer Interfaces the command returns a list of unsigned integer-valued number of frequency steps for each E-field probes.

12.9.18 [:TRIGger]:SWeep:STEP <Step>[,<MProbe>]

Set the incremental frequency step for linear and logarithmic frequency sweeps for one or multiple E-field probes.

Parameters:

The double-precision, floating-point valued parameter of the command specifies the frequency increment. For linear frequency sweeps the parameter gives the frequency increment from one sweep step to the next in hertz. For logarithmic frequency sweeps the parameter specifies the incremental factor from one sweep step to the next.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.19 [:TRIGger]:SWeep:STEP? [<MProbe>]

Query the incremental frequency step for linear and logarithmic frequency sweeps for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the double-precision, floating-point valued linear frequency with up to three decimal places for the sweep modes LIN and LOG, i.e. increment in hertz or factor from one sweep step to the next set by »[:TRIGger]:SWeep:STEP <Step>[,<MProbe>]«, the default value is 1.1. If executed for multiple CI-250 Computer Interfaces the command returns a list of float-valued numbers for each E-field probe.

12.9.20 [:TRIGger]:SWeep:ARBAdd <Freq>[,<MProbe>]

Append single frequency to the list of arbitrary sweep frequencies for one or multiple E-field probes.

Parameters:

The double-precision, floating-point valued parameter of the command specifies the frequency to be appended to the arbitrary frequency list in hertz.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.21 [:TRIGger]:SWeep:ARBClear [<MProbe>]

Clear the list of arbitrary sweep frequencies for one or multiple E-field probes.

Parameters:

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.9.22 [:TRIGger]:SWeep:ARBitrary? [<MProbe>]

Query the arbitrary list of frequencies used for the sweep evaluation in LIST mode of an E-field waveform for one or multiple E-field probes.

Parameters:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a double-precision, floating-point valued list of frequency steps used for sweep evaluation in list mode. The number of frequency steps is the number of frequencies added via the SCPI command »[:TRIGger]:SWeep:ARBAdd <Freq>[,<MProbe>]«. If the number of arbitrary list frequencies is zero the query will return NAN. If executed for multiple CI-250 Computer Interfaces the command returns a list of frequencies for each E-field probe.

12.9.23 [:TRIGger]:SWeep:LIST? [<MProbe>]

Query the list of frequencies used for the sweep evaluation of an E-field waveform for one or multiple E-field probes.

Parameters:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a double-precision, floating-point valued list of frequency steps in hertz with up to three decimal places used for sweep evaluation. The number of frequency steps is the number of samples of the waveform divided by the number of samples per sweep step, rounded down to the nearest integer number, see »:TRIGger:FLENght? [<MProbe>]« and »[:TRIGger]:SWeep:TStep <TStep>[,<MProbe>]«. Frequency values are applied according to the set sweep mode and its parameters beginning with the start frequency for linear and logarithmic sweeps. For arbitrary list sweeps the list's values will be applied in order. A constant frequency is applied in fixed sweep mode. If the number of frequency steps that fit into the waveform exceeds the number of sweep steps the list of frequency steps will be applied repeatedly until a frequency value has been assigned to each sweep step. If the number of sweep steps is zero the query will return NAN. If executed for multiple CI-250 Computer Interfaces the command returns a list of frequencies for each E-field probe.

12.9.24 [:TRIGger]:SWeep:IDX? [<MProbe>]

Query the center indices of the averaged portions of each sweep step for one or multiple E-field probes.

Parameters:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma separated, integer-valued list of index values of the E-field waveform. The indices give the arithmetic mean of the first and last index used for averaging of each sweep step, see »[:TRIGger]:SWeep:TBegin <TBegin>[,<MProbe>]« and »[:TRIGger]:SWeep:TEnd <TEnd>[,<MProbe>]«. The index is useful for overlaying E-field waveforms and averaged sweep values. If executed for multiple CI-250 Computer Interfaces the command returns a list of indices for each E-field probe.

12.9.25 [:TRIGger]:SWeep[:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]

Query averaged E-field component value or magnitude value for each sweep step, for one of:

:X?/:Y?/:Z?

x-, y- or z-axis E-field component values,

:MAGnitude?

E-field magnitude values,

:ALL?

list of all four values above, for each sweep step.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of float-valued averaged If ALL values are queried, a multiple of four values is returned, E-field values for each sweep step of the E-field waveform in V/m. consisting of the averaged x-, y-, z-axis and magnitude values for each sweep step. NAN will be returned if the E-field probe is off, in start-up, if the trigger system's state is not equal to DONE, if there are no valid sweep frequencies or if there is no valid calibration data for this frequency step.

12.9.26 [:TRIGger]:SWeep:RSsi:X/Y/Z/ALL? [<MProbe>]

Query averaged RSSI value for each sweep step of the E-field waveform for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component values for LSProbe 1.2 devices,

:XA?/:YA?/:ZA?:XB?/:YB?/:ZB?
: xa-, ya-, za-, xb-, yb- or zb-axis E-field component values for LSProbe 2.0 devices,

:ALL?
: list of all four for LSProbe 1.2 resp. six values for LSProbe 2.0 devices above in order.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of integer-valued averaged RSSI values for each sweep step of the E-field waveform in LSB. If ALL values are queried, a list of three lists is returned. NAN will be returned if the E-field probe is off, in start-up, if the trigger system's state is not equal to DONE or if or if there are no valid sweep frequencies.

12.9.27 [:TRIGger]:SWeep:WEfield:X/Y/Z/MAG/ALL? [<MProbe>]

Query E-field component or magnitude values of E-field waveform corrected by applying the configured sweep frequencies for one or multiple E-field probes.

Return results for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component values,

:MAGnitude?
: E-field magnitude values,

:ALL?
: list of all four value lists above in order.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1. The second parameter always requires the first parameter to be set.

Return values:

The command returns a list of float-valued E-field values of the sweep frequency corrected E-field waveform in V/m. If ALL values are queried, a list of four lists is returned. NAN will be returned if the E-field probe is off, in start-up, if there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no valid sweep frequencies.

12.9.28 [:TRIGger]:SWeep:BINary? <Wave>[,<MProbe>]

Query averaged and unaveraged sweep corrected E-field component and magnitude values, and center indices of averaged sweep values in binary format for one or multiple E-field probes.

Parameters:

The first mandatory integer-values parameter Wave controls the output of sweep corrected E-field waveform values. If set to 1 waveform output is enabled, if set to 0 waveform output is disabled.

The second optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

Binary data block followed by a carriage return, newline sequence. The first four bytes specify the number of bytes of the binary data block which will be returned following the first four bytes.

For each probe a chunk of binary data will be sent. All values are encoded in little endian format. If no field probe is defined the computer interface serial number, probe serial number, probe version and sweep step count are set to zero and the binary data block ends. Data are ordered as follows:

CI number
: 32 bit unsigned integer value giving the serial number of the corresponding CI-250$^{(+)}$ Computer Interface.

probe number
: 32 bit unsigned integer value giving the serial number of the corresponding E-field probe.

probe version
: 32 bit single-precision, floating-point value giving the version of the corresponding E-field probe.

step count
: 32 bit unsigned integer value giving the number of sweep steps S1 in the E-field waveform of the corresponding E-field probe, see »[:TRIGger]:SWeep:TCNT? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no valid sweep frequencies S1 is set to zero and the binary data block ends.

sample count
: 32 bit unsigned integer value giving the number of samples S2 in the sweep corrected E-field waveform of the corresponding E-field probe.

measurement axes number
: 32 bit unsigned integer value giving the number of evaluated axes, LSProbe 1v4 1 (x), LSProbe 1v2/2v0 3 (x,y,z)

index
: S1 32 bit unsigned integer values giving a list of center index values for the averaged portion of each sweep step of the E-field waveform as described in »[:TRIGger]:SWeep:IDX? [<MProbe>]«.

Frequencies
: S1 64 bit double-precision, floating-point values giving a list of the sweep frequency values for each sweep step of the E-field waveform as described in »[:TRIGger]:SWeep:LIST? [<MProbe>]«.

x-axis averaged E-field
: S1 32 bit single-precision, floating-point values giving a list of averaged x-axis E-field values in V/m of each sweep step within the E-field waveform, see »[:TRIGger]:SWeep[:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«.

y-axis averaged E-field
: S1 32 bit single-precision, floating-point values giving a list of averaged y-axis E-field values in V/m of each sweep step within the E-field waveform, see »[:TRIGger]:SWeep[:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«.

z-axis averaged E-field
: S1 32 bit single-precision, floating-point values giving a list of averaged z-axis E-field values in V/m of each sweep step within the E-field waveform, see »[:TRIGger]:SWeep[:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«.

averaged E-field magnitude
: S1 32 bit single-precision, floating-point values giving a list of averaged E-field magnitude values in V/m of each sweep step within the E-field waveform, see »[:TRIGger]:SWeep[:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«.

x-axis E-field waveform
: S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected x-axis E-field values in V/m of the E-field waveform, see »[:TRIGger]:SWeep:WEfield:X/Y/Z/MAG/ALL? [<MProbe>]«.

y-axis E-field waveform
: S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected y-axis E-field values in V/m of the E-field waveform, see »[:TRIGger]:SWeep:WEfield:X/Y/Z/MAG/ALL? [<MProbe>]«.

z-axis E-field waveform

S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected z-axis E-field values in V/m of the E-field waveform, see »[:TRIGger]:SWeep:WEfield:X/Y/Z/MAG/ALL? [<MProbe>]«.

E-field magnitude waveform

S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected E-field magnitude values in V/m of the E-field waveform, see »[:TRIGger]:SWeep:WEfield:X/Y/Z/MAG/ALL? [<MProbe>]«.

12.10 [:TRIGger]:RPower, Remote Power Measurement Commands

12.10.1 [:TRIGger]:RPower:TRIM <State>[,<MProbe>]

Enable/disable pulse edge trimming.

Parameter:

The mandatory first unsigned integer parameter State controls the trimming of pulse edges. If set to 0 all samples exceeding the pulse threshold will be treated as belonging to a pulse. If set to 1, the first and last sample of the pulse, which exceed the threshold will be trimmed, i.e., will not be used for computation of the arithmetic mean of the pulse. If a pulse contains only one or two values, the pulse's average value is defined as its largest sample value. Pulse length and start position are not affected by pulse trimming.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.2 [:TRIGger]:RPower:TRIM? [<MProbe>]

Query state of puls trimming.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

An unsigned integer value indicating state of pulse trimming, see »[:TRIGger]:RPower:TRIM <State>[,<MProbe>]«.

12.10.3 [:TRIGger]:RPower:DIST <Distance>[<MProbe>]

Set distance between the device under test, e.g., DUT, and field probe for remote power measurements.

Parameter:

The mandatory float value Distance sets the distance between the E-field probe and the DUT in meters. The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.4 [:TRIGger]:RPower:DIST? [<MProbe>]

Query distance between device under test, e.g., DUT, and field probe for remote power measurements.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
A float value indicating distance between E-field probe and the DUT in meters.

12.10.5 [:TRIGger]:RPower:MINTime <MinT>[<MProbe>]

Set minimum required pulse duration in seconds.

Parameter:
The mandatory float value MinT sets the minimum duration of a pulse in seconds. Shorter pulses will be discarded. The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.6 [:TRIGger]:RPower:MINTime? [<MProbe>]

Query minimum required pulse duration in seconds.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
A float value indicating minimum pulse duration in seconds.

12.10.7 [:TRIGger]:RPower:MINSamples <MinS>[<MProbe>]

Set minimum required pulse duration in samples.

Parameter:
The mandatory integer value MinS sets the minimum required duration of a pulse in samples. Shorter pulses will be discarded. The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.8 [:TRIGger]:RPower:MINSamples? [<MProbe>]

Query minimum required pulse duration in samples.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An unsigned integer value indicating minimum required pulse duration expressed in samples.

12.10.9 [:TRIGger]:RPower:THMethod <Method>[<MProbe>]

Set the method for setting the pulse threshold.

Parameter:
The mandatory string value Method sets the method of threshold detection. Parameters are given without quotation marks, valid methods are:

ABS, absolute threshold
When set to ABS, the threshold set by the SCPI command »[:TRIGger]:RPower:ATHold <Threshold>[<MProbe>]« is used.

REL, relative threshold
When set to REL, the threshold set by the SCPI command »[:TRIGger]:RPower:RTHold <Threshold>[<MProbe>]« is used.

HIST, histogram-based threshold
When set to HIST, the pulse threshold is determined based on the distribution of power values in the waveform. Typical probability distributions of power values have one peak at the power level of the inactive transmitter, i.e., noise level, and another peak at the power level of the active transmitter.
The threshold will be placed between these peaks, at the power level in the probability distribution that has the smallest probability according to the waveform's histogram at a resolution of 1 dB. The threshold must have a clearance greater than the value set via »[:TRIGger]:RPower:CLEARance <Clearance>[<MProbe>]« to either probability peak.

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.10 [:TRIGger]:RPower:THMethod? [<MProbe>]

Query the method for setting the pulse threshold.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
A string value indicating the set pulse threshold method, see »[:TRIGger]:RPower:THMethod <Method>[<MProbe>]« for details.

12.10.11 [:TRIGger]:RPower:ATHold <Threshold>[<MProbe>]

Set the absolute threshold for pulse detection.

Parameter:
The mandatory float value Threshold sets the threshold for detecting pulses in dBm. The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.12 [:TRIGger]:RPower:ATHold? [<MProbe>]

Query the absolute threshold for pulse detection.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
A float value indicating the absolue pulse detection threshold in dBm.

12.10.13 [:TRIGger]:RPower:RTHold <Threshold>[<MProbe>]

Set the relative threshold for pulse detection.

Parameter:
The mandatory float value Threshold, sets the threshold for detecting pulses relative to the maximum power value found in the waveform, expressed in dB relative to the maximum value. Values must be greater than zero. E.g., a Threshold value of 10 will set the dection threshold 10 dB below the highest power value in the waveform. The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.14 [:TRIGger]:RPower:RTHold? [<MProbe>]

Query the relative threshold for pulse detection.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
A float value indicating the pulse detection threshold expressed in dB relative to the maximum power value found in the waveform, see »[:TRIGger]:RPower:RTHold <Threshold>[<MProbe>]« for details.

12.10.15 [:TRIGger]:RPower:CLEARance <Clearance>[<MProbe>]

Set the clearance of smallest probability in the distribution to its neighboring probability peaks.

Parameter:

The mandatory float value Clearance sets the clearance for automatic pulse threshold setting in dB. The default value is set to 6 dB. See »[:TRIGger]:RPower:THMethod <Method>[<MProbe>]« for details.

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.16 [:TRIGger]:RPower:CLEARance? [<MProbe>]

Query the clearance of smallest probability in the distribution to its neighboring probability peaks.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A float value indicating the minimum clearence of the smallest probability in the distribution relative to its neighboring probability peaks.

12.10.17 [:TRIGger]:RPower:THold:X/[:Y]/:Z? [<MProbe>]

Query threshold value for pulse detection, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

A float value indicating the respective axis' pulse detection threshold in dBm. NAN will be returned, if there is no valid threshold value.

12.10.18 [:TRIGger]:RPower:MAVG <Count>[<MProbe>]

Set number of samples for moving average filter.

Parameter:

The mandatory integer value Count, sets the number of samples to use for calculating a moving average over Count samples. The filter is off if Count is set to one.

The optional unsigned integer parameter MProbe is described in Section 12.1.

12.10.19 [:TRIGger]:RPower:MAVG? [<MProbe>]

Query number of samples for moving average filter

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

An integer value indicating the number of samples used for calculating a moving average of power values.

12.10.20 [:TRIGger]:RPower[:APOWer]:X/[:Y]/Z? [<MProbe>]

Query averaged x-axis power value via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A float value indicating the arithmetic mean of all power values in the waveform of the respective axis which exceed the set threshold value and minimum pulse length.

12.10.21 [:TRIGger]:RPower:MPOWer:X/[:Y]/:Z? [<MProbe>]

Query power of pulse with the highest averaged power, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A float value indicating the arithmetic mean of all power values of the respective axis of the largest pulse in the waveform.

12.10.22 [:TRIGger]:RPower:DUTY:X/[:Y]/:Z? [<MProbe>]

Query duty cycle of power values, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:

A double value indicating the ratio of the number of the respective axis' samples, which exceed the set threshold value and minimum pulse length, and the total number of samples in the waveform.

12.10.23 [:TRIGger]:RPower:COUNt:X/[:Y]/:Z? [<MProbe>]

Query pulse count of power values, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
An integer value indicating the number of the respective axis' pulses which exceed the set threshold value and minimum pulse length.

12.10.24 [:TRIGger]:RPower:PULses[:TIMe]:X/[:Y]/:Z? [<MProbe>]

Query details of all pulses found in the waveform, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns one or multiple sets of three float values.
The first value indicates the start of the respective axis' pulse expressed in seconds relative to the beginning of the waveform. The second value gives the length of the pulse in seconds. The third value indicates arithmetic mean of all power values belonging to pulse. NAN will be returned if no pulses are detected.

12.10.25 [:TRIGger]:RPower:PULses:STArt:X/[:Y]/:Z? [<MProbe>]

Query start of all pulses found in the waveform. via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns one or multiple integer values indicating the start of the respective axis' pulses expressed in samples relative to the beginning of the waveform. NAN will be returned if no pulses are detected.

12.10.26 [:TRIGger]:RPower:PULses:LENgth:X/[:Y]/:Z? [<MProbe>]

Query length of all pulses found in the waveform, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
The command returns one or multiple values indicating the length of the respective axis' pulses as samples. NAN will be returned if no pulses are detected.

12.10.27 [:TRIGger]:RPower:PULses:Power:X/[:Y]/:Z? [<MProbe>]

Query power values of all pulses found in the waveform, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns one or multiple float values indicating the arithmetic mean of all power values belonging to a single pulse of the respective axis. NAN will be returned if no pulses are detected.

12.10.28 [:TRIGger]:RPower:WPower:X/[:Y]/:Z? [<MProbe>]

Query power value waveform, via :X?/[:Y]?/:Z? return results for x-, y- and z-axis values.

Parameter:
: The optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: The command returns a comma separated list of float-valued power values of the current waveform in dBm of the respective axis, applying the moving average whilst taking the moving average into account. NAN will be returned if the E-field probe is off, in start-up, if there is no valid calibration data or if the trigger system state is not equal to DONE.

12.10.29 [:TRIGger]:RPower:BINary? <Wave>[,<MProbe>]

Query details of all x-axis, y-axis and z-axis pulses found in the waveform in binary format for one or multiple E-field probes.

Parameters:
: The first mandatory integer-valued parameter Wave controls the output of remote power E-field wavefors. If set to 1 waveform output is enabled, if set to 0 waveform output is disabled.

  The second optional unsigned integer parameter MProbe is described in Section 12.1.

Return values:
: Binary data block followed by a carriage return, newline sequence. The first four bytes specify the number of bytes of the binary data block which will be returned following the first four bytes.

  For each probe P a chunk of binary data will be sent, one for each referenced E-field probe. All values are encoded in little endian format. If the probe P is not defined the computer interface serial number, probe serial number, probe serial version and sample count are set to zero and the binary data block ends. Data are ordered as follows:

CI number
: 32 bit unsigned integer value giving the serial number of the corresponding CI-250(+) Computer Interface.

probe number
: 32 bit unsigned integer value giving the serial number of the corresponding E-field probe.

probe version
: 32 bit single-precision, floating-point value giving the version of the corresponding E-field probe.

sample count
: 32 bit unsigned integer value giving the number of samples in the waveform of the corresponding E-field probe.

distance
: 32 bit single-precision, floating-point value giving the distance between DUT and field probe, see »[:TRIGger]:RPower:DIST? [<MProbe>]«.

minimum pulse duration
: 32 bit unsigned integer value giving the minimum pulse duration in samples used for pulse detection, see »[:TRIGger]:RPower:MINSamples? [<MProbe>]«.

moving average filter
: 32 bit unsigned integer value giving the number of samples used for calculating a moving average for pulse detection, see »[:TRIGger]:RPower:MAVG? [<MProbe>]«.

number of active axes
: 32 bit unsigned integer value giving the number of axes for which rpower values and waveforms are returned. LSProbe 1v4 one, LSProbe 1v2 and 2v0 3.

x-axis threshold value
: 32 bit single-precision, floating-point value giving the x-axis threshold value for pulse detection, see »[:TRIGger]:RPower:THold:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

y-axis threshold value
: 32 bit single-precision, floating-point value giving the y-axis threshold value for pulse detection, see »[:TRIGger]:RPower:THold:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

z-axis threshold value
: 32 bit single-precision, floating-point value giving the z-axis threshold value for pulse detection, see »[:TRIGger]:RPower:THold:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

x-axis averaged power

32 bit single-precision, floating-point value giving the averaged x-axis pulses' averaged power value, see »[:TRIGger]:RPower[:APOWer]:X/[:Y]/Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

y-axis averaged power

32 bit single-precision, floating-point value giving the averaged y-axis pulses' averaged power value, see »[:TRIGger]:RPower[:APOWer]:X/[:Y]/Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

z-axis averaged power

32 bit single-precision, floating-point value giving the averaged z-axis pulses' averaged power value, see »[:TRIGger]:RPower[:APOWer]:X/[:Y]/Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

x-axis maximum pulse

32 bit single-precision, floating-point value giving the power value of the largest x-axis pulse, see »[:TRIGger]:RPower:MPOWer:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

y-axis maximum pulse

32 bit single-precision, floating-point value giving the power value of the largest y-axis pulse, see »[:TRIGger]:RPower:MPOWer:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

z-axis maximum pulse

32 bit single-precision, floating-point value giving the power value of the largest z-axis pulse, see »[:TRIGger]:RPower:MPOWer:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

x-axis duty cycle

32 bit single-precision, floating-point value giving the duty cycle of x-axis power values, see »[:TRIGger]:RPower:DUTY:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

y-axis duty cycle

32 bit single-precision, floating-point value giving the duty cycle of y-axis power values, see »[:TRIGger]:RPower:DUTY:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

z-axis duty cycle

32 bit single-precision, floating-point value giving the duty cycle of z-axis power values, see »[:TRIGger]:RPower:DUTY:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the value is set to NAN.

x-axis pulse count

32 bit unsigned integer value giving the pulse count of x-axis power values Px, see »[:TRIGger]:RPower:COUNt:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the set threshold Px is set to zero.

y-axis pulse count

32 bit unsigned integer value giving the pulse count of y-axis power values Py, see »[:TRIGger]:RPower:COUNt:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the set threshold Py is set to zero.

z-axis pulse count

32 bit unsigned integer value giving the pulse count of z-axis power values Pz, see »[:TRIGger]:RPower:COUNt:X/[:Y]/:Z? [<MProbe>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no pulses detected above the set threshold Pz is set to zero.

start of x-axis pulses

Px 32 bit unsigned integer values giving a list of start indexes for all x-axis pulses expressed in samples relative to the beginning of the waveform, see »[:TRIGger]:RPower:PULses:STArt:X/[:Y]/:Z? [<MProbe>]«.

length of x-axis pulses

Px 32 bit unsigned integer values giving a list of pulse lengths for all x-axis pulses expressed in samples relative to the beginning of the waveform, see »[:TRIGger]:RPower:PULses:LENgth:X/[:Y]/:Z? [<MProbe>]«.

arithmetic mean of x-axis pulse power

Px 32 bit single-precision, floating-point values giving a list of the average power values for all x-axis pulses, see »[:TRIGger]:RPower:PULses:Power:X/[:Y]/:Z? [<MProbe>]«.

start of y-axis pulses

Py 32 bit unsigned integer values giving a list of the start of all y-axis pulses expressed in samples relative to the beginning of the waveform, see »[:TRIGger]:RPower:PULses:STArt:X/[:Y]/:Z? [<MProbe>]«.

length of y-axis pulses

Py 32 bit unsigned integer values giving a list of the length of all y-axis pulse expressed in samples relative to the beginning of the waveform, see »[:TRIGger]:RPower:PULses:LENgth:X/[:Y]/:Z? [<MProbe>]«.

arithmetic mean of y-axis pulse power
: Py 32 bit single-precision, floating-point values giving a list of all arithmetic mean values of all y-axis power values belonging to a pulse, see »[:TRIGger]:RPower:PULses:Power:X/[:Y]/:Z? [<MProbe>]«.

start of z-axis pulses
: Pz 32 bit unsigned integer values giving a list of the start of all z-axis pulses expressed in samples relative to the beginning of the waveform, see »[:TRIGger]:RPower:PULses:STArt:X/[:Y]/:Z? [<MProbe>]«.

length of z-axis pulses
: Pz 32 bit unsigned integer values giving a list of the length of all z-axis pulse expressed in samples relative to the beginning of the waveform, see »[:TRIGger]:RPower:PULses:LENgth:X/[:Y]/:Z? [<MProbe>]«.

arithmetic mean of z-axis pulse power
: Pz 32 bit single-precision, floating-point values giving a list of all arithmetic mean values of all z-axis power values belonging to a pulse, see »[:TRIGger]:RPower:PULses:Power:X/[:Y]/:Z? [<MProbe>]«.

sample count
: 32 bit unsigned integer value giving the number of samples S in the waveform of the corresponding E-field probe. The following binary data will contain S values for each of the following values. If there is no valid calibration data or if the trigger system state is not equal to DONE or if the parameter Wave is zero the number of samples is set to zero and the binary data block ends.

x-axis power waveform
: S 32 bit single-precision, floating-point values giving a list of x-axis power values in dBm of the E-field waveform.

y-axis power waveform
: S 32 bit single-precision, floating-point values giving a list of y-axis power values in dBm of the E-field waveform.

z-axis power waveform
: S 32 bit single-precision, floating-point values giving a list of z-axis power values in dBm of the E-field waveform.

12.11 :STATistics Commands

12.11.1 :STATistics:MAster <State>[,<MProbe>]

Set currently selected CI-250(+) Computer Interface to be the master or slave computer interface or software controlled for continuous statistics collection. The active CI-250(+) Computer Interface is set using »:SYSTem:CISerial <Value>«. By default all CI-250 Computer Interfaces are software controlled after enumeration in case of continuous statistics.

Parameters:

Setting State to 1 or MASTER makes the current CI-250$^{(+)}$ Computer Interface the master of the continuous statistics subsystem. A State of 0 resp. SLAVE makes the CI-250$^{(+)}$ Computer Interface a slave of the continuous statistics subsystem, i.e., continuous statistics will be controlled by a different CI-250$^{(+)}$ Computer Interface. A State of 2 or SOFT makes the continuous statistics of the CI-250$^{(+)}$ Computer Interface software based, i.e. statistics will be controlled via the commands »:STATistics:ENable <State>[,<MProbe>]« and »:STATistics:SNAPshot [<Triggered>][,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the state is to be set to 1 the MProbe parameter is ignored by the command.

12.11.2 :STATistics:MAster? [<MProbe>]

Query statistics subsystem master/slave/soft status of the currently active CI-250$^{(+)}$ Computer Interface. By default continuous statistics is software controlled for all enumerated CI-250 Computer Interfaces after start.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns an unsigned integer value containing the master/slave/soft status of the currently active CI-250$^{(+)}$ Computer Interface. Slaves return 0, the master returns 1, software controlled devices return 2.

12.11.3 :STATistics:ENable <State>[,<MProbe>]

Enable or disable statistics acquisition for statistics subsystem master CI-250$^{(+)}$ Computer Interface and/or all soft CI-250 Computer Interfaces. This command is only effective for CI-250 Computer Interfaces configured as the statistics subsystem master CI-250$^{(+)}$ Computer Interface or software controlled CI-250 Computer Interfaces, see »:STATistics:MAster <State>[,<MProbe>]«. Enabling statistics acquisition resets the snapshot counter queried via »:STATistics:COUnt? [<MProbe>]«.

Parameters:

Setting State to 1 activates statistics acquisition, setting State to 0 disables statistics acquisition for one or multiple E-field probes. Changing the state from disabled to enabled will reset and start statistics collection. Changing the state from enabled to disabled will trigger an automatic snapshot identical to issuing »:STATistics:SNAPshot [<Triggered>][,<MProbe>]« and stop statistics collection, see also »:STATistics:SNAPshot [<Triggered>][,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.11.4 :STATistics:ENable? [<MProbe>]

Query status of statistics acquisition for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer value containing the status of statistics acquisition. A value of 1 is returned when statistics acquisition is enabled, 0 is returned if statistics acquisition is disabled. The enable state of the statistics subsystem is controlled by the statistics subsystem master if synchronized statistics is used, see »:STATistics:MAster <State>[,<MProbe>]« and »:STATistics:ENable <State>[,<MProbe>]«. All statistics subsystem slave CI-250 Computer Interfaces are controlled by the statistics master CI-250(+) Computer Interface, their return value is thus always be identical to the master CI-250(+) Computer Interface if connected correctly.

12.11.5 :STATistics:LENgth <Length>[,<MProbe>]

Set number of samples to be used for continuous statistics acquisition for one or multiple E-field probes. The parameter can only be set when statistics acquisition is inactive.

Parameters:
The unsigned integer-valued parameter of the command specifies the number of consecutive samples to be used for statistics acquisition. E.g., »:STATistics:len 100« will record 100 consecutive samples. Setting Length to zero configures indefinite statistics acquisition, i.e., statistics aquisition needs to be terminated by issuing a »:STATistics:ENable? [<MProbe>]« command.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.11.6 :STATistics:LENgth? [<MProbe>]

Query number of statistics samples to be recorded for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of samples to be used for continuous statistics aquisition as specified using the »:STATistics:LENgth <Length>[,<MProbe>]« command. A value of zero indicates indefinite statistics acquisition.

12.11.7 :STATistics:SNAPshot [<Triggered>][,<MProbe>]

Create a snapshot of either continuously collected statistics or of waveforms recorded by the trigger subsystem for one or multiple E-field probes.

Parameters:

The optional integer-valued parameter Triggered selects the source for the statistics snapshot. If the parameter is omitted or set to 0 a snapshot of the continuously acquired statistics is created for subsequent analysis. This type of statistics snapshot is triggered by the CI-250$^{(+)}$ Computer Interface configured as the statistics subsystem master or immediately executed via software for all CI-250 Computer Interfaces configured as soft, see »:STATistics:MAster <State>[,<MProbe>]«. Additionally, statistics acquisition must be enabled using »:STATistics:ENable <State>[,<MProbe>]« before creating a snapshot.

If the parameter Triggered is set to 1 the most recently acquired triggered waveforms are analyzed to obtain a statistics snapshot for subsequent analysis. This kind of snapshot can only be created for one CI-250$^{(+)}$ Computer Interface or multiple CI-250 Computer Interfaces at a time, see the description of the second parameter below.

The second, optional unsigned integer parameter MProbe determines the Multiprobe behavior of the command as described in the parameter of »:SYSTem:CISerial? [<MProbe>]«. If the parameter MProbe is set the parameter Triggered is mandatory. For synchronized continuous statistics only CI-250 Computer Interfaces configured as the statistics master CI-250$^{(+)}$ Computer Interface will output a snapshot trigger signal. In case of software controlled devices a snapshot snapshot is created immediately.

12.11.8 :STATistics:COUnt? [<MProbe>]

Return continuous statistics snapshot counter for one or multiple E-field probes.

The optional unsigned integer parameter MProbe determines the Multiprobe behavior of the command as described in the parameter of »:SYSTem:CISerial? [<MProbe>]«.

Return value:

The command returns an unsigned integer value giving the number of snapshots taken for the selected CI-250$^{(+)}$ Computer Interface since the start of the last enabling of statistics acquisition.

12.11.9 :STATistics:RESolution <Resolution>[,<MProbe>]

Set resolution for histograms and distribution functions for one or multiple E-field probes.

Parameters:

The float-valued parameter Resolution specifies the field strength resolution in dB for all statistics query commands returning histograms and distribution functions. E.g., a value of 1.0 will output histograms with a bin size of 1 dB. Bins are aligned relative to and centered around 1 V/m. The smallest permissible value for Resolution is 0.005 dB. The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.11.10 :STATistics:RESolution? [<MProbe>]

Query resolution in dB for histograms and distribution functions for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns a float value giving the field strength resolution in dB for all statistics query commands returning histograms and distribution functions.

12.11.11 :STATistics:HISTogram:SIZe? [<Triggered>][,<MProbe>]

Query number of bins for histograms and distribution functions for one or multiple E-field probes.

Parameters:
If no parameter is provided or if Triggered is set to 0 the number of bins for the most recently created snapshot histograms and distribution functions based on continuous statistics acquisition is returned. If the parameter Triggered is set to 1 the number of bins for the most recently created snapshot histograms and distribution functions based on triggered waveforms is returned.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the parameter MProbe is set the parameter Triggered is mandatory.

Return value:
The command returns an unsigned integer value giving the number of histogram bins for the set resolution, see »:STATistics:RESolution <Resolution>[,<MProbe>]«. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.12 :STATistics:HISTogram:OFFset? [<Triggered>][,<MProbe>]

Query offset of the first bin of all histograms and distribution functions, expressed as a multiple of the histogram's resolution, i.e., bin size, relative to 1 V/m, for one or multiple E-field probes.

Parameters:
If no parameter is provided or if Triggered is set to 0 the offset for the most recently created snapshot histograms and distribution functions based on continuous statistics acquisition is returned. If the parameter Triggered is set to 1 the offset for the most recently created snapshot histograms and distribution functions based on triggered waveforms is returned.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the parameter MProbe is set the parameter Triggered is mandatory.

Return value:

The command returns an integer value for the presently set resolution, see »:STATistics:RESolution <Resolution>[,<MProbe>]«. E.g., when the resolution is set to 1 dB, a return value of -20 indicates that the first bin of the histogram covers 0.1 V/m ±0.5 dB. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.13 :STATistics:SAMples? [<Triggered>][,<MProbe>]

Query number of sample values used for statistics acquisition for one or multiple E-field probes.

Parameters:

If no parameter is provided or if Triggered is set to 0 the number of samples per axis used for the most recently created statistics snapshot based on continuous statistics acquisition is returned. If the parameter Triggered is set to 1 the number of samples per axis used for the most recently created statistics snapshot based on triggered waveforms is returned, i.e., the number of samples returned by »:TRIGger:LENgth <Length>[,<MProbe>]«.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the parameter MProbe is set the parameter Triggered is mandatory.

Return value:

The command returns an unsigned 64 bit integer value giving the number of samples used to build the respective histogram. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.14 :STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength minimum of the most recent statistics snapshot or waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?

x-, y- or z-axis E-field component value,

:MAGnitude?

E-field magnitude,

:ALL?

all four results above as a list.

Parameters:

If no parameter is provided or if Triggered is set to 0 the E-field strength minimum for the most recently created statistics snapshot based on continuous statistics acquisition is returned. If the parameter Triggered is set to 1 the E-field strength minimum of the most recently created statistics snapshot based on the current waveforms is returned.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the parameter MProbe is set the parameter Triggered is mandatory.

Return value:

The command returns a float-valued E-field minimum value in V/m. If ALL values are queried, a list of four values is returned. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.15 :STATistics:MAXimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength maximum of the most recent statistics snapshot or waveform for one or multiple E-field probes, see »:STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]« for description of parameters and return values.

12.11.16 :STATistics:MEAN:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength arithmetic mean of the most recent statistics snapshot or waveform for one or multiple E-field probes, see »:STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]« for description of parameters and return values.

12.11.17 :STATistics:RMS:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength root mean square of the most recent statistics snapshot or waveform for one or multiple E-field probes, see »:STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]« for description of parameters and return values.

12.11.18 :STATistics:SDEViation:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength standard deviation of the most recent statistics snapshot or waveform for one or multiple E-field probes, see »:STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]« for description of parameters and return values.

12.11.19 :STATistics:Efield? [<Triggered>][,<MProbe>]

Query center field strengths of bins used by histograms and distribution functions for one or multiple E-field probes.

Parameters:

If no parameter is provided or if Triggered is set to 0 the center field strengths of all bins for the most recently created statistics snapshot based on continuous statistics acquisition are returned. If the parameter Triggered is set to 1 the center field strengths of the most recently created statistics snapshot based on triggered waveforms are returned.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the parameter MProbe is set the parameter Triggered is mandatory.

Return values:

The command returns a comma-separated list of float-valued E-field strengths in V/m. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.20 :STATistics:HISTogram:X/Y/Z/MAG? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength histogram of the most recent statistics snapshot or waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component value,

:MAGnitude?
: E-field magnitude.

Parameters:

If no parameter is provided or if Triggered is set to 0 the single axis or magnitude E-field strength histogram for the most recently created statistics snapshot based on continuous statistics acquisition are returned. If the parameter Triggered is set to 1 the E-field strength histogram of the most recently created statistics snapshot based on the current waveforms are returned.

The second, optional unsigned integer parameter MProbe is described in Section 12.1. If the parameter MProbe is set the parameter Triggered is mandatory.

Return values:

The command returns a comma-separated list of unsigned 64 bit integer values specifying the number of samples of a field strength falling into the associated field strength bins returned by »:STATistics:Efield? [<Triggered>][,<MProbe>]«. The bin size is specified by »:STATistics:RESolution <Resolution>[,<MProbe>]«. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.21 :STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength discrete relative probability distribution of the most recent statistics snapshot or waveform for one or multiple E-field probes.

Return result for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component value,

:MAGnitude?
E-field magnitude.

Parameters:
See »:STATistics:HISTogram:X/Y/Z/MAG? [<Triggered>][,<MProbe>]« parameter description for details.

Return values:
The command returns a list of float-valued discrete relative probabilities of single axis or magnitude E-field strength. Each value is associated with a field strength bin returned by »:STATistics:Efield? [<Triggered>][,<MProbe>]«. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.11.22 :STATistics:CDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength discrete cumulative probability distribution of the most recent statistics snapshot or waveform for one or multiple E-field probes, see »:STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]« for description of parameters and return values.

12.11.23 :STATistics:CCDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]

Query single axis or magnitude E-field strength discrete complementary cumulative probability distribution of the most recent statistics snapshot or waveform for one or multiple E-field probes, see »:STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]« for description of parameters and return values.

12.11.24 :STATistics:BINary? [<Triggered>][,<MProbe>]

Query all statistical values of the most recent statistics snapshot or triggered waveform in binary format for one or multiple E-field probes. This command can be used to reduce communications overhead when polling statistical values via software.

Parameters:
See »:STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]« parameter description for details.

Return values:
Binary data block followed by a carriage return, newline sequence. The first four bytes specify the number of bytes of the binary data block which will be returned following the first four bytes.

For each probe P a chunk of binary data will be sent. All values are encoded in little endian format. Data are ordered as follows:

CI number

32 bit unsigned integer value giving the serial number of the corresponding CI-250(+) Computer Interface. If the probe P is not defined the computer interface serial number, probe serial number, probe version and bin count are set to zero and the binary data block ends.

probe number

32 bit unsigned integer value giving the serial number of the corresponding E-field probe. If the E-field probe is off or in start-up the probe serial number and bin count is set to zero and the binary data block ends.

probe version

32 bit single-precision, floating-point value giving the version of the corresponding E-field probe.

bin count

Four bytes specifying the number of bins N contained in the following binary data, the value is a 32 bit unsigned integer value. If there is no valid statistics snapshot data N will have a value of zero and no further data will be returned for the binary data chunk.

measurement value number

Four bytes specifying the number of measurement values contained in the following binary data, the value is a 32 bit unsigned integer value. For LSProbe 1v2 and 2v0 4 (x, y, z, magnitude) and for LSProbe 1v4 1 (x) is returned

histogram offset

32 bit signed integer value as described in »:STATistics:HISTogram:OFFset? [<Triggered>][,<MProbe>]«.

samples

64 bit unsigned integer value as described in »:STATistics:SAMples? [<Triggered>][,<MProbe>]«.

resolution

32 bit single-precision, floating-point value as described in »:STATistics:RESolution? [<MProbe>]«.

minimum

measurement value number 32 bit single-precision, floating-point values as described in »:STATistics:MINimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]«.

maximum

measurement value number 32 bit single-precision, floating-point values as described in »:STATistics:MAXimum:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]«.

arithmetic mean

measurement value number 32 bit single-precision, floating-point values as described in »:STATistics:MEAN:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]«.

root mean square

measurement value number 32 bit single-precision, floating-point values as described in »:STATistics:RMS:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]«.

standard deviation
: measurement value number 32 bit single-precision, floating-point values as described in »:STATistics:SDEViation:X/Y/Z/MAG/ALL? [<Triggered>][,<MProbe>]«.

bins
: N 32 bit single-precision, floating-point values as described in »:STATistics:Efield? [<Triggered>][,<MProbe>]«.

histogram, x
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«.

histogram, y
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

histogram, z
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

histogram, magnitude
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative probability, x
: N 32 bit single-precision, floating-point values as described in »:STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«.

relative probability, y
: N 32 bit single-precision, floating-point values as described in »:STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative probability, z
: N 32 bit single-precision, floating-point values as described in »:STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative probability, magnitude
: N 32 bit single-precision, floating-point values as described in »:STATistics:PDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative cumulative probability, x
: N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«.

relative cumulative probability, y

N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative cumulative probability, z

N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative cumulative probability, magnitude

N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative complementary cumulative probability, x

N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«.

relative complementary cumulative probability, y

N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative complementary cumulative probability, z

N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

relative complementary cumulative probability, magnitude

N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:X/Y/Z/MAG? [<Triggered>][,<MProbe>]«, skipped in case of LSProbe 1v4 devices.

12.11.25 :STATistics:STEPwise:SAMPles <Samples>[,<MProbe>]

Set number of samples to reduce the sampling rate for one or multiple E-field probes.

Parameters:

The unsigned integer-valued parameter of the command specifies the number of samples to combine to reduce the sampling rate. E.g., »:stat:step:sam 100« will generate the average, maximum and minimum field strength value for each interval of 100 samples, thus reducing the sampling rate by a factor of 0.01 after enabling the continuous statistic recording. Setting Samples to zero will disable sampling reduction.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.11.26 :STATistics:STEPwise:SAMPles? [<MProbe>]

Query sampling rate decimation for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer-valued number of samples to reduce the sampling rate, corresponding to the length set by »:STATistics:STEPwise:SAMPles <Samples>[,<MProbe>]«.

12.11.27 :STATistics:STEPwise:X <State>[,<MProbe>]:X

Enable/disable output of respective values via »:STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]« for one or multiple CI-250 Computer Interfaces.

Parameters:
Setting State to 1 activate, setting State to 0 disables the respective output:

:X/:Y/:Z
Enable/disable output of x-, y- or z-axis E-field component values

:MAGnitude
Enable/disable output of E-field magnitude,

:MINimum
Enable/disable output of minimum value for x-, y-, z- and magnitue E-field values.

:MAXimum
Enable/disable output of maximum value for x-, y-, z- and magnitue E-field values.

:MEAN
Enable/disable output of averaged value for x-, y-, z- and magnitue E-field values.

The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.11.28 :STATistics:STEPwise:X? [<MProbe>]:X

Query output of respective values via »:STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]« for one or multiple CI-250 Computer Interfaces.

Return result for one of:

:X/:Y/:Z
output status of x-, y- or z-axis E-field component values

:MAGnitude
output status of E-field magnitude,

:MINimum
output status of minimum value for x-, y-, z- and magnitue E-field values.

:MAXimum
output status of maximum value for x-, y-, z- and magnitue E-field values.

:MEAN
output status of averaged value for x-, y-, z- and magnitue E-field values.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer value containing the status of the output of the respective values via »:STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]«. A value of 1 is returned when the respective values are returned, 0 is returned if output is disabled.

12.11.29 :STATistics:STEPwise:COUNt? [<MProbe>]

Query number of overall stat-stepwise samples since start of continuous statistic or reset of stat-stepwise sampling for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer value stating the number of step-wise samples that were calculated since start of continuous statistic or reset of stat-stepwise sampling. E.g. if step-wise samples was set to four and the sampling rate for the current mode is 500.000 samples per second, after 10 seconds approximately 1.25 Million step-wise samples were received.

12.11.30 :STATistics:STEPwise:CCOUNt? [<MProbe>]

Query number of available samples in step-wise statistics fifo for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned 64 bit integer value stating the number of available values in the step-wise statistics fifo. Maximum number is 1024.

12.11.31 :STATistics:STEPwise:SCOUNt? [<MProbe>]

Query number of overall samples since start of continuous statistic or reset of stat-stepwise sampling for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned 64 bit integer value stating the number of samples used for calculating the step-wise values since start of continuous statistic or reset of stat-stepwise sampling. It is in accordance with the current sampling rate.

12.11.32 :STATistics:STEPwise:SNAPRESet <State>[,<MProbe>]

Enable or disable reset of step-wise statistics on next statistic snapshot signal for one or multiple CI-250 Computer Interfaces.

Parameters:
Setting State to 1 activates ready state for reset on next statistics snapshot signal. Setting State to 0 disables ready state for reset on next statistics snapshot signal. A statistics snapshot signal is either received via the scpi command »:STATistics:SNAPshot [<Triggered>][,<MProbe>]« for not synchronized statistics or the statistic master, or via the dedicated signal line for synchronized statistics. Resetting of step-wise statistics in cojunction with statistics snapshot due to option to reset step-wise statistics for MPRobe systems in a synchronzied fashion. The second optional unsigned integer parameter MProbe is described in Section 12.1.

12.11.33 :STATistics:STEPwise:SNAPRESet? [<MProbe>]

Query state of step-wise statistics reset on next receiving of a statistics snapshot signal for one or multiple CI-250 Computer Interfaces.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer value containing the status of step-wise statistics resetting on next statistics snapshot. A value of 1 is returned when resetting on next statistics snapshot is enabled, 0 is returned if disabled.

12.11.34 :STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]

Query all available values in step-wise statistics fifo in accordance with set values of interest via »:STATistics:STEPwise:X <State>[,<MProbe>]:X« for one or multiple CI-250 Computer Interfaces.

Parameters:

The optional integer-valued parameter Greedy states if the read position of the step-wise value fifo is to be adapted, e.g. set to position of the next incoming value. All following »:STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]« queries will only return future values. If the Greedy parameter is omitted or set to one, the read position of the fifo will be moved up to current fifo write position. If Greedy is set to zero, the fifo read position remains at its current position, so long as no fifo overrun occurs.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

Return Values: For each step-wise value, the minimum, the maximum and the arithmetic mean (in this order) of x-, y-, z- and E-field magnitude will be returned. This results in the command returning »:STATistics:STEPwise:CCOUNt? [<MProbe>]« multiples of at a max of 12 float-valued, comma-separated values. If a return value is diabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«, fewer values are returned.

Measurements are returned in the following order:

- minimum x-axis E-field value if return of x-axis value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum x-axis E-field value if return of x-axis value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged x-axis E-field value if return of x-axis value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- minimum y-axis E-field value if return of y-axis value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum y-axis E-field value if return of y-axis value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged y-axis E-field value if return of y-axis value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- minimum z-axis E-field value if return of z-axis value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum z-axis E-field value if return of z-axis value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged z-axis E-field value if return of z-axis value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- minimum E-field magnitude value if return of magnitude value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum E-field magnitude value if return of magnitude value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged E-field magnitude value if return of magnitude value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«

12.11.35 :STATistics:STEPwise:CVALues? [<Greedy>,<MProbe>]

Query number and all available values in step-wise statistics fifo in accordance with set values of interest via »:STATistics:STEPwise:X <State>[,<MProbe>]:X« for one or multiple CI-250 Computer Interfaces.

Parameters:

The optional integer-valued parameter Greedy states if the read position of the step-wise value fifo is to be adapted, e.g. set to position of the next incoming value. All following »:STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]« queries will only return future values. If the Greedy parameter is omitted or set to one, the read position of the fifo will be moved up to current fifo write position. If Greedy is set to zero, the fifo read position remains at its current position, so long as no fifo overrun occurs.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

Return Values: First the number of available step-wise values is returned. Next for each step-wise value, the minimum, the maximum and the arithmetic mean (in this order) of x-, y-, z- and E-field magnitude will be returned. This results in the command returning »:STATistics:STEPwise:CCOUNt? [<MProbe>]« multiples of at a max of 12 float-valued, comma-separated values. If a return value is diabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«, fewer values are returned.

Measurements are returned in the following order:

- minimum x-axis E-field value if return of x-axis value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum x-axis E-field value if return of x-axis value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged x-axis E-field value if return of x-axis value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- minimum y-axis E-field value if return of y-axis value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum y-axis E-field value if return of y-axis value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged y-axis E-field value if return of y-axis value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- minimum z-axis E-field value if return of z-axis value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- maximum z-axis E-field value if return of z-axis value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged z-axis E-field value if return of z-axis value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- minimum E-field magnitude value if return of magnitude value and minimum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«

- maximum E-field magnitude value if return of magnitude value and maximum is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«
- averaged E-field magnitude value if return of magnitude value and mean is enabled via »:STATistics:STEPwise:X <State>[,<MProbe>]:X«

12.11.36 :STATistics:STEPwise:BINary? [<Greedy>,<MProbe>]

Query all current statist step values in binary format for one or multiple E-field probes. This command can be used to reduce communications overhead when polling step-wise statistics values.

Parameters:

See »:STATistics:STEPwise:VALues? [<Greedy>,<MProbe>]« parameter description for details.

Return values:

Binary data block followed by a carriage return, newline sequence. The first four bytes specify the number of bytes of the binary data block which will be returned following the first four bytes.

For each probe P a chunk of binary data will be sent. All values are encoded in little endian format. Data are ordered as follows:

CI number

32 bit unsigned integer value giving the serial number of the corresponding CI-250$^{(+)}$ Computer Interface. If the probe P is not defined the computer interface serial number, probe serial number, probe version and bin count are set to zero and the binary data block ends.

probe number

32 bit unsigned integer value giving the serial number of the corresponding E-field probe. If the E-field probe is off or in start-up the probe serial number and bin count is set to zero and the binary data block ends.

probe version

32 bit single-precision, floating-point value giving the version of the corresponding E-field probe.

value count

32 bit unsigned integer value giving the number N of the 3*M step-wise values contained in the following binary data. If there is no valid step-wise statistics data , N will have a value of zero and no further data will be returned for the binary data chunk.

axes no

32 bit unsigned integer value giving the number M of the acitve axes. For LSprobe 1.2 4, for LSPRobe 1v4 1.

minimum, x

N 32 bit single-precision, floating-point values giving the minimum step-wise x-axis E-field values in V/m.

minimum, y
: N 32 bit single-precision, floating-point values giving the minimum step-wise y-axis E-field values in V/m, skipped in case of LSProbe 1v4 devices..

minimum, z
: N 32 bit single-precision, floating-point values giving the minimum step-wise z-axis E-field values in V/m, skipped in case of LSProbe 1v4 devices..

minimum, magnitude
: N 32 bit single-precision, floating-point values giving the minimum step-wise E-field magnitude values in V/m, skipped in case of LSProbe 1v4 devices..

maximum, x
: N 32 bit single-precision, floating-point values giving the maximum step-wise x-axis E-field values in V/m.

maximum, y
: N 32 bit single-precision, floating-point values giving the maximum step-wise y-axis E-field values in V/m, skipped in case of LSProbe 1v4 devices..

maximum, z
: N 32 bit single-precision, floating-point values giving the maximum step-wise z-axis E-field values in V/m, skipped in case of LSProbe 1v4 devices..

maximum, magnitude
: N 32 bit single-precision, floating-point values giving the maximum step-wise E-field magnitude values in V/m, skipped in case of LSProbe 1v4 devices..

average, x
: N 32 bit single-precision, floating-point values giving the averaged step-wise x-axis E-field values in V/m.

average, y
: N 32 bit single-precision, floating-point values giving the averaged step-wise y-axis E-field values in V/m, skipped in case of LSProbe 1v4 devices..

average, z
: N 32 bit single-precision, floating-point values giving the averaged step-wise z-axis E-field values in V/m, skipped in case of LSProbe 1v4 devices..

average, magnitude
: N 32 bit single-precision, floating-point values giving the averaged step-wise E-field magnitude values in V/m, skipped in case of LSProbe 1v4 devices..

12.12 :MProbe Commands

12.12.1 :MProbe:SETS?

Query list of defined Multiprobe systems.

Return values:

Comma-separated list of unsigned integers designating all user-defined Multiprobe systems, i.e. excluding "0". NAN is returned if there are no user-defined Multiprobe systems.

12.12.2 :MProbe:FPSerial <MProbe>,<Probe1>[,<Probe2>,...,<ProbeN>]

Define a Multiprobe system by specifying one or multiple E-field probe serial numbers. The old syntax »:MProbe:SET <MProbe>,<Probe1>[,<Probe2>,...,<ProbeN>]« remains supported.

Parameters:

The first unsigned integer parameter MProbe sets the Multiprobe system number for a Multiprobe setup. MProbe must be greater that zero. MProbe does not specify the number of field probes in the Multiprobe system.

The following unsigned integer parameters Probe1 through ProbeN specify the E-field probe serial numbers for each E-field probe in a Multiprobe setup. Individual field probes may be referenced multiple times by one or more Multiprobe systems. Probe serial numbers must be set to one of the active probes queried via »:MEASure[:FProbe]:SERialnumber? [<MProbe>]«, unknown probe serial numbers will cause empty output off Multiprobe commands. Alternatively Probe1 through ProbeN may be given as a string stating the serial number and revision string of the respective E-field probe, separated by a ":", e.g. "3:2.0". In case of enumerated devices with the same serial number but different revisions, e.g. LSProbe 1.2 #45 and LSProbe 2.0 #45 the string containing the serial number and revision has to be stated to avoid ambiguity.

12.12.3 :MProbe:FPSerial? <MProbe>

Query E-field probe serial number(s) for Multiprobe systems. This command is an alias of »:MEASure[:FProbe]:SERialnumber? [<MProbe>]« when used with the same MProbe parameter. The old syntax »:MProbe:GET? <MProbe>« remains supported.

Parameters:

The unsigned integer parameter MProbe specifies the Multiprobe system number defined either automatically, as for setup number 0, or via »:MProbe:FPSerial <MProbe>,<Probe1>[,<Probe2>,...,<ProbeN>]« or »:MProbe:CISerial <MProbe>,<Ci1>[,<Ci2>,...,<CiN>]« for setup numbers greater than zero.

Return values:

Comma-separated list of unsigned integers indicating the E-field probe serial numbers set for the Multiprobe system specified by the parameter MProbe. NAN will be returned instead of probe serial numbers if the specified Multiprobe system has not been configured correctly, a configured E-field probe is off or in start-up.

12.12.4 :MProbe:CISerial <MProbe>,<Ci1>[,<Ci2>,...,<CiN>]

Define a Multiprobe system by specifying one or multiple CI-250$^{(+)}$ Computer Interface serial numbers. The old syntax »:MProbe:SETCi <MProbe>,<Ci1>[,<Ci2>,...,<CiN>]« remains supported.

Parameters:

The first unsigned integer parameter MProbe sets the Multiprobe system number for a Multiprobe setup. MProbe must be greater that zero. MProbe does not specify the number of field probes in the Multiprobe system.

The following unsigned integer parameters Ci1 through CiN specify the CI-250$^{(+)}$ Computer Interface serial numbers of a Multiprobe setup. Individual CI-250 Computer Interfaces may be referenced multiple times by one or more Multiprobe systems. CI-250$^{(+)}$ Computer Interface serial numbers must be set to one of the enumerated CI-250 Computer Interfaces queried via »:SYSTem:CISerial? [<MProbe>]« unknown CI-250$^{(+)}$ Computer Interface serial numbers will cause the command to fail. The command does not depend on the state of the E-field probes. Specifically, the supply laser(s) need not be enabled for the command to produce a valid setup.

12.12.5 :MProbe:CISerial? <MProbe>

Query CI-250$^{(+)}$ Computer Interface serial number(s) for Multiprobe systems. This command is an alias of »:SYSTem:CISerial? [<MProbe>]« when used with an MProbe parameter. The old syntax »:MProbe:GETCi? <MProbe>« remains supported.

Parameters:

The unsigned integer parameter MProbe specifies the Multiprobe system number defined either automatically for setup number 0, or via »:MProbe:FPSerial <MProbe>,<Probe1>[,<Probe2>,...,<ProbeN>]« or »:MProbe:CISerial <MProbe>,<Ci1>[,<Ci2>,...,<CiN>]« for setup numbers greater than zero.

Return values:

Comma-separated list of unsigned integers indicating the CI-250$^{(+)}$ Computer Interface serial numbers for the Multiprobe system specified by the parameter MProbe. NAN will be returned instead of the CI-250$^{(+)}$ Computer Interface serial number if the specified Multiprobe system has not been configured. The output of the command does not depend on the state of the field probes. Specifically, the supply laser(s) need not be enabled for the command to return a valid result.

12.12.6 :MProbe:TPStat:X/Y/Z/MAG/E3/ALL? <TSpec>,<PSpec>,<T.>,<MPr.>

First evaluate statistics of multiple probes individually in time domain, then perform statistic evaluation across these probes. Return result for one of:

:X?/:Y?/:Z?

x-, y- or z-axis E-field component value,

:MAGnitude?
E-field magnitude,

:E3?
combined x-, y- and z-axis E-field component values,

:ALL?
all five results above as a list.

Parameters:

The first string-valued parameter TSpec specifies the initial time-domain statistics operation to be peformed for each field probe. Valid values are MAX, MIN and MEAN, for maximum, minimum and arithmetic mean of field strength values.

The second string-valued parameter PSpec specifies the secondary probe-domain statistics operation to be peformed on the time-domain results of all field probes. Valid values are MAX, MIN and MEAN, for maximum, minimum and arithmetic mean of field strength values.

The third unsigned integer parameter Triggered specifies if the time-domain statistics operation is performed on continuous statistics (set to 0), or the present waveform values (set to 1).

The fourth unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a float-valued E-field strength for the stated MProbe system in V/m. If ALL statistics are queried, a list of five values is returned. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.12.7 :MProbe:RATIO:X/Y/Z/MAG/E3/ALL? <Triggered>][,<MProbe>]

Query the quotient of maximum and arithmetic mean of E-field strength, averaged over multiple field probes. Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component value,

:MAGnitude?
E-field magnitude,

:E3?
combined x-, y- and z-axis E-field component values,

:ALL?
all five results above as a list.

Firstly, the query determines the time-domain maximum for each field probe and then calculates the arithmetic mean across all field probes. Secondly, the query determines the time-domain arithmetic mean for each field probe and then calculates the arithmetic mean across all field probes. Thirdly, the quotient of the prior two values is calculated and returned.

Parameters:

The first unsigned integer parameter Triggered specifies if the time-domain statistics operation is performed on continuous statistics (set to 0), or the present waveform values (set to 1).

The second unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a float-valued E-field strength of the stated MProbe system in V/m. If ALL statistics are queried, a list of five values is returned. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.12.8 :MProbe:CDF[:AT]:X/Y/Z/MAG/E3/ALL? <Probability>,<Trig.>,<MProbe>

Query x-axis E-field value where the discrete cumulative probability distribution exceeds the parameter Probability for all E-field probes of the stated Multi-probe System. Use the most recent statistics snapshot or triggered waveform. Return result for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component value,

:MAGnitude?
: E-field magnitude,

:E3?
: combined x-, y- and z-axis E-field component values,

:ALL?
: all five results above as a list.

Parameters:

The mandatory float-valued parameter Probability sets the threshold value for the query. The value must be greater than zero and less than one. See »:MProbe:RATIO:X/Y/Z/MAG/E3/ALL? <Triggered>][,<MProbe>]« for the description of the parameters Triggered and MProbe.

Return values:

The command returns a float-valued E-field strength. If ALL statistics are queried, a list of five values is returned. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.12.9 :MProbe:CDF:WAVEFORM:X/Y/Z/MAG/E3/ALL? <Triggered>,<MProbe>

Query discrete cumulative probability distribution of the E-field strength for all E-field probes of the stated Multi-probe System. Return result for one of:

:X?/:Y?/:Z?
: x-, y- or z-axis E-field component value,

:MAGnitude?
E-field magnitude,

:E3?
combined x-, y- and z-axis E-field component values,

:ALL?
all five results above as a list.

Parameters:
See »:MProbe:RATIO:X/Y/Z/MAG/E3/ALL? <Triggered>][,<MProbe>]« for the description of the parameters Triggered and MProbe.

Return values:
The command returns a list of float-valued probability values. Each value is associated with a field strength bin returned by »:MProbe:Efield? <Triggered>,<MProbe>«. If ALL statistics are queried, a list of five lists is returned. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.12.10 :MProbe:PDF:X/Y/Z/MAG/E3/ALL? <Triggered>,<MProbe>

Query discrete relative probability distribution of the E-field strength for all E-field probes of the stated Multi-probe System. Use the most recent statistics snapshot or triggered waveform. Return result for one of:

:X?/:Y?/:Z?
x-, y- or z-axis E-field component value,

:MAGnitude?
E-field magnitude,

:E3?
combined x-, y- and z-axis E-field component values,

:ALL?
all five results above as a list.

Parameters:
See »:MProbe:RATIO:X/Y/Z/MAG/E3/ALL? <Triggered>][,<MProbe>]« for the description of the parameters Triggered and MProbe.

Return values:
The command returns a list of float-valued probability values. Each value is associated with a field strength bin returned by »:MProbe:Efield? <Triggered>,<MProbe>«. If ALL statistics are queried, a list of five lists is returned. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.12.11 :MProbe:Efield? <Triggered>,<MProbe>

Query center field strengths of bins used by all Mulitprobe distribution queries.

Parameters:

If the first mandatory parameter Triggered is set to 0 the center field strengths of all bins for the most recently created statistics snapshot based on continuous statistics acquisition are returned. If the parameter Triggered is set to 1 the center field strengths of the most recently created statistics snapshot based on triggered waveforms are returned.

The second, unsigned integer parameter MProbe is described in Section 12.1.

Return values:

The command returns a comma-separated list of float-valued E-field strengths in V/m. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

12.12.12 :MProbe:AMAGnitude? <Triggered>,<MProbe>[,<RProbe>]

Query averaged magnitude of a Multiprobe system.

Parameters:

The first parameter Triggered is used to select the source of statistics data. If set to zero snapshots of continuously collected data will be used for averaged magnitude calculation. If set to one triggered waveform data will be used to calculate the averaged magnitude.

The second unsigned integer parameter MProbe is described in Section 12.1.

The third optional parameter specifies the number of reference probes RProbe used in the Multiprobe system. If omitted no reference probes will be used. The last RProbe E-field probes are used as reference probes.

Return values:

RProbe plus one float-valued E-field magnitude values will be returned. The first value is generated by calculating the arithmetic mean of the arithmetic mean of all magnitude values for the first MProbe minus RProbe E-field probes. The following RProbe floating point value(s) give the arithmetic mean of the magnitude values for each reference probe.

NAN will be returned if the Multiprobe system setup is invalid, a E-field probe is off, a probe is in start-up, there is no snapshot data available or if the statistical data could not be computed.

12.12.13 :MProbe:MAXStatistics? <Triggered>,<MProbe>

Query maximum E-field statistics summary of a Multiprobe system.

Parameters:

The first parameter Triggered is used to select the source of statistics data. If set to zero snapshots of continuously collected data will be used for statistical summary calculation. If set to one triggered waveform data will be used to calculate the statistical summary.

The second parameter MProbe specifies the total number of E-field probes in the Multiprobe system whose statistical summary is to be calculated.

Return values:

List of twelve 32 bit single-precision, floating-point values containing the following statistics:

- The arithmetic mean of the maximum x-axis E-field component values of every probe in the specified Multiprobe system.
- The arithmetic mean of the maximum y-axis E-field component values of every probe in the specified Multiprobe system.
- The arithmetic mean of the maximum z-axis E-field component values of every probe in the specified Multiprobe system.
- The arithmetic mean of the maximum x-, y- and z-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation of the maximum x-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation of the maximum y-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation of the maximum z-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation of the maximum x-, y- and z-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation in dB of the maximum x-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation in dB of the maximum y-axis E-field component values of every probe in the specified Multiprobe system.
- The standard deviation in dB of the maximum z-axis E-field component values of every probe in the specified Multiprobe system.

- The standard deviation in dB of the maximum x-, y- and z-axis E-field component values of every probe in the specified Multiprobe system.

NAN will be returned if the Multiprobe system setup is invalid, any E-field probe of the specified system is off, a probe is in start-up, there is no snapshot data available or if the statistical data could not be computed.

12.13 :VIRTual Computer Interface Commands

12.13.1 :VIRTual:CISerial?

Query serial numbers of connected virtual computer interfaces.

Return values:
Unsigned integer-valued comma-separated list of all connected virtual computer interface serial numbers. If no virtual computer interfaces are enumerated, the command will return NAN.

12.13.2 :VIRTual:CONnect [<CI>]

Connect a new virtual computer interface.

Parameter:
The optional unsigned integer parameter CI specifies the serial number of the virtual computer interface. If omitted the default serial number is set to 1. Alternatively, a string stating the field probe serial number, the field probe revision and computer interface serial number separated by a ":" can be given, e.g. "567:1.2:5". This will have the same effect as using the following three commands with the respective parameters: »:VIRTual:CONnect [<CI>] 3«, »:VIRTual:FPVersion 1.2« and »:VIRTual:FPSerial <Value> 567«.

12.13.3 :VIRTual:DISConnect

Disconnect currently active computer interface if it is a virtual computer interface.

12.13.4 :VIRTual:FPSerial <Value>

Set virtual E-field probe serial number for currently selected virtual computer interface.

Parameter:
The optional unsigned integer parameter Value sets the desired virtual E-field probe serial number. The default value is 1. The E-field probe serial number can only be set when the laser supply of the virtual E-field probe is off.

12.13.5 :VIRTual:FPSerial?

Query E-field probe serial number for currently selected virtual computer interface.

Return value:
: The command returns the unsigned integer value giving the virtual field probe's serial number. NAN is returned if the virtual field probe is off, in start-up or if the currently active computer interface is not virtual.

12.13.6 :VIRTual:FPRevision <Value>

Set virtual E-field probe revision for currently selected virtual computer interface.

Parameter:
: The unsigned integer parameter Value sets the desired virtual E-field probe revision 0, 1, 2 or 3. The default value is 2. The E-field probe revision number can only be set when the laser supply of the virtual E-field probe is off.

12.13.7 :VIRTual:FPRevision?

Query virtual E-field probe revision number for currently selected virtual computer interface.

Return value:
: The command returns the unsigned integer valued virtual field probe's revision number. NAN is returned if the currently active computer interface is not virtual.

12.13.8 :VIRTual:FPVersion

Set virtual E-field probe version for currently selected virtual computer interface.

Parameter:
: The float parameter Value sets the desired virtual E-field probe version 1.2 or 2.0. The default value is 1.2. The E-field probe version can only be set when the laser supply of the virtual E-field probe is off.

12.13.9 :VIRTual:FPVersion?

Query E-field probe serial number for currently selected virtual computer interface.

Return value:
: The command returns the virtual field probe's version string. NAN is returned if the currently active computer interface is not virtual.

12.13.10 :VIRTual:TEMPerature <Temperature>

Set E-field probe internal temperature for the currently selected virtual computer interface.

Parameter:
: The float-valued temperature in °C sets the internal temperature of the virtual E-field probe. The default is 40 °C.

12.13.11 :VIRTual:TEMPerature?

Query E-field probe internal temperature of the currently selected virtual computer interface.

Return value:
: The command returns the virtual field probe's temperature in °C. NAN is returned if the active computer interface is not virtual.

12.13.12 :VIRTual:ADCTemperature <Temperature>

Set E-field probe internal ADC temperature in LSB for the currently selected virtual computer interface.

Parameter:
: The float-valued ADC temperature in LSB sets the internal temperature of the virtual E-field probe. The default is 2344.0 LSB.

12.13.13 :VIRTual:ADCTemperature?

Query E-field probe internal temperature of the currently selected virtual computer interface.

Return value:
: The command returns the virtual field probe's the ADC temperature in LSB. NAN is returned if the active computer interface is not virtual.

12.13.14 :VIRTual:VOLTage <Voltage>

Set E-field probe supply voltage for the currently selected virtual computer interface.

Parameter:
: The float-valued voltage in V sets the supply voltage of the virtual E-field probe. The default is 2.1 V.

12.13.15 :VIRTual:VOLTage?

Query virtual E-field probe supply voltage.

Return value:
The command returns the float-valued virtual E-field probe supply voltage value in V. NAN will be returned if the active computer interface is not virtual.

12.13.16 :VIRTual:ACCeleration <ACCx>,<ACCy>,<ACCz>

Set the x-, y- and z-axis acceleration values for the currently selected virtual E-field probe.

Parameters:
The three float-valued parameters set the acceleration values in g, i.e., multiples of $9.81\,\mathrm{m/s^2}$, for the virtual E-field probe. The default values are 0.

12.13.17 :VIRTual:ACCeleration?

Query the x-, y- and z-axis acceleration values for the currently selected virtual E-field probe.

Return values:
The command returns a comma-separated list of three float values giving the x-, y- and z-axis acceleration in g, i.e., multiples of $9.81\,\mathrm{m/s^2}$. NAN will be returned if the active computer interface is not virtual.

12.13.18 :VIRTual:CW <RSSIxa>,<RSSIya>,<RSSIza>[,<RSSIxb>,<RSSIyb>,<RSSIzb>]

Set xa-, ya-, za-, xb-, yb- and zb-axis CW RSSI values of the currently selected virtual E-field probe.

Parameters:
The first three unsigned integer parameters xa-, ya- and za-axis RSSI value set the signal strength indicated by the virtual field probe's marked x-, y-, z- ADCs. The second three mandatory unsigned integer parameters xb-, yb- and zb-axis RSSI value set the signal strength indicated by the virtual field probe's ADCs opposite the marked x-, y-, z-axis in case of virtual LSProbe 2.0 devices. If the b-axis values are omitted, the first three values will be used for virtual LSProbe 2.0 devices. The default values are 0.

12.13.19 :VIRTual:CW?

Query xa-, ya-, za-, xb-, yb- and zb-axis RSSI values of the currently selected virtual E-field probe.

Return values:
The command returns a comma-separated list of six unsigned integer values giving the x-, y- and x-axis RSSI values. NAN will be returned if the active computer interface is not virtual.

12.13.20 :VIRTual:EField <Exa>,<Eya>,<Eza>[,<Exb>,<Eyb>,<Ezb>]

Set xa-, ya-, za-, xb-, yb- and zb-axis E-field values of the currently selected virtual E-field probe.

Parameters:

The first three float valued parameters xa-, ya- and za-axis E-field strengths set the signal strength indicated by the virtual field probe's marked x-, y-, z- ADCs. The second three mandatory float valued parameters xb-, yb- and zb-axis E-field strengths set the signal strength indicated by the virtual LSProbe 2.0's ADCs opposite the marked x-, y-, z-axis. If the b-axis values are omitted, the first three values will be set for LSprobe 2.0 devices. The E-field values are converted to RSSI values using the currently set mode, frequency and temperature. RSSI values will not be adjusted when mode, frequency or temperature are changed. E-field values exceeding the calibrated signal range will be limited to the maximum or minimum calibrated value. The default values are the minimum calibrated value for the currenlty set mode, frequency and temperature.

12.13.21 :VIRTual:EField?

Query x-, y-, z-axis for LSProbe 1.2, resp. xa-, ya-, za-, xb-, yb- and zb-axis fpr LSProbe 2.0 E-field values of the currently selected virtual E-field probe.

Return values:

The command returns a comma-separated list of three, resp. six float values giving the xa-, ya-, za-, xb-, yb- and zb-axis E-field values. Values for xb, yb and zb values will only be returned for LSProbe 2.0 devices in case of active axes, i.e. mode 0, 5 and 8. NAN will be returned if the active computer interface is not virtual or the laser in not enabled.

12.13.22 :VIRTual:NOIse <NOISExa>,<NOISEya>,<NOISEza>[,<NOISExb>, <NOISEyb>,<NOISEzb>]

Set the added noise amplitude of the currently selected virtual E-field probe.

Parameters:

The first three unsigned integer parameters xa-, ya- and za-axis NOISE set the maximum added RSSI value noise amplitude to the xa- ya- and za- axis CW RSSI values. The mandatory second three unsigned integer parameters xb-, yb- and zb-axis NOISE set the maximum added RSSI value noise amplitude. If the b-axis values are omitted, the first three values will be used for virtual LSProbe 2.0 devices. The time-average of the values is zero. Ranges are distributed evenly between -1 times the given amplitudes and +1 times the given amplitudes. The default values are 0.

12.13.23 :VIRTual:NOIse?

Query xa-, ya-, za-, xb-, yb- and zb-axis noise amplitude of the currently selected virtual E-field probe.

Return values:

The command returns a comma-separated list of six unsigned integer values giving the maximum amplitude of added x-, y-, and z-axis noise in LSB. NAN will be returned if the active computer interface is not virtual.

12.13.24 :VIRTual:PULse <RSSIxa>,<RSSIya>,<RSSIza>,[<RSSIxb>,<RSSIyb>, <RSSIzb>],<T>,<Ton>

Set the parameters of the virtual pulse signal for currently selected virtual E-field probe.

Parameters:

RSSIx(a)
: Unsigned integer value setting the x(a)-axis RSSI pulse value

RSSIy(a)
: Unsigned integer value setting the y(a)-axis RSSI pulse value

RSSIz(a)
: Unsigned integer value setting the z(a)-axis RSSI pulse value

RSSIxb
: Unsigned integer value setting the xb-axis RSSI pulse value, optional

RSSIyb
: Unsigned integer value setting the yb-axis RSSI pulse value, optional

RSSIzb
: Unsigned integer value setting the zb-axis RSSI pulse value, optional

T
: Unsigned integer value setting the pulse period expressed as a number of samples

Ton
: Unsigned integer value setting the ON-time at the beginning of reach pulse period expressed as a number of samples.

12.13.25 :VIRTual:PULse?

Query the pulse parameters of the currently selected virtual E-field probe.

Return values:

The command returns a comma-separated list of eight unsigned integer values as described in the parameter's description of »:VIRTual:PULse <RSSIxa>,<RSSIya>,<RSSIza>,[<RSSIxb>,<RSSIyb>, <RSSIzb>],<T>,<Ton>«. NAN will be returned if the active computer interface is not virtual.

12.13.26 :VIRTual:ELIST <Exa1>,<Eya1>,<Eza1>,[<Exb1>, <Eyb1>,<Ezb1>][,...,<EzbN>]

Append sets of x-, y- and z-axis E-field values to list of the currently selected virtual E-field probe 1.2, resp. append sets of xa-, ya-,za-, xb-,yb- and zb-axis E-field values to list of the currently selected virtual E-field probe 2.0.

Parameters:

For LSProbe 1.2 devices: multiples of three float-valued E-field strengths, specifying x-, y- and z-axis E-field values. For LSProbe 1.2 devices: multiples of six float-valued E-field strengths, specifying xa-, ya-, za-, xb-, yb- and zb-axis E-field values. The command accepts up to three resp. six times 256 values. The E-field values are converted to RSSI values using the currently set mode, frequency and temperature. RSSI values will not be adjusted when mode, frequency or temperature are changed. E-field values exceeding the calibrated signal range will be limited to the maximum or minimum calibrated value.

12.13.27 :VIRTual:ELIST?

Query the list of E-field values of the currently selected virtual E-field probe.

Return values:

The command returns a comma separated, float-valued list of all xa-, ya-, za-, xb-, yb- and zb-axis E-field values of the arbitrary E-field value list. NAN will be returned if the active computer interface is not virtual or if the list is empty.

12.13.28 :VIRTual:LIST <RSSIxa1>,<RSSIya1>,<RSSIza1>,<RSSIxb1>,<RSSIyb1>, <RSSIzb1>[,...,<RSSIzbN>]

Append sets of x-, y- and z-axis RSSI values to list of the currently selected virtual E-field probe 1.2, resp. append sets of xa-, ya-,za-, xb-,yb- and zb-axis RSSI values to list of the currently selected virtual E-field probe 2.0.

Parameters:

For LSProbe 1.2 devices: multiples of three integer-valued RSSI values, specifying x-, y- and z-axis RSSI values. For LSProbe 1.2 devices: multiples of six integer-valued RSSI values, specifying xa-, ya-, za-, xb-, yb- and zb-axis RSSI values. The command accepts up to three resp. six times 256 values.

12.13.29 :VIRTual:LIST:ALTER <Factor>

Multiplies the sets of xa-, ya-, za-, xb-, yb- and zb-axis RSSI values of the current list of the currently selected virtual E-field probe with the factor Factor.

Parameters:
Positive float valuedd number specifying the factor with which the list of xa-, ya-, za-, xb-, yb- and zb-axis RSSI values is to be multiplied.

12.13.30 :VIRTual:LIST?

Query the list of arbitrary RSSI values of the currently selected virtual E-field probe.

Return values:
The command returns a comma separated, unsigned integer list of the RSSI values of the set arbitrary RSSI value list. NAN will be returned if the active computer interface is not virtual or if the list is empty.

12.13.31 :VIRTual:LCNt?

Query number of samples in arbitrary E-field resp. RSSI values list of the currently selected virtual E-field probe.

Return value:
Unsigned integer-valued number of samples in arbitrary E-field resp. RSSI value list. NAN will be returned if the active computer interface is not virtual.

12.13.32 :VIRTual:LCLear

Clear arbitrary E-field resp. RSSI value list of the currently selected virtual E-field probe.

12.14 :STReam Recording Commands

12.14.1 :STReam:MAster <State>

Set currently selected CI-250$^{(+)}$ Computer Interface to be the master computer interface for stream recording.

Parameter:
Setting State to 1 makes the current CI-250$^{(+)}$ Computer Interface the master during stream recording. A State of 0 makes the CI-250$^{(+)}$ Computer Interface a slave during stream recording, i.e., stream synchronization is controlled by a different CI-250$^{(+)}$ Computer Interface.

12.14.2 :STReam:MAster? [<MProbe>]

Query master/slave status of the currently active CI-250$^{(+)}$ Computer Interface during stream recording.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns an unsigned integer value containing the stream recording master/slave status of the currently active CI-250$^{(+)}$ Computer Interface. Slaves return 0, the master returns 1.

12.14.3 :STReam:LENgth <Length>[,<MProbe>]

Set number of samples to be recorded during stream recording for one or multiple E-field probes. The parameter can only be set when stream recording is inactive.

Parameters:
The unsigned integer-valued parameter of the command specifies the number of consecutive samples to be streamed. E.g., »:STReam:len 100« will record 100 consecutive samples. Setting Length to zero configures indefinite streaming, i.e., streaming needs to be terminated by issuing a »:STReam:ENable? [<MProbe>]« command.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.14.4 :STReam:LENgth? [<MProbe>]

Query number of stream samples to be recorded for one or multiple E-field probes.

Parameter:
The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:
The command returns the unsigned integer-valued number of samples to be streamed as specified using the »:STReam:LENgth <Length>[,<MProbe>]« command. A value of zero indicates indefinite streaming.

12.14.5 :STReam:OUTput <OUT>[,<MProbe>]

Set output of stream recording to file or to specific host and port setting for one or multiple E-field probes.

Parameters:

String parameter with quotes specifying the output direction of the stream data. If set to "FILE", the binary stream data is written to binary file with the file prefix set via »:STReam:PREfix? [<MProbe>]«.This is the default. A string parameter with quotes specifying the host and port, separated by a ":" will send the binary data to the set client, e.g. "localhost:10005" to write data to port 10005 on the local computer.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.14.6 :STReam:OUTput? [<MProbe>]

Query output of stream data for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a string value containing the stream output direction, e.g. "FILE" or "HOST:PORT".

12.14.7 :STReam:ENable <State>[,<MProbe>]

Enable or disable stream recording for one or multiple E-field probes.

Parameters:

Setting State to 1 activates stream recording. If »:STReam:OUTput <OUT>[,<MProbe>]« is set to "FILE", two new stream files will be created for each addressed CI-250(+) Computer Interface. A lut-file containing the status data and a bin-file containing the measurement data. If »:STReam:OUTput <OUT>[,<MProbe>]« is set to "HOST:PORT", for each addressed CI-250(+) Computer Interface two client connections to the set host and port will be opened, one for the status data and one for the measurement data. The first data being sent is the ASCII encoded filenames, to which the data would have been written if the output was set to file. All further data being sent is in binary format. Setting State to 0 disables stream recording and closes the associated stream file(s). See Section 13.1.8 for details about the stream file format.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.14.8 :STReam:ENable? [<MProbe>]

Query status of stream recording for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns an unsigned integer value containing the stream recording status. A value of 1 is returned when stream data acquisition is enabled, 0 is returned if stream data acquisition is disabled.

12.14.9 :STReam:PROgress? [<MProbe>]

Query number of samples in current stream recording for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns an unsigned 64 bit integer value giving the number of samples that have been recorded for the selected CI-250(+) Computer Interface since the start of stream recording.

12.14.10 :STReam:SKIp <SkipCnt>[,<MProbe>]

Set number of stream samples to be skipped for one or multiple E-field probes. Parameter may only be set if stream data acquisition is disabled.

Parameters:

The unsigned integer-valued parameter SkipCnt specifies the number of samples to be skipped after recording a sample during stream recording. A SkipCnt of 99 will reduce the data rate by a factor of 100. A SkipCnt of 0 will skip no samples.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.14.11 :STReam:SKIp? [<MProbe>]

Query number of stream samples to be skipped for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns the unsigned integer-valued number of samples to be skipped after recording a sample during stream recording, it corresponds to the value set using »:STReam:SKIp <SkipCnt>[,<MProbe>]«. If executed for multiple CI-250 Computer Interfaces the command returns a list of unsigned integer-valued numbers for values to skip for each E-field probe of the respective list.

12.14.12 :STReam:PREfix <String>[,<MProbe>]

Set file prefix for stream recording for one or multiple E-field probes. The parameter can only be set when stream recording is disabled.

Parameters:

String parameter with quotes specifying the stream log file prefix. String may not exceed 127 characters. The default value is set to "stream". E.g., »:str:pre "StreamFile"« will result in a log files named "StreamFile_PP_YYYYMMDD_hhmmss_msmsms.csv" to be saved when enabling stream recording and stream output is set to file. See Section 13.1.8 for a detailed description of stream file naming conventions and the stream file format.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.14.13 :STReam:PREfix? [<MProbe>]

Query file prefix for stream recording for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a string value without quotes specifying the set stream log file prefix, see »:STReam:PREfix <String>[,<MProbe>]« for more details.

12.14.14 :STReam:SYNC <Sync>[,<MProbe>]

Set synchronization source for stream recording for one or multiple E-field probes.

Parameters:

String parameter without quotes specifying the synchronization source, valid values are OFF, EXT and EXT2. When set to OFF stream recording will start immediately upon enabling using the »:STReam:ENable <State>[,<MProbe>]« command. When set to EXT the CI-250(+) Computer Interface's BNC connector will be used to synchronize stream recoding slaves with the stream recording master. When set to EXT2 the CI-250(+) Computer Interface's RJ45 socket will be used to synchronize stream recoding slaves with the stream recording master. When set to EXT or EXT2 the slave/master status set using the »:STReam:MAster <State>« command determines the input/output configuration of the respective connector.

The second, optional unsigned integer parameter MProbe is described in Section 12.1.

12.14.15 :STReam:SYNC? [<MProbe>]

Query synchronization source for stream recording for one or multiple E-field probes.

Parameter:

The optional unsigned integer parameter MProbe is described in Section 12.1.

Return value:

The command returns a string value without quotes specifying the set stream synchronization source, see »:STReam:SYNC <Sync>[,<MProbe>]« for more details.

13 File Formats

Except for streaming files, see Section 13.1.8, all data used by the LUMILOOP TCP Server and LUMILOOP GUI are stored in the form of tabulator-separated plain ASCII text files. The uniform file extension is `.csv`. Lines are separated by newline characters (ASCII code `0xa`), columns are separated by tabulators (ASCII code `0x09`). In the case of the Generic Calibration Result Files, see Section 13.3, UTF-8 encoding is allowed in addition.

Numbers are expressed as plain decimal integers, as floating-point numbers using "." as the decimal separator, or in exponential format using "." as the decimal separator and "e" as the exponential separator, e.g., "1.2e3" encoding a value of 1,200.

In all examples given below "⊣" denotes a tabulator, ↵ a newline character, and "↙" a line wrap indicating that the contents of the next line in this document belong to the same line of the `.csv` file.

13.1 LUMILOOP GUI Log Files

The filename of all LSProbe LUMILOOP GUI log files, formatted as "PREFIX lsprobe_XvY_N_YYYYMMDD_hhmmss_SSS", consists of an adjustable file prefix "PREFIX", the device type "lsprobe", the LSProbe version "XvY" and serial number "N", followed by the file creation time string "YYYYMMDD_hhmmss_SSS". "YYYY", "MM", "DD", "hh", "mm", "ss" and "SSS" denote the year, month, day, hour, minute, second and millisecond of log file creation with their respective number of digits. The number of digits used for the E-field probe serial number depends on the numeric value of the serial number.

The file's prefix can be adapted for each subsystem separately via the "Configure Log" Dialog in the "File" menu, as depicted in Figure 132. The default file prefix states the type of the data, e.g. "live", "scope", ...

If a log file is created using the GUI's "Quick Save" button and the "Apply settings to all Devices" option is disabled, all presently displayed values of the active E-field probe will be saved to a newly created file. If 'Apply settings to all Devices" option is enabled, all current values for all devices enumerated by the LUMILOOP GUI will be saved to a newly created file for each device.

The first line of all log files contains a header starting with a hash mark (#), which describes the contents of each column in the remainder of the file.

13.1.1 Live Data Logger

The file format for all live log files contains at least 13 columns described with their column headers and unit values in the table below.

Continuous logging will add one line for for every newly polled set of values. If more than one E-field probe is present one log file will be created for every E-field probe.

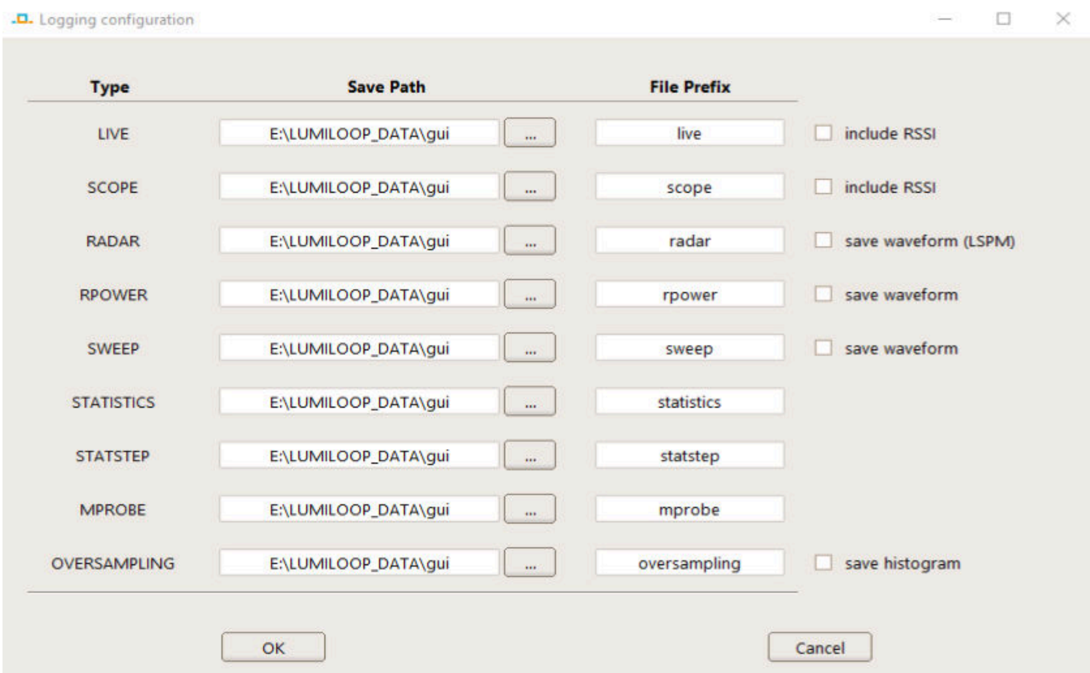


Figure 132: *LUMILOOP GUI "Configure Log" Dialog*

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
2	Mode		Measurement mode, see Table 1, page 24
3	f	Hz	Compensation frequency
4	Ex	V/m	X-axis component of E-field
5	Ey	V/m	Y-axis component of E-field
6	Ez	V/m	Z-axis component of E-field
7	Emag	V/m	E-field magnitude
8	fLpE	Hz	E-field low pass filter frequency
9	ACCx	g	X-axis acceleration in multiples of 9.81 m/s^2
10	ACCy	g	Y-axis acceleration in multiples of 9.81 m/s^2
11	ACCz	g	Z-axis acceleration in multiples of 9.81 m/s^2
12	fLpACC	Hz	Acceleration low pass filter frequency
13	FP_Temp	°C	Temperature inside the E-field probe
14	RSSIx	LSB	X-axis raw RSSI value, optional for LSProbe 1.2 devices
15	RSSIy	LSB	Y-axis raw RSSI value, optional for LSProbe 1.2 devices

Column	Header	Unit	Description
16	RSSIz	LSB	Z-axis raw RSSI value, optional for LSProbe 1.2 devices
14	RSSIxa	LSB	Xa-axis raw RSSI value, optional for LSProbe 2.0 devices
15	RSSIya	LSB	Ya-axis raw RSSI value, optional for LSProbe 2.0 devices
16	RSSIza	LSB	Za-axis raw RSSI value, optional for LSProbe 2.0 devices
14	RSSIxb	LSB	Xb-axis raw RSSI value, optional for LSProbe 2.0 devices
15	RSSIyb	LSB	Yb-axis raw RSSI value, optional for LSProbe 2.0 devices
16	RSSIzb	LSB	Zb-axis raw RSSI value, optional for LSProbe 2.0 devices

Example of live log file:

```
#t ⇥Mode ⇥f in Hz⇥Ex in V/m⇥Ey in V/m⇥Ez in V/m⇥Emag in V/m⇥fLpE in↙
    Hz ⇥ACCx in gee⇥ACCy in gee⇥ACCz in gee⇥fLpA in Hz ⇥FP_Temp⇥↙
   RSSIx⇥RSSIy⇥RSSIz↵
3569229678.874 ⇥0⇥100000000⇥0.155352 ⇥0.258098 ⇥0.204308 ⇥0.363993↙
    ⇥0⇥-0.02381 ⇥-0 ⇥0.916667 ⇥0⇥30.0625⇥2729 ⇥3131 ⇥2788↵
3569229678.910 ⇥0⇥100000000⇥0.172794 ⇥0.23228⇥0.230869 ⇥0.370287 ⇥0↙
   ⇥-0.011905⇥-0 ⇥0.952381 ⇥0⇥30.0625⇥2790 ⇥3042 ⇥2881↵
```

13.1.2 Field Scope Data Logger

The file format for all field scope log files contains at least seven columns described with their column headers and unit values in the table below.

Continuous logging will create a new log file for every newly recorded set of waveforms. If more than one E-field probe is present one log file will be created for each E-field probe.

Optionally, the RSSI values can be saved additionally to each file via enabling the "include RSSI" checkbox in the "Configure Log"'s "SCOPE" settings as depicted in Figure 132.

Column	Header	Unit	Description
1	Mode		Measurement mode, see Table 1, page 24
2	f	Hz	Compensation frequency
3	Ex	V/m	X-axis component of E-field
4	Ey	V/m	Y-axis component of E-field
5	Ez	V/m	Z-axis component of E-field
6	Emag	V/m	E-field magnitude
7	Frame		Frame indicator, Frame is identical for waveform values belonging to the same burst frame, valid values are 0 and 1

Column	Header	Unit	Description
8	RSSIx	LSB	X-axis raw RSSI value, optional, LSProbe 1.2 devices
9	RSSIy	LSB	Y-axis raw RSSI value, optional, LSProbe 1.2 devices
10	RSSIz	LSB	Z-axis raw RSSI value, optional, LSProbe 1.2 devices
8	RSSIxa	LSB	Xa-axis raw RSSI value, optional, LSProbe 2.0 devices
9	RSSIya	LSB	Ya-axis raw RSSI value, optional, LSProbe 2.0 devices
10	RSSIza	LSB	Za-axis raw RSSI value, optional, LSProbe 2.0 devices
11	RSSIxb	LSB	Xb-axis raw RSSI value, optional, LSProbe 2.0 devices
12	RSSIyb	LSB	Yb-axis raw RSSI value, optional, LSProbe 2.0 devices
13	RSSIzb	LSB	Zb-axis raw RSSI value, optional, LSProbe 2.0 devices

Example of field scope log file:

```
#Mode→f in Hz→Ex in V/m→Ey in V/m→Ez in V/m→Emag in V/m→Frame→RSSIx→RSSIy→RSSIz
0→300000000→0.521039 →0.617975 →0.580272 →0.995033 →0→2726 →2913 →2708
0→300000000→1.031266 →0.301601 →0.610625 →1.235854 →0→2809 →2875 →2712
```

13.1.3 Radar Data Logger

The file format for all radar log files contains at least 16 columns described with their column headers and unit values in the table below. The number of columns is dependent on the number of detected pulses for all component and magnitude E-field values. For every pulse, a triple of columns consisting of the sample index of the start of the pulse, the length of the pulse in samples and averaged E-field value for the pulse will be added to the radar log file. First, Nx value triples for the x-axis component values will be added, followed by Ny, Nz and Nmag value triples for the other component's and magnitude's values. The pulse counts Nx, Ny, Nz and Nmag are given in columns 13 through 16.

Continuous logging will create a new line in the log file for every newly recorded set of waveforms. If more than one E-field probe is present one log file will be created for every E-field probe.

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
2	Mode		Measurement mode, see Table 1, page 24
3	f	Hz	Compensation frequency

Column	Header	Unit	Description
4	Samp		Number of samples in waveform evaluated for radar detection
5	Th Ex	V/m	Threshold value for radar pulse detection for x-axis E-field component
6	Th Ey	V/m	Threshold value for radar pulse detection for y-axis E-field component
7	Th Ez	V/m	Threshold value for radar pulse detection for z-axis E-field component
8	Th Emag	V/m	Threshold value for radar pulse detection for E-field magnitude
9	Avg Ex	V/m	Arithmetic mean of all pulses' x-axis component averaged pulse E-field values
10	Avg Ey	V/m	Arithmetic mean of all pulses' y-axis component averaged pulse E-field values
11	Avg Ez	V/m	Arithmetic mean of all pulses' z-axis component averaged pulse E-field values
12	Avg Emag	V/m	Arithmetic mean of all pulses' E-field magnitude maximums
13	CNTx		Number of pulses detected for x-axis component of E-field
14	CNTy		Number of pulses detected for y-axis component of E-field
15	CNTz		Number of pulses detected for z-axis component of E-field
16	CNTmag		Number of pulses detected for E-field magnitude
17...	IDXxN		Start sample index of N^{th} x-axis pulse
18...	LenxN		Length of N^{th} x-axis pulse
19...	ExN	V/m	N^{th} x-axis pulse's averaged E-field strength
17...	IDXyN		Start sample index of N^{th} y-axis pulse
18...	LenyN		Length of N^{th} y-axis pulse
19...	EyN	V/m	N^{th} y-axis pulse's averaged E-field strength
17...	IDXzN		Start sample index of N^{th} z-axis pulse
18...	LenzN		Length of N^{th} z-axis pulse
19...	EzN	V/m	N^{th} z-axis pulse's averaged E-field strength
17...	IDXmagN		Start sample index of N^{th} magnitude pulse
18...	LenmagN		Length of N^{th} magnitude pulse number
19...	EmagN	V/m	N^{th} E-field magnitude pulse's averaged E-field strength

Example of radar log file:

```
#t ⊣Mode ⊣f⊣Samp ⊣Th Ex⊣Th Ey⊣Th Ez⊣Th Emag⊣Avg Ex ⊣Avg Ey ⊣Avg Ez↙
    ⊣Avg Emag ⊣CNTx ⊣CNTy ⊣CNTz ⊣CNTmag ⊣IDXxN⊣LenxN⊣ExN⊣IDXyN⊣↙
   LenyN⊣EyN⊣IDXzN⊣LenzN⊣EzN⊣IDXmagN⊣LenmagN⊣EmagN⏎
3686020200.686 ⊣0⊣100000000⊣2000 ⊣1⊣1⊣1⊣1⊣3.209332 ⊣3.73031⊣↙
   6.117472 ⊣7.927801 ⊣2⊣2⊣2⊣2⊣727⊣25 ⊣3.280829 ⊣1727 ⊣25 ⊣↙
   3.137834 ⊣727⊣25 ⊣3.64109⊣1727 ⊣25 ⊣3.819531 ⊣727⊣25 ⊣6.061644↙
    ⊣1727 ⊣25 ⊣6.173299 ⊣727⊣25 ⊣7.865721 ⊣1727 ⊣25 ⊣7.989881⏎
3686020295.037 ⊣0⊣100000000⊣2000 ⊣2⊣2⊣2⊣2⊣NaN⊣3.983445 ⊣6.006153 ⊣↙
   7.300573 ⊣0⊣2⊣2⊣2⊣73 ⊣25 ⊣3.833957 ⊣1073 ⊣25 ⊣4.132933 ⊣73 ⊣25↙
    ⊣5.802957 ⊣1073 ⊣25 ⊣6.209348 ⊣73 ⊣25 ⊣7.056664 ⊣1073 ⊣25 ⊣↙
   7.544483⏎
```

13.1.4 Remote Power Data Logger

The file format for all rpower log files contains at least 22 columns described with their column headers and unit values in the table below. The number of columns is dependent on the number of detected pulses for all component E-field values. For every pulse a triple of columns consisting of the sample index of the start of the pulse, the length of the pulse in samples and averaged power value for the pulse will be added to the remote power log file. Therefore, the number of columns per row may vary. First, Nx value triples for the x-axis component values will be added, followed by Ny and Nz value triples for the other component's values. The pulse counts Nx, Ny and Nz are given in columns 20 through 22.

Continuous logging will create a new line in the log file for every newly recorded set of waveforms and change of an remote power parameter. If more than one E-field probe is present one log file will be created for every E-field probe.

If a log file is created using the GUI's "Quick Save" button and "Apply settings to all Devices" is disabled all presently displayed values of the active E-field probe will be saved to a newly created file. If 'Apply settings to all Devices" is enabled, all current values for all devices enumerated by the LUMILOOP GUI will be saved to a newly created file for each device.

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
2	Mode		Measurement mode, see Table 1, page 24
3	f	Hz	Compensation frequency
4	Samp		Number of samples in waveforms evaluated for remote power measurements
5	Dist	m	Set distance between DUT and LSProbe 1.2/1.4/2.0 E-field probe for remote power measurements

Column	Header	Unit	Description
6	minS		Set minimum required pulse duration in samples for remote power measurements
7	MAVG		Set number of samples for moving average filter for remote power measurements
8	Th Px	dBm	Threshold value for remote power pulse detection for x-axis component
9	Th Py	dBm	Threshold value for remote power pulse detection for y-axis component
10	Th Pz	dBm	Threshold value for remote power pulse detection for z-axis component
11	Avg Px	dBm	Arithmetic mean of all pulses' x-axis component averaged pulse power values
12	Avg Py	dBm	Arithmetic mean of all pulses' y-axis component averaged pulse power values
13	Avg Pz	dBm	Arithmetic mean of all pulses' z-axis component averaged pulse power values
14	Max Px	dBm	Power of pulse with the highest averaged power of all x-axis pulses
15	Max Py	dBm	Power of pulse with the highest averaged power of all y-axis pulses
16	Max Pz	dBm	Power of pulse with the highest averaged power of all z-axis pulses
17	Duty Px		Duy cycle of x-axis' power values
18	Duty Py		Duy cycle of y-axis' power values
19	Duty Pz		Duy cycle of z-axis' power values
20	CNTx		Number of pulses detected for x-axis component
21	CNTy		Number of pulses detected for y-axis component
22	CNTz		Number of pulses detected for z-axis component
23...	IDXxN		Start sample index of N^{th} x-axis pulse number Px
24...	LenxN		Length of N^{th} x-axis pulse number Px
25...	PxN	dBm	N^{th} x-axis pulse's averaged power
23...	IDXyN		Start sample index of y-axis pulse number Py
24...	LenyN		Length of N^{th} y-axis pulse number Py
25...	PyN	dBm	N^{th} y-axis pulse's averaged power
23...	IDXzN		Start sample index of z-axis pulse number Pz
24...	LenzN		Length of N^{th} z-axis pulse number Pz

Column	Header	Unit	Description
25...	PzN	dBm	N^{th} z-axis pulse's averaged power

Example of remote power log file:

```
#t ⊣Mode ⊣f in Hz⊣Samp ⊣Distance in m⊣minS ⊣MAVG ⊣Th Px in dBm ⊣Th ↙
   Py in dBm ⊣Th Pz in dBm ⊣Avg Px in dBm⊣Avg Py in dBm⊣Avg Pz in ↙
   dBm⊣Max Px in dBm⊣Max Py in dBm⊣Max Pz in dBm⊣Duty Px⊣Duty Py⊣↙
   Duty Pz⊣CNTx ⊣CNTy ⊣CNTz ⊣IDXxN⊣LenxN⊣PxN in dBm ⊣IDXyN⊣LenyN⊣↙
   PyN in dBm ⊣IDXzN⊣LenzN⊣PzN in dBm↵
3686021230.715 ⊣0⊣100000000⊣2000 ⊣1⊣1⊣1⊣24 ⊣24 ⊣24 ⊣NaN⊣27.233963⊣↙
   30.800714⊣NaN⊣27.553953⊣31.089708⊣NaN⊣0.025⊣0.025⊣0⊣2⊣2⊣73 ⊣25↙
    ⊣26.901731⊣1073 ⊣25 ⊣27.553953⊣73 ⊣25 ⊣30.501774⊣1073 ⊣25 ⊣↙
   31.089708↵
3686021340.892 ⊣0⊣100000000⊣2000 ⊣1⊣1⊣1⊣21.228788⊣23.228786⊣↙
   27.228786⊣25.432882⊣26.876173⊣30.67668 ⊣25.598619⊣26.897095⊣↙
   30.899572⊣0.025⊣0.025⊣0.025⊣2⊣2⊣2⊣688⊣25 ⊣25.263922⊣1688 ⊣25 ⊣↙
   25.598619⊣688⊣25 ⊣26.855204⊣1688 ⊣25 ⊣26.897095⊣688⊣25 ⊣↙
   30.44792 ⊣1688 ⊣25 ⊣30.899572↵
```

If the “save waveform” checkbox in the “Logging Configuration” dialog is enabled, an additional remote power waveform log file is saved, containing the radiated power corrected waveform values of the current waveform after application of the set moving average filer. The file format for all remote power scope log files contains five columns described with their column headers and unit values in the table below.

Continuous logging will create a new log file for every newly recorded set of waveforms. If more than one E-field probe is present one log file will be created for each E-field probe.

Column	Header	Unit	Description
1	Mode		Measurement mode, see Table 1, page 24
2	f	Hz	Compensation frequency
3	MAVG_Px	dBm	X-axis power value waveform after application of moving average filter
4	MAVG_Py	dBm	Y-axis power value waveform after application of moving average filter
5	MAVG_Pz	dBm	Z-axis power value waveform after application of moving average filter

Example of rpower waveform log file:

```
#Mode⊣freq ⊣MAVG_Px⊣ in dBmMAVG_Py in dBm⊣MAVG_Pz in dBm↵ ⊣
0⊣100000000⊣ -4.874056 ⊣  4.764642 ⊣ -3.880440↵
0⊣100000000⊣ -4.874056 ⊣  4.703126 ⊣ -3.880440↵
```

13.1.5 Sweep Data Logger

The file format for all sweep log files contains seven columns described with their column headers and unit values in the table below. One line is written for each sweep step.

Continuous logging will create a new log file for every newly recorded set of waveforms and change of a sweep parameter. If more than one E-field probe is present one log file will be created for every E-field probe.

Column	Header	Unit	Description
1	Mode		Measurement mode, see Table 1, page 24
2	f	Hz	Compensation frequency
3	Index		Center sample index
4	Ex	V/m	Averaged x-axis component of E-field
5	Ey	V/m	Averaged y-axis component of E-field
6	Ez	V/m	Averaged z-axis component of E-field
7	Emag	V/m	Averaged E-field magnitude

Example of sweep log file:

```
#Mode⊣f in Hz⊣Index⊣Ex in V/m⊣Ey in V/m⊣Ez in V/m⊣Emag in V/m↵
0⊣500000000⊣3999 ⊣0.942343 ⊣0.877695 ⊣1.692045 ⊣2.126859↵
0⊣505000000⊣8999 ⊣0.764156 ⊣0.804063 ⊣2.251321 ⊣2.510102↵
```

If the "save waveform" checkbox in the "Logging Configuration" dialog is enabled, an additional sweep waveform log file is saved, containing the efield values of the current waveform. The file format for all sweep waveform log files contains six columns, described with their column headers and unit values in the table below.

Column	Header	Unit	Description
1	Mode		Measurement mode, see Table 1, page 24
2	f	Hz	Compensation frequency
3	Ex	V/m	X-axis component of E-field for sweep
4	Ey	V/m	Y-axis component of E-field for sweep

Column	Header	Unit	Description
5	Ez	V/m	Z-axis component of E-field for sweep
6	Emag	V/m	E-field magnitude for sweep

Example of remote power scope log file:

```
#Mode	f in Hz	Index	Ex in V/m	Ey in V/m	Ez in V/m	Emag in V/m
0	100000000	0.319049	0.214852	0.174621	0.422429
0	100000000	0.310704	0.211782	0.156046	0.407111
```

13.1.6 Statistics Data Logger

The file format for all statistics log files contains at least 32 columns described with their column headers and unit values in the table below. The number of columns is dependent on the number of E-field strength bins in the recorded histogram. There is at least one bin in the histogram. For every bin four columns consisting of the number of x-, y-, z-axis and magnitude samples detected for the corresponding bin will be added to the statistics log file. The number of bins is specified in column number 28.

Continuous logging will add a new line to the log file for every newly recorded statistics snapshot. If more than one E-field probe is present one log file will be created for every E-field probe.

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-0 01 00:00:00 UTC
2	Mode		Measurement mode, see Table 1, page 24
3	f	Hz	Compensation frequency
4	Type		Statistics type, 0 for continuous statistics, 1 for triggered statistics
5	Minimum Ex	V/m	E-field x-axis component minimum
6	Minimum Ey	V/m	E-field y-axis component minimum
7	Minimum Ez	V/m	E-field z-axis component minimum
8	Minimum Emag	V/m	E-field magnitude minimum
9	Maximum Ex	V/m	E-field x-axis component maximum
10	Maximum Ey	V/m	E-field y-axis component maximum
11	Maximum Ez	V/m	E-field z-axis component maximum
12	Maximum Emag	V/m	E-field magnitude maximum
13	Arithmetic Mean Ex	V/m	E-field x-axis component arithmetic mean

Column	Header	Unit	Description
14	Arithmetic Mean Ey	V/m	E-field y-axis component arithmetic mean
15	Arithmetic Mean Ez	V/m	E-field z-axis component arithmetic mean
16	Arithmetic Mean Emag	V/m	E-field magnitude arithmetic mean
17	Root Mean Square Ex	V/m	E-field x-axis component root mean square
18	Root Mean Square Ey	V/m	E-field y-axis component root mean square
19	Root Mean Square Ez	V/m	E-field z-axis component root mean square
20	Root Mean Square Emag	V/m	E-field magnitude root mean square
21	Standard Deviation Ex	V/m	E-field x-axis component standard deviation
22	Standard Deviation Ey	V/m	E-field y-axis component standard deviation
23	Standard Deviation Ez	V/m	E-field z-axis component standard deviation
24	Standard Deviation Emag	V/m	E-field magnitude standard deviation
25	Samples		Number of samples used for statistics evaluation
26	Resolution	dB	E-field resolution for histogram output
27	Offset		offset of minimum bin in histogram
28	Bins		Number of bins in E-field value histogram
29...	CNTxN		Bins number of x-axis E-field values from first up to N^{th} bin of histogram
29+N...	CNTyN		Bins number of y-axis E-field values from first up to N^{th} bin of histogram
29+2*N...	CNTzN		Bins number of z-axis E-field values from first up to N^{th} bin of histogram
29+3*N...	CNTmagN		Bins number of E-field magnitude values from first up to N^{th} bin of histogram

Example of statistics log file:

```
#t ⊣Mode ⊣f in Hz⊣Type ⊣Minimum Ex in V/m⊣Minimum Ey in V/m⊣Minimum↙
    Ez in V/m⊣Minimum Emag in V/m⊣Maximum Ex in V/m⊣Maximum Ey in ↙
   V/m⊣Maximum Ez in V/m⊣Maximum Emag in V/m⊣Arithmetic Mean Ex in↙
    V/m⊣Arithmetic Mean Ey in V/m⊣Arithmetic Mean Ez in V/m⊣↙
   Arithmetic Mean Emag in V/m⊣Root Mean Square Ex in V/m ⊣Root ↙
   Mean Square Ey in V/m ⊣Root Mean Square Ez in V/m ⊣Root Mean ↙
   Square Emag in V/m ⊣Standard Deviation Ex in V/m ⊣Standard ↙
   Deviation Ey in V/m ⊣Standard Deviation Ez in V/m ⊣Standard ↙
```

```
    Deviation Emag in V/m ⊣Samples⊣Resolution in dB ⊣Offset ⊣Bins ⊣↙
    CNTxN⊣CNTyN⊣CNTzN⊣CNTmagN⏎
3565261205.605 ⊣0⊣100000000⊣0⊣0.13693⊣0.016042 ⊣0.117557 ⊣0.213673↙
     ⊣141.416473 ⊣38.725765⊣11.891866⊣146.639175 ⊣1.415222 ⊣↙
    0.447755 ⊣0.304661 ⊣1.572223 ⊣12.207644⊣3.499163 ⊣0.887066 ⊣↙
    12.730366⊣12.125352⊣3.470403 ⊣0.833109 ⊣12.632927⊣317452 ⊣30 ⊣↙
    -1 ⊣3⊣1125 ⊣313385 ⊣2942 ⊣305436 ⊣9099 ⊣2917 ⊣29281⊣285640 ⊣↙
    2531 ⊣0⊣314510 ⊣2942⏎
3565261228.359 ⊣0⊣100000000⊣1⊣0.161065 ⊣0.016042 ⊣0.127204 ⊣↙
    0.234153 ⊣126.76519⊣36.919006⊣10.40519 ⊣132.357941 ⊣1.396783 ⊣↙
    0.441806 ⊣0.304875 ⊣1.54563⊣11.939714⊣3.483666 ⊣0.986952 ⊣↙
    12.476414⊣11.858323⊣3.45571⊣0.93873⊣12.380923⊣10000⊣30 ⊣-1 ⊣3⊣↙
    29 ⊣9877 ⊣94 ⊣9843 ⊣63 ⊣94 ⊣1005 ⊣8903 ⊣92 ⊣0⊣9906 ⊣94⏎
```

13.1.7 Multiprobe Data Logger

For each Multiprobe system a separate log file will be created with the respective Multiprobe-system number, i.e. the last number of the corresponding ISO norm, stated in the file name. E.g. for a Multiprobe system setup for measurement of the standard "ISO 114511-2" the mprobe log file name "lsprobe_mprobe_2_YYYY....csv" is appointed.

Continuous logging will add a new line for every newly recorded set of Multiprobe statistics.

If a log file is created using the GUI's "Quick Save" button and "Apply settings to all Devices" is disabled all presently displayed values of the active E-field probe will be saved to a newly created file. If 'Apply settings to all Devices" is enabled, all current values for all devices enumerated by the LUMILOOP GUI will be saved to a newly created file for each device.

"ISO 114511-2" Multiprobe log file

The file format contains at least 9 columns described with their column headers and unit values in the table below. The number of columns are dependent on the number of E-field probes in a Multiprobe system.

The serial numbers of all E-field probes in a Multiprobe system, their operating mode and frequency are stored in column 7 onward. There is at least one E-field probe in the Multiprobe system.

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
2	Type		Multiprobe Statistics type, 0 for continuous statistics, 1 for triggered statistics
3	AMAG_RP |E|	V/m	Averaged magnitude at the reference point, e.g. reference line if more than three probes are part of the setup

Column	Header	Unit	Description
4	AMAG_CP1 |E|	V/m	Averaged magnitude at the control point one, NAN if the setup does not contan control probes, e.g. one and four probe setups
5	AMAG_CP2 |E|	V/m	Averaged magnitude at the control point two, NAN if the setup does not contan control probes, e.g. one and four probe setups
6	LSProbe count		Number of LSProbes in the Multiprobe system
7...	SernoxN		LSProbe 1.2/1.4/2.0 E-field probe serial number of N^{th} E-field probe in the Multiprobe system
8...	ModexN		Operating mode of N^{th} E-field probe in the Multiprobe system
9...	FreqxN	Hz	Operating frequency of N^{th} E-field probe in the Multiprobe system

Example of Multiprobe log file:

```
#t ⊣Type ⊣AMAG_RP |E|⊣AMAG_CP1 |E| ⊣AMAG_CP2 |E| ⊣LSProbe count⊣↙
   SernoxN⊣ModexN ⊣FreqxN↵
1654848776.682 ⊣0⊣1.812⊣1.575⊣1.169⊣3⊣343⊣0⊣100000000.000⊣186⊣0⊣↙
   100000000.000⊣458⊣0⊣100000000.000↵
```

"ISO 11452-11 / IEC 61000-4-21" Multiprobe log file

The file format contains at least 18 columns described with their column headers and unit values in the table below. The number of columns are dependent on the number of E-field probes in a Multiprobe system.

The serial numbers of all E-field probes in a Multiprobe system, their operating mode and frequency are stored in column 16 onward. Although the standard requires eight probes in the setup, the Multiprobe system can be configured to contain least one E-field probe.

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
2	Type		Multiprobe Statistics type, 0 for continuous statistics, 1 for triggered statistics
3	Mean Emax x	V/m	Arithmetic mean of E-field x-axis component maximum values for all E-field probes in a Multiprobe system
4	Mean Emax y	V/m	Arithmetic mean of E-field y-axis component maximum values for all E-field probes in a Multiprobe system
5	Mean Emax z	V/m	Arithmetic mean of E-field z-axis component maximum values for all E-field probes in a Multiprobe system
6	Mean Emax xyz	V/m	Arithmetic mean of E-field x-axis, y-axis and z-axis component maximum values for all E-field probes in a Multiprobe system

Column	Header	Unit	Description
7	SDev Emax x	V/m	Standard deviation of E-field x-axis component maximum values for all E-field probes in a Multiprobe system
8	SDev Emax y	V/m	Standard deviation of E-field y-axis component maximum values for all E-field probes in a Multiprobe system
9	SDev Emax z	V/m	Standard deviation of E-field z-axis component maximum values for all E-field probes in a Multiprobe system
10	SDev Emax xyz	V/m	Standard deviation of E-field x-axis, y-axis and z-axis component maximum values for all E-field probes in a Multiprobe system
11	SDev in dB Emax x	V/m	Standard deviation in dB of E-field x-axis component maximum values for all E-field probes in a Multiprobe system
12	SDev in dB Emax y	V/m	Standard deviation in dB of E-field y-axis component maximum values for all E-field probes in a Multiprobe system
13	SDev in dB Emax z	V/m	Standard deviation in dB of E-field z-axis component maximum values for all E-field probes in a Multiprobe system
14	SDev in dB Emax xyz	V/m	Standard deviation in dB of E-field x-axis, y-axis and z-axis component maximum values for all E-field probes in a Multiprobe system
15	LSProbe count		Number of LSProbes in the Multiprobe system
16...	SernoxN		LSProbe 1.2/1.4/2.0 E-field probe serial number of N^{th} E-field probe in the Multiprobe system
17...	ModexN		Operating mode of N^{th} E-field probe in the Multiprobe system
18...	FreqxN	Hz	Operating frequency of N^{th} E-field probe in the Multiprobe system

Example of Multiprobe log file:

```
#t ⊣Type ⊣Mean Emax_x⊣Mean Emax_y⊣Mean Emax_z⊣Mean Emax_xyz⊣SDev ↙
   Emax_x⊣SDev Emax_y⊣SDev Emax_z⊣SDev Emax_xyz⊣SDev_dB Emax_x ⊣↙
   SDev_dB Emax_y ⊣SDev_dB Emax_z ⊣SDev_dB Emax_xyz ⊣LSProbe count↙
   ⊣SernoxN⊣ModexN ⊣FreqxN⏎
1654848822.538 ⊣1⊣0.772⊣3.042⊣3.713⊣2.509⊣0.475⊣3.495⊣3.166⊣2.802⊣↙
   4.167⊣6.644⊣5.356⊣6.514⊣8⊣186⊣0⊣100000000.000⊣3⊣0⊣100000000.000↙
   ⊣343⊣0⊣100000000.000⊣458⊣0⊣100000000.000⊣267⊣0⊣100000000.000⊣↙
   431⊣0⊣100000000.000⊣356⊣0⊣100000000.000⊣344⊣0⊣100000000.000⏎
```

"ISO 11451-5" Multiprobe log file

The file format contains at least 29 columns described with their column headers and unit values in the table below. The number of columns are dependent on the number of E-field probes in a Multiprobe system.

The serial numbers of all E-field probes in a Multiprobe system, their operating mode and frequency are stored in column 16 onward. Although the standard requires eight points in the setup, the Multiprobe system can be configured to contain least one E-field probe up to twelve.

Column	Header	Unit	Description
1	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
2	Type		Multiprobe Statistics type, 0 for continuous statistics, 1 for triggered statistics
3	CDF TH		cumulative probability distribution threshold
5	MEAN_P(MEAN_t)x	V/m	E-field x-axis component arithmetic mean over all probes and time
6	MEAN_P(MEAN_t)y	V/m	E-field y-axis component arithmetic mean over all probes and time
7	MEAN_P(MEAN_t)z	V/m	E-field z-axis component arithmetic mean over all probes and time
8	MEAN_P(MEAN_t)mag	V/m	E-field magnitude arithmetic mean over all probes and time
9	MEAN_P(MEAN_t)xyz	V/m	E-field x-axis, y-axis and z-axis components arithmetic mean over all probes and time
10	MEAN_P(MAX_t)x	V/m	E-field x-axis component maximum value over time and averaged over all probes
11	MEAN_P(MAX_t)y	V/m	E-field y-axis component maximum value over time and averaged over all probes
12	MEAN_P(MAX_t)z	V/m	E-field y-axis component maximum value over time and averaged over all probes
13	MEAN_P(MAX_t)mag	V/m	E-field magnitude maximum value over time and averaged over all probes
14	MEAN_P(MAX_t)xyz	V/m	E-field x-, y- and z-axis components maximum value over time and averaged over all probes
15	MEAN_P(MAX_t)x/ MEAN_P(MEAN_t)x	V/m	E-field x-axis component arithmetic mean
16	MEAN_P(MAX_t)y/ MEAN_P(MEAN_t)y	V/m	E-field magnitude arithmetic mean
17	MEAN_P(MAX_t)z/ MEAN_P(MEAN_t)z	V/m	E-field x-axis component root mean square
18	MEAN_P(MAX_t)mag/	V/m	E-field y-axis component root mean square

Column	Header	Unit	Description
	MEAN_P(MEAN_t)mag		
19	MEAN_P(MAX_t)xyz/ MEAN_P(MEAN_t)xyz	V/m	E-field z-axis component root mean square
21	CDF(P,TH,Ex)	V/m	E-field x-axis component standard deviation
22	CDF(P,TH,Ey)	V/m	E-field y-axis component standard deviation
23	CDF(P,TH,Ez)	V/m	E-field z-axis component standard deviation
24	CDF(P,TH,Emag)	V/m	E-field magnitude standard deviation
25	CDF(P,TH,Exyz)		Number of samples used for statistics evaluation
26	LSProbe count		Number of LSProbes in the Multiprobe system
27...	SernoxN		LSProbe 1.2/1.4/2.0 E-field probe serial number of Nth E-field probe in the Multiprobe system
28...	ModexN		Operating mode of Nth E-field probe in the Multiprobe system
29...	FreqxN	Hz	Operating frequency of Nth E-field probe in the Multiprobe system

Example of Multiprobe log file:

```
#t ⊣Type ⊣CDF_TH ⊣MEAN_P(MEAN_t)_x ⊣MEAN_P(MEAN_t)_y ⊣MEAN_P(MEAN_t↙
    )_z ⊣MEAN_P(MEAN_t)_mag ⊣MEAN_P(MEAN_t)_xyz ⊣MEAN_P(MAX_t)_x⊣↙
    MEAN_P(MAX_t)_y⊣MEAN_P(MAX_t)_z⊣MEAN_P(MAX_t)_mag⊣MEAN_P(MAX_t)↙
    _xyz⊣MEAN_P(MAX_t)_x/MEAN_P(MEAN_t)_x ⊣MEAN_P(MAX_t)_y/MEAN_P(↙
    MEAN_t)_y ⊣MEAN_P(MAX_t)_z/MEAN_P(MEAN_t)_z ⊣MEAN_P(MAX_t)_mag/↙
    MEAN_P(MEAN_t)_mag ⊣MEAN_P(MAX_t)_xyz/MEAN_P(MEAN_t)_xyz ⊣CDF(P↙
    ,TH,Ex) ⊣CDF(P,TH,Ey) ⊣CDF(P,TH,Ez) ⊣CDF(P,TH,Emag) ⊣CDF(P,TH,↙
    Exyz) ⊣LSProbe count⊣SernoxN⊣ModexN ⊣FreqxN↵
3683873566.259 ⊣0⊣100000000⊣0⊣0.8⊣0.155727 ⊣0.181752 ⊣0.195949 ⊣↙
    0.341922 ⊣0.177809 ⊣2.868008 ⊣8.6506 ⊣10.124656⊣14.746159⊣↙
    7.214421 ⊣18.416919⊣47.595626⊣51.669944⊣43.127263⊣40.573961⊣↙
    0.220673 ⊣0.195659 ⊣0.171692 ⊣0.328284 ⊣0.186423 ⊣0⊣8⊣186⊣0⊣↙
    100000000.000⊣3⊣0⊣100000000.000⊣343⊣0⊣100000000.000⊣458⊣0⊣↙
    100000000.000⊣267⊣0⊣100000000.000⊣431⊣0⊣100000000.000⊣356⊣0⊣↙
    100000000.000⊣344⊣0⊣100000000.000↵
3683873582.640 ⊣0⊣100000000⊣1⊣0.8⊣0.157887 ⊣0.207932 ⊣0.217084 ⊣↙
    0.376413 ⊣0.194301 ⊣2.675192 ⊣8.479201 ⊣9.880226 ⊣14.395745⊣↙
    7.01154⊣16.943749⊣40.778636⊣45.513357⊣38.244557⊣36.085957⊣↙
    0.218273 ⊣0.195434 ⊣0.173181 ⊣0.334387 ⊣0.187499 ⊣0⊣8⊣186⊣0⊣↙
    100000000.000⊣3⊣0⊣100000000.000⊣343⊣0⊣100000000.000⊣458⊣0⊣↙
    100000000.000⊣267⊣0⊣100000000.000⊣431⊣0⊣100000000.000⊣356⊣0⊣↙
```

```
100000000.000⊣344⊣0⊣100000000.000↵
```

13.1.8 Stream Files in Binary Format

The format "PREFIX_FPSN_TYPE_CISN_YYYYMMDD_hhmmss.bin" and "PREFIX_FPSN_TYPE_CISN_YYYYMMDD_hhmmss.lut" containing the following information is used for all binary stream files.

PREFIX
: File prefix set by the user, its default value is "stream".

FPSN
: Field probe serial number, e.g. FP38.

TYPE
: Field probe type, e.g., 1v2 for LSProbe 1.2.

CISN
: CI-250 serial number, e.g. CI556.

YYYYMMDD_hhmmss
: Year, month, day of the month, hour, minute and second of the start of the stream file.

Stream files are optimized for small file size and low processor load. Files with the extension ".bin" contain e-field values for all axes, including frame indicators. Files with the extension ".lut" contain auxiliary information about device, mode, frequency, correction, temperature and skip count. They start with a 64 bit unsigned integer value indicating the streaming sample in the .bin file from which on the new look-up table is valid. For LSProbe devices they have a size of 33 bytes and the following structure:

Data	Offset	Size	Description
Sample Start Index	0	8	Stream sample start index of LUT, 64 bit, little-endian unsigned integer
Serial number	8	2	Field probe serial number, 16 bit, little endian, unsigned integer
Optical FP	10	1	Optical field probe present yes/no?, 8 bit, little endian, unsigned integer
Mode	11	1	Field probe mode, 8 bit, little endian, unsigned integer
Frequency	12	8	Field probe frequency in hertz, 64 bit, double-precision, little-endian floating-point value
Temperature	20	4	Field probe temperature in °C, 32 bit, single-precision, little-endian floating-point value
Accredited Cal.	24	1	Accredited calibration files used yes/no?, 8 bit, little endian, unsigned integer

Data	Offset	Size	Description
Wideband Corr.	25	4	Wideband correction files used, bandwidth in MHz, 32 bit, single-precision, little-endian
Skip Count	29	4	Stream recording skip count, 32 bit, little endian, unsigned integer value

Binary measurement data files contain arbitrary number e-field value blocks. Each block contains synchronized x-, y- and z-axis RSSI values and a combined frame and axes number indicator for each sampling instant. Each block has a a size of thirteen bytes and the following structure:

Data	Size	Description
frame	1	Frame information for the current sample, alternating between zero and one, added by the number of axes, in this case three, i.e. the value alternates between three and four, 8 bit unsigned integer
Ex	4	X-axis E-field value, 32 bit single-precision, little-endian floating-point value
Ey	4	Y-axis E-field value, 32 bit single-precision, little-endian floating-point value
Ez	4	Z-axis E-field value, 332 bit single-precision, little-endian floating-point value

The frame information byte contains information about the device type, number of channels and the frame indicator. The device used for the following data tuple can be either a power meter (bit 7/MSB =1) or a field probe (bit 6 = 1). Bit 4 and 5 indicate the number of axis of the device (3 axis for LSProbe, 1-3 axis/channels for LSPM). Bit 0/LSB is the frame indicator. For the continuous modes (mode 0-3 & mode 8-11), the frame indicator change its value from zero to one and vice versa, when new LF data is received. For the burst modes (mode 5-7), the frame indicator change its value when a new burst frame is received.

13.1.9 Stream Files in CSV Format

The Bin2Csv.exe program which is part of the Lumiloop Installer can be used to generate CSV files from binary stream files described in the previous section. CSV output files have the following format:

Column	Header	Unit	Description
1	Mode		Measurement mode, see Table 1, page 24, optional
2	Freq	Hz	Compensation frequency, optional

Column	Header	Unit	Description
3	Ex	V/m	X-axis component of E-field
4	Ey	V/m	Y-axis component of E-field
5	Ez	V/m	Z-axis component of E-field
6	Emag	V/m	E-field magnitude, optional
7	Frame		Frame indicator
11 / 14	T	°C	Temperature inside the E-field probe, optional
12 / 15	Skip		Skip count used during stream recording, optional
13 / 16	SerNo		Field probe serial number, optional

The Bin2Csv.exe program accepts an arbitrary number of command line switches followed by the file name(s) of one or more binary stream files. One CSV file will be generated for every bin file, replacing the extension "bin" by "csv". Note that the Bin2Csv.exe program can be used for both E-field and power value stream files. The stream file type will be detected automatically. The following command line switches are supported for E-field stream files, redundant parameters will be ignored silently:

-h
: display usage information and quit program,

-m
: enable optional E-field magnitude column,

-s
: set sample index for the start of binary to CSV conversion, default is zero,

-e
: set sample index for the end of binary to CSV conversion, default is last sample in bin file,

-l
: set number of samples to be converted to CSV format, relative to start sample index if specified, defaults to all samples in bin file,

-M
: enable optional mode column,

-F
: enable optional frequency column,

-T
: enable optional temperature column,

-S
: enable optional skip count column.

13.1.10 GUI load file format

The file format for files that can be viewed with the LUMILOOP GUI contains at least 1 column. Either efield x-component, y-component, z-component or efield magnitude values or any combination thereof has to be contained. The first line must contain a comment line starting with "#" where the column names are stated. The LUMILOOP GUI searches case insensitive for the strings containing "ex", "ey", "ez", "emag" or "|e|". Units have to be in 'V/m". All other columns will be ignored. Multiple data sets for the same efield component must be clearly distinguishable via their column header, e.g. "Ex_probe1" and "Ex_probe2".

Example of file:

```
#Ex_p1 in V/m⇥Ey_p1 in V/m ⇥Ez_p1 in V/m ⇥Emag_p1 in V/m ⇥Ex_p2 in ↙
   V/m ⇥Ey_p2 in V/m ⇥Ez_p2 in V/m ⇥Emag_p2 in V/m↵
0.508⇥0.267⇥0.507⇥0.765⇥0.152⇥0.582⇥0.165⇥0.623↵
0.570⇥0.657⇥0.865⇥1.226⇥0.270⇥0.420⇥0.472⇥0.687↵
```

13.2 extCalLog TCP-Server Logger

For each TCP client connection, with the exception of the LUMILOOP GUI, a flag can be set via »:CALibration:LOGging <Value>« to enable logging of specific field probe status information and current E-field values every time one of the following SCPI queries is sent by a client which previously set its log flag set to 1. Additionally, the command »:CALibration:LOGging:GLObal <Value>« can be used to enable logging for all connected clients

The file format for all calibration log files for LSProbe 1.2 field probes contains twenty-one columns described with their column headers and unit values in the table below.

Column	Header	Unit	Description
1	RSSIx	LSB	X-axis raw RSSI value
2	RSSIy	LSB	Y-axis raw RSSI value
3	RSSIz	LSB	Z-axis raw RSSI value
4	T	°C	Temperature inside the E-field probe
5	f	Hz	Compensation frequency
6	Ex	V/m	X-axis component of E-field
7	Ey	V/m	Y-axis component of E-field
8	Ez	V/m	Z-axis component of E-field
9	Emag	V/m	E-field magnitude
10	Serno CI		CI-250$^{(+)}$ Computer Interface serial number
11	Serno FP		LSProbe 1.2/1.4/2.0 E-field probe serial number

Column	Header	Unit	Description
12	Mode		Measurement mode, see Table 1, page 24
13	FW CI		CI-250(+) Computer Interface firmware version
14	Server Built date		LUMILOOP TCP Server built date formatted as YYYYMMDD
15	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
16	cal:corr		Correctionf actors enabled state, see :CALibration:CORRfactor <Value>[,<MProbe>]
17	fLpE	Hz	E-field low pass filter frequency
18	ACCx	g	X-axis acceleration in multiples of 9.81 m/s^2
19	ACCy	g	Y-axis acceleration in multiples of 9.81 m/s^2
20	ACCz	g	Z-axis acceleration in multiples of 9.81 m/s^2
21	xyzma		Inidcator which SCPI query prompted logging of actual line

Example of extCalLog file:

```
#RSSIx ⊣RSSIy⊣RSSIz⊣T⊣f⊣Ex ⊣Ey ⊣Ez ⊣Emag ⊣SerNo CI ⊣SerNo FP ⊣Mode↙
    ⊣FW CI⊣Server built date⊣t   cal:corr ⊣fLPP ⊣ACCx ⊣ACCy ⊣ACCz↙
    ⊣xyzma↵
8586.5341⊣6726.4829⊣6777.9604⊣61.3347⊣1100000000.000 ⊣20.727396⊣↙
   0.742691 ⊣0.771910 ⊣20.755057⊣611⊣10 ⊣0⊣13916⊣20240503 ⊣↙
   3734408730 ⊣0⊣100.000000 ⊣0.092⊣-0.216 ⊣0.891⊣c↵
8585.7794⊣6728.1175⊣6780.4787⊣61.3390⊣1100000000.000 ⊣20.685341⊣↙
   0.741557 ⊣0.788026 ⊣20.713624⊣611⊣10 ⊣0⊣13916⊣20240503 ⊣↙
   3734408733 ⊣0⊣100.000000 ⊣0.101⊣-0.216 ⊣0.931⊣c↵
```

The file format for all calibration log files for LSProbe 2.0 field probes contains thirty columns described with their column headers and unit values in the table below.

Column	Header	Unit	Description
1	RSSIxa	LSB	Xa-axis raw RSSI value
2	RSSIya	LSB	Ya-axis raw RSSI value
3	RSSIza	LSB	Za-axis raw RSSI value
4	RSSIxb	LSB	Xb-axis raw RSSI value
5	RSSIyb	LSB	Yb-axis raw RSSI value
6	RSSIzb	LSB	Zb-axis raw RSSI value
7	T	°C	Temperature inside the E-field probe

Column	Header	Unit	Description
8	f	Hz	Compensation frequency
9	Ex	V/m	X-axis component of E-field
10	Ey	V/m	Y-axis component of E-field
11	Ez	V/m	Z-axis component of E-field
12	Emag	V/m	E-field magnitude
13	Serno CI		CI-250$^{(+)}$ Computer Interface serial number
14	Serno FP		LSProbe 1.2/1.4/2.0 E-field probe serial number
15	Mode		Measurement mode, see Table 1, page 24
16	FW CI		CI-250$^{(+)}$ Computer Interface firmware version
17	Server Built date		LUMILOOP TCP Server built date formatted as YYYYMMDD
18	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
19	cal:corr		Correctionf actors enabled state, see :CALibration:CORRfactor <Value>[,<MProbe>]
20	fLpE	Hz	E-field low pass filter frequency
21	ACCx	g	X-axis acceleration in multiples of 9.81 m/s^2
22	ACCy	g	Y-axis acceleration in multiples of 9.81 m/s^2
23	ACCz	g	Z-axis acceleration in multiples of 9.81 m/s^2
24	xyzma		Inidcator which SCPI query prompted logging of actual line
25	Exa	V/m	Xa-axis E-field value
26	Eya	V/m	Ya-axis E-field value
27	Eza	V/m	Za-axis E-field value
28	Exb	V/m	Xb-axis E-field value
29	Eyb	V/m	Yb-axis E-field value
30	Ezb	V/m	Zb-axis E-field value

Example of extCalLog file:

```
#RSSIxa⊣RSSIya ⊣RSSIza ⊣RSSIxb ⊣RSSIyb ⊣RSSIzb ⊣T⊣f⊣Ex ⊣Ey ⊣Ez ⊣↙
   Emag ⊣SerNo CI ⊣SerNo FP ⊣Mode ⊣FW CI⊣Server built date⊣t⊣cal:↙
   corr ⊣fLPE ⊣ACCx ⊣ACCy ⊣ACCz ⊣xyzma⊣Exa⊣Eya⊣Eza⊣Exb⊣Eyb⊣Ezb↵
8586.5341⊣6726.4829⊣6777.9604⊣8923.9665⊣6840.3538⊣6856.1332⊣61.3347↙
   ⊣1100000000.000 ⊣20.727396⊣0.742691 ⊣0.771910 ⊣20.755057⊣611⊣10↙
    ⊣0⊣13916⊣20240503 ⊣3734408730 ⊣0⊣100.000000 ⊣0.092⊣-0.216 ⊣↙
```

```
    0.891⊣c⊣20.256231⊣0.754630 ⊣0.627769 ⊣21.198561⊣0.730753 ⊣↙
    0.916051↩
8585.7794⊣6728.1175⊣6780.4787⊣8920.7270⊣6838.9120⊣6858.1501⊣61.3390↙
    ⊣1100000000.000 ⊣20.685341⊣0.741557 ⊣0.788026 ⊣20.713624⊣611⊣10↙
     ⊣0⊣13916⊣20240503 ⊣3734408733 ⊣0⊣100.000000 ⊣0.101⊣-0.216 ⊣↙
    0.931⊣c⊣20.242027⊣0.765145 ⊣0.643102 ⊣21.128653⊣0.717969 ⊣↙
    0.932950↩
```

The file format for all calibration log files for LSProbe 1.4 field probes contains fifteen columns described with their column headers and unit values in the table below.

Column	Header	Unit	Description
1	RSSIx	LSB	X-axis raw RSSI value
2	T	°C	Temperature inside the E-field probe
3	f	Hz	Compensation frequency
4	Ex	V/m	X-axis component of E-field
5	Serno FP		LSProbe 1.2/1.4/2.0 E-field probe serial number
6	Mode		Measurement mode, see Table 1, page 24
7	FW LSProbe		LSProbe 1.4 firmware version
8	Server Built date		LUMILOOP TCP Server built date formatted as YYYYMMDD
9	t	s	Timestamp expressed as a float number of seconds since 1904-01-01 00:00:00 UTC
10	cal:corr		Correctionf actors enabled state, see :CALibration:CORRfactor <Value>[,<MProbe>]
11	fLpE	Hz	E-field low pass filter frequency
12	ACCx	g	X-axis acceleration in multiples of 9.81 m/s^2
13	ACCy	g	Y-axis acceleration in multiples of 9.81 m/s^2
14	ACCz	g	Z-axis acceleration in multiples of 9.81 m/s^2
15	xyzma		Inidcator which SCPI query prompted logging of actual line

Example of extCalLog file:

```
#RSSIx ⊣T⊣f⊣Ex ⊣SerNo FP ⊣Mode ⊣FW CI⊣Server built date⊣t⊣cal:corr↙
     ⊣fLPE ⊣ACCx ⊣ACCy ⊣ACCz ⊣xyzma↩
8586.5341⊣31.3347⊣1100000000.000 ⊣20.727396⊣5⊣0⊣13916⊣20240503 ⊣↙
    3734408730 ⊣0⊣100.000000 ⊣0.092⊣-0.216 ⊣0.891⊣c↩
8585.7794⊣31.3390⊣1100000000.000 ⊣20.685341⊣5⊣0⊣13916⊣20240503 ⊣↙
```

```
3734408733 ⊣0⊣100.000000 ⊣0.101⊣-0.216 ⊣0.931⊣c↵
```

13.3 Generic Calibration Result Files

To simplify the conversion of resulting corrections factors for the usage in the LUMILOOP TCP Server a generic calibration result file is described in the following.

Generic calibration result files are a dialect of CSV files using the formatting conventions outlined in Section 13 on page 13. It is a subset of the CSV format. No quotation or other escapes are allowed. An additional metadata part is added at the beginning of the file. The metadata lines have to begin with »#« (here comment char) and they contain a key and a value separated by »:«. Additional whitespace at the begin or end will be ignored. Lines starting with a comment char and not containing a known key will also be ignored, but it is possible that additional keys will be introduced in the future.

The data part starts with the first line not starting with a comment char. This line is the table header.

13.3.1 Metadata

The following keys must or may (informational) occure in the metadata section. They keys are case sensitive and must be written as given below. If they are composed a single space separates the words.

Certificate Identifier A unique identifier for the calibration certificate

Date of Calibration Last day of the calibration (local time of calibration laboratory) in the form `YYYY-MM-DD`.

Calibration Laboratory Short form name of the calibration laboratory (e.g. NPL, PTB, METAS, etc.)

Object generic name of device (e.g. field probe, power meter)

Manufacturer Manufacturer of the device, here LUMILOOP

Type the full Type/name of device as indicated on the type plate or in the corresponding documents (for CalImport it has to be LSProbe 1.2 E|F|G|X or LSProbe 2.0)

Serial Number Serial number of calibrated device

Nominal Field The nominal value of the field in V/m used for calibration as a float in the form `xx.xx V/m` rounded to the least significant digit

Date of Factory Calibration Date of the factory calibration ("Date of Manufacturer Calibration" is deprecated)

Ambient Temperature (informational) Ambient temperature e.g. in the chamber/tem-cell as a float in °C in the form `yy.y °C`

Ambient Humidity (informational) Relative ambient humidity as a float in % in the form `zz.z %`

Customer (informational)

Order Number (informational)

Date of Certificate (informational) Date of approval of the certificate (local time of calibration laboratory)

Approved by (informational) Person who has approved the certificate

Description (informational) Description of the calibration, might be used to distinguish calibrations for different purposes

Accredited by (informational) Accreditation body and indentifier

13.3.2 Data

The data section consists of eight respective fifteen entries per line. Each axis has to be measured for each frequency and mode to be calibrated. The column order has to follow the description in the following tables. The values for each axis are always measured when the respective axis is parallel to the field polarization. For LSProbe 2.0 a- and b-axis are measured at the same time. This means E_cal,xa and E_cal,xb etc. are the same. The values of the axes orthogonal to the field polarization are not part of this file. But they will be logged by the TCP Server see Section 13.2 on page 292. The values must have the same value and precision as the values in the calibration certificate.

For LSProbe 1.2/1.4/2.0 E-field probe1.2 measurements the following data is required:

Column	Header	Description
1	Mode	Field probe mode, as queried using »:MEASure[:FProbe]:MODe? [<MProbe>]«; at the moment only modes 0 and 3 are supported by CalImport
2	Frequency/Hz	Calibration frequency, as queried using »:SYSTem:FREQuency? [<MProbe>]«
3	E_cal,x/(V/m)	X-axis field strength of the calibration setup
4	E_disp,x/(V/m)	X-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«, using the »X« variant of the SCPI command
5	E_cal,y/(V/m)	Y-axis field strength of the calibration setup
6	E_disp,y/(V/m)	Y-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«, using the »Y« variant of the SCPI command
7	E_cal,z/(V/m)	Z-axis field strength of the calibration setup
8	E_disp,z/(V/m)	Z-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:X/Y/Z/MAG/ALL? [<MProbe>]«, using the »Z« variant of the SCPI command

For LSProbe 1.2/1.4/2.0 E-field probe2.0 measurements using the high-band detectors the following data is required, for the low-band detector the b-colums (xb, yb, zb) are ignored:

Column	Header	Description
1	Mode	Field probe mode, as queried using »:MEASure[:FProbe]:MODe? [<MProbe>]«; at the moment only modes 0 and 3 are supported by CalImport
2	Frequency/Hz	Calibration frequency, as queried using »:SYSTem:FREQuency? [<MProbe>]«
3	E_cal,xa/(V/m)	xa-antenna field strength of the calibration setup
4	E_disp,xa/(V/m)	xa-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]«, using the »XA« variant of the SCPI command
5	E_cal,ya/(V/m)	ya-axis field strength of the calibration setup
6	E_disp,ya/(V/m)	ya-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]«, using the »YA« variant of the SCPI command
7	E_cal,za/(V/m)	za-axis field strength of the calibration setup
8	E_disp,za/(V/m)	za-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]«, using the »ZA« variant of the SCPI command
9	E_cal,xb/(V/m)	xb-axis field strength of the calibration setup
10	E_disp,xb/(V/m)	xb-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]«, using the »XB« variant of the SCPI command
11	E_cal,yb/(V/m)	yb-axis field strength of the calibration setup
12	E_disp,yb/(V/m)	yb-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]«, using the »YB« variant of the SCPI command
13	E_cal,zb/(V/m)	zb-axis field strength of the calibration setup
14	E_disp,zb/(V/m)	zb-axis field strength, as queried by »:MEASure[:FProbe][:Efield]:XA/XB/ZA/XB/YB/ZB? [<MProbe>]«, using the »ZB« variant of the SCPI command

13.3.3 Ensuring data integrity

To ensure data integrity, an additional field with the key Hash may be appended to the file. Be aware that this does not protect against active manipulation of the file. The value must contain »`sha256`« to indicate the hash algorithm followed by »`:`« and the hash encoded as hex-string. The hash is calculated from all bytes preceding the line containing the hash, i.e. all bytes including the line break preceding the characters »`#Hash:`«. The algorithm used for hashing must be SHA-256 and all line breaks must be `LF`/(`0x0A`).

```
#Hash: sha256:xxyyzzaabbcc...
```

13.3.4 Example

LSProbe 1.2 Generic calibration result file:

```
#Certificate Identifier: PI:20210707:abc⏎
#Date of Calibration: 2021-06-28⏎
#Date of Factory Calibration: 2021-03-14⏎
#Calibration Laboratory: Circlelab⏎
#Object: field probe⏎
#Manufacturer: LUMILOOP⏎
#Type: LSProbe 1.2 E⏎
#Serial Number: 42⏎
#Nominal Field: 13.37 V/m⏎
#Customer: Fieldtesters, 01001 Musterhausen, GERMANY⏎
#Date of Certificate: 2021-06-28⏎
#Description: Pulse measurements⏎
Mode ⊣Frequency/Hz ⊣E_cal,x/(V/m)⊣E_disp,x/(V/m) ⊣E_cal,y/(V/m)⊣E_disp,y/(V/m) ⊣E_cal,z/(V/m)⊣E_disp,z/(V/m)⏎
3⊣10000⊣13.00⊣12.59⊣13.12⊣10.99⊣13.05⊣12.55⏎
3⊣200000000⊣13.20⊣13.00⊣13.35⊣13.42⊣13.01⊣12.99⏎
0⊣2000000000 ⊣13.54⊣13.01⊣13.35⊣13.42⊣13.01⊣12.99⏎
0⊣4000000000 ⊣13.67⊣13.50⊣13.35⊣13.42⊣13.01⊣12.99⏎
#Hash: sha256:c0211ed4cb01667ec2e83baa9267e01766436246b6b3284b08402318bb569f90⏎
```

13.3.5 Generation of this file format using spread sheet software

If other solutions are not applicable the file can also be generated using a spread sheet software (e.g. LibreOffice Calc, Microsoft Excel). Other more automated solutions are prefered to reduce mistakes.

Arange the data like given in the table below and export it as CSV with tab as delimiter, a point as decimal separator and no quotation marks. This can be changed in Save File dialog or via format of cells.

	A	B	C	…
20	Mode	Frequency/Hz	E_cal,x/(V/m)	…
21	0	9000	13.00	…
⋮	⋮	⋮	⋮	⋮

Meta data has to be added manually in CalImport.

13.4 Calibration Files

Each LSProbe 1.2/1.4/2.0 E-field probe comes with a detailed set of factory calibration files used for linearity compensation, frequency compensation, temperature compensation and E-field strength calibration. Optionally, correction factor files can be added. Calibration files are stored in one directory per E-field probe, directory names consist of »sn« or in case of LSProbe 2.0 devices »2v0_sn« followed by the decimally coded LSProbe 1.2/1.4/2.0 E-field probe serial number without leading zeros. Calibration directories are stored in the directory specified via the `CAL_PATH` "LUMILOOP.ini"-file variable. The CSV file conventions detailed in section 13 apply to all calibration files.

The contents of all calibration files are protected against inadvertent modification by means of a decimally coded integer checksum in the last column of each calibration file's first line. The checksum is calculated by adding all ASCII code values of the calibration file starting with the first character of the second line of the respective calibration file.

13.4.1 Factory Linearity, Frequency and Temperature Compensation Files

One factory linearity, frequency and temperature compensation file, or short LFT file, exists for every factory calibrated frequency and E-field probe mode. LFT file names consist of »sn« followed by the decimally coded LSProbe 1.2/1.4/2.0 E-field probe serial number, »m« followed by the decimally coded mode number, »f« followed by the decimally coded frequency value in hertz, followed by ».csv«.

The temperatures have to be in an ascending order.

The first line of LFT files starts with a hash mark character (»#«) and gives context information for the LFT file. It does not give column names for the data in the remainder of the CSV file. The first line's columns have the following contents:

Column	Unit	Description
1		LSProbe 1.2/1.4/2.0 E-field probe serial number as decimally coded integer value
2		Measurement mode, see Table 1, page 24
3	Hz	Measurement frequency
4		Time stamp of first calibration temperature for given frequency and mode

Column	Unit	Description
5	°C	Ambient temperature of first calibration temperature for given frequency and mode
6	LSB	E-field probe internal temperature ADC value of first calibration temperature for given frequency and mode
7		Time stamp of second calibration temperature for given frequency and mode
8	°C	Ambient temperature of second calibration temperature for given frequency and mode
9	LSB	E-field probe internal temperature ADC value of second calibration temperature for given frequency and mode
10		Time stamp of third calibration temperature for given frequency and mode
11	°C	Ambient temperature of third calibration temperature for given frequency and mode
12	LSB	E-field probe internal temperature ADC value of third calibration temperature for given frequency and mode
13		Time stamp of fourth calibration temperature for given frequency and mode
14	°C	Ambient temperature of fourth calibration temperature for given frequency and mode
15	LSB	E-field probe internal temperature ADC value of fourth calibration temperature for given frequency and mode
16		Checksum for rest of file as described in Section 13.4

The following lines of LFT files of LSProbe 1.2 calibration data and of LSProbe 2.0 mode 2, 3, 6 and 7 calibration data have the following contents:

Column	Unit	Description
1	dBm	Power level used for given mode, frequency and all temperatures given in the first line of the file
2	LSB	X-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
3	LSB	Y-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
4	LSB	Z-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
5	LSB	X-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column

Column	Unit	Description
6	LSB	Y-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
7	LSB	Z-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
8	LSB	X-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
9	LSB	Y-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
10	LSB	Z-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
11	LSB	X-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
12	LSB	Y-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
13	LSB	Z-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column

The following lines of LFT files of LSProbe 2.0 mode 0 and 4 calibration data have the following contents:

Column	Unit	Description
1	dBm	Power level used for given mode, frequency and all temperatures given in the first line of the file
2	LSB	Xa-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
3	LSB	Ya-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
4	LSB	Za-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
5	LSB	Xb-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
6	LSB	Yb-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column
7	LSB	Zb-axis RSSI value for first calibration temperature for given frequency, mode and power value in first column

Column	Unit	Description
8	LSB	Xa-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
9	LSB	Ya-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
10	LSB	Za-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
11	LSB	Xb-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
12	LSB	Yb-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
13	LSB	Zb-axis RSSI value for second calibration temperature for given frequency, mode and power value in first column
14	LSB	Xa-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
15	LSB	Ya-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
16	LSB	Za-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
17	LSB	Xb-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
18	LSB	Yb-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
19	LSB	Zb-axis RSSI value for third calibration temperature for given frequency, mode and power value in first column
20	LSB	Xa-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
21	LSB	Ya-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
22	LSB	Za-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
23	LSB	Xb-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
24	LSB	Yb-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column
25	LSB	Zb-axis RSSI value for fourth calibration temperature for given frequency, mode and power value in first column

13.4.2 Factory Field Strength Calibration Files

One factory E-field calibration file, or short FE file, exists for every factory calibrated E-field probe mode. FE file names consist of »sn« or in case of LSProbe 2.0 devices »2v0_sn« followed by the decimally coded LSProbe 1.2/1.4/2.0 E-field probe serial number, »m« followed by the decimally coded mode number, followed by ».csv«.

The first line of FE files starts with a hash mark character (»#«) and gives context information for the FE file. It does not give column names for the data in the remainder of the CSV file. The first line's columns have the following contents:

Column	Unit	Description
1		LSProbe 1.2/1.4/2.0 E-field probe serial number as decimally coded integer value
2		Measurement mode, see Table 1, page 24
3	V/m	E-field strength during calibration of given mode
4	LSB	E-field probe internal temperature ADC value during calibration of given mode
5		Time stamp during calibration of given mode
6		Checksum for rest of file as described in Section 13.4

The following lines of FE files of LSProbe 1.2 calibration data and of LSProbe 2.0 mode 2, 3, 6 and 7 calibration data have the following contents:

Column	Unit	Description
1	Hz	Frequency for given mode and ambient temperature
2	LSB	x-axis RSSI value for given E-field strength and mode in first column
3	LSB	y-axis RSSI value for given E-field strength and mode in first column
4	LSB	z-axis RSSI value for given E-field strength and mode in first column

The following lines of FE files of LSProbe 2.0 mode 0 and 4 calibration data have the following contents:

Column	Unit	Description
1	Hz	Frequency for given mode and ambient temperature
2	LSB	xa-axis RSSI value for given E-field strength and mode in first column
3	LSB	ya-axis RSSI value for given E-field strength and mode in first column
4	LSB	za-axis RSSI value for given E-field strength and mode in first column
5	LSB	xb-axis RSSI value for given E-field strength and mode in first column

Column	Unit	Description
6	LSB	yb-axis RSSI value for given E-field strength and mode in first column
7	LSB	zb-axis RSSI value for given E-field strength and mode in first column

13.4.3 Field Strength Correction Files

At least one accredited E-field calibration file, or short AE file, exists for every accredited calibrated LSProbe 1.2/1.4/2.0 E-field probe. The number of files is depending on the calibration requirements. Most of the time two files exists, one for mode 0, another for mode 3. If the probe is multi-level calibrated then there exists a file for every combination of mode and field level. An AE file contains correction factors expressed in decibel, the correction factor will be applied to the base E-field derived from the supplied internal calibration data. A value greater than zero will make the output E-field value larger, values smaller than zero lower the output E-field value.

AE file names take generally the format `AvBsnX_E_mM.csv`, it consists of multiple parts: `AvB` denotes the LSProbe 1.2/1.4/2.0 E-field probe version, e.g. 1v2, 2v0, (the dot in the version number is replaced with a "v"), `X` the LSProbe 1.2/1.4/2.0 E-field probe serial number, e.g. 436, `E` the nominal field strength in V/m (without the unit) and `M` denotes the field-probe mode. For the LSProbe 1.2/1.4/2.0 E-field probe1.2 there are two other deprecated file name formats: `snX_E_mM.csv` and `snX.csv`. These files can still be used with the current LUMILOOP TCP Server. The latter format also has some differences in the file format itself. It contains only the first two of the described three lines. This format neither does distinguish the modes, nor does it support multi-level calibration (only explicitly by manually swapping the AE files).

For example, `1v2sn436_10_m0.csv` and `1v2sn436_10_m3.csv` are the AE files for LSProbe 1.2/1.4/2.0 E-field probe1.2 serial number 1, at 10 V/m in mode 0 and mode 3. The LUMILOOP TCP Server will parse all AE files according to their contents, ignoring the individual file names.

The first three lines of an AE file start with a hash or number sign (»#«) and give meta information for the AE file and the calibration conditions, it does not give column names for the data in the remainder of the CSV file. The values are separated by tabulators. The first line's columns have the following contents:

Column	Unit	Description
1		LSProbe 1.2/1.4/2.0 E-field probe serial number as decimally coded integer value
2	°C	Average E-field probe internal temperature during calibration
3		Maximum time stamp during calibration
4		Checksum for rest of file as described in Section 13.4

The second line of the AE file contains a calibration certificate string/identifier that extends to the end of the line. Normally the calibration certificate string is prefixed with the (short) name of the calibration laboratory.

The third line of the AE file contains two columns. The first column gives the field probe operating mode which the AE applies to, the second column gives the nominal calibration field-strength (in V/m without the unit), supporting multilevel calibration. (Both values as given by the file name).

The following lines of an AE file have the following contents:

The following lines of AE files of LSProbe 1.2 calibration data and of LSProbe 2.0 mode 3 calibration data have the following contents:

Column	Unit	Description
1	Hz	Frequency for accredited E-field calibration
2	dB	x-axis correction value for the given frequency
3	dB	y-axis correction value for the given frequency
4	dB	z-axis correction value for the given frequency

The following lines of AE files of LSProbe 2.0 mode 0 have the following contents:

Column	Unit	Description
1	Hz	Frequency for accredited E-field calibration
2	dB	xa-axis correction value for the given frequency
3	dB	ya-axis correction value for the given frequency
4	dB	za-axis correction value for the given frequency
5	dB	xb-axis correction value for the given frequency
6	dB	yb-axis correction value for the given frequency
7	dB	zb-axis correction value for the given frequency

14 Specifications

14.1 E-Field Probe 1.2

Table 39: *LSProbe 1.2 ´Field Probe specifications*

Supported Frequency Ranges	Variant
9 kHz ... 8.2 GHz	E (Standard), G (15 kV/m)
10 Hz ... 8.2 GHz	F
Detectors	
Low Band	(10 Hz) 9 kHz ... 400 MHz
High Band	30 MHz ... 8.2 GHz
Field Strength Range, Dynamic Range: Variants E, F	
10 Hz ... 30 MHz (F)	<4 V/m ... >7 kV/m, >65 dB
9 kHz ... 30 MHz (E)	<1 V/m ... >10 kV/m, >80 dB
30 MHz ... 4 GHz	<0.1 V/m ... >1.5 kV/m, >84 dB
4 GHz ... 6 GHz	<0.5 V/m ... >1 kV/m, >65 dB
6 GHz ... 8.2 GHz	<3 V/m ... >1 kV/m, >50 dB
Field Strength Range, Dynamic Range: Variant G	
9 kHz ... 30 MHz	<1 V/m ... >10 kV/m, >80 dB
30 MHz ... 3 GHz	<1 V/m ... >15 kV/m, >84 dB
3 GHz ... 6 GHz	<10 V/m ... >15 kV/m, >64 dB
6 GHz ... 8.2 GHz	<15 V/m ... >10 kV/m, >56 dB
Damage Level	>25 kV/m (CW)
Sampling Rate, Minimum Pulse Width	
Burst Mode	2 MSamples/s, 500 ns
Continuous Mode	500 kSamples/s, 2 µs
One Axis Continuous Mode	2 MSamples/s, 500 ns
Analog Rise Time	
Low Band, low bandwidth	1.9 ms
Low Band, high bandwidth	770 ns
High Band	330 ns
Resolution	<0.01 dB
Typical Worst-Case Isotropy Error	
@ 1 GHz	±1.0 dB
@ 3 GHz	±1.7 dB
@ 6 GHz	Please see Application Note 8.
Amplitude Accuracy	Accredited Cal. at PTB, Germany
9 kHz ... 30 MHz	±0.6 dB
30 MHz ... 1 GHz	±1.0 dB
1 GHz ... 8.2 GHz	±1.4 dB
Linearity Error	±0.2 dB relating to 10 V/m
Temperature Stability	±0.1 dB
Standard Fiber Optic Cables	5 m permanently attached, 15 m FC/ST extension, two E2000 Sacrificial Cable Kits
Max. Fiber Optic Cable Length	1,000 m
Fiber Cable Bending Radius	>30 mm
Ambient Temperature	10 °C ... 40 °C
Dimensions (W × D × H)	46 × 46 × 114 mm³

14.1.1 Typical Isotropy

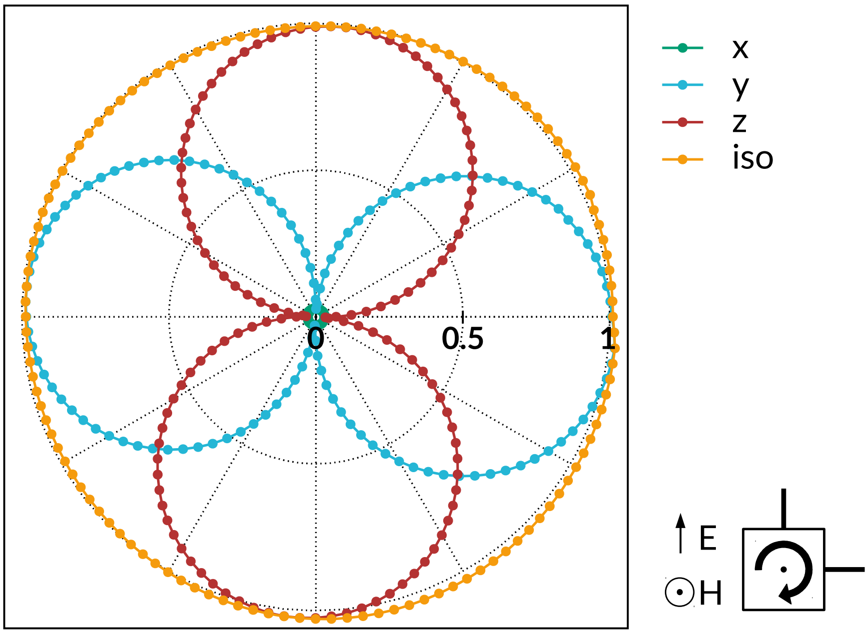


Figure 133: *Isotropy at 1 GHz, rotating around magnetic field vector*

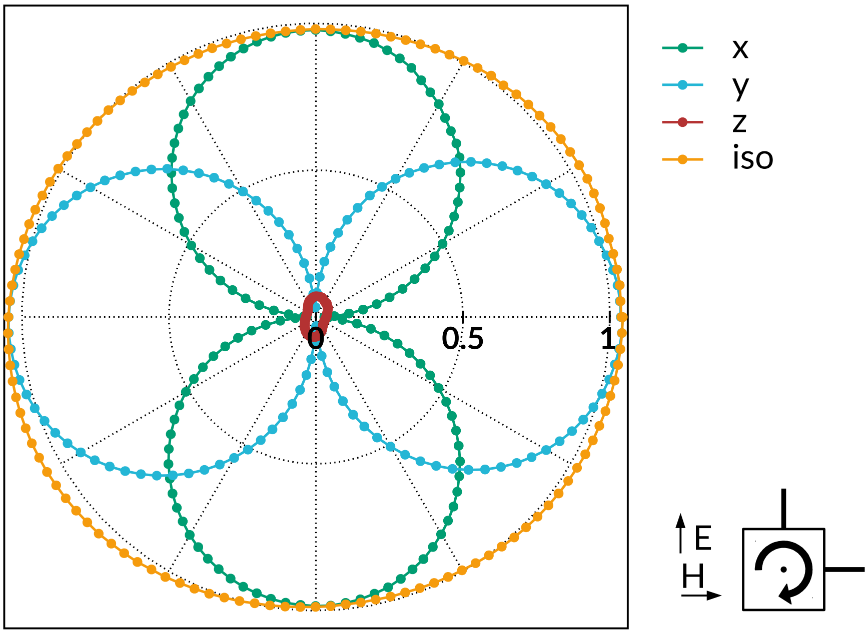


Figure 134: *Isotropy at 1 GHz, rotating in E-H-Plane*

14.1.2 Typical Dynamic Range

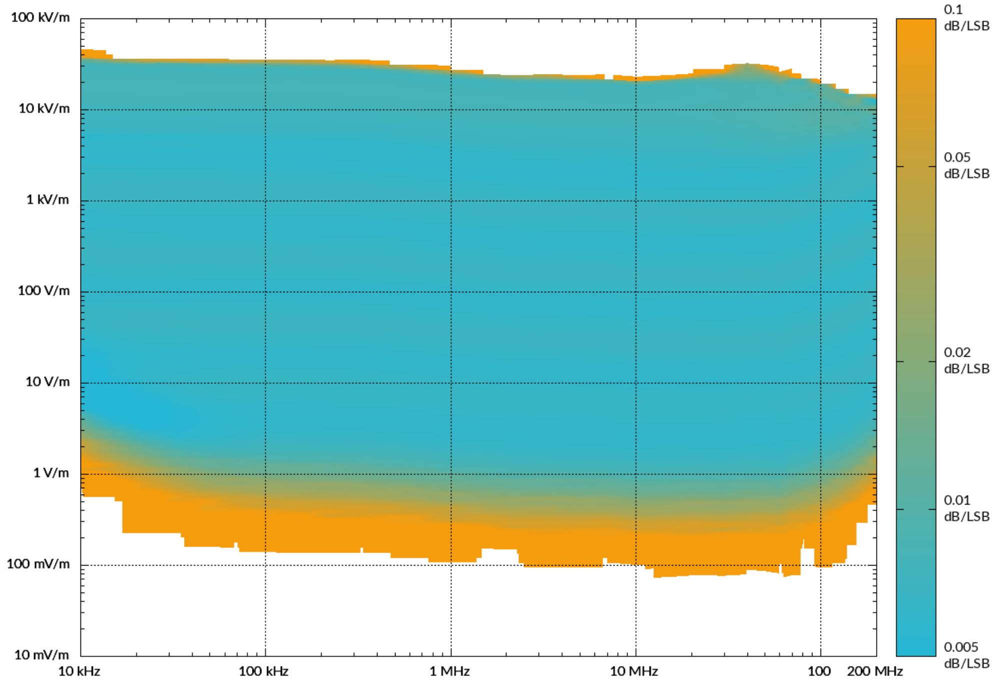


Figure 135: *Typical dynamic range, low band*

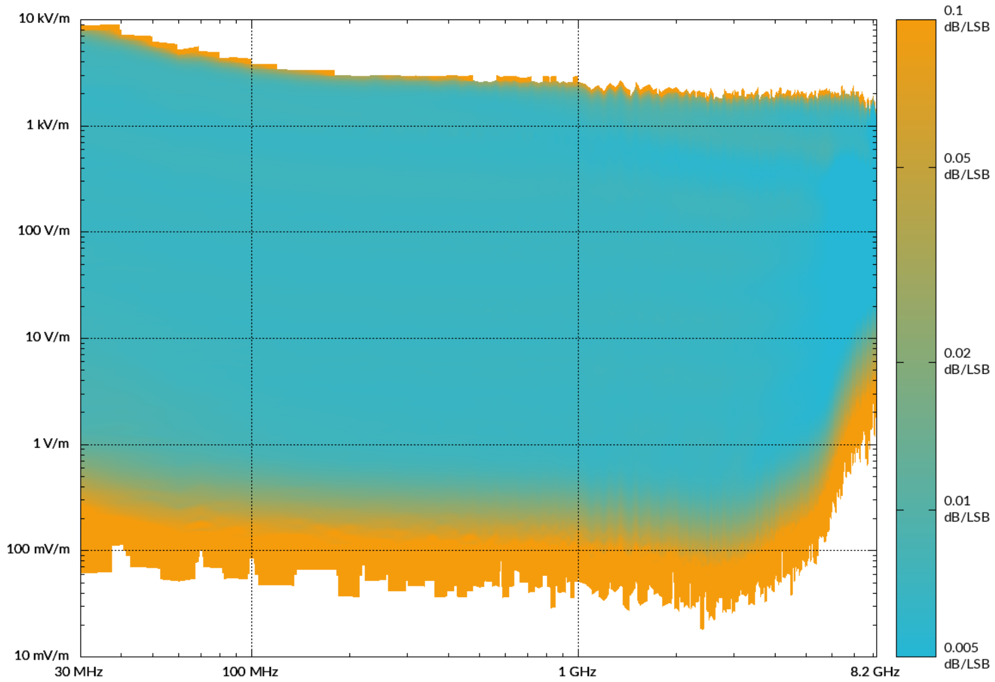
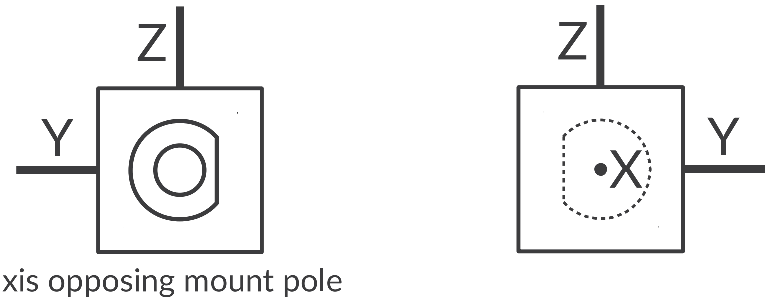


Figure 136: *Typical dynamic range, high band*

14.1.3 Mechanical orientation

For rough orientation, the direction of the antennas is marked on the protective cover of the E-field probe. A flat on the bottom of the mounting pole helps to achieve an exact orientation of the probe. The y-axis antenna opposes this flat.



(a) LSProbe 1v2, view from bottom

(b) LSProbe 1v2, view from top

Figure 137: *Mechanical orientation of the antennas*

By acquiring data of the built-in acceleration sensor, the orientation of the field probe can also be checked by software.

14.2 E-Field Probe 2.0

Table 40: *LSProbe 2.0 Field Probe specifications*

Supported Frequency Ranges	
Low Band Detector	9 kHz ... 1 GHz
High Band Detector	700 MHz ... 18 GHz
Field Strength Range	
9 kHz ... 1 GHz	<1 V/m ... >5 kV/m
1 GHz ... 18 GHz	<1 V/m ... >1 kV/m
Damage Level	
9 kHz ... 1 GHz	>25 kV/m
1 GHz ... 18 GHz	>5 kV/m
Sampling Rate, Minimum Pulse Width	
Burst Mode	2 MSamples/s, 500 ns
Continuous Mode	500 kSamples/s, 2 µs
Single Axis Continuous Mode	2 MSamples/s, 500 ns
Analog Rise Time	
Low Band, low bandwidth	2 ms
Low Band, high bandwidth	<1.5 µs
High Band	<7 ns
Resolution	<0.05 dB
Typical Worst-Case Isotropy Error	
@ 1 GHz	±0.5 dB
@ 6 GHz	±1.5 dB
@ 18 GHz	±1.0 dB
Amplitude Accuracy	Accr. Cal. at AMETEK, Germany
10 kHz ... < 10 MHz	±1.3 dB
10 MHz ... 1 GHz	±1.5 dB
> 1 GHz ... 18 GHz	±1.0 dB
Linearity Error	±0.2 dB relating to 10 V/m
Fiber Optic Connectors	FC/ST
Standard Fiber Optic Cables	5 m permanently attached, 15 m FC/ST extension, two E2000 Sacrificial Cable Kits
Max. Fiber Optic Cable Length	500 m
Fiber Optic Cable Bending Radius	>30 mm
Ambient Temperature	10 °C ... 40 °C
Dimensions (W × D × H)	46 × 46 × 114 mm^3

14.2.1 Typical Dynamic Range

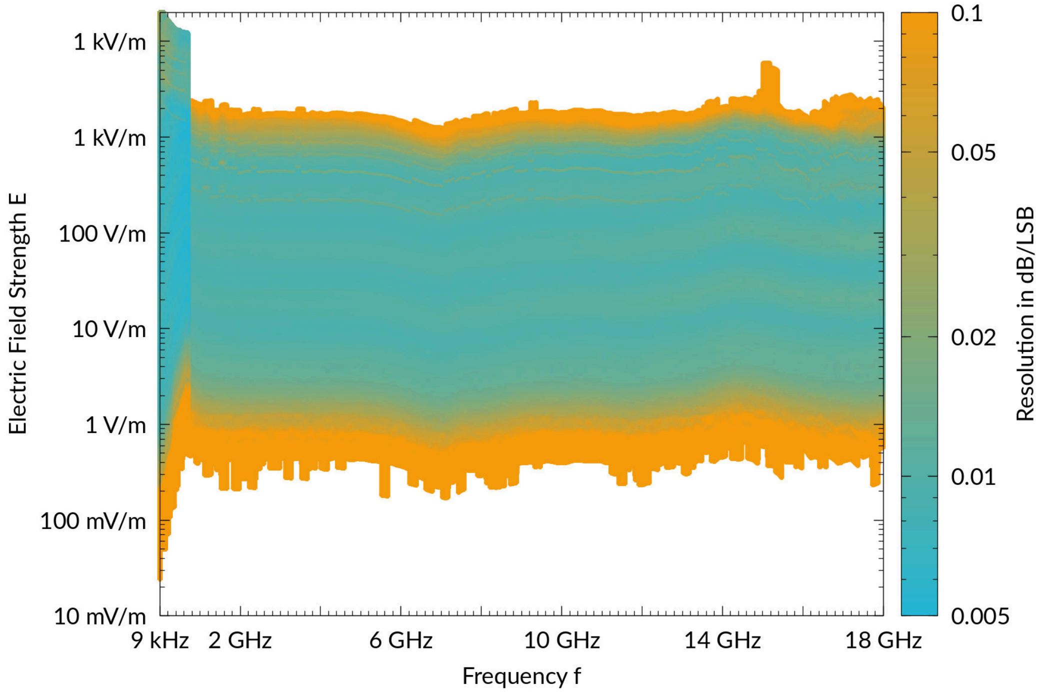
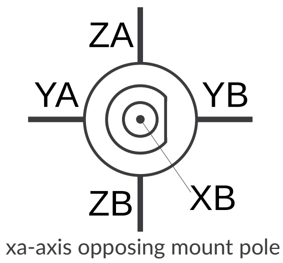


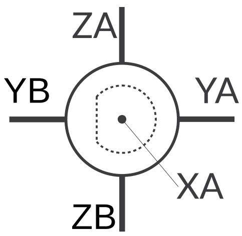
Figure 138: *Typical dynamic range, low band*

14.2.2 Mechanical orientation

For rough orientation, the direction of the antennas is marked on the protective cover of the E-field probe. A flat on the bottom of the mounting pole helps to achieve an exact orientation of the probe. The y-axis antenna opposes this flat.



(a) LSProbe 2v0, view from bottom



(b) LSProbe 2v0, view from top

Figure 139: *Mechanical orientation of the antennas*

By acquiring data of the built-in acceleration sensor, the orientation of the field probe can also be checked by software.

14.3 Computer Interface

Table 41: *Computer Interface specification*

	CI-250	CI-250$^+$
PC Interface	USB 2.0	Gigabit Ethernet
Application Software	LUMILOOP TCP Server, LUMILOOP GUI	LUMILOOP TCP Server (running on CI-250$^+$), LUMILOOP GUI
Trigger Voltage	5 V	5 V
Trigger Connector	BNC	BNC
Laser Wavelength	830 nm	830 nm
Laser, Max. Output Power	1,000 mW	1,000 mW
Laser Class	1M	1M
Laser Shutdown Time	6 ms	6 ms
Fiber Optic Connectors	FC/ST	FC/ST
Number of Fiber Optic Couplers	>6	>6
Input Voltage	5 V DC ±5 %	85-305 V, 47-440 Hz
Input Current	<3 A	
Output Voltage		5 V DC
Output Current		<3 A
Ambient Temperature	10 °C ... 40 °C	10 °C ... 40 °C
Dimensions (W × D × H)	135 × 120 × 38 mm^3	200 × 88 × 150 mm^3
Certifications	CE, IEC 60825-1:2014	CE, IEC 60825-1:2014

15 Warranty Conditions

1. The period of warranty shall start from the date of delivery of the product stated on the delivery note and shall cover a period of 24 months.
2. These warranty conditions apply to devices purchased in Germany. These conditions of warranty also apply if these devices are exported abroad and meet the technical requirements (e.g., voltage, frequency) for the respective country and which are suitable for the respective climatic and environmental conditions.
3. Every and all parts of the product are under LUMILOOP's warranty coverage against any defect that may occur during production, assembly and/or defective parts.
4. A warranty event does not lead to a new warranty period. The warranty period for built-in spare parts ends with the warranty period for the entire device.
5. Within the warranty period, if the product fails because of general material and workmanship, or mounting faults, it will be repaired without demanding any charge.
6. Free repair and product exchange obligations will be annulled under the following conditions:
   a) If the product becomes faulty due to use contrary to the terms or conditions stated in the user's manual,
   b) If the product has been opened, used, or previously repaired by unauthorized persons,
   c) Use of the product by plugging into inappropriate voltages or with faulty electric installation,
   d) If the product serial number has been altered or removed,
   e) If the fault or damage to the product occurred during the transportation outside of the responsibility of LUMILOOP GmbH,
   f) A break or scratch to the product's exterior while in the customer's possession,
   g) Damage from chemical and electrochemical effects of water,
   h) If the product is damaged due to use with spare parts, accessories or devices purchased from other companies which are not original parts.
   i) Those damages caused by natural disasters such as fire, lightning, flood, earthquake, etc.

7. A short report prepared by the LUMILOOP GmbH will determine whether the damage was caused by improper use.
8. Customers are required to initially report any conflicts between themselves and an authorized reseller to the address below:

   Gostritzer Str. 63
   01217 Dresden, Germany
   Phone: +49 (0)351 85097870
   E-mail: info@lumiloop.de

EC DECLARATION OF CONFORMITY

We,	LUMILOOP GmbH, Gostritzer Str. 63, 01217 Dresden, GERMANY,

declare under sole responsibility that the:

Model / Part Name: LSProbe E-Field Probe Systems and Components
Model / Part Numbers: 1003, 1005, 1011, 1012, 1013, 1017, 1020, 1111, 1112, 1113, 1120, 1231, 3001, 3011, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3101, 3103, 3104, 3105, 3106, 3107, 3108
Date of Declaration: December 11, 2024

to which this declaration relates, meets the requirements and is in conformity with the relevant EC Directives listed below using the relevant section(s) of the following EC harmonized standards and other normative documents:

Applicable Directives:

2014/35/EU (Low Voltage Directive)

2014/30/EU (EMC Directive)

2011/65/EU (RoHS), Directive (EU) 2015/863 (RoHS3)

Applicable harmonized standards and/or other normative documents:

EN 61010-1:2010	Safety requirements for electrical equipment for measurement, control, and laboratory use Part 1: General requirements
EN 61326-1:2013	Electrical equipment for measurement, control and laboratory use – EMC requirements Part 1: General requirements
EN 60825-1:2014	Safety of laser products Part 1: Equipment classification and requirements
EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Authorized Signatories:

LUMILOOP GmbH
Eike Suthau, Managing Director

This declaration attests the compliance with the stated directives. It does not imply any assurance of characteristics.

17 Revision History

2016/06/24

- Initial release.

2016/06/28

- Sacrificial optical cable assembly added.
- Analog rise time values corrected.

2016/07/11

- Radar measurements added.

2017/02/09

- Statistical evaluation for continuous and triggered measurement, SCPI commands and GUI support added.
- Multiprobe mode, SCPI commands and GUI support added.
- MProbe parameter added for almost all SCPI commands.
- Make »:syst:reg:get?« return NAN when requesting invalid register.
- Reference field strength for E-field calibration changed to 10 V/m.
- Factory and accredited calibration timestamp query using »:CALibration:TStamp? [<MProbe>]« command added.
- External calibration data can be disabled using SCPI command. New SCPI commands: »:CALibration:CORRfactor? [<MProbe>]« and »:CALibration:CORRfactor <Value>[,<MProbe>]«.
- Firmware-Update command requires revision number as to avoid inadvertent flashing.
- TCP server status messages for laser and E-field probe status added.
- At startup TCP server prints table of available calibration data.
- At startup TCP server prints table of connected CIs and firmware revision numbers.
- Reduced memory footprint by using dynamic trigger buffer size.
- GUI log files extended and corrected.
- GUI "Quick Save" button added.
- GUI shows notification during firmware updates.
- GUI shows difference between TCP server and last GUI setting.
- Ext1 RJ45 external trigger added to computer interface, TCP server and GUI.
- GUI shows laser current and received signal strength in "Laser Status" tool tip.
- GUI shows calibration dates and certificate number in tool-tips.
- GUI shows number of radar pulses.
- GUI can control multiple computer interfaces using "All" button.
- TCP server no longer accepts frequencies outside the calibrated range.
- Alignment of E-field axis and acceleration sensor axis.
- External trigger documentation in manual added.
- Add documentation and support files for EMC32.

- Installer includes FTDI USB driver.
- Installer sets system environment variables instead of user environment variables.
- Documentation of calibration CSV file format added.
- Documentation of sacrificial cable kit added.
- Introduce support for mode 1 and 5 for systems newer than February 2017.
- Remove "Auto" button from GUI for consistency with TCP server.
- Add optional RSSI value logging for basic and scope logs.
- Allow input and output of SCPI commands via standard I/O of TCP server.
- Support dynamic adding and removing of CIs.
- Use previously defined environment variables during installation.
- Add Start menu entry for all users during installation.
- Terminate TCP server on receiving Ctrl-C.
- Fix TCP server parsing of commands using both semicolon and newline.
- Check decimal separator in calibration CSV files.
- Add support for serial protocol emulation in mode 1.
- Add virtual computer interface and field probe support.
- Documentation for RadiMation.
- Documentation and support files for Win6000.

2017/07/24

- Section "Warranty Conditions" added.
- EC Declaration of Conformity added.
- Radar Measurement: improved detection of very short pulses (2 µs).
- Application of temperature-compensated calibration improved.
- »:SYSTem:FREQuency <Frequency>[,<MProbe>]« SCPI command Bug fixed: RSSI value corresponding to highest calibrated E-field value correctly adapted to new set frequency.
- Statistics: Enable bin sizes of over 2 billion samples.
- Computer interface firmware with support for stream recording included.
- Support for stream recording in TCP server and GUI added.
- Debug flags for stream recording, triggering and interpolation added.
- Bin2Csv executable for converting binary stream files to CSV format added.
- »:TRIGger:DONE? [<Timeout>,<MProbe>]« SCPI command to check state of trigger system added.
- »[:TRIGger]:RADar:COUnt:X/:Y/:Z/:MAG/[:ALL]? [<MProbe>]« SCPI command to query number of radar pulses added.
- Documentation and support files for BAT-EMC.
- Support for arbitrary order of columns in CSV file for virtual probes read-in added in GUI.
- Better visibility of current mode and mode changes in GUI.
- Connection tab moved to leftmost position in GUI.

2018/03/06

- Support for frequency sweeps added.

- »:CALibration:TStamp? [<MProbe>]« returns NAN if there is no calibration data.
- »*RST« reloads calibration data from disk.
- TCP server console thread retains previously assigned computer interface serial number.
- Support of zip-format for calibration data added.
- »:MProbe:MAXStatistics? <Triggered>,<MProbe>« memory leak fixed.
- Reduced interpolation time by 60 %.
- Proper exception handling for unexpected client disconnect added.
- Calculate averaged ADC temperature values using all calibration files instead of last read value.
- Save low-pass filtered ADC temperature values when recording waveform.
- Re-interpolate calibration data if temperature ADC value changes by more than 1 LSB (formerly 5 LSB). Re-interpolate at most once per second.
- »:SYSTem:FREQuency? [<MProbe>]« returns frequency rounded to 3 decimal places.
- »:SYSTem:FREQuency:MINimum? [<MProbe>]« and »:SYSTem:FREQuency:MAXimum? [<MProbe>]« added for query of calibrated frequency range.
- LSPROBE_COM_PORT environment variable added, default value set to COM10
- Number of maximum clients raised to 32.
- Support for emulator communication debugging added. Use »:SYSTem:DEBUG <Value/Flag1[,Flag2]...>« with flag 4 for enabling echo of incoming commands and flag 8 for enabling echo of outgoing messages.
- Display of sample indicator field as time in GUI fixed.
- Automatic frequency limit according to calibration in GUI added.
- Compensation frequency indicator field displays valid frequency range when hovering mouse pointer over it.
- Computer interface firmware will automatically update after computer interface enumeration.
- GUI popup upon laser enabling if calibration data is missing for connected field probe(s).
- Mode 1 and 5 via GUI selectable while laser is disabled.
- 'LSProbe-EMC-Startscript.pl' installed to the bin subfolder of the installation path.
- Update of specifications and front page image, added accessories to user's manual.
- Basic Mode and Expert Mode added to LUMILOOP GUI.
- Optional check for software updates added to LUMILOOP GUI.

2020/11/24

- Bug fix: for synchronized streaming 2 LUTE changes in one 256 frame, accidentally used frequency value as ADC temperature value -> fixed and sanity checks added.
- Bug fix: »:SYSTem:FREQuency:MAXimum? [<MProbe>]« for mode 1,5 and frequency < 30 MHz, wrong number returned.
- Bug fix: TCP server crashed when sending data to closed TCP client socket.
- Bug fix: statistics data was returned for a few µs after »stat:en 0« and statistics beause of mutex error.
- Firmware fix: prevent self-triggering on external trigger polarity change.

- Bug fix: »stat:pdf:all?«, »stat:cdf:all?«, »stat:ccdf:all?« -> wrong order of return values.
- Bug fix: TCP server crash on »stat:snap 1« without waveform (state not done).
- Bug fix: prevent bind to already used TCP port.
- Bug fix: reset RSSI averaging in mode 1 if detector changes with set frequency.
- Bug fix: log frequency as 64 bit value when streaming, added logging of probe serial number.
- Bug fix: »trig:arm« race condition fixed by handshake flag in computer interface and modified trigger state transitions.
- Bug fix: maximum calibrated value for Ey and Ez swapped in GUI.
- Bug fix: acceleration values in GUI displayed upside-down.
- Bug fix: EMC32 .DeviceConfiguration files, wait after frequency setting not after E-field query.
- Bug fix: return correct number of commas for more that 64k return values.
- Upgrade SCPI library to newest version (2018-03-09).
- Error message if maximum frequency of snXmY.csv file not equal maximum frequency of snXmYfZ.csv files.
- Support multi-level and multi-mode accredited calibration data using snX_Y.csv files.
- »:SYSTem:WAIT <Sec>« added to wait for a number of milliseconds.
- »:CALibration:LOGging <Value>« added for accredited calibration.
- »:SYSTem:AUTOCONnect <State>« added to reduce interference with other FTDI USB devices.
- Computer interface polling intervall set to 1 s, only call CreateDeviceInfoList() if number of connected USB devices has changed.
- »:MEASure[:FProbe]:RSsi:X/Y/Z/ALL/XA/YA/ZA/XB/YB/ZB? [<MProbe>]« ALL variant added.
- »:MProbe:SETS?« added for query of list of defined Multiprobe systems.
- »:TRIGger:POINts <Points>[,<MProbe>]« added for point triggering.
- Command line prompt with history and shortcuts added for TCP server.
- Loop command for all SCPI commands added for TCP server.
- »:MProbe:TPStat:X/Y/Z/MAG/E3/ALL? <TSpec>,<PSpec>,<T.>,<MPr.>« added for statistics evaluation across multiple probes in TCP server, controls added to GUI.
- Simplify SCPI syntax for MEAS and TRIG subsystems.
- »[:TRIGger]:RADar:THreshold:AUTO <State>[,<MProbe>]« and »[:TRIGger]:RADar:THreshold:AUTO? [<MProbe>]« added .
- »[:TRIGger]:RADar:THreshold <Value>[,<MProbe>]« and »[:TRIGger]:RADar:THreshold? [<MProbe>]« added.
- »[:TRIGger]:RADar:BINary? [<MProbe>]« added.
- Ask for confirmation before closing TCP server due to error.
- »:SYSTem:ERRor[:NEXT]?« and »:SYSTem:ERRor:COUNt?« extended for detailed error messages.
- »:MEASure[:FProbe][:Efield]:VBW <Frequency>[,<MProbe>]« added to support low frequency operation with high video bandwidth detector and software-based video band-

width setting.

- Extend operating frequency range for modes 2, 6 and 10 to low frequencies, add forbidden frequency range to avoid aliasing.
- Stricter sanity checks for all calibration data files.
- »:MEASure[:FProbe]:ICapable? [<MProbe>]« to query support for modes 1, 5 and 9.
- Remote power measurement subsystem added to TCP server and GUI.
- »:SYSTem:DFLags?« added for textual debug flag setting and query.
- »[:TRIGger]:RADar:Efield:X/Y/Z/MAG? [<MProbe>]«,
  »[:TRIGger]:RADar:STArt:X/Y/Z/MAG? [<MProbe>]«,
  »[:TRIGger]:RADar:LENgth:X/Y/Z/MAG? [<MProbe>]« added for individual pulse queries.
- »[:TRIGger]:RADar:TRIM <State>[,<MProbe>]« to control behavior at pulses' edges.
- Stricter sanity checks for pulse modulation of virtual probes.
- »:TRIGger:FLENght? [<MProbe>]« added for query of waveform length, including all trigger points.
- »:TRIGger:PTTimes? [<MProbe>]« added to query trigger timing.
- »[:TRIGger]:SWeep:TCNT? [<MProbe>]« added to query number of sweep steps that fit into waveform.
- Create separate waveform log files for sweep waveforms in GUI.
- Create separate log files for all Multiprobe logs in GUI.
- Add support for new modes 8, 9, 10 and 11 in TCP server and GUI, update manual.
- Added new threshold methods, pulse trimming and individual pulse lengths to GUI.
- Display pulse average values in GUI's waveform.
- Add support for ar emcware.
- Install 32 bit or 64 bit version of TCP server and support libraries depending on host system.
- Include LabView RTE in installer.
- Cleanup of TCP server startup messages and summary tables.
- »[:TRIGger]:SWeep:ARBitrary? [<MProbe>]« added.
- Bin2CSV: support 64 bit frequency value and serial number in streaming files.
- New streaming files with separate LUT and data files, also supported by Bin2CSV.
- GUI: display only firmware version of computer interface.
- GUI: improve error handling when failing to connect to TCP server or parse ini file.
- Complete re-write of CalImport tool.
- Configuration environment variables replaced by ini file.
- LSPROBE_1.2_PATH environment variable added for third party applications.
- Laser-Debugging GUI added.
- EMC32 ISO 11451-2 functionality added.

2024/07/18

- Bug fix: after mode change reset x-, y-, and z-axis low-pass filtered value, not only x-axis' one
- Bug fix: Mode 1: frequency change over 30 MHz, wait for USB-FIFO read (e.g., correct

detector values) before parsing of new SCPI command allowed
- Bug Fix: Mode 1 Emulator: left-over delay (answer time) of one second for each query
- Bug Fix: Radar SCPI commands with MProbe and threshold parameter
- Single LUMILOOP TCP Server for all LSProbe and LSPM devices
- Improvement: Mode 3 is now (serial number > 590, calibration date after 2021/10/20) factory calibrated in the frequency range 9 kHz – 400 MHz (Variants E and G), old probes can be recalibrated on request
- Frequency set out of calibrated frequency range: will not be forced to nearest calibrated, error will be added to error queue and all measurement SCPI queries will yield NAN, after changing mode frequency will still be diverted to the nearest supported frequency
- Added support for LSProbe 2.0
- Added support for LSProbe 1.4
- Added additional statistics control: software controlled continuous statistic sampling
- Added lazy calibration data loading mode of operation option for start of TCP-Server
- CalImport: added further calibration laboratories
- Added "cr" shortucut SCPI command for overview list of calibration data with key elements
- trigger system ADC value queries »:TRIGger[:WAVeform]:ACCeleration:X/Y/Z? [<MProbe>]«, »:TRIGger[:WAVeform]:TEMPerature? [<MProbe>]«, »:TRIGger[:WAVeform]:VOLTage? [<MProbe>]« with MProbe parameter: for each probe same number of values will be returned, if value is not occupied empty string will be returned
- improved Timeout detection directly after laser enabling
- improved timeout log
- improved laser regulation
- streaming E-field value binary logging
- added streaming to client connection
- new Python based LUMILOOP-GUI for simultanous LSPM and LSProbe handling and visualization of log files
- one second delay after disabling laser for reliable and safe startup
- »:SYSTem:LHFrequency <Frequency>[,<MProbe>]«, »:SYSTem:LHFrequency? [<MProbe>]« added for setting and query of crossover frequency of low to high band detector in Mode 1
- ini-file parameter "LEGACY_IDN" added for reliable third party integration software support
- added TCP Server terminal SCPI command history extended to past TCP Server instances
- added suport for multiple calibration data sets
- added new subsystems Statstep
- added new subsystems Oversampling
- added support for arbitrary sweep steps
- added support for silent installation

2025/05/13

- Bug fix: adjusted allowed mode list for LSProbe 2v0, disabled Mode 5, 6, 7, 10 (burst mode for low-band detector disabled, single axis high sampling rate Mode for low-band detector disabled)
- Bug-fix: field trigger Mode 9 for LSProbe 2.0 fixed
- added support for Trigger signal relay for LSProbe and LSPM
- improved error message if TCP Server is already running
- LUMILOOP GUI: Added "Table" GUI mode
- updated BAT-EMC script for pulse evaluation to use trigger source "ANY"
- added ELEKTRA description to user manual for CW measurements
- added »[:TRIGger]:RADar:SOURce <Source>[,<MProbe>]« and »[:TRIGger]:RADar:SOURce? [<MProbe>]« for setting and query of radar source

2025/08/15

- Bug fix: +Devices: flush file operation(s)
- Bug fix: +Devices: +device management dialog:handle zip calibration files
- adjusted upper frequency range in high-band detector modes for LSProbe 2v0
- Pulse Evaluation: TRIM option has no impact on individual pulse length and start index
- Pulse Evaluation: pulses starting before or extending after trigger waveform and single frames in burst modes are ignored as their timing is unknown
- added »:STATistics:LENgth <Length>[,<MProbe>]« and »:STATistics:LENgth? [<MProbe>]« for setting and query of continuous statistics length parameter
- improved laser over-current error handling during start-up, retry five times
- +Devices: added memory screening, open info dialog if less than 10 % free
- LUMILOOP-GUI: improved/faster saving of long waveforms to disc
- uninstaller: installation directory from environment variable `LUMILOOP_PATH` taken, previously taken from relative path of uninstaller file
- uninstaller: user confirmation dialogs added

18 Accessories

Fiber Connector Cleaning Kit

- optical fiber microscope
- lint-free cassette cleaner wipes
- unfilled isopropyl alcohol (IPA) pipette bottle
- spare FC/ST dust caps and two E2000 locking caps

E2000 Sacrificial Cable Kit

- prevents contamination of connectors
- quick and simple replacement in case of connector burn-in
- includes two 0.5 m E2000 to ST/FC cables
- includes E2000 and ST/FC couplers

Optic Fiber Cable Extension

- fiber optic cable with ST/FC connectors
- includes ST/FC coupler
- arbitrary length of cable available on request

Tabletop Probe Stand Base

- quick positioning for table and ground-plane setups
- horizontal probe position 100 mm relative to all edges
- relative permittivity better than 2.7 @ 1 kHz

Tabletop Probe Stand Mounting Base

- to position the field sensors center at 100 mm, 125 mm, 150 mm, 200 mm or 300 mm above surface
- well-defined field probe alignment with quick mount/release
- relative permittivity better than 2.7 @ 1 kHz

Flexible Probe Stand

- flexible tripod feet for versatile positioning
- vertical position approximately 150 to 220 mm above surface
- strong magnetic feet with rubber coating
- no metal parts
- quick mount/release